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PERSPECTIVES OF BIOFUEL SECTOR DEVELOPMENT IN POLAND IN COMPARISON TO CO_2 EMISSION STANDARDS*

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Abstract. Biofuels for transport belong to a sector, which functions in a volatile global environment (macro). Until the end of 2010, European Union had promoted the production and development of vegetable based biofuels for transport as a way to reduce the emission of greenhouse gases (nonobligatory Directive 2003/30/EC, with indicator of replacing 5.75% of all transport fossil fuels with biofuels in 2010, reached in about 80%). Currently, bio-components with high CO_2 emission reduction and biofuels produced from inedible plants and raw material waste are being promoted. The Directive 2009/28/EC, which has been in force since 2011, has imposed mandatory obligation on all subjects, who participate in the cycle of biofuels and bioliquid production, to fulfill criteria of sustainable production, including CO_2 emission reduction to at least the threshold level (e.g. at least 50% reduction by 2017). In the article, rating method for CO_2 reduction in the international law setting have been presented – BIOGRACE 4 calculator and value of CO_2 emission reduction in five plants, where biofuels are produced with use of three methods.

Key words: biofuels, CO_2 emission reduction, BIOGRACE, SimaPro

INTRODUCTION

Climate change is one of the most serious ecological problems. United Nations Framework Convention on Climate Change calls for "stabilization of greenhouse gas

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concentrations in the atmosphere at the level that would prevent dangerous anthropogenic interference with the climate system...” [United Nations... 1992, Article 2]. The concentration of CO_2 in the atmosphere will continue to grow, if no significant changes are implemented and fossil fuels will continue to be main source of energy services [Hoffert et al. 1998].

In the modern world, we observe the negative impact of human activity on the environment with growing concern. In effect, the need to strive for more sustainable development arose, which assumed consciously creating the relation between the economy growth and care for the environment.

Directive 2009/28/EC of the European Parliament and of the council of 23 April 2009 on the promotion of the use of energy from renewable sources imposed an obligation, on all subjects, who participate in the cycle of biofuels and bioliquids production to fulfill the criteria of sustainable production. One of the foremost important criteria is the requirement to reduce GHG (greenhouse gases) emission in the full cycle of biofuels and bioliquids production. The extent of this limitation should be equal to at least 35% (from 1.04.2013 for the installations operating since 23.01.2008), 50% by 2017 as well as 60% by 2018 (for installations, which started production after 1.01.2017). In order to meet the requirements placed upon Poland by the EU, it is necessary to evaluate the actual reduction of CO_2 emissions in the plants producing biofuels.

Use of the first generation biofuels brought a range of controversies, mainly because of their influence on the international food markets and food safety, especially in reference to the most vulnerable regions of global market. It elicited many relevant questions on the topic biofuel potential, which is questioning the replacement of the fossil fuels and durability of biofuel production [Moore 2008]. For example, aside from the risk that higher food prices may lead to serious negative impact on food safety, therefore the demand for biofuels could put another strain on the natural resources with potentially damaging environmental and social effects. Currently, about 1% (14 million hectares) out of all globally available arable lands is used for biofuel production, delivering 1% of global fuels for transport. Undoubtedly, increasing this participation up to 100% is unrealistic due to necessity of securing global food supplies as well as vast lands essential to its production [Brennan and Owende 2010]. Subsequently, in order to reduce the shortcomings of the first generation biofuels, the second generation of biofuels has been introduced. Their technological process was adjusted to produce fuel out of the entire plant mass coming from specialized energy crops or agricultural waste, forest waste or remains from wood production, thus not from the food plants.

The position of the European Union on the effective reduction of CO_2 is that it is necessary to develop the second generation of biofuels (obtained i.a. from processing lignocellulosic plants or waste raw materials). Use of the waste raw materials, which are useless in food production, is the essence of the second generation biofuels. In comparison to the first generation biofuels, higher quality of the second generation is of great significance, as the motorization industry and its users are more willing to accept them. Technologies of commercial production have not been prepared in detail in satisfactory manner [Merkisz and Kozak 2007].

