Economic efficiency of the technologies of agricultural biomass use for energy purposes

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Abstract. The research presents analysis of the technologies of conversion of bioenergy agricultural raw materials. Purchase of bioenergy equipment is impossible without investments into bioenergetics. Thus, there is a necessity to develop an investment project. The article defines main indicators for investment project assessment, i.e. net present value, internal rate of return, modification internal rate of return, discounted payback period, investment profitability index, and gives classification of investment projects. The works proves that, considering substantial differences of different kinds of energy products and ways of their obtaining, analysis of biomass conversion technologies should be made separately for each kind of it. It is confirmed that biogas is one of the most prospective energy resources, supplying improvement of ecological conditions of production processes. The author of the article argues reasonability to apply technologies of briquetting and pelleting of dry biomass. The research studies methodological approaches to determination of prime cost of a unit of energy of the main kinds of biomass conversion. It is proved that, comparing to traditional energy products, such as natural gas, stove fuel, petrol and diesel fuel, prime cost of the energy products, obtained by conversion of agricultural biomass, is substantially lower, proving economic efficiency and reasonability of the technologies application.

Key words: bioenergetics, biotechnologies, economic effect, prime cost, biogas, agricultural biomass.

INTRODUCTION

Raise of agriculture performance efficiency is currently of urgent necessity. Intensification of agriculture development is, on one hand, a guaranty for increase of production output, but on the other hand, a reason for natural resources exhaustion. Thus, it is of great importance to study bioresource potential of agricultural enterprises. An adequate approach to efficient use of bioresource potential, particularly agricultural biomass, for energy needs will decrease the high dependence of agricultural branch on prices for fossil fuels and support improvement of food safety of the country, as well as reduction of environmental pollution.

Economic (value) approach is an important methodic approach to analysis of efficiency of the technologies of agricultural biomass use. The approach is based on market fundamentals to determine efficiency of its use.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

The problems of bioenergetics development and assessment of bioenergy potential of agricultural enterprises are revealed in scientific works of the following scientists, i.e. Heletukha H., Zheliezna T., Kudria S., Tytko R., Cherevko H., Horyński M., Majcher Ja and others. [1-5].

At the level of investment projects, economic efficiency is studied in scientific works of Baydala N., Kniaz S., Pauk O., Orlyk O., Bartashevska Yu., Isaieva T. and others. [6-9].

However, the scientists pay attention mainly to prime cost of a unit of products, while it is more reasonable to pay attention to prime cost of a unit of energy, and the article is devoted to the issue.

OBJECTIVES

The aim of the research is to argue methodology of economic analysis of the technology of conversion of bioenergy agricultural raw material.

MAIN RESULTS OF THE RESEARCH

Residuals of agricultural production need appropriate utilization and conversion into energy products both for increase of production efficiency and for environmental protection.

Considering the economic criterion, an integral criterion of economic efficiency can be presented by prime cost of a unit of energy, which is influenced by cost of primary products, cost of technological equipment, expenses for labor, additional material and energy expenses, energy value and cost of the obtained power product, etc. Prime cost of a unit of energy is substantially influenced by conversion technology, as well as the kind of energy products, in particular, electric energy, thermal energy and technological cold.

Application of energy resources requires permanent improvement of the technologies of their producing.

Purchase of bioenergy equipment is impossible without attraction of investments into bioenergetics. Thus, there is a necessity to develop an investment project, which is supplied with adequate conditions and determination of investments efficiency.

According to the Law of Ukraine [10], an investment project is a complex of measures (organizational-legal, managerial, analytical, financial and engineering-technical), determined on the base of the national system of values and tasks of innovative development of the national economy and focused on development of separate branches, sectors of the economy, productions, regions, which are to be implemented by the subjects of investment activity with application of values, defined by the regulations of the Law.

