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METHOD FOR ESTIMATION OF EFFICIENCY OF USING THE BIOMASS FOR ENERGY

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Key words: bioenergy, costs, efficiency, calculation, method, model, environment.

Abstract

The method for estimation of the economic and energetic efficiency of the implementation of renewable energy sources has been elaborated. The main focus was laid on biomass as a source of energy. The method and relevant model is applied during the realisation of the interdisciplinary project "Modelling of biomass utilisation for energy purpose". Use of biomass for energy, as the renewable energy source is to be a way to protect the environment. Therefore economic analyses have to take into consideration also environment costs. Research to be undertaken within above mentioned project will provide data enabling rational choice of kind and technology of production of energy crop the most convenient from economic and ecological points of view. The choice has to include in reckoning local conditions, effecting both the yield and quality of product.

METODA SZACOWANIA EFEKTYWNOŚCI ZASTOSOWANIA BIOMASY DO CELÓW ENERGETYCZNYCH

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Key words: bioenergia, koszty, efektywność, kalkulacja, metoda, model, środowisko naturalne.

Abstrakt

Opracowano metodę oceny ekonomicznej i energetycznej efektywności zastosowania odnawialnych źródeł energii, ze szczególnym uwzględnieniem biomasy. Metoda ta oraz odpowiedni model są stosowane podczas realizacji interdyscyplinarnego projektu „Modelowanie wykorzystania biomasy do celów energetycznych". Wykorzystanie biomasy jako odnawialnego źródła energii ma sprzyjać ochronie środowiska, dlatego analiza ekonomiczna musi uwzględniać koszty natury ekologicznej. Badania, które mają być prowadzone w ramach wspomnianego projektu, dostarczą danych umożliwiających racjonalny, z ekonomicznego i ekologicznego punktu widzenia, wybór rodzaju technologii produkcji roślin energetycznych. Wybór powinien uwzględniać warunki miejscowe, mające wpływ na plon i jakość produktu.

Introduction

The increases in the cost of fossil fuels as a result of the strong energy demand of the fast industrially growing Asian countries and the ongoing evolution of agriculture in Western countries, are leading to a more specific focus linked to energy issues in the rural areas (RIVA 2006). One has also not to forget the perspective of depletion of non-renewable energy resources as well as the environment aspects of the growing energy use. Therefore, this century could see a significant switch from a fossil fuel to renewable energy sources. According to BEST (2006) such a situation will cause that in this century the development of bioenergy based economy, with agriculture and forestry as the leading sources of biomass for biofuels can be expected.

The proposed solutions must be ecologically sustainable, environmentally acceptable for public and the delivered unitary costs need to be lower than for fossil fuels (SIMS 2003). On that score, results of researches carried out in different countries are not always univocal. According analyses of the Flemish Institute for Technological Research – VITO (Belgium) the biodiesel, as compared to the diesel oil, causes lower emission of greenhouse gases but is more harmful from the point of view of other environmental impacts (NOCKER et al. 1998, NOCKER et al. 2000, SPIRINCX et al. 2000). Its burning causes acidification of the atmosphere, eutrophication, formation of photochemical oxidants, as well as radioactive and non-radioactive wastes. As a result, the biodiesel is about two times more harmful for the environment than the diesel oil (NOCKER et al. 1998). Instead, according to German studies (PUPPEN 2002) the only negative impact of biodiesel, as compared to the diesel oil, would be the deterioration of the ozonosphere.

The above divergences show that continuation of researches is necessary. The diversity of potential energy sources as well as local conditions and technologies to be applied create a large field to studies and analyses.

The purpose of this paper is an attempt to present the method for estimation of the economic and energetic efficiency of the implementation of biomass for energy purposes.

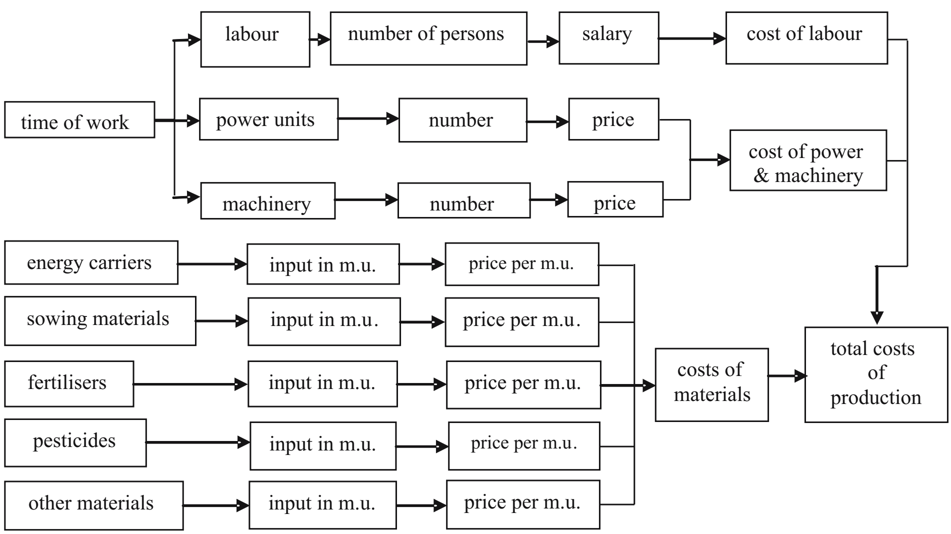
The biomass is closely connected with agriculture and in Poland it is now the main renewable energy source. Besides, dedicated woody and herbaceous crops for energy were shown to provide soil and water quality benefits. They ensure the decreasing of runoff, sediment losses and nutrient transport compared with traditional agricultural crop production (TOLBERT 2002).