PURPOSE OF METHODS OF THE STUDIES

The purpose of this publication is to present the changes, which take place in the way transport biofuels sector functions in Poland as a consequence of the EU regulations regarding reduction of CO_2 emissions imposed on Polish companies.

This paper introduces methods of calculation of greenhouse gases emissions, with particular attention to the reduction of CO_2 emissions in the context of volatile conditions of the environment, where the biofuel sector is functioning. BIOGRACE method was applied while carrying out the investigation regarding the level of CO_2 emissions in five plants. Furthermore, the macro setting has been depicted, along with the competing sectors with biofuels for transport. In consequence, this allowed formulating conclusions how the companies in the biofuel sector will function in the future.

ESTIMATION METHOD FOR GREENHOUSE GASES EMISSION

Estimating reduction of GHG emission in biofuels for transport is possible with use of a few methods presented on Figure 1. Proposed methodology is not limited to the Biograce quantitative method (method recommended by EC in order to calculate the reduction of CO_2 emission), but it has been broadened out by LCA method, which rates the life cycle of biofuels for transport and raw materials used for its production, through the use of SimaPro tool as well as method of Cumulative Energy Demand.

The foundations included in the Directive 2009/28/EC determine the production and the application of transport biofuels and bioliquids in Poland, as well as in the entire European Union. Key records of this document refer to introduction of so called criteria of sustainable biofuel development and minimal required levels of GHG reduction. Execution of this directive aims to limit uncontrolled exploitation of natural environment, as well as reduce the negative impacts of fuels sector on the environment. One of the key fields for sustainable development is achieving the minimal levels of reduction of greenhouse gases emissions originating from biofuels production in comparison to fossil fuels.

In order to standardize the way in which greenhouse gases emissions are calculated in the life cycle of biofuels, the Directive 2009/28/EC sets out a clear calculation procedure represented by the following formula:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} - e_{ee}$$

where:

- E – total emissions from the use of the fuel;
- e_{ec} – emissions from the extraction or cultivation of raw materials;
- e_l – annualised emissions from carbon stock changes caused by land-use change;
- e_p – emissions from processing;
- e_{td} – emissions from transport and distribution;
- e_u – emissions from the fuel in use;
- e_{sca} – emission saving from soil carbon accumulation via improved agricultural management;

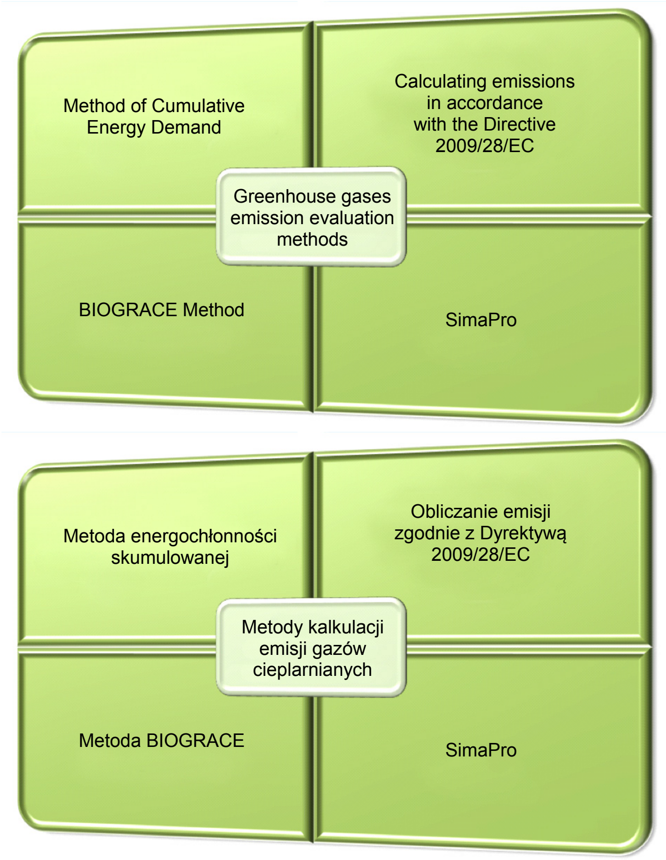

Fig. 1. Greenhouse gases emission evaluation method
Source: own elaboration.
Rys. 1. Metody szacowania emisji gazów cieplarnianych
Źródło: opracowanie własne.