To estimate efficiency of the investments, one can use methodic approaches UNIDO [11, p.12], methodology of the World Bank [12, p. 550], methods of the European Bank for Reconstruction and Development [12, p. 551], methodology of the International Consulting Firm "Ernst&Young" [13, p. 17] and others. The mentioned methodologies can be divided into two groups: simple (statistical) and dynamic (discounting methods).

Statistical indicators are based on statistical methods of calculation, because they do not consider time factor. The group includes the following indicators, i.e. economic added value, investment payback period, accounting rate of profitability [14, p. 25].

Dynamic indicators consider changes of money value in time and expect bringing of the value of all money flows to a common way of their discounting. Dynamic methods to estimate efficiency of innovative projects include net present value (NPV), internal rate of return (IRR), discounted payback period (DPP), profitability index (PI) [15, p. 483; 16, p. 143], modification internal rate of return (MIRR) and duration (D) [14, p. 25].

Special attention is paid to classification of investment projects, making generalization of researches of the scientists [17, 18, 19]. Thus, the author of the article specifies the following classification features: according to the sphere of resources application – productive, scientific-technical, commercial, financial, economic, social-economic; according to the mechanism of resources application – real, financial; according to interdependence – conditionally independent, dependent (mutually exclusive, substituting, supplementing); according to the term – short-time, medium-time, long-time; according to the objective – investment projects of development, investment projects of financial revival; according to the amount of investment resources – small, medium, large; according to the origin of investment resources – projects, financed from internal sources, external and mixed ones; according to the degree of risk – risky, and high risky; according to the degree of liquidity – high liquid, medium liquid, low liquid, non-liquid; according to the focus – commercial, social, ecological, economic.

Concerning the described classification, the projects, which are focused on application of the energy of agricultural enterprises biomass are medium-time, ecological, economic, social, technical, medium difficult ones.

Development of the methods of efficiency of agricultural production residuals utilization for energy needs is complicated because biomass differs in its origin, processing technology, capacities of processing enterprises, etc. Thus, development of a single unified methodology is a complicated task. Tasks of the methodology of efficiency of agricultural production residuals utilization for energy needs should be solved separately for each kind of biomass, way of its processing and production capacities. It is particularly needed for determination of prime cost of a unit of energy, obtained from different kinds of biomass and with application of different technologies of its conversion.

Let us consider methodological approaches to determination of prime cost of a unit of energy of the main ways of biomass conversion.

Assessment of prime cost of a unit of energy, obtained by the technology of methane fermentation of agricultural biomass conversion. Utilization of animal droppings is usually done by means of anaerobic fermentation with producing of high quality, ecologically clean and biologically active fertilizers and biogas, which can be used for production of thermal and electric energy. In such case, the obtained biogas can be used as gaseous motor fuel for the installations, operating in cogeneration regime, or as gaseous fuel for traditional heat generators.

Application of biogas as a fuel, besides the energy effect, also has an ecological effect, which can be quantitatively expressed in the form of sell of quotas for carbon dioxide (CO_2) exhausts and prevention of losses for recovery of population health, which is lost because of deterioration of environmental parameters by exhausts of thermal power engineering.

Generally, prime cost of a unit of energy is defined as a ratio of total expenses, but cost of by-products and additional financial revenues, and amount of produced energy. The indicator will substantially depend on enterprise capacities, kind of the process of anaerobic fermentation, primary raw materials and the obtained by-product.

Prime cost of a unit of energy, obtained from utilization of animal droppings in biogas installation with application of the obtained biogas for generating of thermal and electric energy in cogeneration regime, as the most efficient way to use the obtained biofuel, can be calculated according to the following formula:

$$C_e = \frac{E_{sep} - C_{of} - M_{co_2}}{E}, \qquad (1)$$

where E_{sep} – expenses for supply of energy production, UAH;

C_{of} – cost of sell of organic fertilizers, UAH;

M_{co_2} – money revenues from sell of quotas for carbon dioxide, UAH;

E – total amount of produced electric and thermal energy, kg.

