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ЭКОНОМИКО-ЭНЕРГЕТИЧЕСКАЯ ОЦЕНКА ЭФФЕКТИВНОСТИ ВЫРАЩИВАНИЯ И ИСПОЛЬЗОВАНИЯ БИОЭНЕРГЕТИЧЕСКИХ КУЛЬТУР

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ECONOMIC-ENERGY EFFICIENCY EVALUATION OF GROWING AND USE OF BIOENERGY CROPS

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Аннотация

В статье определены перспективные направления решения проблемы энергозависимости Украины от импортных энергоресурсов путем развития биоэнергетики. Охарактеризовано потенциал страны для выращивания биоэнергетических культур в условиях Винницкой области с целью определения целесообразности и перспективности использования этих культур как источника альтернативной энергии. Проанализировано влияние почвенно-климатических условий на качество выращенной биомассы. На основе результатов проведенных расчетов энергетической и экономической эффективности выращивания биоэнергетических культур выявлен ряд недостатков в процессе производства биомассы и указано на важность повышения урожайности данных растений. Предложено комплекс мероприятий для повышения урожайности указанных культур путем разработки современных технологий их выращивания, уменьшение потерь урожая при сборе и освоение новых перспективных технологий выращивания биоэнергетических культур. Сделано обзор потенциала отечественной биоэнергетики в разрезе твердотопливной биомассы фитоэнергетических растений энергетической вербы, мискантуса и свитчграса. Выделено ряд факторов, сдерживающих развитие биоэнергетики в Украине и обобщено спектр проблем, требующих немедленного решения.

Abstract

The promising directions for solving problems of the country's energy dependence on imported energy resources through the development of bioenergy are justified. The potential of Ukraine for growing bioenergy crops and the research and production activities of one of the experimental and breeding stations in Vinnytsia region to determine the effectiveness of growing and using these crops has been characterized. The influence of soil and climatic conditions on the quality of the grown biomass (using the example of Uladovo-Lyulinetsk experimental selection station of the Vinnytsia region) was analyzed. Based on the results of calculations of the energy and economic efficiency of growing bioenergy crops, a number of shortcomings in the biomass production process were identified and the importance of increasing the yield of these plants was pointed out. Measures to increase the yield of these crops through the development of modern technologies of their cultivation, reducing crop losses in the collection and development of new promising technologies for growing bioenergy crops were proposed.

The potential of domestic bioenergy in terms of solid fuel biomass of phyto-energy plants of energy willow, miscanthus and switchgrass is considered. A number of factors hindering the development of bioenergy in Ukraine are highlighted and the range of problems that need immediate solution is summarized.

Ключевые слова: энергозависимость, возобновляемая энергетика, биомасса, биотоплива, энергетические культуры, мискантус, свитчграс, энергетическая верба, экономическая эффективность, экономико-энергетическая оценка.

Keywords: energy dependence, renewable energy, biomass, biofuels, energy crops, miscanthus, switchgrass, energy willow, economic efficiency, economic and energy evaluation.

The problem formulation. Due to the rapid depletion of traditional energy resources in the world, limited and irrational use of fossil fuels, rising prices and high dependence of the world on their imports, the need to increase the share of alternative energy sources in the overall structure of energy consumption is becoming increasingly important. Involvement of renewable fuel sources in the general energy balance with simultaneous implementation of energy efficiency measures is especially important for Ukraine. This will not only increase energy security, but also improve the relevant environmental and social parameters. Sustainable use of biomass in Ukraine will reduce energy dependence on foreign energy suppliers. The transition to the use of alternative fuels will further contribute to the development of the economy (reduction of heat tariffs, creation of new jobs, additional contributions to the budget, etc.). The success and cost-effectiveness of alternative energy projects depend on the quality of research and development in the field of growing and processing bioenergy crops. In this context, the issues of economic and energy assessment of the efficiency of cultivation and use of bioenergy crops require particularly detailed study and analysis of prospects for practical implementation.

Analysis of recent research and publications. Leading domestic scientists, namely Hrytsyshyn M.I., Perepelytsia N.M. [2], Kaletnik H.M., Skoruk O.P., Branitsky Yu. Yu. [4], Roik M.V. [13, 14], Sinchenko V.M. [15] and others. However, the systematization of the results of scientific research and the formation of proposals for further implementation and implementation of scientific developments in the cultivation of energy crops in the direction of improving the country's energy security remains an insufficiently solved task.

