Production Cost Estimates for Silage from Energy Crops

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Abstract. The cost of silage produced from seven potential energy crops in Latvia according to the technologies advised by scientists in the prices of 2009 was calculated in the present paper. It was stated that the average cost of growing, harvesting, and ensilaging crops is approximately LVL 490 ha^{-1} in year 1 and ranges within 8% depending on the chosen technology map for growing crops and the biotechnological properties of crops. The cost of producing maize silage was LVL 608 ha^{-1} or LVL 12.15 t^{-1}. However, it is necessary to define more precisely the outcomes of production technology and biogas in order to make general conclusions on the use of energy crops for energy production.
Key words: renewable energy, silage for biogas, energy crops, production costs.

Introduction

Latvia has undertaken to increase significantly the amount of using renewable energy sources, reaching a proportion of 40% for renewable energy in its total energy consumption in the year 2020. The output of electrical energy from renewable energy sources (RES) has to increase from 3030 GWh in 2010 to 5191 GWh in 2020, i.e. by 71%. It is planned that in 2020 hydro energy will account for 57% (97% in 2008), but the output of electricity from biomass and wind will account for 24% and 18%, respectively, of the total electric energy generated from RES. Besides, the output of electricity from biomass will increase from 70 GWh in 2010 to 584 GWh in 2020 (Ministry of Economics, 2010). A possibility of producing new products that feature a stable demand would positively affect the development of farms. Farmers want to use such a possibility. The administrative decisions made in 2010 concerning biogas facilities composed the entire amount of 467959 MWh set by the public seller (Latvenergo), reaching the total number of decisions of 60; this means that 60 businessmen have the right to sell the electricity produced by them according to the purchase obligation (Ministry of Economics, 2010). The area sown with maize, which is the main crop for biogas production, also increases. In 2009, the sown area has increased by 66.9% compared with to 2008; thus, reaching 9.8 thousand ha; an average yield has also increased from 213 to 230 cnt ha^{1} (CSB of Latvia, 2009). Yet, the yields significantly lag behind the experiments conducted by Latvian scientists where the yields exceed 650 cnt ha^{-1} (seminar "Maize for Biogas and Feed Production" at the Research and Training Farm "Vecauce", Latvia University of Agriculture, 20 August 2010). Even if taking into consideration the fact that real and experimental yields cannot be compared directly, a three times lower yield is impressive. A question arises whether maize is an optimal crop for silage production to produce energy in all the regions of Latvia. Latvian scientists have not given an unambiguous answer to it and possibly will not do it ever. The production of silage is determined by not only soil specifics and climatic conditions, but also by farm specialisation and product logistics. Therefore, new varieties of crops, which are suitable for biogas production, are searched for in Latvia. The present paper analyses plants of various species that are viewed by specialists in crop farming as potential for biogas production in Latvia include grasses: alfalfa, galega, tall fescue, and red canary grass; oil crops: winter rape, sunflower; and a biomass crop: maize. The research aim is to ascertain the costs of producing silage from the above-mentioned crops and to make their mutual comparisons per 1 ha and 1 t of output. The crops and their production technologies – land tillage, fertiliser doses, harvesting etc. – were chosen according to the recommendations of A. Adamovičs, a crop farming specialist at Latvia University of Agriculture as well as interviewing agricultural practitioners.

Data and methods

The methodology of the Latvian Rural Advisory and Training Centre (LLKC) "Calculations of Gross Margin for Farms" was used for calculations. The LLKC report "Calculations of Gross Margin for Farms" is issued every year by means of co-funding of the Ministry of Agriculture of

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the Republic of Latvia. A table, which includes incomes and expenditures of production is used for calculating gross margins. The main items in the table include incomes from products sold, raw material costs (seed, fertiliser, plant protection etc.), costs of operations performed manually and by machines, and the result part – gross margin 1 (income minus raw material costs), gross margin 2 (income minus raw material costs minus costs of operations performed manually and by machines), gross margin 3 (gross margin 2 plus national and the EU support). The methodology was not used completely, since biomass for energy production is an intermediate product. Therefore, a potential gain from biomass sales was not calculated, but only the costs per 1 ha of land utilised and per 1 t of biomass produced were calculated in the research.

