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RECENZENCI:
dr hab. Agnieszka Dołhańczuk-Śródka, prof. UO
dr hab. inż. Stanisław Gajda, prof. UO
dr hab. Daniel Janecki
prof. zw. dr hab. Jan Róg

KOREKTA TECHNICZNA:
mgr inż. Marzena Wiener

SKŁAD I ŁAMANIE:
dr inż. Dariusz Suszanowicz

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32-800 Brzesko, pl. Kazimierza Wielkiego 14
NIP 869-103-66-47, REGON 122818358
Telefon: +48 504 004 517
e-mail: office@coti.info.pl
www.coti.info.pl

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REVIEWERS:
dr hab. Agnieszka Dołhańczuk-Śródka, prof. UO
dr hab. inż. Stanisław Gajda, prof. UO
dr hab. Daniel Janecki
prof. zw. dr hab. Jan Róg

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mgr inż. Marzena Wiener

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dr inż. Dariusz Suszanowicz

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31-623 Brzesko, pl. Kazimierza Wielkiego 14
NIP 869-103-66-47, REGON 122818358
Mobile: +48 504 004 517
e-mail: office@coti.info.pl
www.coti.info.pl

SPIS TREŚCI

Antonina KALINICHENKO[1], Oleksandr KALINICHENKO[2], Maksym KULYK[2]

ASSESSMENT OF AVAILABLE POTENTIAL OF AGRO - BIOMASS AND ENERGY CROPS PHYTOMASS FOR BIOFUEL PRODUCTION IN UKRAINE

OCENA DOSTĘPNEGO POTENCJAŁU FITOMASY Z UPRAW ROLNICZYCH DO PRODUKCJI BIOPALIW NA UKRAINIE

Summary. Scientific article carefully examines publications concerning the problem of using biomass as a renewable energy source in Ukraine**.** It is necessary to introduce plant recourses into fuel and energy complex of our country. Purpose. Assess the available potential of agrobiomas and phytomass of energy crops for the production of biofuels in Ukraine. Methods. Field study, laboratory analysis, analytical approach. Results. The article presented detailed assessment technique, determined potential and calculated energy efficiency of using agro-biomass and energy crops phytomass for biofuel production in Ukraine. During the years of the experiment energy crops had much more yield of equivalent fuel than agro-biomass of agricultural crops had. According to energy potential energy willow, silver grass (Miscanthus giganteus) and switch grass (Panicum virgatum) provide the greatest yield of equivalent fuel (in the range of 8.4 - 18.7 t eq. f./ha) in comparison with plant residues of field crops. Conclusions. Use of agro-biomass as well as energy crops phytomass for biofuel production allows to decrease Ukraine energy dependence upon non-renewable energy sources and to increase population welfare.

Key words: energy, energy crops, plant biomass, energy capacity, energy potential

Introduction

Today the active use of nonrenewable resources requires involving of alternative for steadily increase of mankind’s need for energy. Development and use of alternative energy source, in particular plant residues, agro - biomass and energy crops phytomass is very important for Ukraine [2,10].

Today plant biomass as biofuel occupies the fourth place in the world according to output. The part of biomass in total output of primary energy is 10% in the world and this part is less than 2% in Ukraine [28]. That is why the problems of wide introduction of renewable energy sources into economics of our country and study of plant resource potential are very urgent.

[1] Independent Department of Process Engineering, University of Opole, R. Dmowskiego 7-9, 45-365 Opole, Poland, phone: +48 77 401 66 97, e-mail: akalinichenko@uni.opole.pl
[2] Poltava State Agrarian Academy, 36003, Poltava, Skovorody 1/3, Ukraine

As the author notes [38] crisis in the East of Europe has highlighted a number of weaknesses of the Ukrainian energy sector: excessive dependence on Russia, grid instability, economic inefficiency and lack of flexibility. The renewable energy sources can become part of the solution of the Ukrainian energy equation. Increasing the share of renewable energy will translate into an increase in Ukraine's energy security, which is also in the interests of Poland and the European Union.

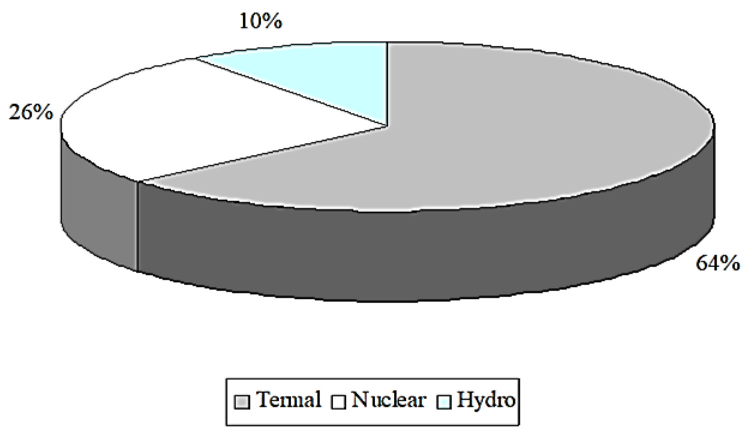

Fig. 1. Installed capacity of power plants in Ukraine Source: UA Energy [25]

"Energy strategy of Ukraine till 2030 year" [8] expects dynamic growth of biomass energy usage up to 5 million ton of oil equivalent or 2.5% from total power consumption in 2015 year and in 2030 year growth up to 20 million ton or 10% [6].