Expenses for energy production are influenced by the following indicators, i.e. cost of raw materials, depreciation cost for equipment and constructions, salary of employees, cost of the used energy for supply of fermentation process, cost of materials, cost of technical maintenance and repair, transportation cost, overheads, general economic expenses, as well as expenses for storage of the obtained products, which are calculated according to the common methodology.

Cost of primary raw material and products of anaerobic processing, i.e. organic fertilizers, is forced by their market value. Money revenues from sell of quotas for carbon dioxide are calculated as a product of the amount of prevention of formation and price of a unit of the quotas. Cost of the prevented losses for recovery of population health, lost because of deterioration of environmental parameters by exhausts of thermal power engineering, is measured according to the amounts of substitution of the final kinds of energy, obtained with application of bioenergy technologies according to the methodology, which is described in [4].

Amount of the obtained energy (electric and thermal) is calculated as:

$$E = N_{bg} \cdot \alpha \cdot Q_{bg}^{l} , \quad (2)$$

where α – maximum potential of methane formation, calculated per 1 kg of dry organic matter of dung/droppings, m^3 CH_4/kg DOM;

Q_{bg}^{l} – low calorific capacity of methane, MJ/m^3.

Annual amount of the obtained biogas is measured by the following dependence:

$$N_{bg} = n_{an} \cdot \beta \cdot K_1 \cdot K_2 \cdot T_{sf} , \quad (3)$$

where n_{an} – livestock of cows, animals;

β – daily output of droppings per 1 animal, measured in dry organic matter (DOM), kg DOM/animal;

K_1 – coefficient of residuals output, characterizing number of animals, kept indoor;

K_2 – coefficient of availability, characterizing amount of dung, which can be collected and technically brought to a biogas installation;

T_{sf} – duration of a stall-feeding period, days.

Depending on its type and size, a cogeneration installation, which operates on biogas as a primary source of energy, can supply the following efficiency of energy transformation, presented in the form of an efficiency factor, such as: electric – from 31 to 43 %; thermal – 42 to 59 %, and total efficiency factor of the cogeneration installation – from 80 to 90 %.

Thus, amount of the produced electric and thermal energy, wil respectively constitute

$$E_{ee} = E \cdot \eta_e , \quad (4)$$

$$E_{te} = E \cdot \eta_t , \quad (5)$$

where η_e and η_t – electric and thermal efficieny factor of the cogeneration installation, respectively.

Difference between "green" tariffs and obtained prime cost of electric and thermal energy will make effect from application of the used technology of utilization of animal breeding residuals.

Determination of prime cost of a unit of energy, obtained by the technologies of ethyl fermentation conversion of agricultural biomass. Bioethanol belongs to alternative fuels. Raw material for bioethanol production, such as sugar and starch, is rather expensive, used for people's food and as forage for cattle. Thus, one should try to minimize their use for energy purposes. It is also necessary to make scientific argumentation of a maximum possible share of the raw material, which can be used for energy production. To decrease prime cost of bioethanol, it is required to make prime cost of raw material much lower and optimize the production process. Thus, considering the above mentioned, bioethanol production applies maize, sugar beets and other sugar and starch containing crops.

According to the research [20] concerning analysis of sugar beets processing for biofuel, one ton of sugar beets can produce 80-100 liter of bioethanol, depending on digestion. Thus, to produce 1 liter of bioethanol it is necessary to process 12,5…15,6 t of sugar beets. Concerning output of bioethanol per 1 ha of field, it is calculated according to sugar beets yield, i.e. 350 hwt/ha of sugar beets can produce 2,8…3,5 thousand liter of bioethanol; 400 hwt/ha – 3,2…4,0 thousand liter; 500 hwt/ha – 4,0…5,0 thousand liter, and yield of 600 hwt/ha gives approximately 6 thousand liter of bioethanol.