The prices of seed of crops were taken from a price list of "Latvijas šķirnes sēklas" Ltd for 2009, and the prices of fertilisers and plant protection means were taken from a price list of "Latagra" Ltd for 2009.

The costs of manual and machine operations compose the costs of special machinery, product transportation, and biomass preparation machinery. The necessary data for calculating the costs of manual and machine operations were obtained from the annual LLKC survey "The Pricelist of Machinery Services in Latvia in 2009", agricultural producers of Zemgale as well as specialists in special machinery (tunnel technology). The costs include the value added tax (21% rate). Trench technology is used for ensilaging biomass, except the cost calculation for maize biomass, which includes the cost of ensilaging biomass using tunnel technology.

The biomass and all the resources used for its production are transported at a distance of 10-15 km and 10-12 t are delivered per one transportation – such an assumption is based on the recommendations of specialists in crop farming.

The surface area of polythene film used for ensilaging biomass is assumed 0.84 m^2 per 1 t of biomass. The assumption is based on the LLKC specialists' recommendation that 70 metres of a film of 6 m width are needed for covering 500 t of biomass. Compacting biomass in a trench requires 3.6 minutes per 1 t of biomass, since a compacting of 500 t of biomass takes 30 hours on average.

Plants of various species that are viewed by specialists in crop farming as potential for biogas production in Latvia include grasses: alfalfa, galega, tall fescue, and red canary grass; oil crops: winter rape, sunflower; and a biomass crop: maize were researched. Within the present research, these plants are regarded as biomass plants, as the output is calculated in total tons per hectare of biomass.

A general description of plants used in the calculation is given in the publication "Production and Use of Energy Crops" by A.Adamovičs and his colleagues.

The alfalfa genus (Medicago L.) is rich in juice. Only two species of it may be grown for biomass production in Latvia. Yellow or crescent-shaped alfalfa (M. falcata L.) is perennial grass. This species is rich in form and very valuable owing to its drought and cold resistance. In Latvia, it grows in wild hilly permeable to water places.

Hydride alfalfa or bastard alfalfa (M. media Pers. syn. M. varia Martin.) is a natural crossbreed of yellow alfalfa and the cultivated one; it is often classified as a separate species. Hydride alfalfa is more popular on Latvia's conditions, as it is more productive than yellow alfalfa. This species is plastic and adapts well to growing on various conditions.

Galegas are the grasses of the pea genus (Leguminosae), and this genus comprises 8 species, of which only two – Eastern galega (Galega orientalis Lam.) and herbal galega (Galega officianalis Lam.) is widely used. Eastern galega is grown for biomass.

Tall fescue (Phalaris arundinacea (L.) Raush.) is a twining grass having long and strong roots. The grass is up to 2 m high and very leafy. The grass's lifespan reaches 10 years if it is sown, yet, in the wild its lifespan is unlimited. In the wild, it usually grows in meadows and on banks of rivers and lakes.

Red canary grass (Festuca arundinacea Schreb.) is a perennial twining grass. It grows up to 1.5 m high, its stalks are rougher, its leaves are wider compared with meadow fescue; it can be productive for 8-10 years.

Rape (Brassica napus ssp. oleifera Metzg) belongs to the mustard genus (Cruciferae), cabbage family (Brassicaceae). This plant has well-developed taproots and strong 1.1-1.9 m high stalks.