According to the Energy Strategy of Ukraine 2030, it is planned that the share of alternative energy will amount to 11% of the total amount of energy produced in Ukraine in 2020. These 11% account for 12000 megawatt (6800 megawatt will be delivered by hydroelectric power stations and pumped-storage hydroelectric power stations, 5200 megawatt will be delivered by small hydro power stations, wind power stations, solar power stations, biomass and biogas), (fig. 2) [4].

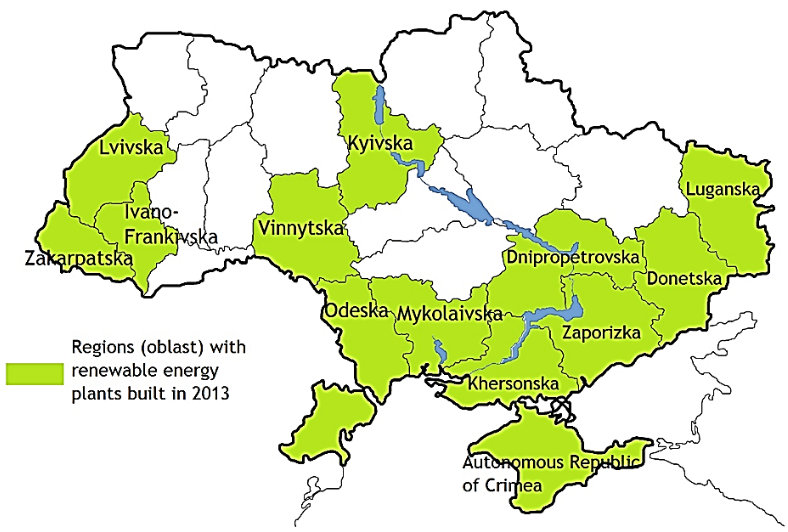

Fig. 2. Regions with renewable energy plants built in Ukraine Source: UA Energy [25]

Currently in Ukraine there are many solar power stations; wind power stations; biomass and biogas plants; and about 100 small hydro electric power stations across different regions (oblast) of Ukraine.

Literature review

Ukraine has great potential of biomass available for energy usage [1] and substantial prerequisites for expanding usage of plant residues for biofuel purposes such as production of solid, liquid and gas fuel.

Winter wheat, corn, sunflower and soybean occupy the largest sown areas in Poltava region as well as in Ukraine [9]. These crops are used for producing bread, groats, oil and feed for animals [24]. By - products as straw, stems, stubbles, bean valves and peelings are usually left in the field (fig. 3) and hardly used for animal husbandry purposes.

a) b) c)

Fig. 3. Plant residues of crops:
a) straw of grain, b) corn stems, c) sunflower strems [17]

Involving agro-biomass into energy production can satisfy nearly 13 percent of primary energy demand in Ukraine. However, bioenergy sector in Ukraine must develop consequently and reasonably taking into account possible effect on the national economics and environment [3]. Very precise assessment of biomass potential is considerably important for stable and economically sound biomass use for energy purposes (table 1).

Table 1. Potential of agro - biomass in Ukraine [3]

Oblast	Available potential, thousand. t.o.e. (ton of oil equivalent)
Vinnytsia	663
Poltava	625
Kirovograd	538
Dnipropetrovsk	536
Cherkasy	502
Odessa	489
Sumy	422
Others	Less than 400

Vinnytsia, Poltava, Kirovograd, Dnipropetrovsk, Cherkasy, Odessa and Sumy oblasts have the greatest potential of agro - biomass (more than 400 thousand t.o.e).

Today biomass provides nearly 2 billion tons of equivalent fuel per year or 14 percent of primary energy consumption in the world. Energy production from renewable sources covers 7 percent of power consumption in EU member countries, and biomass covers 4 percent in particular [29].

Biomass in Ukraine occupies the leading place among other energy sources forming considerable market part of renewable energy sources, providing production of heat and different kind of biofuel: solid (pellets, granules), liquid(bioethanol, diesel biofuel) and gaseous (biogas) [42].

The use of materials from natural resources in production and consumption processes has many environmental, economic and social consequences that extend beyond borders and affect future generations. They have consequences on: The rates of extraction and depletion of renewable and non-renewable natural resource stocks, and the extent of harvest and natural productivity of renewable resource stocks [31].