Formulation of the article goals. The purpose of the article is to conduct an economic and energy assessment of the cultivation efficiency and use of bioenergy crops and identify promising areas of practical implementation of their bioresource potential in the direction of improving the energy efficiency of thermal energy systems.

The main material. In modern geoeconomic conditions, Ukraine is endowed with a synergy of natural-climatic and trade-economic conditions. The country's share of Europe's agricultural land is about 20%, of which 27% is arable land, and the land supply rate is 0.9 hectares per person, which is the highest among EU countries. The volume of blacksoil is estimated at 8% of world reserves, which opens up opportunities for Ukrainian industry to grow the vast majority of both agricultural and energy crops. All this, together with a powerful human potential, provides Ukraine with a guarantee not only of food security, but also the prospect of becoming an active player in the global biofuel market [1].

In the context of the economic crisis, in Ukraine there is a question of a rational solution to the problem of chronic dependence on imported energy resources due to the priority of the use of renewable energy sources. Among the optimal areas of renewable energy is biomass, the supply of which in Ukraine is almost the highest in Europe [3]. Its main sources include secondary resources of vegetative origin (straw, husks, stems, corn cobs, tree pruning), the potential of which is estimated at 50 million tons / year, and specific energy plants that provide significant increases in biomass that can be used. for the generation of thermal energy, the amount of which, according to scientists, can meet about 12-15% of Ukraine's needs. In addition to the energy effect, this direction will help to improve the environmental situation through the absorption of CO_2 and reduce emissions of pollutants into the air [9].

It should be noted that Ukraine has significant potential for cultivating the studied bioenergy crops. Soil and climatic conditions of most regions of the country contribute to the intensive transformation of solar energy into energy-intensive biomass of C_4 plants. These crops are unpretentious to soil fertility, do not require special application of fertilizers and pesticides, prevent soil erosion, create conditions for protection of agroecosystems and prevention of degenerative processes, as well as reduce the cost of biomass. Therefore, these types of crops can be grown on infertile soils, which, according to statistics, in Ukraine there are more than 8 million hectares [6]. Thus, according to European experts, the area of land available for growing energy crops in 2020 will increase to 20.5 million hectares, and in 2030 - up to 26.2 million hectares. In Europe, for farmers it is a profitable business and improving the condition of land, for local communities - rent, job creation, for the country - energy independence, improving the environment.

Ukraine is one of the energy-deficient countries, according to the Ministry of Energy and Coal Industry, the state's energy dependence on fossil fuel supplies is about 70%. In total, 114.8 million tons of fuel were consumed in 2019, of which only 53% were of own origin [7]. In 2019, the use of natural gas in Ukraine compared to 2018 decreased by 7% - from 32.3 billion cubic meters to 29.8 billion cubic meters while imports increased by 34.9% to 14.2 billion cubic meters. Accordingly, the structure of the modern fuel and energy complex of the state is based on imports of energy raw materials, the cost of which is constantly growing due to the rapid trend of increasing world consumption, which, according to world experts, by 2050 will increase more than twice. At the same time, almost 40% of energy needs will be covered by renewable energy sources, including about 30% - by biomass [15]. Due to favorable soil and climatic conditions for growing plants, one of the most promising types of alternative energy in Ukraine is phytoenergy, which is based on bio-raw materials of plant origin. Therefore, given the significant potential of plant resources in Ukraine, a promising way out of the energy crisis is the development of the bioenergy industry. The theoretical potential of biomass to ensure the production of biofuels in Ukraine, according to scientists, is about 50 million tons, but economically advantageous - 27 million tons. In modern conditions, one of the most profitable alternative fuel resources is solid biomass of plant origin, as evidenced by the rapid development of the production and use of solid biofuels in the domestic market of Ukraine and the growth of its exports mainly to EU countries. In 2015, Ukraine supplied about 1 million tons of pellets to foreign markets [9].

Currently, there are a number of companies in Ukraine that cultivate energy crops for market purposes, as well as conduct extensive research. A significant contribution belongs to the Institute of Bioenergy Crops and Sugar Beets of NAAS of Ukraine, in particular, in the field of research and selection of energy willow, poplar, miscanthus and switchgrass, which are relatively new "energy carriers" for Ukraine. The main advantages of plant biomass as an energy source include the environmental cleanliness of emissions compared to fossil fuels, the lack of negative impact on the balance of carbon dioxide in the atmosphere.