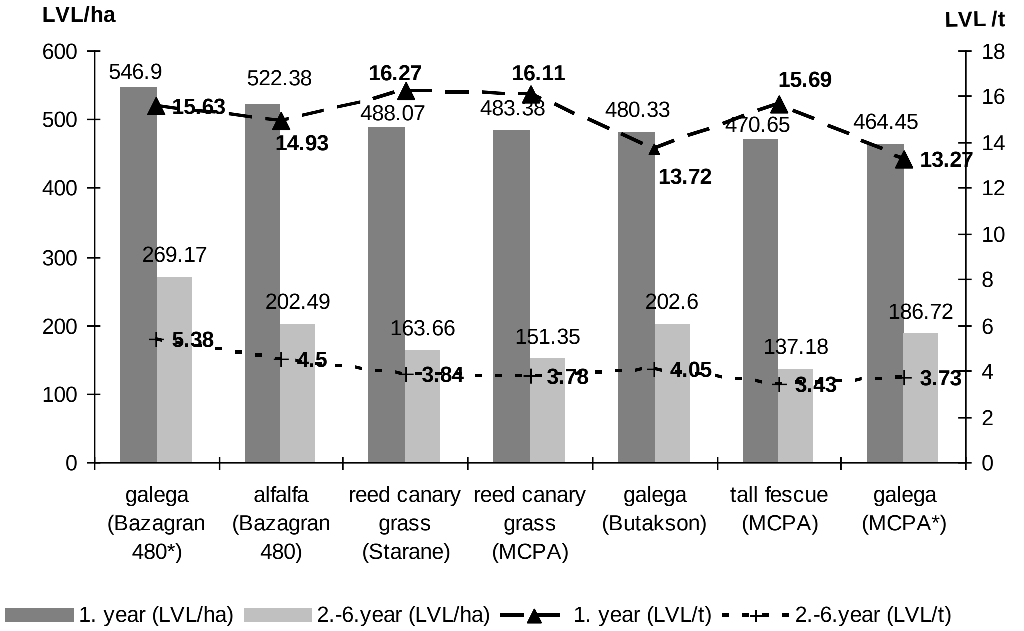
Common sunflower (Helianthus annuus L.) is an annual plant of the aster family (Asteraceae). The domestic sunflower's (H. cultus Wenzl.) subspecies (ssp. sativus Wenzl.) is used for biomass production.

Maize (Zea mays L.) is an annual cross-pollination caulescent plant belonging to the grass genus and having a well-developed but shallow root system. Its stalks are broad and lodge resistant with a diameter of 1.5-3.5 cm and 0.6-6 m high.

The content of dry matter of biomass is of great importance to produce biogas. It is different for the biomass plants that are researched: 15-23% for grasses, maize has also a high content of dry matter of approximately 19%, while oil plants have a relatively low content of dry matter or 12-14% (Adamovičs A, et. al., 2007).

Results and discussion

According to agronomy specialists, Latvia's climatic conditions are suitable for growing grasses for biomass production. The wide choice of grass species and their various agricultural and biological properties allow any farm to find an appropriate grass for it. Growing perennial grasses is related to lower intensity of field works during Years 2-6, which significantly reduces the cost of biomass. Latvia has the highest proportion of agricultural land per capita in the EU or 1.08 hectares per resident compared with the average 0.41 hectares per resident in the EU, which is regarded as an important factor for successful development of biogas production (Nielsen J.B.H., Oleskowicz-Popiel P., Al Seadi T., 2007). Presently, Latvia does not lack agricultural lands, which allows the country to increase agricultural output extensively (by increasing the area of agricultural land). It is seen in Figure 1 presenting a summary of production costs for grasses, using various technologies and means for growing plants.