Biomass of perennial energy crops is the most suitable raw material for production of all kinds of biofuel and for obtaining cheap energy in many countries of the world. Energy crops are plants characterized by perennial life cycle and capable to accumulate substantial phytomass due to intensive growth and development during the period from early spring till late autumn осені (fig. 4) [34].

a) b) c)

Fig. 4. Energy crops: a) silver grass, b) nergy willow, c) switchgrass [17]

Energy crops are herbaceous plants, shrubberies, fast - growing trees or other kinds of plants, biomass of which can be used for biofuel production (solid fuel, liquid soil and gas fuel) [18].

Foreign scientists [40,41,39] established the peculiarities of usage of switchgrass and silver grass biomass in energy and fibre production: high index of net energy production per one hectare; low cost; low plant requirement in nutrients; low ash content in raw material, high coefficient of moisture usage; wide area of plant distribution; simple cultivation, adaptability to cultivation on low-productive soils and capability of carbon preserving in soil. The scientists recommend growing energy crops on low productive soils, degraded lands not changing land use on marginal lands.

Liska, 2017 [36] established the level of soil organic carbon and its quantity from plant material. This scientist's results of the USA and India researches showed that transformation of harvest remains to organic carbon and CO_2 is mostly conserving process taking place all over the world. It has been determined that carbon emission and CO_2 quantity from plant residues per energy unit in biofuel do not depend upon amount of excluded residues and raw material location.

Authors of the article [33,37,43] having analyzed the current situation and future potential of marginal land resources in China as well as potential of agriculture and forestry had determined that development and function of traditional agriculture in food production can contribute to the sustainable development of China's social, economic and environmental life, energy savings and reduction of hazardous emissions. China has enormous energy potential of marginal land resources and environmental construction of the country can be improved due to combined energy agriculture.

The author [32] pointing out soil changes on perennial plantations of energy crops established that pH level in soil layers of 0 - 30 cm decreases, available phosphorus content in soil increases by 8 - 13 percent, calcium and magnesium changes are slight (apart of silver grass plantations, there the first index decreased) and changes of general nitrogen content were relatively high (4 percent more than on control variants). Thus, the risk of damaging environment perennially cultivating energy crops (willow, silver grass, sida hermaphrodita) is slight while simultaneously increasing organic carbon content in soil.

Energy crops are a source of carbon neutral raw material. They protect soil from different kinds of erosion, improve biological diversity and microclimate, favour to accumulation of humus and organic matter and development of soil fauna, and minimize application of herbicides, pesticides and mineral fertilizers. Energy crops can be used for decreasing water pollution while purification of sewage and refuse tit [14,15].

M.V. Roik with coauthors shares this point of view [26] and affirms that energy crops are perspective and profitable plants for cultivation on low productive soil.

Switchgrass (Panicum virgatum), silver grass (Miscanthus giganteus) and energy willow are the most widespread energy crops in Ukraine [16].

1. Switchgrass is a warm-season, perennial grass, forming strong root system and vertical hollow stems of different colours growing up to 3 metres tall. The inflorescence of this grass is panicle. Reproduction is by seed and from clonal offsets of the rhizomes. Switchgrass provides yield up to 18 t/ha of dry mass with energy capacity of 17 MJ/kg [15].
2. Silver grass (Miscanthus giganteus) is a warm-season, perennial grass, forming strong root system and vertical stems growing up to 5 metres tall. Vegetative reproduction. Yield is 20 - 30 t/ha of dry mass with energy capacity of 18 - 19 MJ/kg [17].
3. Energy willow is a ligneous and shrubby plant of Salicaceae species, having a rapid growth. Willow does not make great demand on the soil and moisture.Vegetative

reproduction. Yield is up to 30 t/ha of dry mass with energy capacity of 18 - 20 MJ/kg [18].

According to natural and economic factors Ukraine belongs to countries with favorable conditions for both food and energy security. The country has a significant potential for creation of stable market for energy crops and using their raw materials for the biofuel industry [19].

The territory of Ukraine is divided into three natural and climatic zones: Polisia, Forest-steppe and Steppe. These zones have specific soils, climate, temperature regimes, rainfall and crop production technologies.

The main types of soils in Polisia are sod-podzolic soils with different degrees of podzol and mechanical composition. Climatic conditions are characterized by moderately continental climate. The annual precipitation varies from 550 to 650 mm.

The main types of soils in Forest-steppe are clear-gray loess, gray loess, dark gray podzol, chernozem podzol, typical chernozem, meadow chernozem and meadow soils. Climatic conditions are diverse (higher average annual air temperature). The annual rainfall varies from 450 to 550 mm.

The main types of soils in Steppe are chernozem and chestnut, common meadow black soil, meadow - chestnut, meadow and saline soils. Climatic conditions are continental. Annual precipitation varies from 350 to 450 mm.