e_{ccs} – emission saving from carbon capture and geological storage;
e_{ccr} – emission saving from carbon capture and replacement; and
e_{ee} – emission saving from excess electricity from cogeneration.

While calculating the greenhouse gases emissions in the biofuel life cycle using aforementioned formula, it is worth noticing that the emissions from the extraction or cultivation of raw materials, e_{ec} does not include capturing CO_2 during raw material cultivation. Nevertheless, it includes the emission emissions from the extraction or cultivation process itself, from the collection of raw materials, from waste and leakages, and from the production of chemicals or products used in extraction or cultivation.

Greenhouse gas emissions from fuels, E, shall be expressed in terms of grams of CO_2 equivalent per MJ of fuel, gCO_{2eq}/MJ. Only for transport fuels, values calculated in terms of gCO_{2eq}/MJ may be adjusted in order to consider differences between fuels in useful work done, expressed in km/MJ. Such adjustments shall be made only where evidence of the differences in useful work done is provided.

The greenhouse gases taken into account for the purpose of calculations shall include: CO_2 (carbon dioxide), N_2O (nitric oxide) and CH_4 (methane). For the purpose of calculating CO_2 equivalence, those gases shall be valued as follows: CO_2 – 1, N_2O – 296, CH_4 – 23.

Annualised emissions from carbon stock changes caused by land-use change (e_l) will be calculated by dividing total emissions equally by 20 years. For the calculation of those emissions, the following rule is applied:

$$e_l = (CS_R - CS_A) \times 3664 \times 1/20 \times 1/P - e_B$$

where:

- e_l – annualised greenhouse gas emissions from carbon stock change due to land-use change (measured as mass of CO_2-equivalent per unit of energy produced using biofuel);
- CS_R – the carbon stock per unit area associated with the reference land use (measured as mass of carbon per unit area, including both soil and vegetation). The reference land use shall be the land use in January 2008 or 20 years before the raw material was obtained, whichever is later;
- CS_A – the carbon stock per unit area associated with the actual land use (measured as mass of carbon per unit area, including both soil and vegetation). In cases where the carbon stock accumulates over more than one year, the value attributed to CS_A shall be the estimated stock per unit area after 20 years or when the crop reaches maturity, whichever is earlier;
- P – productivity of the crop (measured as biofuel or bioliquid energy per unit area per year); and
- e_B – bonus of 29 gCO_{2eq}/MJ biofuel or bioliquid granted if biomass is obtained from rehabilitated degraded land.

Greenhouse gas emission saving / limit from biofuels and bioliquids shall be calculated as follows:

$$\text{SAVING / LIMIT} = (E_F - E_B)/E_F$$

where:

- E_F – total emissions from the biofuel or bioliquid (newest available value of average emissions derived from petrol extraction sites and diesel oil used within the European Community territory, provided under the Directive 98/70/EC. In case, when no such data is available, the following value shall be applied: 83.8 gCO_{2eq}/MJ);
- E_B – total emissions from the fossil fuel comparator.

ESTIMATING GHG EMISSIONS WITH BIOGRACE CALCULATOR

Estimating greenhouse gases emission is possible with the use of tools designed for its calculation. Currently, BIOGRACE calculator version 4 is one of the most popular in

Europe. This calculator was developed by the international consortium within BIOGRACE project named “Harmonized Calculations of Biofuel Greenhouse Gas Emissions”. Main reasons for its popularity include:

- full compatibility with methodology described in the Directive 2009/28/EC
- compatibility with additional requirements defined in EC announcements,
- ongoing harmonization of calculation procedures,
- free accessibility,
- regular update of the calculator according to future requirements of the Directive over the period of five years starting in 2012.