The method for evaluation the economic and energetic efficiency of renewable energy sources

The model method will be applied to evaluate different forms of the production and use the energy from biomass. The data necessary to build the model are collected on farms engaged in production of crops for energy. For all operations connected with production of particular energy crops the following data are registered:

[1] the name of the operation,
[2] the date of execution,
[3] time of work, hours,
[4] hectares of field works,
[5] number of engaged persons, power units and machines,
[6] inputs of energy carriers, according their kinds, volumes and prices,
[7] inputs of a sowing material (seeds, seedlings or quicksets), amounts and prices,
[8] inputs of fertilisers: kind of fertiliser, amount and price,
[9] inputs of pesticides: kind of the chemical, amount and price,
[10] other inputs: specification, amount and price,
[11] harvested product: kind, amount, and market price.

Data listed in points [1]-[6] are registered for all operations, the other – only for convenient works (for instant point [9] for plant protection and [11] for harvest. The above data produce the base for calculation production costs (Fig. 1). Cost of labour is a result of multiplication of number of workers, time



m.u. = measure unit

Fig. 1. Scheme of production costs of energy crop

of work and salary (including all taxes and allowances) per unit of time. Cost of power (tractors, engines and so on) and machinery includes here depreciation, storage and conservation, insurance (if it refers), repair and maintenance. Cost of energy is calculated separately, like other material inputs: (seeds, seedlings or quicksets, fertilisers, pesticides, etc.). The amount of material used in relevant units of measure is multiplied by price per unit of measure.

The same data can be used to calculate the direct and indirect energy inputs (Fig. 2). In this case the monetary units are replaced by relevant energy equivalents (MJ) per unit of measure. In a case of tractors and implements the mass of these stuff has been taken as a unit of measure. In a case of fertilisers and other chemicals the units of measure are kilograms of net ingredient (for instance kg of N in nitrogen fertilisers or kg of P_2O_5 in a case of phosphorous fertilisers). In a case of seeding material this are unitary direct and indirect energy inputs per unit of measure of seeds, seedlings or quicksets.

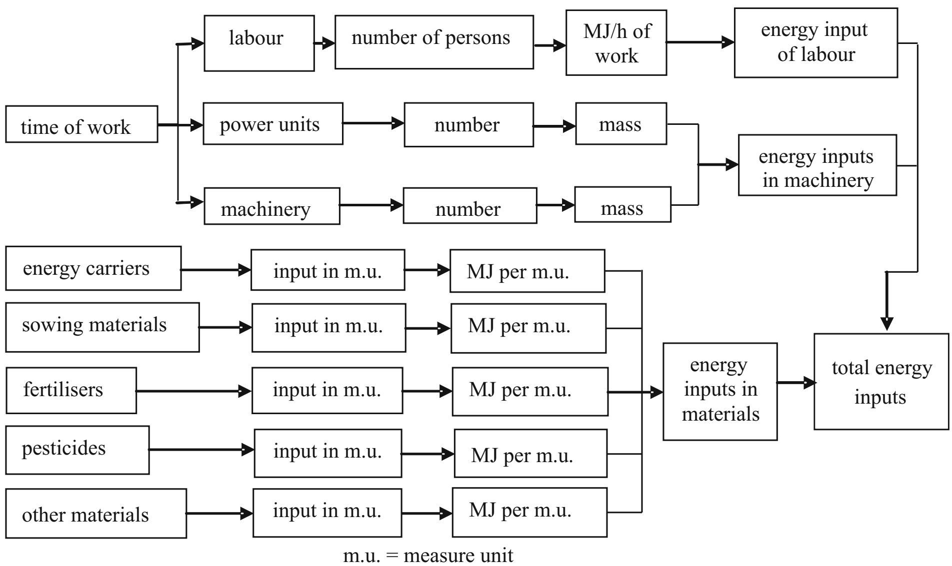


Fig. 2. Scheme of direct and indirect energy inputs for production of energy crop

Total amounts of production costs as well as direct and indirect energy inputs together with market value of produced energy crop and its calorific value create the base of model for evaluation of the economic and energetic efficiency of the bioenergy production (Fig. 3).