Distribution of potential of energy crops across the territory of Ukraine is quite diverse from 9 thousand t.o.e. (Uzhgorod oblast) to 736 thousand t.o.e. (Zhytomyr oblast). Zhytomyr, Chernigiv, Kyiv, Odessa, Zaporizhia, Kherson oblasts and Crimea are characterized by the highest energy crops potential (more than 400 thousand t. o. e.) (tab. 2).

Table 2. Potential of energy crops in Ukraine [18,19]

Oblast	Available potential, thousand t.o.e. (tons of oil equivalent)
Zhytomyr	736
Chernigiv	546
Kyiv	417
Poltava	405
Others	less 400

In 1975 International Federation of Institutes of Prospective Research initiated foundation of a new field of agroecosystem research in terms of energy expenditure on food, feed and raw materials for light industry.

Crop production is the only branch of agriculture involving the process of energy consumption, as well as its reproduction. In other branches of agriculture energy is transformed into different forms.

Energy is a measurement (joule) of movement of matter. It is not an object or a phenomenon, but only its characteristic. Energy neither arises nor disappears from anything, but only changes from one form to another. The concept of "energy" connects all phenomena of nature and economic system. Energy can be produced, transferred, consumed and measured.

The concentration (power) of solar energy reaching the Earth's surface, on average, does not exceed kW/m^2. The coefficient of efficiency of solar energy entering the photosynthesis of carbohydrates (glucose) in plant leaves or grass does not exceed 1 percent, and in wood - only 0,1percent [30].

Different kinds of plants have different ability to accumulate kinetic energy of the sun and posses different energy value.

Thus, solar energy loses to 99.9 percent of primary energy, dissipating it even in less quality form having concentrated in a higher energy quality form of interatomic bond in a plant. In the process of carbonization, the plant biological mass losing half of the concentrated solar energy with a coefficient of 0.5, transforms the energy balance into more concentrated form in the mineral coal components [30].

The further process of increasing concentration of solar energy in coal or any derivatives of plant biomass used by the modern economy as energy carriers (turf, coal, oil, gas) is the conversion (interconversion) of their internal energy into a mechanical work of steam turbines, internal combustion engines or into electric energy (a quarter of a coal energy). In this case, the integrated coefficient of solar energy conversion into electric energy will be 0.000125 (0.0125%), hence 99.9875% has been lost, but energy concentration has increased by 8000 times. 8000 J of solar energy are spent in order to get 1J of electric energy.

Solar equivalent can be a measurement of energy quality [30]:

$$К_с = \frac{Е_с}{Е_к} \qquad (1)$$

where:

$К_с$ - coefficient of energy quality, solar equivalents,

$Е_с$ - solar energy coming to conversion, [J],

$Е_к$ - energy, as a result of direct or sequential conversion of solar energy, [J].

Equivalent of equivalent fuel can be more efficient characteristic of energy quality (eq. f.) [13]:

$$К_п = \frac{К_с}{К_{с.у.п}}, \qquad (2)$$

where:

$К_п$ - degree of energy concentration in the given kind of fuel relatively energy concentration in equivalent fuel, eq. f.,

$К_с$ - solar equivalent of the given form of energy, [J],

$К_{с.у.п.}$ - solar equivalent of equivalent fuel, [J].

Specific heat capacity of equivalent fuel combustion is 29.3 MJ /kg and its solar equivalent is 2000 so in order to get 1kg of fuel it is necessary to spend 29.3 MJ·2000 = 5860 MJ = 5.86 GJ of solar energy [13].

Values of $К_с$ and $К_п$ equivalents for different types of energy carriers are given in the table 3.

Table 3. Coefficients of energy quality(equivalents) and conversion (interconversion) [13,30]

Energy Carriers	**Solar equivalent**	**Equivalent of fuel Equivalent**	**Coefficient of technical conversion**
Sunlight	1	0.0005	Into electric - to 0.1
Plant mass (wood)	1000	0.5	
Fossil fuel			
Coal, oil, gas (for equivalent fuel)	2000	1	Into thermal - to 0.6 in mechanical - to 0.4 into electric - to 0.5
Mechanical energy			
Stream of falling water, flows, wind	6000	3	Into electric - 0.97
Electric energy	8000	4	in mechanical - 0.99

Thus, determination of available potential of crops biomass and energy crops phytomass for biofuel production is an urgent problem nowadays.

Research methods and material

The experiment combined the study of available potential of agro - biomas of the following plants: winter wheat, corn, sunflower (agricultural crops) and switchgrass, silver grass (Miscanthus giganteus), energy willow (energy crops).

Generally accepted methods [6,7] as well as special methods [11,27,35] have been used in the research.

The energy assessment of energy crops cultivation is useful for determination degree of means of production usage, solar radiation, soil and climatic conditions and other factors effecting crop yield and establishing ecologically permissible limits of energy load per unit area. The energy assessment unlike cost assessment helps to determine the effectiveness of cost regardless of market conditions changes and inflationary processes.