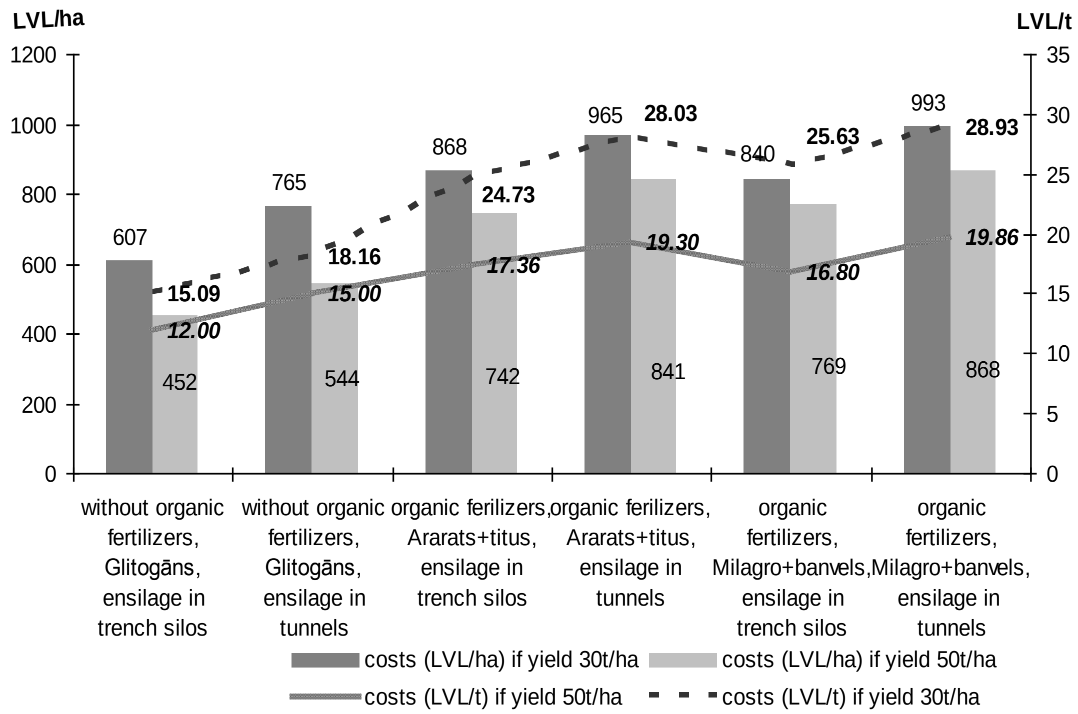


Source: authors' calculations

Fig. 1. **Costs of growing grasses in Year 1 and Years 2-6, LVL/ha, LVL/t**

In total, the average variable costs of cultivation, harvesting, and ensilaging grasses in Year 1 is approximately LVL 490 ha^{-1} and does not exceed 8% depending on the chosen technology map for growing crops and the biotechnological properties of crops. In the technology maps, a special attention was paid to choosing plant protection means and their impact on the cost. Bazagran 480, which is an expensive herbicide (its price was LVL 28.75 per litre in 2009), has the greatest impact on the cost. It has to be noted that Bazagran 480 and MCPA are not recorded in the Latvian Plant Protection Register as usable for growing galega. Therefore, these scenarios of growing plants may be regarded as theoretical and are marked with the asterisk sign (*). If calculated per hectare, the highest costs are obtained for growing alfalfa, yet its production is justified owing to the high yield of this plant, thus keeping the costs of biomass slightly below LVL 15 t^{-1}; a better result is provided only by galega, using the herbicide Butakson. By intensively growing red canary grass, the costs per hectare are below the average value, yet its costs per ton are relatively high: 16.11 LVL t^{-1} in the year of introduction; yet its production costs decrease during Years 2-6, amounting to 3.78. It has to be concluded that the choice of herbicide may significantly affect the cost of biomass (Bazagran 480), yet in general, it depends on the structure of costs (Figure 4). A greater investment in Year 1 for red canary grass and tall fescue is paid back by smaller investments in Years 2-6.

Among the producers of biogas, maize is very popular. This may be explained by its high yield of biomass, high content of dry matter, and popularity in Germany. The experience taken over from this country had the largest effect on the development of biogas production from crops in Latvia. Maize is a crop to be grown intensively; it requires a lot of warmth, light, and moisture.