According to the research [2], average prime cost of bioethanol makes above 4 UAH/l. According to its calorific capacity at the level of 22,5 MJ/l [22], prime cost of a unit of energy C_{Eet} is measured as:

$$C_{Eet} = \frac{C_{et}}{Q_{et}} , \quad (6)$$

where C_{et} – prime cost of bioethanol, UAH/l;

Q_{et} – energy value of bioethanol, MJ/l;

Thus, for the mentioned indicators, average cost of a unit of energy of bioethanol constitutes

$$C_{Eet} = \frac{4}{22,5} = 0,178 \text{ UAH/MJ.}$$

Actual prime cost of bioethanol is mainly influenced by the type of agricultural crops and their yield capacity. Potential output of bioethanol per one hectare of different agricultural crops greatly differs (fig. 1).

Under crisis conditions in Ukraine's sugar beet branch and fall of demand for white beet sugar, as well as attempts to improve energy independence, bioethanol production on the base of sugar beet is a reasonable solution.

Bioethanol production is made of sugar production residuals, i.e. treacle, but it can be also produced of intermediate products of sugar beet processing, i.e. beet (diffusion) juice, sugar syrup, greens, etc. Use of intermediate products enables balancing of Ukraine's needs for sugar and protection as well as extension of land area for growing of sugar beets because of bioethanol production [20].

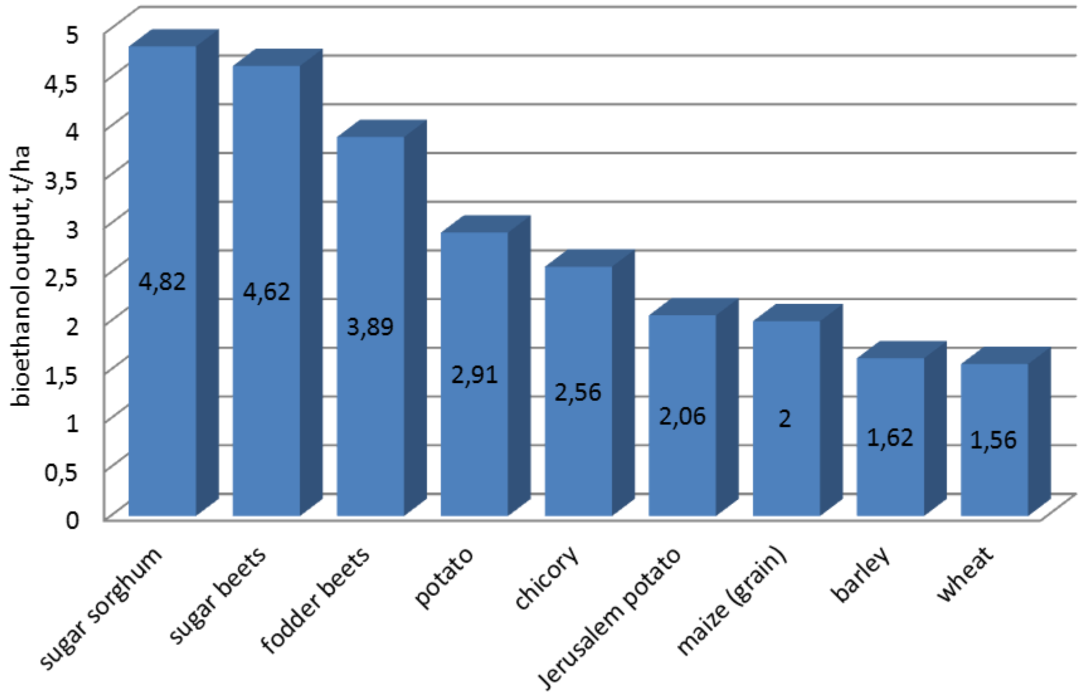

Fig. 1. Potential output of bioethanol per 1 ha of cropping area of different agricultural crops [23].