In Europe, there is a growing interest in crops grown for biomass as a source of renewable CO_2 - neutral energy and as a source of fiber for the production of paper and other renewable materials. To do this, many different species of plants are studied, such as willow, eucalyptus, poplar, as well as annual and perennial cereals. On the basis of the received practical developments of scientists of the Institute we will carry out the detailed characteristic of separate profitable kinds of researched energy cultures, among which miscanthus, energy willow and switchgrass.

Miscanthus is the most promising plant for the production of solid biofuels compared to other crops, due to its biological potential. The stems of the plant can reach up to 4 meters in height and contain 64-71% cellulose, which determines its high energy value. One ton of dry biomass of miscanthus is equivalent to 400 kg of crude oil, 1.7 tons of wood, 515 cubic meters. m of natural gas, or 620 kg of coal. As the experience of cultivation of miscanthus shows, the crop can be harvested annually by 20-25 tons of dry biomass from 1 ha for 20 years after two cycles of vegetation after the plantation of this plant Miscanthus is used as fuel in thermal power plants for electricity production, also burned in conventional solid fuel boilers for heating residential and industrial premises. For combustion in conventional solid fuel boilers, the finished crushed mass of miscanthus is pre-pressed into briquettes or fuel pellets. Important characteristics of miscanthus fuel pellets are environmental friendliness and energy safety, fire safety during storage, minimal emissions of carbon monoxide into the atmosphere during combustion and the absence of unpleasant odors, so the use of such biofuels will not contribute to the greenhouse effect. The energy value obtained during the combustion of miscanthus is equal to wood and is up to 19 MJ / kg. Ash after burning miscanthus can be used as a potash fertilizer on the same plantation [13].

Switchgrass is used in the production of solid biofuels and the pulp industry. In Ukraine, switchgrass is used as a phytoenergy crop for the production of solid fuels in the form of briquettes and pellets, as well as liquid biofuels in the form of ethanol and butanol, is a new crop that requires research to determine its growth, development and productivity, development of technological processes. Switchgrass is undemanding to agro-climatic conditions, has a high natural resistance to diseases and pests, which contributes to stable yields of dry biomass on low-fertile and eroded soils. Under such conditions, the height of switchgrass plants reaches from 1.0 to 2.5 m, and the yield of dry biomass from 7 t / ha to 14.2 t / ha, depending on the variety. With proper plant care, a biomass crop can be harvested for 15 years. The structure of switchgrass biomass has typical components for biofuel raw materials: about 50% carbon, 43% oxygen and 6% hydrogen. Dry biomass has a low ash content - up to 2-4%, relatively low content of potassium and sodium in combination with high content of calcium and magnesium, which contribute to high combustion temperatures and reduce the likelihood of slag during combustion in boilers. The cost of switchgrass biomass in different countries ranges from 15 to 40 euros / t of dry matter. In North and South America, a large number of varieties of switchgrass have been created that can be used in Europe and Ukraine after detailed study. According to scientific studies, varieties originating from South America are suitable for growing in both the Southern and Northern territories of Europe, but their cold resistance is lower compared to varieties of northern origin. [4].

Promising sources of raw materials for the production of solid biofuels include varieties of fast-growing willow (Salix Viminalis), which has gained popularity as a source of energy among highly developed European countries such as Denmark, Ireland, Sweden, Poland, England and others. Today, the largest area under this crop is occupied in Sweden (about 20 thousand hectares) and Poland (more than 6 thousand hectares). Willow is not demanding to the presence of nutrients, so it can grow on unproductive, acidic and wet soils [5]. In Ukraine, the use of willow biomass as an energy raw material is also widely developed. Currently, the area of energy willow plantations in our country is about 5,000 hectares [9]. To create energy plantations, it is important to choose a variety of willow for cultivation in certain soil and climatic conditions. One of the most promising species for growing on energy plantations is the willow.

Here are the key soil and climatic conditions for the growth of bioenergy crops, grouped by scientists from the Institute of Bioenergy Crops and Sugar Beet NAAS on the basis of experiments conducted in the Vinnytsia region, in areas where black soil predominates deep low humus, average humus content 7% (Table 1).