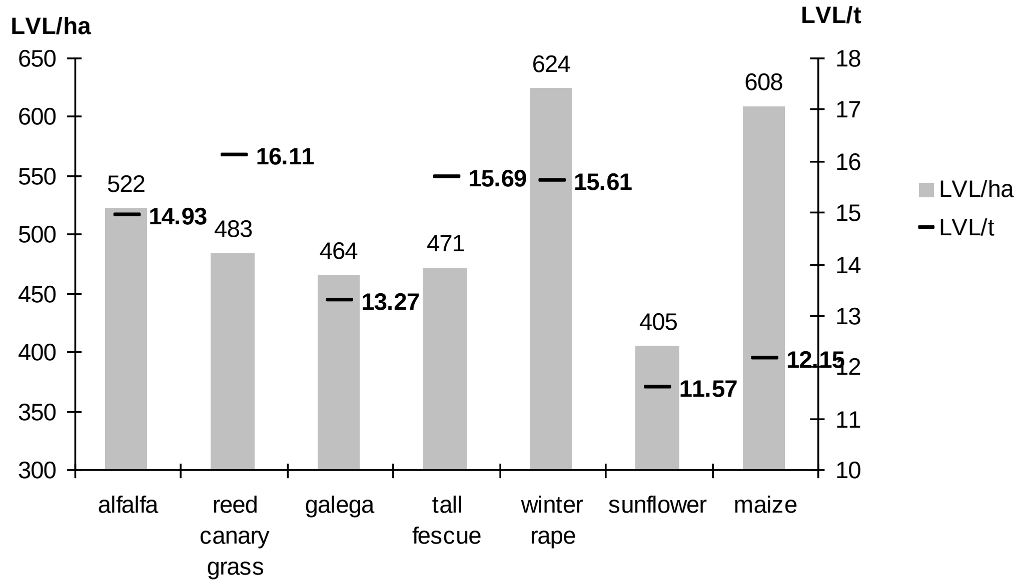
Source: authors' calculations

Fig. 2. **Production costs of silage from maize**

Six technology maps for growing maize were used in the present research. Four of them, which are based on scientific research, were developed by a professor A. Adamovičs, the other two were developed by farmers and based on their experience in farming. The technology maps of the practitioners feature less fertilisers, and no manure is used at all. The costs of maize biomass produced in such a way are lower, but a special attention has to be paid on the threat of depleting agricultural land, which endangers the sustainable production of biogas. The technology of ensilaging biomass significantly affects the production of it. After comparing the traditional technology of ensilaging biomass in trenches in Latvia with ensilaging biomass using tunnel technology, one has to conclude that the costs increase by one fifth in case of tunnel technology. It has to be noted that the cost of ensilaging biomass in trenches does not include the expenditure on constructing a trench, which is not included in variable costs and which is not necessary if using tunnel technology for ensilaging biomass. By intensifying production and saving funds on technical infrastructure, the impact of technology of ensilaging biomass on the cost of production loses its significance. In general, the technology maps of the agricultural practitioners are much cheaper if comparing the best technology map of the practitioners (ensilaging biomass in trenches) with the best one recommended by the scientists (Milagro + Banvels, ensilaging biomass in trenches). Both technology maps consider a yield of

50 t ha^{-1}: the technology map of the scientists is 40% more expensive, respectively, LVL 12.00 t^{-1} and LVL 16.80 t^{-1} or 70% costlier at a yield of 30 t ha^{-1}. According to the technology maps developed by the scientists, the cost of silage produced does not significantly change depending on the plant protection means. The impact of one weight unit on the costs of silage increase significantly considering the total variable costs. Respectively, with a decrease in the yield of maize by a ton, its cost increases by LVL 0.41 – in case of the practitioners a decrease was only LVL 0.16.

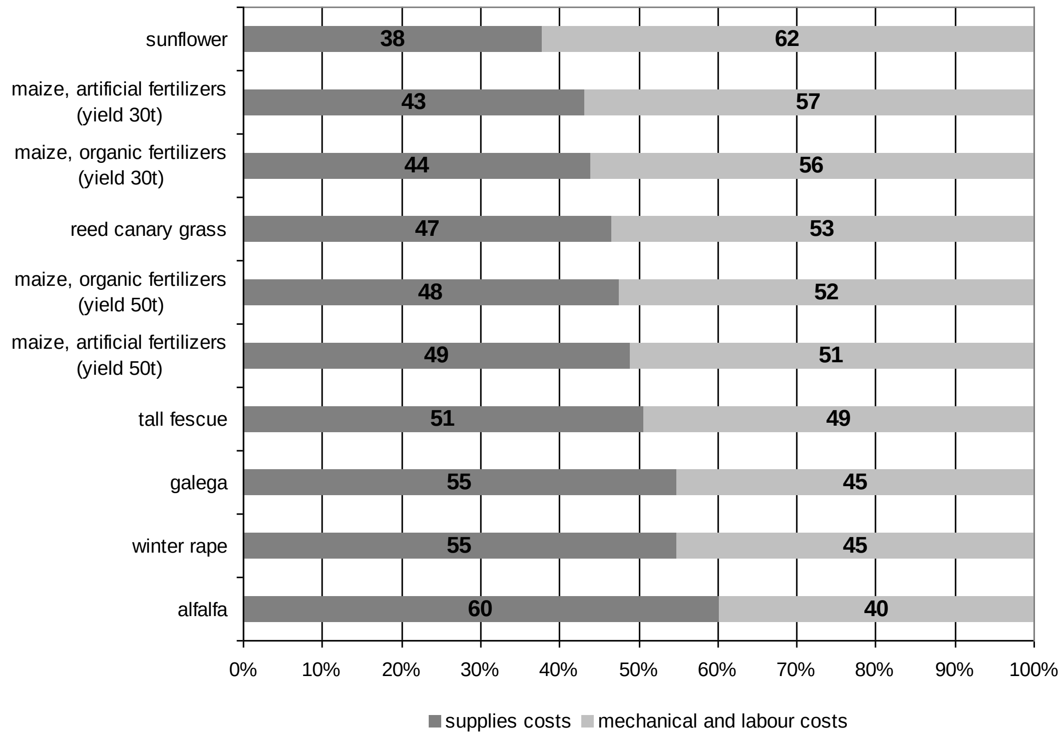
In producing silage for biogas production, the choice of particular crops will be determined by not only the cost of silage, but also soil properties, the location of agricultural land, farm management specifics etc. Nevertheless, it is possible to compare the costs of silage within the present research.