This calculator enables estimation of GHG emissions from farming and emission restrictions in the entire life cycle of biofuels (LCA) in reference to 1 MJ of produced fuel. In reference to aforementioned, the production and use of 1 MJ of fuel is the functional unit in BIOGRACE. Estimation of emission is possible for three main greenhouse gases: CO_2, CH_2 and N_2O. In addition, the calculator offers the possibility of viewing aggregated values of emissions expressed in carbon dioxide equivalent.

With use of this tool, it is possible to calculate the greenhouse gases for the cultivation of eight plants: wheat, sugar beet, corn, rape, sunflower, palm oil, soybean and sugarcane, which are currently used as a substrate in the production process of biofuels for transport. In additions, BIOGRACE calculator annotates 22 pathways of biofuel production from aforementioned plants. Unfortunately, this tool does not take into account lignocellulosic plants, which constitute substrate in the production process of the second generation biofuels, as well as pathways in the production of these biofuels.

According to BIOGRACE methodology, estimation of GHG at the cultivation phase of the raw material includes:

- production of seed/planting material,
- nitrogen fertilizer (N),
- phosphorous fertilizer (P_2O_5),
- potassium fertilizer (K_2O),
- calcium fertilizer (CaO),
- use of crop protection chemicals,
- fuel consumption for the execution of all field operations,
- N_2O field emission,
- annualised emissions due to carbon stock changes according to land use change,
- emissions from the accumulation of carbon in soils through improved agriculture.

Important position in the calculations of farming GHG emissions is taken by the emission extent of these gases, which originate at the production of nitrogen fertilizers. In EU, the average emission arising from the production of nitrogen fertilizers is 58 860.6 g eq CO_2 kg^{-1} of raw material. However, some countries assume lower values by obtaining data from nitrogen plants. In Poland, IUNG-PIB [the Institute of Soil Science and Plant Cultivation – State Research Institute] similarly aimed to determine the actual level of GHG emissions originating in the production of nitrogen fertilizers, turned to Zakłady Azotowe Puławy [Nitrogen Plant Puławy] with proposal to make emission data available for particular assortment of manufactured fertilizers. Obtained data indicated lower emission in this plant than the average for the entire EU. Another step of the Ministry of Agricultural and Rural Development (MRiRW) was an attempt to obtain detailed data from all nitrogen fertilizer manufacturers in Poland. The analysis of obtained results demonstrated the following emission values for nitrogen fertilizers: 3253.2 g CO_2 eq/kg N for rape (with use of 60% N in RSM [highly concentrated nitrogen fertilizer] and 40% in nitrate, which results from PSPO [the Polish Association of Oil Producers] information on fertilizing rape for biofuel purposes) as well as 3414.2 g CO_2 eq/kg N for grain.

Basing on the data obtained by MRiRW [Ministry of Agricultural and Rural Development], estimated levels of farming GHG emissions for Poland are smaller by 6 g CO_2 eq/MJ, with average level of fertilizing wheat, corn and rape, in comparison to the standard emission value for nitrogen fertilizers established for the EU. This way, the values exceeding standards for NUTS 2 [Nomenclature of territorial units for statistics – basic regions for the application of regional policies] have decreased to lower level than these values [Faber 2011].

BIOGRACE calculator is not a tool deprived of shortcomings. One of the major drawbacks is lack of unified evaluation methodology of N_2O land emission connected to the application of nitrogen fertilizers and degradation of leafs remaining on the plantations as well as grain waste after the harvest. Estimation of this parameter is charged with high uncertainty depending on the selected method, which is clearly underlined in the BIOGRACE calculator methodology.