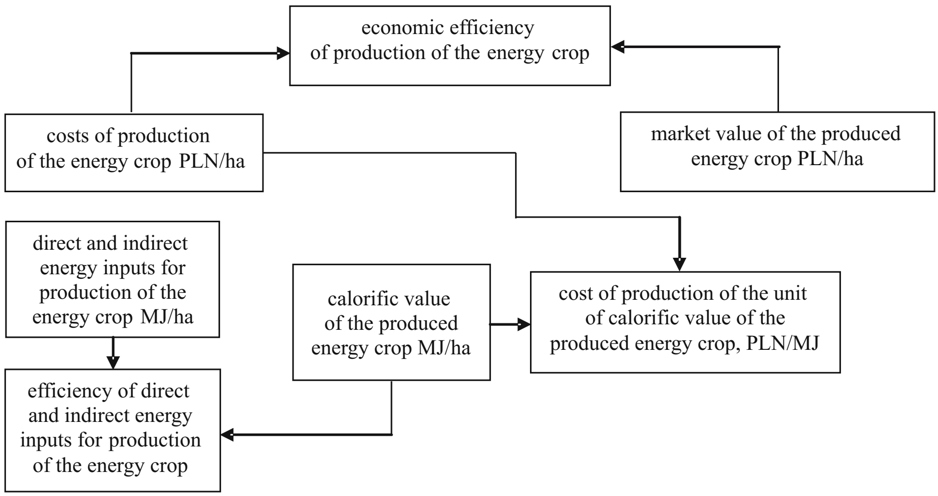


Fig. 3. Scheme of the model for evaluation the economic and energy efficiency of production of energy crops

The economic efficiency of production of i-th energy crop can be calculated using the following formula:

$$E_{ci} = \frac{P_{ci}}{N_{ci}} \tag{1}$$

Where:
E_{ci} – efficiency of production of i-th energy crop;
P_{ci} – market value of produced i-th energy crop, PLN ha^{-1};
N_{ci} – costs of production of i-th energy crop, PLN ha^{-1}.

For comparative purposes, the cost of production of the unit of the calorific value of i-th energy crop should be determined:

$$C_{ci} = \frac{Q_{ci}}{N_{ci}} \text{ (PLN MJ}^{-1}\text{)} \tag{2}$$

Where:
C_{ci} – the cost of production of the unit of the calorific value of i-th energy crop, PLN MJ^{-1};
Q_{ci} – calorific value of produced energy crop, MJ ha^{-1}.

The knowledge of the cost of production per unit of the calorific value of the energy crop makes it possible to compare different renewable energy sources and different technologies of their production. It can also serve as a meter to evaluate a purposefulness of the use of renewable energy source instead of a fossil energy carrier.

The use of renewable energy source is justifiable under condition that its calorific value is higher than direct and indirect energy inputs for its production. The purposefulness of use of a biofuel is the bigger; the higher is the efficiency of direct and indirect energy inputs for its production. To calculate this efficiency, the following equation can be applied:

$$En_{ci} = \frac{Q_{ci}}{Ie_{ci}} \tag{3}$$

Where:

En_{ci} – the efficiency of direct and indirect energy inputs for production of i-th energy crop;

Ie_{ci} – direct and indirect energy inputs for production of i-th energy crop.

An attempt to verify the proposed method

Before implementation of the discussed method, which will be applied during works within the economic section of the interdisciplinary project "Modelling of biomass utilisation for energy purpose", realised in the frame of EOG Financial Mechanism and Norwegian Financial Mechanism (NMF) by the Consortium Agreement called "Virtual Institute of Sustainable Development" (VISA), its verification basing on data from available literature is purposeful. A comparative analysis of the efficiency of direct and indirect energy inputs for Biodiesel oil production according to kind of the crop and applied technology. The results of earlier research carried out in Poland (PODKÓWKA 2004) and in the USA (PIMENTEL, PATZEK 2005) will be used as input data. The rape (yield 25 dt ha^{-1}) produced under Polish conditions and soybean (yield 26.7 dt ha^{-1}) produced under American conditions were taken as the raw material for biofuel production. Two variants of the technology of extraction of oil and estrification were considered: the one used in Poland (A) and the other used in the USA (B). The results of calculation show that there are differences in the process efficiency and that the effect of applied technology is in this case more strongly pronounced than the one of the kind of crop being used as the source of row material. In all cases the efficiency, calculated using the formula (3) was below 1 if the by-products are not taken into account

(Tab. 1). According to technology applied 14 to 37 percent more energy is required to produce 1000 kg of Biodiesel oil than the product can deliver. However, in a case of using by-products (straw in the case of rape) for energy purposes, the energy efficiency growth up to 1.36-1.60.