Table 1

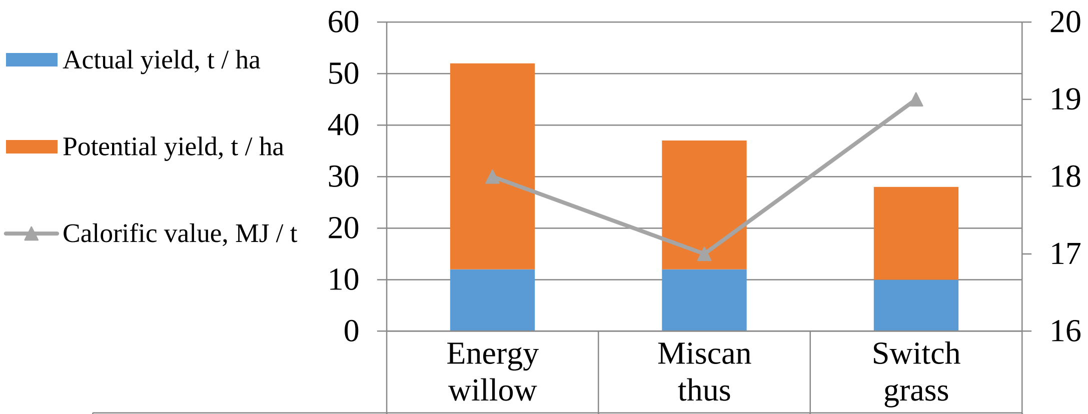
Soil and climatic conditions for growing bioenergy crops

Indicator	Energy willow	Miscanthus	Switchgrass
Soil	unproductive, degraded		
The slope of the field	>5 C°		
Acidity, pH	5 - 7	6,5 – 7,5	5 - 7
Depth of groundwater	up to 2 m	4 m	5 m
Precipitation per year, mm	not less than 700	500 - 700	400 - 600
Climatic zone	sufficient moisture during the year	sufficient and unstable moisture during the year	unstable and insufficient moisture during the year

Source: [13]

In general, Vinnytsia region is a powerful industrial and agricultural region, whose innovative activity demonstrates efficiency in a range of areas. One of such important strategic directions is bioenergy, as modern changes in the energy vector of the state provide for the creation of a reliable and efficient breeding base of energy crops, development of projects to attract investment in the agro-industrial complex to build potential facilities for bioethanol, biodiesel, biogas and solid biofuels. and introduction of an alternative energy consumption system. According to the Ministry of Agrarian Policy, the technically achievable energy potential of Vinnytsia region by agricultural by-products is 0.69 million tons. According to this indicator, the region ranks 6th among other regions of Ukraine [4].

The next stage of research is highlighted in Fig. 1 and fig. 2, from which it follows that the actual yield achieved in the Vinnytsia region is somewhat low. Energy willow showed a result of 12 t / ha, while the average in Ukraine - 26 t / ha. Under the conditions of reaching the maximum values of potential yield, the energy yield of willow can increase more than 3 times - up to 40 t / ha, which will increase the energy efficiency of their cultivation.



	Energy willow	Miscan thus	Switch grass
Potential yield, t / ha	40	25	18
Actual yield, t / ha	12	12	10
Calorific value, MJ / t	18	17	19

Fig. 1. Energy efficiency of growing energy plants in the Vinnytsia region
Source: summarized by the authors

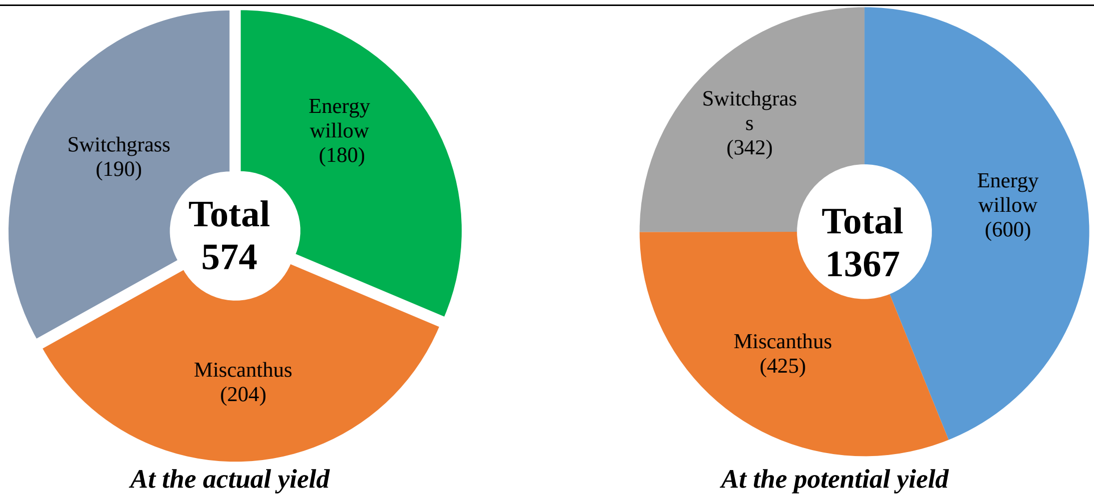


Fig. 2. Energy yield, MJ / ha per year
Source: summarized by the authors

Based on the analyzed data, we calculate the economic efficiency of growing biomass of energy crops (table 2)