Moreover, BIOGRACE method does not consider coal ground confiscation in the calculations, which is consistent with methodology defined in the attachment to the Directive 209/28/EC. Yet, taking into account this coal ground confiscation remarkably influences the results of entire emission from plant cultivation for the energy purposes. Perennial crops more effectively bind atmosphere originated CO_2 with soil as a result of photosynthesis process and root expansion, which aids over ground part throughout the entire long-term use of the plantation. Nonetheless, in case of annual plants used for the first generation biofuel production, we deal with the CO_2 emission from the soil (negative values of confiscation). As a result, it is essential to include also this parameter, in the future, in the GHG emission calculations.

LIFE CYCLE ASSESSMENT [*LCA*] OF BIOFUELS FOR TRANSPORT AND RAW MATERIALS USED FOR THEIR PRODUCTION WITH USE OF SIMAPRO TOOL

Similarly to BIOGRACE calculator, SimaPro is a valuable tool enabling evaluation of emissions related to cultivation of raw materials and production of biofuels. However, SimaPro is software, in which GHG emission accounts for only one of the elements making up the entire influence on the biofuel life cycle environment, while BIOGRACE calculator, as indicated above, focuses only on the emission calculations.

BIOGRACE calculator, as a tool, is fully compliant with the Directive 209/28/EC and it may be used for verification of results obtained by SimaPro tool. As the research, carried out by many experts, shows, the results of entire GHG emissions from biomass production evaluated by BIOGRACE calculator and SimaPro program differ almost twofold. It indicates vast influence of applied methodology on the final calculation results. It mainly derives from ascribing unequal values in particular material and energy categories to greenhouse gases emissions in the biomass production process.

SimaPro software is a tool based on the LCA (Life Cycle Assessment) of transport fuels. Life Cycle Assessment is a technique aiming to rate the environmental hazards related to the system of choice or actions, equally throughout the identification and rating of influence of these materials, energy and waste on the environment, as well as rating what effects these materials, energy and waste imprint on the environment. This assessment refers to the entire life of the product or actions starting with the extraction, mineral raw material processing, product manufacturing process, distribution, application, reuse, maintenance, recycling and final development, as well as transport.

LCA directs the investigation on influences of the production process on the particular ecosystem, human health and exploited resources. Considering the commitments imposed by the European Union on the Member States regarding the minimization of effects, which petrol industry imprints on the environment, the LCA method proves to be a useful tool in meeting these obligations. This method includes entire life cycle of petrol from the moment of raw material extraction throughout its production and usage as well as procedures of how to deal with fuels that do not meet subject standards.

SimaPro software was developed by the Dutch company, PRé Consultants. This tool is equipped with numerous features, which enable performance of detailed analysis with simultaneous retaining of the universality for its multiple applications. SimaPro is tailored with 17 methods of determining the effect of products on the environment. The most popularized influence methods among them are the following: CML 1992 and 1996, Eco-indicator 99, Eco-points and Eco-95. All of these methods can be edited and expanded. The software is also fully integrated with such databases as: Ecoinvent v. 2, US LCI, ELCD, US Input Output, UE and Danish Input Output, Dutch Input Output, LCA Food, Industry data v. 2, which contain detailed information used in development of LCA models.

SimaPro software uses eco-indicators. This method is based on the rating of damages induced onto the environment by the process or the product. The damage rating is carried out on the basis of estimated burdens assigned to specific categories of influence. Investigation also includes influence on: human health, ecosystem quality and amount of natural resources.

Standard eco-indicators are drawn up for materials, production, transport and energy processes as well as waste management. While calculating eco-indicators for specific processes, all of their elements are accounted for. In relation to manufactured materials, such as mineral fertilizers, the cycle from extraction to obtaining ready material has to be considered. This indicator refers only to 1 kg of material. In case of production processes, the emission from processed and emissions originating from energy use are accounted for. The indicator demonstrates the unit of product obtained from the process, such as 1 m^2 or 1 kg.