Energy capacity is the widely used index for establishing the degree of crop energy efficiency. This index describes ratio of total energy consumption of crop production to gross output. That is, energy capacity reflects the degree of rational use of aggregate energy expenditures in gross crop production [12].

Yield of main products was determined by recalculation of each crop yield on standard humidity and purity. By-products yield was established applying special methods such as generalized evaluation of technically available biomass potential [6].

Potential of plant residues of crops was determined according to formula:

$$П_{рр} = ВЗ_{оп} \cdot К_{рр}\,(1 - К_в)\,К_{ев}, \quad (3)$$

where:
$П_{pp}$ - potential of plant residues of crops, [t/ha],
$ВЗ_{оп}$ - gross yield of main products, [t/ha],
$К_{pp}$ - coefficient of plant residues,
$К_{в}$ - coefficient of plant residues losses,
$К_{ев}$ - coefficient of plant residues usage.

Energy potential of plant residues ($ЕП_{pp}$) was determined according to formula:

$$ЕП_{pp} = \frac{П_{pp} \cdot К_{т.з}}{700} \tag{4}$$

where:
$ЕП_{pp.}$ - energy potential of plant residues of crops, t eq. f.;
$П_{pp}$ - potential of plant residues, [t],
$К_{т.з}$ - lower heat of plant residues combustion, [kilocalorie/kg],
7000 - caloric power of 1 kg oil equivalent, kilocalorie.

Experiments of energy crops cultivation were carried out according to the methodical recommendations of V. L. Kurylo and other scientists [22,20]. Accounting of harvest of vegetative above - ground mass of plants was done according to A. A. Babych's method [23]. Energy efficiency was estimated by methods of R.V. Morozova and Ye. M. Fedorchuka [21].

The statistical processing of the obtained research results was carried out applying the methods of dispersion, correlative and regressive analysis using the licensed computer program Statistica - 6.0.

Research results

Comparative assessment of agro - biomass and phytomass of energy crops according to the production period has been done due to the summarized research results (tab. 5).

Table 5. Logistics chain of plant cultivation and tending, harvesting main products and by - products of energy crops, 2013 - 2016 years

Crops	**Year**															
	2013				**2014**				**2015**				**2016**			
	sp*	**s**	**a**	**w**	**sp**	**s**	**a**	**w**	**sp**	**s**	**a**	**w**	**sp**	**s**	**a**	**w**
Winter wheat			[light green]		[green]	[orange]	[light green]		[green]	[orange]	[light green]		[green]	[orange]		
Corn	[cyan]	[green]	[orange]		[light green]	[green]	[orange]		[light green]	[green]	[orange]		[light green]	[green]	[orange]	
Sunflower	[cyan]	[green]	[orange]		[light green]	[green]	[orange]		[light green]	[green]	[orange]		[light green]	[green]	[orange]	
Switchgrass	[cyan]	[green]			[green]	[green]		[orange]				[orange]	[green]			[orange]
Miscanthus	[cyan]	[green]			[green]	[green]		[orange]				[orange]	[green]			[orange]
Willow	[cyan]	[green]			[green]	[green]		[orange]				[orange]	[green]			[orange]
Signs:																
	[cyan] - sowing / planting								[green] - plants tending							
	[orange] - harvesting main products and by - products															

*Note: sp – spring period, s - summer period, a - autumn period, w - winter period
Source: author's development

Efficiency of power consumption in the process of cultivating energy crops is determined by four groups of factors:

1) bioclimatic conditions,
2) degree of plant production technology development,
3) technical support,
4) organization and economic (fig. 6).

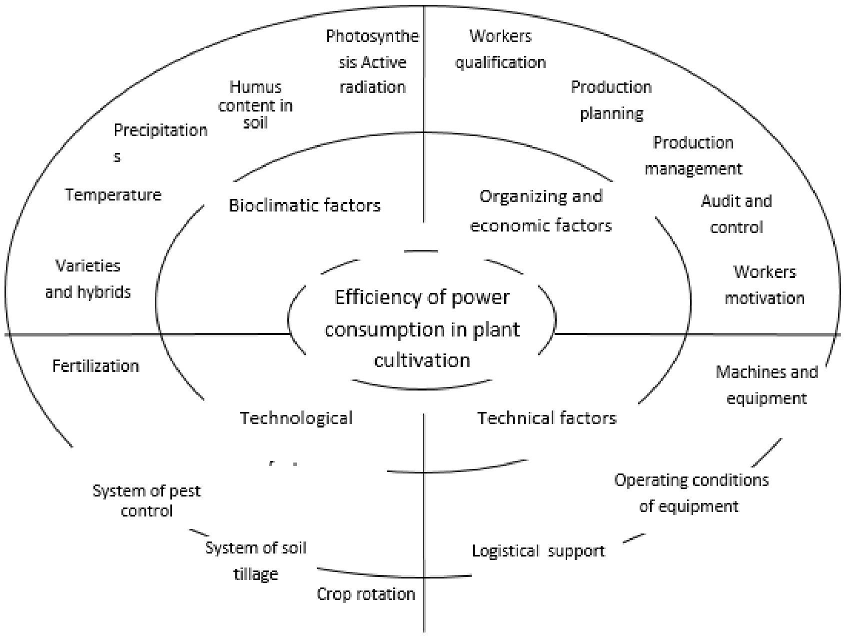

Fig. 6. Factors of energy efficiency of crop cultivation [11]

It is necessary to take into account that all components of the system are closely connected and interdependent planning actions to increase power consumption efficiency.