Table 1
Inputs and effects of biodiesel production depending on kind of crop and the applied technology

Specification	GJ per 1000 kg of Biodiesel			
Energetic plant	Rape		Soybean	
Variant of technology	A	B	A	B
Energy inputs per:				
production of biomass	28.8	28.8	27.8	27.87
extraction of oil and estrification total	22.9 51.7	15.1 43.9	22.9 50.7	15.17 42.9
Received product (Biodiesel oil)	37.7	37.7	37.7	37.7
Energy efficiency	0.73	0.86	0.74	0.88

Source: author's calculation basing on PODKÓWKA (2004), PIMENTEL and PATZEK (2005)

Above example of application shows that proposed method can be used for evaluation of different crops as a raw material for bioenergy production as well as different technology variants. There is a need to collect more input data, specific for different local conditions.

Research programmes carried out in the frames of the interdisciplinary project by 6 institutes will provide data on yields, calorific values of different energy crops, volumes and kinds of emissions etc. under different habitat and applied technology. Thanks of it more holistic analysis of economic and energy efficiency will be possible, taking into account environment costs. This is important not only because of divergences between results of different research results. Also knowledge of influence of different factors, such as kind of soil and climate, technology and scale of production on efficiency of production of biomass for energy is necessary. Research by DENISIUK and PIECHOCKI (2005) show that the chemical composition of straw of the same species of cereals produced in Denmark and in Poland is not the same. Consequently, also characteristic of straw as a fuel differs according to the place of production. The knowledge of interrelations between different factors will help to make a choice of the most convenient energy crop with regard to economic and environment criteria.

Conclusion

According to technology applied 14 to 37 percent more energy is required to produce an unit of mass of Biodiesel oil than the product can deliver.

Exemplary analysis shown the usability of the proposed method for evaluation of efficiency of biomass production for energy. Its results show that the choice of suitable technology can improve the efficiency of embodied energy inputs for Biodiesel production.

The diversity of both natural conditions and other factors having an effect on economic and energy efficiency of production of different energy crops cause that continuation of research in this field is necessary. Use of biomass for energy, as the renewable energy source is to be a way to protect the environment. However, results of researches of effect of biofuels on environment, carried out in different countries, are not always univocal. Therefore, economic analyses have to take into consideration also environment costs.

Research to be undertaken within the interdisciplinary project "Modelling of biomass utilisation for energy purpose" should provide data enabling rational choice of kind and technology of production of energy crop the most convenient from economic and ecological points of view. The choice has to include in reckoning local conditions, effecting both the yield and quality of product. That is why results from different habitats are needed.

References

BEST G. 2006. *Alternative Energy Crops for Agricultural Machinery Biofuels – Focus on Biodiesel*. Agricultural Engineering International: the CIGR Ejournal. Invited Overview, 13(VIII).

DENISIUK W.H., PIECHOCKI J. 2005. *Techniczne i ekologiczne aspekty wykorzystania słomy na cele grzewcze*. Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego w Olsztynie.

NOCKER L. DE, SPIRINCKX C., PANIS L. 2000. *Comparison of externalities of the biodiesel fuel chains for passenger transport in Belgium*. VITO, Flemish Institute for Technological Research, pp. 1-3.

NOCKER L. DE, SPIRINCKX C., TORFS R. 1998. *Comparison of LCA and external cost analysis for biodiesel and diesel*. VITO, Flemish Institute for Technological Research, pp. 1-10.

PODKÓWKA W. 2004. *Kierunki wykorzystania rzepaku*. W: *Biopaliwo gliceryna pasza z rzepaku*. Wydawnictwo Uczelniane Akademii Techniczno-Rolniczej w Bydgoszczy, ss. 36-41.

PUPPEN D. 2002. *Environmental evaluation of biofuels*. Periodica Polytechnica Ser. Soc. Man. Sci., 10(1): 95-116.

RIVA G. 2006. *Utilisation of Biofuels on Farm*. Agricultural Engineering International: the CIGR Ejournal. Invited Overview, 15(VIII).

SIMS R.E.H. 2003. *Climate Change Solutions from Biomass, Bioenergy and Biomaterials*. CIGR Ejournal. Invited Overview, 11(V).

SPIRINCX C., NOCKER L. DE, PANIS L.I. 2000. *Comparative externality analysis and life cycle assessment of biodiesel and fossil Diesel fuel*. 1st World Conference on Biomass for Energy and Industry, Sevilla. Proceedings, 1: 171-173.

TOLBERT V.R. 2002. *Environmental sustainability of dedicated bioenergy feedstocks: summary of research results*. 12th European Conference on Biomass for Energy, Industry and Climate Protection, Amsterdam. Proceedings, 1: 148-151.

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