SimaPro software is successively applied in more than 80 countries throughout the world, which places it as one of the top tools for product life cycle analysis. Use of this software in estimating the GHG emission level is not deprived of shortcomings. One of the major ones is the uncertainty of obtained results, which is associated with quality of implemented data and assigning the GHG emission to particular material and energy amounts. As a result, own studies or verified literature sources should be the source of data for analysis.

THE INFLUENCE OF CO_2 EMISSION REDUCTION ON BIOFUEL INDUSTRY IN POLAND

In this part of the article, an analysis of real CO_2 emission reduction values for transport biofuels, produced in plants located at Warmian-Masurian, Pomeranian and Kuyavian-Pomeranian provinces have been presented. The plants producing the following biofuels have been analysed:
- bioethanol produced in 2-stage method from wheat (two plants),
- bioethanol produced in 1-stage method from beet molasses (one plant),
- biodiesel produced from rape oil (two plants).

BIOGRACE version 4.0c calculator, modified accordingly to the needs of each plant, has been used during calculations. The modifications in no way have decreased the life cycle analysis range for each biofuel, and it remained consistent with the one used to designate the standard values for the Annex V to Directive 2009/28/EC.

The analysis of data presented in Table 1 allows indicating influence of the adopted method of bioethanol production on the reduction of CO_2 emission. In the first two

Table 1. Comprehensive list representing reduction of CO_2 emission in studied plants
Tabela 1. Zestawienie redukcji emisji CO_2 w badanych zakładach

Plant Zakład	Type of the technology used in the production of bioethanol Rodzaj technologii wytwarzania bioetanolu	Value of CO_2 emission reduction according to the Directive 2009/28/EC Wartość redukcji emisji CO_2 zgodnie z Dyrektywą 2009/28/EC (%)	Value of CO_2 emission reduction calculated with the use of BIOGRACE 4.0c calculator Wartość redukcji emisji CO_2 obliczono z wykorzystaniem kalkulatora BIOGRACE 4.0c (%)
1	2	3	4
1	2-stage warm mashing production technology (wheat) Zacieranie na ciepło, 2-fazowa technologia produkcji (pszenica)	17	–26 - –22
2	2-stage warm mashing production technology (wheat) Zacieranie na ciepło, 2-fazowa technologia produkcji (pszenica)	17	–1-3
3	Enzymatic hydrolysis of substrates 1-stage technology (beet molasses) Hydroliza enzymatyczna substratów, 1-fazowa technologia (melasa buraczana)	52	44-48
4	Use of purchased un-pressed rape oil in the plant, but with extraction, refinement and esterification Wykorzystanie zakupionego oleju rzepakowego bez tłoczenia w zakładzie lecz z ekstrakcją, rafinacją oraz estryfikacją	38	32-36

Table 1 – cont. / Tabela 1 – cd.

1	2	3	4
5	Use of purchased un-pressed rape oil in the plant but with extraction, refinement and esterification Wykorzystanie zakupionego oleju rzepakowego bez tłoczenia w zakładzie lecz z ekstrakcją, rafinacją oraz estryfikacją	38	45-49

Source: Borowski et al. [2014].
Źródło: Borowski i in. [2014].

plants bioethanol was manufactured out of wheat with use of 2-stage warm mashing method. The differences in the reduction value of CO_2 emission, calculated with BIOGRACE 4.0c calculator, are caused by the type of technological fuel used in these two plants. In the first plant, bituminous coal is used in the production process. Negative reduction values of CO_2 emission will not allow, without the change of the technology, to fulfill the criteria for sustainable development. On the other hand, the second plant uses natural gas (burned in the high-performance cauldrons), which is characterized by much higher emission reduction in comparison to the plant No. 1. Nevertheless, in both cases it will not be possible to fulfill the norms contained in the Directive 2009/28/EC without technological changes.