Yield of crops by-products has been established according to the research results **(**tab. 4 - 5).

Table 4. Yield of crops, t/ha (2014 - 2016 years)

Crop	Years			Average
	2014	2015	2016	
Winter wheat	4.0	3.8	4.2	4.0
Corn	6.1	5.7	6.6	6.1
Sunflower	1.9	2.2	2.2	2.1
HSR_{05}	1.2	1.1	1.8	–

Source: author's development

Depending upon vegetation years of the experiment in 2014 - 2016 years crop productivity of corn was 6.1; 5.7 and 6.6 t/ha(according to years), winter wheat productivity was 4.0, 3.8 and 4.2 t/ha, sunflower productivity was1.9; 2.2 and 2.2 t/ha, on average crops productivity was the following 6.1, 4.0 and 2.1 t/ha.

Part of unused plant residues is reasonably to involve into biofuel production. Potential of plant residues of crops was determined according to the reduction coefficients and yield of main products (tab. 5).

Table 5. Potential of plant residues of crops for biofuel production, t/ha (2014 - 2016 years)

Crop	Coefficient	Years			Average
		2014	2015	2016	
Winter wheat	1.0	4.0	3.8	4.2	4.0
Corn	1.3	7.9	7.4	8.6	8.0
Sunflower	2.2	4.2	4.8	4.8	4.6
Totally		16.1	16.0	17.6	-

Source: author's development

On average during three years of the research corn and sunflower have the greatest amount of plant residues (accordingly 8.0 and 4.6 t/ha) and winter wheat has 4.0 t/ha of plant residues (fig. 7). Total amount of plant residues in 2014 year was16.1 t/ha, in 2015 year was16.0 t/ha and in 2016 year was 17.6 t/ha.

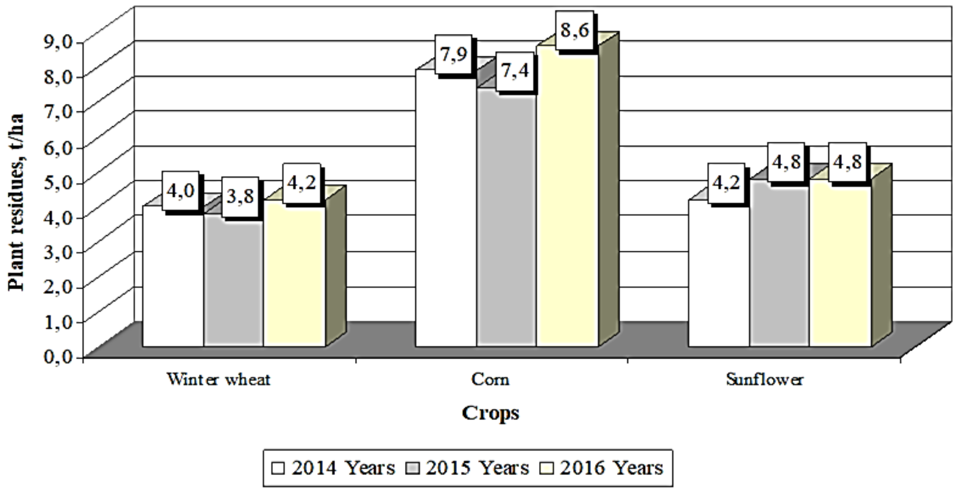

Fig. 7. Potential of plant residues of crops, 2014 - 2016 years

Energy potential of plant residues of crops in accordance with raw material energy capacity is given in the table 6.

Table 6. Energy potential of plant residues of crops, tons eq. f./ha (2014 - 2016 years)

Crop	Years			Average
	2014	2015	2016	
Winter wheat	2.3	2.6	4.9	3.3
Corn	4.5	5.3	9.8	6.5
Sunflower	3.0	3.0	6.0	4.0
Total	9.8	10.8	20.6	-

Source: author's development

On average during three years of the experiment energy potential of corn and sunflower plant remains was the highest (6.5 t oil equivalent, 4.0 t oil equivalent), energy potential of winter wheat plant remains was 3.3 t oil equivalent. Total energy potential of plant residues of crops in 2014 year was 9.8 t oil equivalent, in 2015 year energy potential was 10.8 t oil equivalent and in 2016 year energy potential was 20.6 t oil equivalent.

Yield of dry phytomass of energy crops varied from 1.3 to16.8 t/ha (table 7).