It should be noted that the peculiarity of these energy crops is that in the first years after planting they form the root system and increase biomass, so they are unproductive. Cost-effective yields can be achieved in the 3rd year of vegetation for willow and switchgrass and in the 5th year of vegetation for miscanthus. Therefore, the period of full payback of plantations of bioenergy crops - from 5 to 10 years [14].

Table 2

Theoretical calculation of economic efficiency of growing bioenergy crops in the Vinnytsia region, per 1 hectare of crops, 2019

№	Indicators	Energy willow	Miscanthus	Switchgrass
At the actual yield				
1	The cost of dry biomass, UAH	4200	3120	1900
2	Cost of 1 ton of dry biomass (UAH / t)	350	260	190
3	Sales price, UAH / t	734	504	360
4	Sales revenue, UAH	8808	6048	3600
5	Profit, UAH	4608	2928	1700
6	The level of profitability, %	109,7	93,8	89,4
At the potential (maximum) yield				
7	The cost of dry biomass, UAH	9200	5000	3150
8	Cost of 1 ton of dry biomass (UAH / t)	230	200	175
9	Sales price, UAH / t	734	504	360
10	Sales revenue, UAH	29360	12600	6480
11	Profit, UAH	20160	7600	3330
12	The level of profitability, %	219,1	152,0	105,7

Source: calculated by the authors

From the table. 2 it follows that with the actual yield of energy crops the highest profitability per 1 ha of crops has the cultivation of energy willow (although its cost of cultivation is quite high - 350 UAH / t, but the selling price, which is 2 times higher than the cost of its cultivation, provides stable high product profitability). The profitability of miscanthus (93.8%) and switchgrass (89.4%) also has a high level (for each hryvnia of advanced expenses UAH 0.93 and UAH 0.89 profit, respectively) are obtained. The growth of the level of product profitability under these conditions is significant: energy willow - 2 times; miscanthus - by 58.2 points; switchgrass - by 16.3 points. The potential profit, under the conditions of commercial sale of biomass, under these conditions will increase 3.36 times (from 9236 UAH / ha at the actual yield, to 31090 UAH / ha under the condition of achieving the maximum yields of the studied energy crops). From a hectare of plantation you can collect about 25 tons of crop per year, harvesting every three years, that is, to get cod every year, you need to plant plantations, taking into account the rotation of plants. For example, if the harvest is at intervals of three years, it is logical to plant the plantation in three measures (years) to have a harvest of one third of the total area each year.

We consider the direction of biofuel production development from energy crops to be promising, first of all, due to the difficult situation of providing Ukraine's energy needs with its own energy resources. In accordance with the updated Energy Strategy of Ukraine for the period up to 2030, in terms of energy intensity of GDP, our country is several times higher than the developed countries of Western and Eastern Europe. Thus, the energy intensity of Ukraine's GDP is 0.55 tons at $ 1,000 GDP compared to 0.1 - for Germany, 0.2 - for Poland and 0.46 - for Russia. Given the country's dependence on imports of energy sources such as gas and oil, high energy intensity limits the competitiveness of national production and places a heavy burden on the economy. In addition to economic and environmental feasibility, the use of energy crops is necessary for Ukraine to strengthen national energy security, as well as to join the European and world energy community. According to the Secretariat of the Energy Charter, the potential for energy savings in Ukraine is 27 million tons AD. (equivalent to about 12 billion euros), or 25% of final consumption of all energy resources [3]. The use of renewable fuel sources is one of the most important areas of Ukraine's energy policy aimed at saving traditional fuel and energy resources and improving the environment. Increasing the share of alternative energy sources in Ukraine's energy balance will increase the level of diversification of energy sources, which will help strengthen the country's energy independence. In addition, according to the Concept of implementation of state policy in the field of heat supply, approved by the order of the Cabinet of Ministers of August 18, 2017 № 569-r, [11] aims to achieve 30% share of renewable energy in the overall balance in 2019-2025 heat supply systems, and in the period 2026-2035 - up to 40%. Ways to achieve these goals are described in the National Renewable Energy Action Plan for the period up to 2020 (NREAP), approved by the Order of the Cabinet of Ministers of October 1, 2014 № 902-r [12]. According to this Plan, the goal is to achieve 11% of RES in gross final energy consumption in 2020. At the same time, only in the heating sector is expected to contribute biomass in the amount of 5000 thousand tons AD / year, which will be 85% of the contribution of all RES in this sector in 2020. The planned figures for the contribution of biomass correspond to the replacement of natural gas in the amount of 6.25 billion cubic meters. m / year in the thermal energy sector and 0.95 billion m^3 / year in the electricity sector (predicting that 90% of electricity capacity on solid biomass will operate in the mode of thermal power plants - TPP), which together should replace natural gas in the amount of 7.20 billion cubic meters / year [9].