Plant no. 3, where bioethanol is produced from beet molasses with 1-stage method, is characterized by much higher level of reduction of CO_2 emission. Similar reduction level calculated with BIOGRACE calculator as well as the EU standards provides high probability of achieving recommended level. As the investigation indicates, it will be possible in this plant due to employing ethanol drainage method, which is described as possible lowest emission method through thorough verification of the origin of raw materials, which are applied in the production process, in order to determine the actual emission from plant cultivation in specific regions and countries.

Remaining two plants manufacture the first generation biodiesel. Their production relies on the purchased rape oil. In the plants, the oil undergoes the processes of extraction, refinement and esterification. The differences in reduction of CO_2 emissions result from the scale of production. Annual production capacity of these plants is shaped in following levels: plant 4 – 1 606 000 l/year, plant 5 – 3 650 000 l/year. The fifth plant has much higher chances of meeting the required reduction level of CO_2 emissions through decreasing the amount of energy used for the esterification process (% increasing the reduction value will directly depend on decrease of the amount of energy destined for biodiesel 1 MJ during the esterification process in the plant).

In Table 2, a list of macroeconomic and competition factors has been presented, which have an effect on shaping the biofuel industry in Poland. The table also includes hazards, which are related to the specific factors.

Table 2. List of factors influencing transport biofuels sector in Poland
Tabela 2. Zestawienie czynników mających wpływ na sektor biopaliw transportowych w Polsce

Macroeconomic and competition factors Czynniki makroekonomiczne i konkurencyjne	
Legal, international (U) Prawne, międzynarodo-we (U)	unfavourable variables of the first generation, uncertainties for the second generation due to small scale production zmienne niekorzystne pierwszej generacji, niepewne dla drugiej generacji przy malej skali produkcji
Legal, national Prawne, krajowe	unfavourable, delay in OZE act [Renewable Energy Source Act], amendment of biofuel acts niekorzystne, zwlekanie z ustawą o OZE [Odnawialne Źródła Energii], nowelizacja ustaw biopaliwowych
Technical and technological Techniczno- -technologiczne	necessity of modernization within the period of 2-3 years, transition to new technologies of the second-third generation within the period of the next 7 years, new raw materials – unfavourable konieczność modernizacji w ciągu 2-3 lat, przejście w okresie 7 lat na nowe technologie drugiej-trzeciej generacji, nowe surowce – niekorzystne
Ecological Ekologiczne	unfavourable, growing expectations in relation to sustainable development criteria (KZR), ILUC [indirect land use change] threats niekorzystne, rosnące wymagania odnośnie do kryterium zrównoważonego rozwo-ju (KZR), zagrożenia typu ILUC
Economical Ekonomiczne	crisis, no funds to support OZE kryzys, brak środków na wsparcie OZE
Political Polityczne	diminishing role of farming lobby in Poland, fight for the power of farming in EU – lower power many failures nikła rola lobby rolnego w Polsce, walka o siłę rolnictwa w UE – mniejsza siła, wiele porażek
Competitive Konkurencyjne	large number of substitutes, new products, improved, intensive competition fight on the fuel market, black market on the fossil fuels and biofuels market, biofuels for transport, fight on the global, not regional, markets as majority of OZE duża liczba substytutów, nowe, udoskonalone produkty, ostra walka konkurencyjna na rynku paliw, czarny rynek na rynku paliw i biopaliw, biopaliwa transportowe, walka na rynkach globalnych, a na nielokalnych jak większość OZE

Source: own elaboration.
Źródło: opracowanie własne.