Approximate prime cost of bioethanol, produced of treacle and surplus of sugar beets constitutes 8 UAH/l [24]. Prime cost of a unit of energy C_{Eem} is measured as:

$$C_{Eet} = \frac{8}{22,5} = 0,356 \text{ UAH/MJ}$$

Approximate prime cost of bioethanol, produced of grain constitutes 2,5-2,7 UAH/l [21]. Prime cost of a unit of energy C_{Eet} is measured as:`

$$C_{Eet} = \frac{2,6}{22,5} = 0,116 \text{ UAH/MJ}$$

Approximate prime cost of bioethanol, produced of potato constitutes 17,78 UAH/l [25]. Prime cost of a unit of energy C_{Eet} is measured as:

$$C_{Eet} = \frac{17,78}{22,5} = 0,79 \text{ UAH/MJ}$$

Estimation of prime cost of a unit of energy, obtained by the technologies of etherification conversion of agricultural biomass. Internal combustion engines use two types of biofuel, i.e. bioethanol and biodiesel, depending on organization of their operation principle. It is mentioned above that biodiesel is produced with application of the technologies of etherification of oils, obtained from oilseeds, such as rape, sunflower, soybean and others.

Meal and glycerin are by-products of biodiesel production. Estimating prime cost of a unit of the main product, it is necessary to extract cost of by-products, in sale prices, from the total amount of expenses for production.

According to the research of the scientists [20], prime cost of 1 liter of biodiesel constitutes 5,93 UAH/l.

Calculation of prime cost of a unit of energy, obtained by the technologies of solid agricultural biomass conversion. Prime cost of a unit of energy, obtained from pellets (briquettes) C_{Epel} is calculated by the formula:

$$C_{Epel} = \frac{C_{pel}}{Q_{pel}}, \quad (7)$$

where C_{pel} - prime cost of pellets (briquettes), UAH/kg;

Q_{pel} – energy value of pellets (briquettes), MJ/kg.

Energy value of straw pellets constitutes 16,5 MJ/kg, thus, cost of a unit of energy C_{Epel} will constitute:

$$C_{Epel} = \frac{1,6}{16,5} = 0,097 \text{ UAH/MJ.}$$

Considering the fact that density of straw briquettes is lower than in pellets, their energy value is also lower and constitutes 15, 4 MJ/kg. Consequently, prime cost of a unit of energy of briquettes constitutes 0,117 UAH/MJ.

Energy value of pellets of sunflower husk constitutes 18,5 MJ/kg, and prime cost of a unit of energy C_{Epel} will constitute:

$$C_{Epel} = \frac{1,3}{18,5} = 0,07 \text{ UAH/MJ.}$$

Energy value of briquettes of sunflower husk makes 21 MJ/kg, and prime cost of a unit of energy – 0,071 UAH/MJ.

To argue reasonability of application of the technologies of briquetting and pelleting of dry biomass, the work presents comparative characteristics of different kinds of fuel and products of their processing according to their calorific capacity (table 1).

Table 1. Calorific capacity of different kinds of fuel

Kind of fuel	Calorific capacity, MJ/kg
Natural gas	35-38*
Coal	15-25
Fuel for engines	42,5
Fuel oil	42
Branches of fruit trees	10,5
Grapevine	14,2
Wood chips and sawdust	10,5-21,0
Briquettes of wood	16,8-21,0
Granules of wood	17,5-19,5
Straw	10,5-12,5
Straw in wads	14,2
Granules of straw	16,5-18,8
Briquettes of straw	15,4-21,0
Briquettes of glume	16,7
Sunflower stems	12,5
Briquettes of sunflower husk	21,0-21,8
Granules of sunflower husk	18,5-20,0
Maize stems	12,5
Briquettes of cobs	18,0

*Calorific capacity of natural gas, as well as other gaseous fuels, is presented in MJ/m^3

One should note that fuel granules (briquettes) have high competitive capacity, as compared to other kinds of traditional fuel. Contrary to fossil fuels, price for biofuel does not depend on conjuncture and political jumps of prices for traditional kinds of fuel and on ecological taxes, but is determined only by current expenses and cost of raw material.

Prime cost of the energy of conversion of the biomass, obtained by different technologies, is presented in the table 2.