Let`s calculate the feasibility of growing and processing of the described energy plants in the Vinnytsia region. Thus, the production of biofuels from biomass of energy crops involves the use of agricultural land, namely arable land, the area of which in the Vinnytsia region, as of 01.01.2019, according to the State Geocadastre [6] is 1725.5 thousand hectares. If we set aside 7% for sowing energy crops, we will get an area of 120.8 thousand hectares. Allocating for their cultivation area in accordance with the reduction of profitability. Thus, we will allocate 100,000 hectares, miscanthus and switchgrass to grow 10.4 thousand hectares each. As a result, it is possible to obtain, according to the average yield, dry weight of energy willow 2.6 million tons, miscanthus 192.4 thousand tons and switchgrass 145.6 thousand tons (table 3).

Table 3

Calculation of bioraw materials energy efficiency

Crop	Area of plantations, thousand hectares	Average annual dry mass yield (30% moisture), thousand tons	Yield of solid biofuel (10% moisture), thousand tons / year	Volume of natural gas that can be replaced, million m^3	Cost of replaced natural gas, UAH million *
Energy willow	100	2600	2080	1040,0	8696,3
Miscanthus	10,4	192,4	154	77,0	643,8
Switchgrass	10,4	145,6	116,5	58,3	487,5
Total	**120,8**	**2938**	**3231,7**	**1175,3**	**9827,7**

** for the calculation we take the price of 8361.85 UAH / thousand m^3, which is used in the calculation of heating services of budgetary institutions.*
Source: calculated by the authors

The calorific value of one kilogram of dry willow biomass averages 18 MJ. Thus, 1 ton of dry vine biomass (10% moisture) can replace 750 kilograms of coal or 500 cubic meters of natural gas, which means that 1 hectare of vine can annually produce environmentally friendly fuel equivalent to about 20 tons of coal or 13,000 cubic meters of natural gas. At the same time, the cost of vines in comparison with other types of fuel is much lower, which in these proposed scales can save gas in the amount of 1.175 billion cubic meters, or at a cost of exactly 9.827 billion UAH (Table 3). In addition, vine biomass can also be mixed with coal and coal waste without replacing the design of furnaces. In 2019, the use of natural gas in Ukraine amounted to 29.8 billion cubic meters. m, Vinnytsia region in 2019 consumed 821.5 million cubic meters. m, of which 1.3 million cubic meters. m - heating of budget organizations [8]. So, if you transfer the entire budget area to solid fuel boilers, the need for biomass of energy willow will be 2.6 thousand tons, which can be obtained from an area of 100 hectares, with an average yield of 26 t / ha, or 216 ha with a minimum - 12 t / Ha. Given that the collection of biomass is carried out every three years, it is necessary to plant an area of 300 hectares with an average yield, or 650 hectares with a minimum. The cost of the replaced gas will be UAH 11.885 million. The average selling price of dry biomass of energy willow in accordance with market conditions is 743 UAH / t, respectively, the cost of the required amount of biofuel will be 1.932 million UAH, additionally taking into account 579.54 thousand UAH of transportation costs, we will receive 2.512 million UAH of heating costs of budgetary institutions of Vinnytsia under the conditions of transition to energy willow as a heat source, this, in turn, will save UAH 9.373 million of budget funds.