Table 7. Yield of energy crops phytomass, t/ha (2014 - 2016 years)

Variants	Years			Average
	2014	2015	2016	
Switchgrass	11.3	13.7	14.1	13.0
Miscanthus giganteus	11.6	15.0	15.5	14.0
Energy willow	12.9	14.6	16.8	14.8
HSR_{05}	0.44	1.25	1.47	0.41

Source: author's development

Energy willow provided the highest yield (from 12.9 to 16.8 t/ha), silver grass (Miscanthus giganteus) provided less yield (from 1.6 to 15.5 t/ha) and switchgrass provided the least yield (from 11.3 to 14.1 t/ha), figure 8.

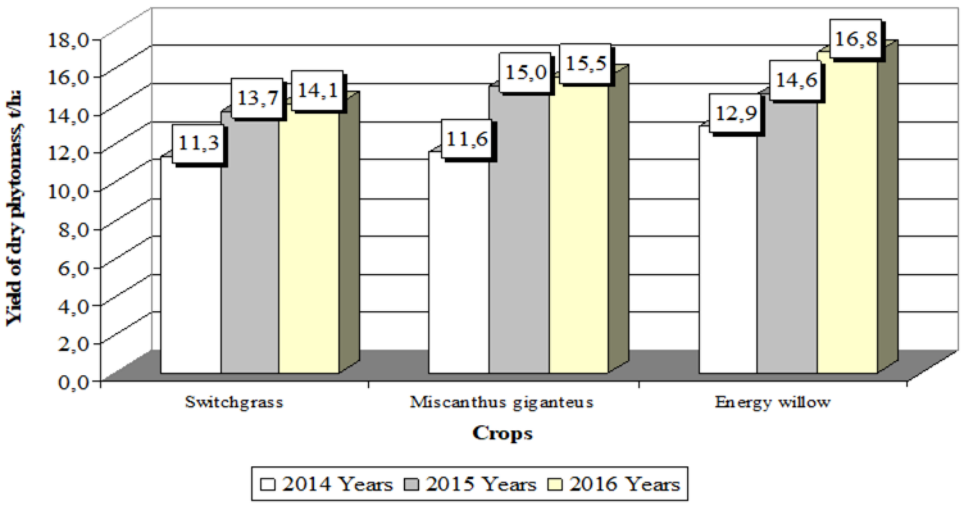

Fig. 8. Yield of energy crops phytomass, 2014 - 2016 years. Source: author's development

On average during three years of the experiment energy willow, silver grass(Miscanthus giganteus) and switchgrass provided high and stable yield of dry phytomass (14.8 t/ha, 14.0 t/ha, 13.0 t/ha respectively).

Above-ground vegetative mass of energy crops had different energy capacity (from 17 to 19 MJ/kg). Energy capacity depended upon moisture content in raw material and species plant peculiarities (tab. 8).

Table 8. Energy potential of phytomass of energy crops, t eq. f./ ha (2014 - 2016 years)

Crop	Years			Average
	2014	2015	2016	
Switchgrass	8.4	8.7	17.1	11.4
Miscanthus giganteus	9.2	9.5	18.7	12.5
Energy willow	9.0	10.3	19.3	12.9
Total	26.6	28.5	55.1	-

Source: author's development

On average during three years of the experiment energy willow and silver grass had the highest energy potential of phytomass(respectively 12.9 and 12.5 t eq. f./ha. Switchgrass had less energy potential of phytomass (11.4 t eq. f./ha).

Total energy phytomass potential was 26.6 t eq.f. in 2014 year, 28.5 t eq. f. was in 2015year and 55.1 t eq. f was in 2016 year.

Comparison of plant raw material potential shows that energy crops had higher yield of equivalent fuel per hectare than field crops had (fig. 9).