CONCLUSION

Basic method for calculating reduction of CO_2 emission is BIOGRACE calculator, and remaining methods, which have been described in the paper, constitute its complementation. It results from the fact that only this method is fully compliant with the Directive 2009/28/EC. However, other methods should not be omitted as they allow including additional elements, which influence reduction of CO_2 emissions unconsidered in BIOGRACE method. One of the major drawbacks of BIOGRACE method is lack of unified evaluation methodology of N_2O land emission connected to the application of nitrogen fertilizers and degradation of leafs remaining on the plantations and grain waste after the harvest. Depending on the selected method, estimation of value of this parameter is burdened with high uncertainty. Moreover, BIOGRACE method does not consider coal ground confiscation in the calculations, which is consistent with methodology defined in the Annex to Directive 209/28/EC. However, taking into account this coal ground confiscation remarkably influences the results of entire emission from plant cultivation on the energy purposes.

Presented investigation results, in reference to reduction of CO_2 emissions, indicate that the plants, where natural gas is used as technological fuel in high-performance cauldrons instead of bituminous coal, are characterised by high reduction in value of CO_2 emissions. Use of bituminous coal in the plants producing bioethanol with 2-stage method may cause negative reduction values of CO_2 emissions. Meeting the criteria of sustainable development will most likely be impossible for these plants.

The effective way to reduce the value of CO_2 emissions in case of bioethanol production at plants with high production capacity is employing low energy consuming ethanol drainage method. On the other hand, the most significant effects at the plants manufacturing the first generation biodiesel on the base of rape oil can be achieved through increasing the scale of production.

Not all of the analysed plants will be able to reduce CO_2 emissions to the level required by the EU. The plants, which base their production on 2-stage wheat technology, will have no opportunity to achieve the required level of CO_2 emission reduction neither currently nor in the future. In the third plant, reduction of CO_2 emission to the level of 50% is very likely by 2017 through application of ethanol drainage method. However, out of the plants, which production is based on purchased rape oil, plant five has higher chance to achieve appropriate level of CO_2 emissions reduction through decreasing the energy amount destined for the esterification process.

It seems that increasing the reduction of CO_2 emissions is possible through the change of raw material used in the production process. Nevertheless, the modification will not be possible in all existing plants, due to already acquired infrastructure, as well as technological parameters of installed devices.

Limitations of CO_2 emissions can also be found in acquired raw material. Use of reduced values of emission accounted for cultivation of plants intended for fuel production provides benefits in high CO_2 emission reduction, up to 5%. Moreover, decreasing the distance of raw material transport for biofuel production also influences the final result of reduction in CO_2 emission. For instance, increasing the distance, from which raw material is transported for biofuel production, by 50 km causes the emission to rise by 0.52 g CO_2 $eqMJ^{-1}$.

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PERSPEKTYWY ROZWOJU SEKTORA BIOPALIW W POLSCE NA TLE NORM EMISJI CO_2

Streszczenie. Biopaliwa transportowe należą do sektora funkcjonującego w zmiennym otoczeniu globalnym (makro). Do końca 2010 roku Unia Europejska promowała produkcję i rozwój roślinnych biopaliw transportowych jako sposobu na ograniczenie emisji gazów cieplarnianych (nieobligatoryjna Dyrektywa 2003/30/EC, ze wskaźnikiem 5,75% udziału energetycznego biokomponentów w 2010 roku, osiągniętym w około 80%). Obecnie promuje się biokomponenty o wysokiej redukcji emisji CO_2 i biopaliwa produkowane z roślin niejadalnych i surowców odpadowych. Kolejna Dyrektywa 2009/28/EC, obowiązująca od początku 2011 roku, nałożyła na wszystkie podmioty uczestniczące w cyklu produkcji biopaliw i biopłynów obligatoryjny obowiązek spełnienia kryteriów zrównoważonej produkcji, w tym redukcji emisji CO_2 do wartości co najmniej progowych (np. min. 50% redukcji w 2017 roku). W artykule przedstawiono (na tle międzynarodowych uwarunkowań prawnych) metodę oceny redukcji CO_2 – kalkulator BIOGRACE 4 i wartość redukcji emisji CO_2 w pięciu zakładach produkujących biopaliwa trzema metodami.

Słowa kluczowe: biopaliwa, redukcja emisji CO_2, BIOGRACE, SimaPro

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