Table 2. Prime cost of the energy of conversion of the biomass, obtained by different technologies

Technologies	Raw material	Measuring unit	Prime cost
Anaerobic fermentation	Animal droppings	UAH/MJ	0,192
Ethyl fermentation of agricultural biomass conversion	Maize	UAH/MJ	0,33
	Sugar beets	UAH/MJ	0,41
	Treacle	UAH/MJ	0,26
	Wheat	UAH/MJ	0,36
	Potato	UAH/MJ	0,79
	Sorghum	UAH/MJ	0,27
Etherification of agricultural biomass conversion	Rape	UAH/MJ	0,31
Conversion of solid agricultural biomass	Pellets of straw	UAH/MJ	0,097
	Pellets of wood	UAH/MJ	0,128
	Pellets of sunflower husk	UAH/MJ	0,070
	Briquettes of wood	UAH/MJ	0,048
	Briquettes of straw	UAH/MJ	0,117
	Briquettes of sunflower husk	UAH/MJ	0,017
Gasification of biomass by pyrolysis technology	Biomass	UAH/MJ	0,082
Petrol	Oil	UAH/MJ	0,53
Diesel fuel	Oil	UAH/MJ	0,53
Stove fuel	Oil	UAH/MJ	0,25

According to the obtained results of the research, one can confirm that the lowest prime cost of a unit of energy can be obtained by means of conversion of solid biomass, particularly pellets and briquettes of straw, wood and sunflower husk, with their following combustion or gasification. Besides, it is worth to mention that application of different conversion technologies results in obtaining of energy products, differing in their kinds and value, such as liquid and gaseous motor fuel, which can be efficiently transformed into electric and thermal energy, using it in internal and external combustion engines (ICE and ECE) of cogeneration regime.

Solid biomass can be the most efficiently utilized into thermal energy, which can be used directly in technological processes, or transformed into other kinds of energy with application of ICE and ECE, operating in cogeneration regime. However, application of a multi-step transformation of energy causes decrease of its general efficiency factor (EF), that should be concerned in argumentation of energy system structure.

One should stress that it is possible to use a prospective pyrolysis technology for efficient converting of solid agricultural biomass into liquid and gaseous energy products.

Comparing to traditional energy products, such as natural gas, stove fuel, petrol and diesel fuel, prime cost of the obtained energy products is substantially lower, because of agricultural biomass conversion, proving economic efficiency of the technologies. Besides, one should note that utilization of biomass for energy needs makes a considerable ecological effect because of a zero quantitative balance of carbon dioxide and oxygen in the nature.

Consumption quality of energy is defined by its kind. Electric energy is of the highest value, because it can be efficiently transformed into all other kinds of energy. Its transportation and storage is simpler and more efficiency, as compared to other kinds of energy. Production of electric energy can use all other kinds of energy, but a considerable share of their energy is lost. Besides, installations, applying electric energy, have comfortable regulation of energy flow and thus, can be easily used in automated technological lines. It is also important to note that only electric energy can be used in electric technologies.

CONCLUSIONS

1. The article defines main indicators to assess investment projects, i.e. net present value, internal rate of return, modification internal rate of return, discounted payback period, investment profitability index. The indicators belong to dynamic (discount) ones, where discounting is a principal notion.

2. Considering substantial differences of energy products kinds and ways of their producing, analysis of the technologies of biomass conversion should be done separately for each of them.

3. Biogas, produced by processing of biomass by different technologies, is one of the most prospective energy resources, because biogas technologies supply efficient processing of organic residuals and improve ecological conditions of production processes. Biogas can be also used as motor fuel for heat engines, operating in cogeneration regime and producing electric and thermal energy.

4. Concerning high-energy value of briquetted and pelleted biomass, its utilization is a prospective and reasonable direction.

5. Comparing to fossil fuels, prime cost of the energy products, obtained by means of agricultural biomass conversion, is substantially lower, proving economic efficiency and reasonability of the technologies use.

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