Additionally, we will calculate the heating of a room with an area of 1000 sq.m with different types of fuel: gas, coal, fuel oil and biomass of energy willow (Table 4). The need for thermal energy per hour will be 1000 square meters. m * 0.216 MJ = 216MJ / year. Taking into account the average boiler efficiency of 70% and 10% of the loss during transportation, the total specific amount of heat will be 302.4 MJ / h. The average calorific value of natural gas is 33.5 MJ / cubic meter, coal is 27 MJ / kg, dry mass of energy willow (10% moisture) is 18 MJ / kg.

Table 4

Economic and energy assessment of the different fuels use on the example of the heating area of 1000 square meters as of 2019.

Type of fuel	Fuel consumption, kg (m3) / h	Fuel demand for the heating season, t (thousand m^3) *	Thermal energy demand MJ / 1mkv / h	Fuel cost per season, thousand UAH	Savings, thousand UAH
Natural gas	9	36,72	0,216	307,4	-
Coal	11	44,88	0,216	278,3	72,0
Oil fuel	7,5	30,6	0,216	312,1	38,2
Energy Willow	17	69,36	0,216	65,91**	284,4

* heating season count - 170 days, duration 4080 hours.

** 30% is additionally included in the cost as costs for biomass transportation.

Source: calculated by the authors

Thus, from these calculations it is noticeable that the cost of heating with energy willow is the most profitable option, as the cost of 1 MJ of heat is 6 kopecks, in contrast to 27 kopecks. when using natural gas, and heating of 1000 sq.m of the area by a willow will allow to save 284,4 thousand UAH for 4080 hours of the heated season.

A practical confirmation of the declared efficiency is the solid fuel boiler house in the city of Vinnytsia, with a total capacity of 5.2 MW, which was put into operation in July 2016 and is an example of the transition from gas to alternative fuels. It works on wood chips and by the end of the year has saved 2.2 million cubic meters. m of gas. And the funds that were previously spent on the purchase of expensive gas, today remain in Vinnytsia and Vinnytsia region and replenish local budgets [10].

It is worth to mention that this technology of work on chips is not for ordinary domestic boilers, because for the efficiency of equipment and the feasibility of growing willow for self-sufficiency, the capacity must be at least 0.5 MW. The minimum starting volume should be 100-200 hectares of willow next to the boiler, then it will be a profitable business. 300 hectares of adult plantations will give 5.5-6 thousand tons of cod per year (at the rate of 18-20 tons per 1 hectare), which is approximately 10,000 Gcal of heat or UAH 14.6 million in average tender sales prices of UAH 1,460 per 1 Gcal, ie 1 ha of plantations gives a revenue of 45 thousand UAH in terms of heat. The cost of investment in 1 ha of energy willow plantations with a volume of 300 ha is, according to the Agro-Energy Company Salix Energy [5], 1000 Euro / ha (30.67 thousand UAH), this amount includes land preparation, purchase of quality planting material, professional planting and care in the first three years of plantation life. Thus, the cost of the plantation with the calculated maximum area of 650 hectares will cost UAH 19.94 million, with annual savings of UAH 9.373 million, the payback of such a plantation will be a little more than two years.

The proposed option of obtaining heat based on the use of bioenergy raw materials is promising for both the public sector and the utilities sector, as it provides a number of advantages (Fig. 3).