Source: authors' calculations

Fig. 3. **Costs of silage from energy crops in Year 1 (year of introduction)**

The popularity of growing maize corresponds to the gained results that show a low cost for intensive production or LVL 12.15 t^{-1}. However, when analysing the data, the period of reproduction of grasses up to 6 years, theoretically even 10 years, has to be taken into account, which significantly reduces the costs of silage over the next years after fields are sown with this crop. Silage made from winter rape is expensive both in terms of cost per 1 hectare and per 1 ton. Using rape for silage is also inefficient due to its low content of dry matter. Yet, it has to be remembered that rape is a valuable oil crop, which is used for biofuel production. Opposite results are shown by another oil crop – sunflower; the cost of silage produced from equal to LVL 11.57 t^{-1}. Although the gained results are optimistic, the practical use of sunflower is affected by the very low content of dry matter – less than 10%, while at the beginning of blooming, the content reaches 12-14%.



Source: authors' calculations

Fig. 4. **Structure of variable costs in growing energy crops, percentage**

In growing energy crops, the structure of costs may be itemised as follows: raw material costs, and costs of manual and machine operations. The ratios of these costs might change in case farmers exploit their own machinery. In the present research, the costs are calculated as if these were services that are purchased, or in case operations are performed according to another technology map, or whether digestate from biogas production or manure is used as a fertiliser. After analysing the exogenous factors constituting the cost, one can state that the raw material costs area affected by the availability and price of financial capital (loans for operational capital), whereas the costs of machinery and labour are impacted by the price of fuel.

Karina Ēriksone and her colleagues compared the costs of energy crops in the EU countries, and found that the costs were relatively lower in the East European countries, respectively, 41.3 % of unit cost for services of producing energy crops in the North Europe (Ericsson K., Rosenquist H., Nilsson L.J. 2009). On the one hand, the differences in price levels and the relatively large areas of agricultural land per capita establish prerequisites for efficient production of biogas and electric energy. On the other hand, there are significant differences in the yields of energy crops that are lower in the North-Eastern Europe. The yield can be affected not only by climatic conditions, but also by the technology of growing crops (Gaile Z., 2010; Kopmanis J., Gaile Z., 2010). The output of biogas produced from the silage of energy crops is also important, which significantly influences the costs of electric energy per one hectare of land utilised or per one unit of money invested, as, for instance, the average output of biogas produced from red canary grass is 263l kg_{vsd}^{-1}, but from maize it is 553l kg_{vsd}^{-1} (Dubrovskis V., Adamovičs A., Plūme I., 2009). Therefore, it is necessary to develop optimal technologies of growing energy crops that could be used for the production of silage in practise, and to measure the output of biogas and the content of methane. It is needed to have a possibility to identify the necessary cost per unit of energy and to make a generalisation on the efficiency of consumed resources.

Conclusions

- The production of biogas from silage has a stabilising role in energy production, thus making it less dependent on the availability of remnants in livestock farming.
- The average costs of growing, harvesting, and ensilaging crops are approximately LVL 490 ha^{-1} in Year 1 and ranges within 8% depending on the chosen technology map for growing crops and the biotechnological properties of crops.
- The costs of silage produced from maize is significantly affected by the amount and type of fertiliser used. The technology maps of the farmers feature less fertilisers, and no manure is used at all. The cost of maize biomass produced in such a way is 40% lower, but a special attention has to be paid on the threat of depleting agricultural land, which endangers the sustainable production of biogas.
- The use of oil crops for producing silage cannot be justified neither economically nor from the point of view of energy gains, since their content of dry matter, which is important in biogas production, is low – up to 12% of total weight, which is twice as less as in grasses.

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