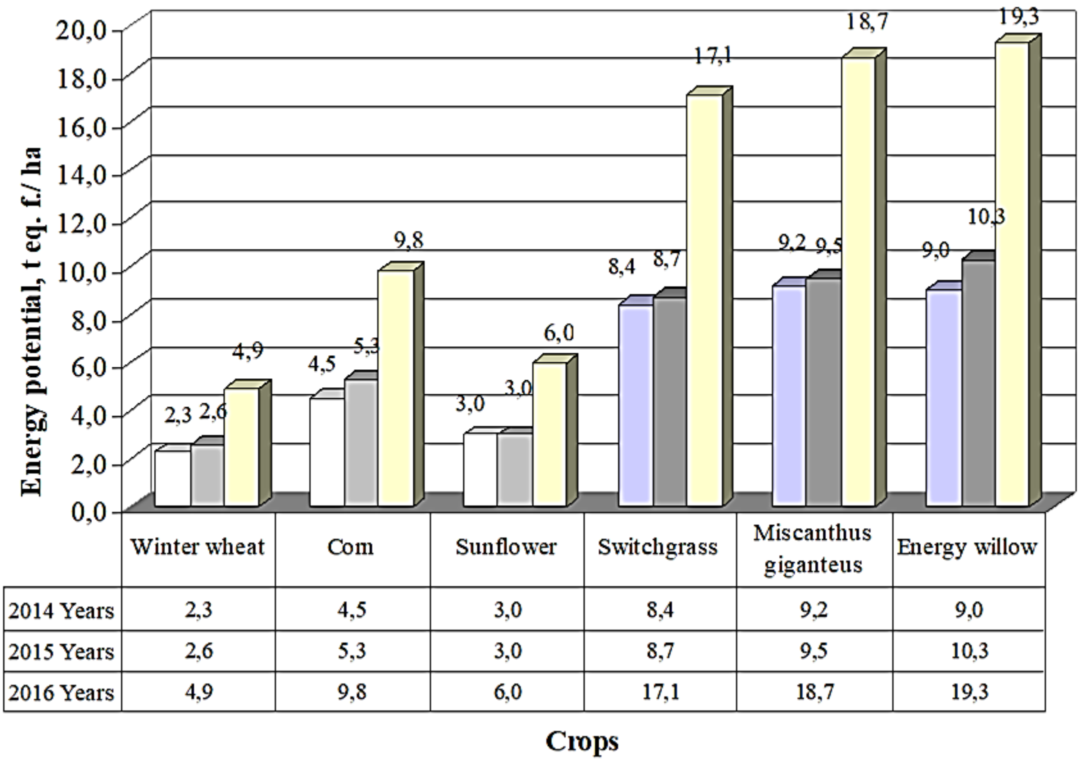

Fig. 9. Energy potential of field plant residues and phytomass of energy crops ton eq.f./ha (average during 2014 - 2016 years.). Source: author's development

Field crops provided low alternative fuel yield: winter wheat from 2.3 to 4.9 t eq.f./ha; corn from 4.5 to 9.8 t eq. f./ha and sunflower from 3.0 to 6.0 t. eq. f./ha.

Among energy crops willow provided the greatest energy capacity of raw material and high biofuel yield (from 10.3 to 19.3 t. eq. f./ha), silver grass provided from 9.2 to 18.7 t eq. f./ha and switchgrass provided from 8.4 to 17.1 t eq. f./ha.

Conclusions

1. Ukraine has great potential of agro-biomass to satisfy both domestic needs and foreign market with alternative biofuel. Large areas of marginal lands should be used to grow energy crops as a raw material for biofuel production.
2. Sunflower and corn provide the highest energy potential and the largest amount of plant residues of field crops. Winter wheat provides much less amount. Among energy crops willow, silver grass (Miscanthus giganteus) have the highest phytomass yield and energy potential, switchgrass has less phytomass yield.
3. Energy willow, silver grass (Miscanthus giganteus) and switchgrass provide the highest yield of equivalent fuel per hectare(in the range of 8.4 - 18.7 t eq. f./ha) in comparison with plant residues of field crops (2.3 - 9.8 t eq. f./ha).
4. During research years agro-biomass of crops and energy crops phytomass can provide biofuel yield from 42.8 (2014 year) to 75.8 (2016 year) t eq. f./ha.
5. Taking into account gross main production and available potential of plant residues in Ukraine it is possible to get from 13452.7 to 59649.7 thousand t eq. f./ha.
6. Having grown energy crops on marginal land with area of 1.7 million ha it is possible to get from14.3 to 31.2 million t eq.f./ha.
7. Use of agro-biomass as well as energy crops phytomass for biofuel production allows to decrease Ukraine energy dependence upon non-renewable energy sources and to increase population welfare.

So, study of plant residues usage as raw materials for biofuel taking into account energy crops potential is perspective approach of further research.

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OCENA DOSTĘPNEGO POTENCJAŁU FITOMASY Z UPRAW ROLNYCH DO PRODUKCJI BIOPALIW NA UKRAINIE

[1] Samodzielna Katedra Inżynierii Procesowej, Uniwersytet Opolski, Opole, Polska
[2] Połtawska Państwowa Akademia Rolnicza, Połtawa, Ukraina

Streszczenie: Przedstawiono analizę publikacji wyświetlających problem wykorzystania biomasy jako odnawialnego źródła energii na Ukrainie. Wykorzystanie biomasy w systemie paliwowo-energetycznym kraju jest bardzo ważnym zadaniem. Celem badań była ocena dostępnego potencjału biomasy rolnej oraz fitomasy z upraw energetycznych do produkcji biopaliwa. Przedstawiono technikę oceny, określono potencjał i obliczono efektywność energetyczną wykorzystania biomasy na Ukrainie. Udowodniono że wykorzystanie biomasy rolniczej do celów energetycznych w Ukrainie pozwala zmniejszyć zależność energetyczną kraju od nieodnawialnych źródeł energii.

Słowa kluczowe: energia, rośliny energetyczne, biomasa roślinna, wartość opałowa, potencjał energetyczny