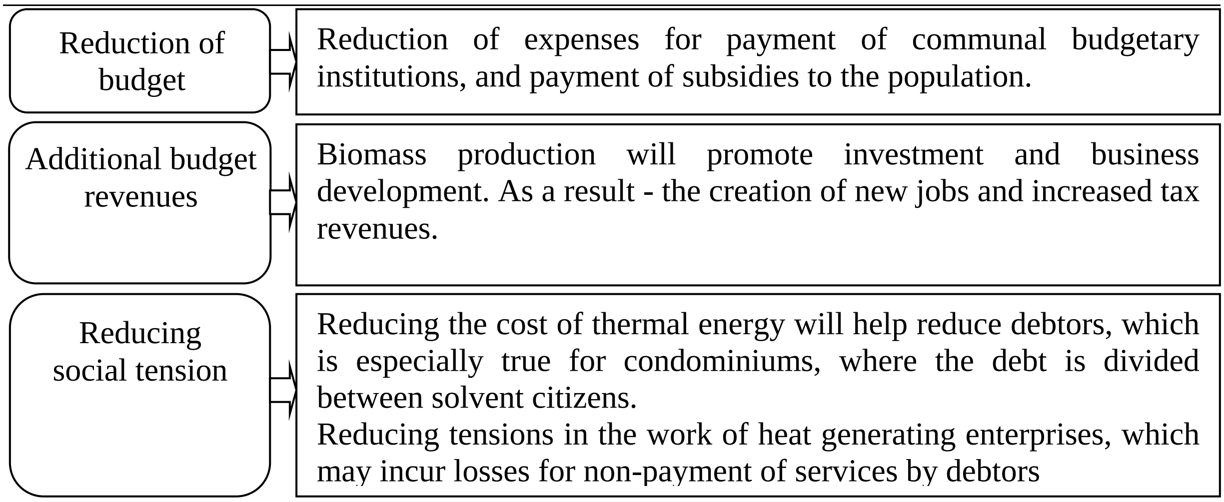


Fig.3. The main advantages of bio raw materials using as a source of thermal energy for the utilities sector
Source: generated by the authors

Thus, this type of heating will provide, firstly, cheaper energy, and secondly, filling budgets through additional investment in production and services, as well as reduce social tensions due to cheaper services, which in turn will allow to pay more fully for services provided by on the part of heat consumers.

Given the results of research, it should be noted that the potential of domestic bioenergy is quite high, as only solid fuel biomass of energy willow, miscanthus and switchgrass can replace about 10 billion cubic meters of natural gas. However, as noted by scientists Hrytsyshyn M.I. and Perepelytsia N.M. [2] there are a number of factors that hinder the development of bioenergy in Ukraine, in particular:

- the unresolved issue of the land market and the low, compared to other European countries, "green" tariff for energy produced from solid biomass;

- lack of mechanisms for providing preferences, benefits and subsidies to companies that are willing to invest in the implementation of agro-energy projects, which creates a large investment burden for the investor at the initial stage of planting.

- lack of objective information on the potential effectiveness of invested capital.

Most business projects offered to domestic producers justify the economic efficiency of investment, referring to foreign experience. However, such calculations do not correspond to the realities of doing business in the Ukrainian legislative field. Therefore, to maximize the economic potential of the industry of bioenergy resources, development and strengthening of its position in international and domestic markets, it is necessary to solve a number of urgent problems, such as:

- determining the feasibility of attracting investment in the formation of the material and technical base for growing bioenergy crops;

- creation of favorable regulatory and legal and organizational and economic conditions for increasing the raw material base and processing sector of the bioenergy sector, increasing the efficiency of their operation [2].

Conclusions. Thus, the aggravation of the problem of environmental pollution, lack of fossil energy resources and their growing shortage has led to the expansion of the use of alternative energy sources, including bioenergy crops used for the production of various types of biofuels. Ukraine has all the necessary prerequisites for this, namely: favorable soil and climatic conditions; a sufficient amount of land withdrawn from agricultural use, allowing the country to take a leading position among European countries in the production and use of biofuels from biomass.

The analysis of economic and energy assessment of the use of different types of heating is the most promising due to the low cost per unit of thermal energy is the use of energy willow. The proposed option of transferring budgetary institutions of the region to use this type of fuel will save about 9 million UAH of budget funds.

The calculations revealed certain shortcomings in the process of growing biomass, namely low yields of energy willow. 12 tons of biomass were collected from a hectare of plantation, with an average of about 25 tons. Therefore, the main way to increase the economic efficiency of growing energy crops is to increase yields.

The main measures to increase yields should be:

- development of modern technologies for growing energy crops;

- introduction of resource-saving technologies (use of high-yielding varieties under the conditions of ensuring the implementation of technological operations in accordance with agro-technical requirements;

- reduction of crop losses during harvesting;

- increase of production culture, provision of insurance protection of crops;

- development of schemes of means of protection of power plantations, mechanized harvesting and processing of a crop taking into account available material and technical base of research station;

- development of promising technologies for growing bioenergy crops, which are planned for industrial processing into biofuels, etc.

In addition, to receive cod annually, it is necessary to plant plantations taking into account the rotation of plants, ie a three-year cycle. Thus, increasing the efficiency of growing bioenergy crops, promoting the production and use of biofuels, will create additional employment and become a source of budget replenishment, and further allow Ukraine to get rid of the status of energy-deficient state and strengthen economic and energy independence.

Prospects for further research are to substantiate innovative technologies for growing bioenergy varieties of plants and develop conceptual directions for the implementation of heat generation systems using solid fuel boilers on biofuels, which will increase energy independence and reduce unit cost of thermal energy.

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