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Renewable materials as feedstock for energy production and other applications

In recent years increased interest in raw materials of biological origin have been observed. These products, including energy carriers, are perceived as friendly to the natural environment and human health, therefore societies with high ecological awareness have often chosen such products increasingly. In the oil and energy sector some factors stimulating the development of such products may also be distinguished. The main usage of resources of biological origin, was briefly discussed in the article. Legal, and technological aspects, as well as interaction with the environment of biomass being a part of RES (Renewable Energy Sources), were also presented.

Key words: renewable sources, GHG emission, products of biological origin.

Surowce odnawialne do produkcji energii i innych zastosowań

W ostatnich latach obserwuje się zwiększenie zainteresowania surowcami pochodzenia biologicznego. Produkty te, włączając nośniki energii, są postrzegane jako przyjazne dla środowiska naturalnego i zdrowia człowieka. Dlatego też społeczeństwa o wysokiej świadomości ekologicznej wybierają takie produkty coraz częściej. Również w sektorze naftowym i energetycznym można wyróżnić pewne czynniki stymulujące rozwój takich produktów. W artykule przedyskutowano główne zastosowania surowców pochodzenia biologicznego. Przedstawiono również prawne i technologiczne aspekty a także i interakcję ze środowiskiem naturalnym biomasy będącej częścią OZE (Odnawialne Źródła Energii).

Słowa kluczowe: surowce odnawialne, emisja GHG, produkty pochodzenia biologicznego.

Introduction

The first factor is the high ecological awareness of the end user. In this case we can refer to the voluntary use of renewable natural resources. The application of biobases in lubricants is an example of this area. This is now a quite dynamically developing sector of industry, which is especially visible in the field of standardisation [20, 24]. Moreover, according to research performed by Dutch scientists [2], the perception of a bio-based economy is positive. Most participants of the research had positive attitude towards bio-based technologies. They linked them to positive notions such as sustainability, environmental friendliness, naturalness and an ecological feeling. Other perceptions of participants, such as genetic modification, higher prices and improper land use, were regarded as negative. Participants stressed that these technologies shall be sustainable and eco-friendly and do not have negative effects, such as leading to food shortages or deforestation. Moreover, during the research it was found that when participants were direct consumers of bio-based technology, such as bioplastics, they were often willing to pay a little more for it, with emphasis on "a little", provided the product is proven to be truly eco-friendly [2]. So, because of that reason, the way of confirmation of the sustainability or eco-friendly character of products, is very important. This is the reason why, among others, sustainability certification schemes are on the rise. Certification schemes are voluntary or mandatory. A specific case is that which takes place in the biofuel sector, where voluntary schemes can are treated as mandatory [7].

The European Union policy is the second mentioned factor, and thereby – of individual Member States. This policy is expressed in pieces of legislation, such as directives, which are then implemented to the national legislation via acts and regulations. In the field of renewable energy sources use the 2009/28/EC directive, referred to as the RED directive (from English *Renewable Energy Directive*), is the key European piece of legislation [23]. It has set the target of: 20% gross share of energy from renewable sources (RES) in 2020, including 10% in the transport.

Poland, as a Member State is obliged to implement the directive provisions, and has also been systematically increasing the share of energy originating from renewable sources, both in the field of energy used for transport purposes as well as to generate electricity, heat and cold. An increase in the electricity share in the RES in the years 2005–2014 is presented in figure 1 [15], while figure 2 illustrates an increase in biofuels and other renewable fuels share in transport fuels measured by means of the National Indicator Target [9].

Targets for 2020 are fixed, but policies beyond this year are still being developed. A key example is a draft of the RED II Directive. The draft sets new targets and makes revision of RED provisions. The review has four main objectives:

- Contribute to limiting the global average temperature increase to not more than 2°C, with the view of achieving 1.5°C in line with the EU's commitment towards Paris COP 21 objectives,
- achieve in a cost effective way a share of at least 27% of renewable energy in the EU by 2030,
- making the EU economy more energy secure, by reducing its import dependence,
- contribute to becoming the world leader in renewable energy and a global hub for developing advanced and competitive renewable energy technologies [16].

To achieve the goals listed above, the draft adopts, among others, the following provisions:

- minimum share of low emission fuels (including biofuels listed in Annex IX of ILUC and electricity coming from renewable sources) 6.8% by 2030,
- minimum share of advanced biofuels (Annex IX A of ILUC) 3.6% by 2030,

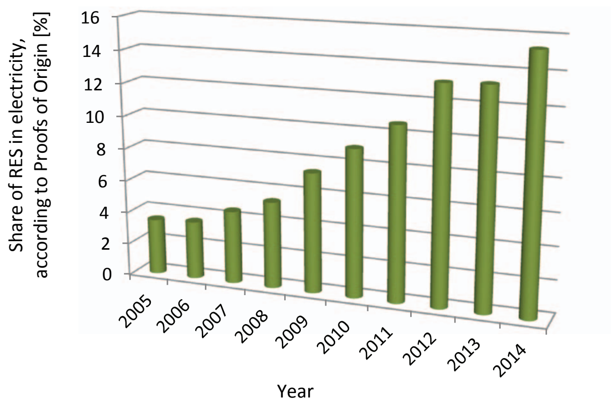

Fig. 1. Increase in the share of electricity from RES in the years 2005–2014

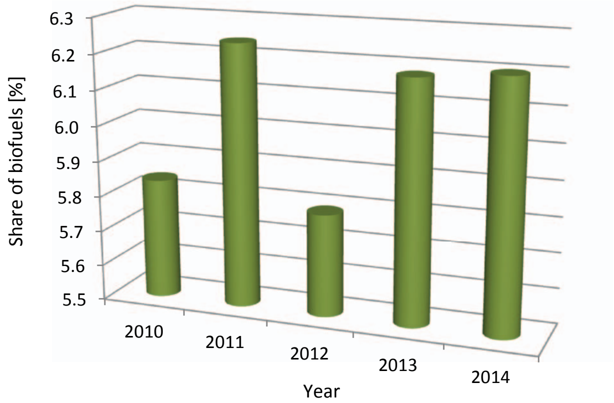

Fig. 2. Increase in biofuels and other renewable fuels share in transport fuels [9]

- limit of 1.7% for the use of biofuel produced from raw materials listed in Annex IX B of ILUC (UCO, animal fat),
- gradual reduction of the use of conventional (crop) biofuel down to 3.8% by 2030.

It seems that in the motor fuel and biofuel sector, feedstock listed in Annex IX A will gain importance. Besides advanced biofuels, low emission fuels such as electricity and CNG/LNG are expected to be developed. To improve the eco-friendliness, those fuels are still being tested [5].

Products of Biological Origin for Other Applications

Products of biological origin, hence from renewable sources, in the field of petroleum products include biolubricants and other operational fluids, like hydraulic fluids and also bioplastics. All these products are currently part of the growing branch of the economy called the bio-based economy. The rate of a development of this branch can be shown by the example of bioplastics. According to [4] the global biopolymer production capacity in 2011 reached 1166 thousand of tonnes while in 2017 it will reach 6158 thousand of tonnes (see figure 3).

Such products cited above are described as "environmentally friendly" but the lack of standards and technical vocabulary describing those products and lubricants makes the development of the market for such lubricants difficult. Standards and definitions are available only for their individual groups, e.g. for hydraulic fluids (ISO 15380); however, explicit descriptions and definitions (including biodegradability, renewability, toxicity for the water environment) consistent for all types of such products are still unavailable.

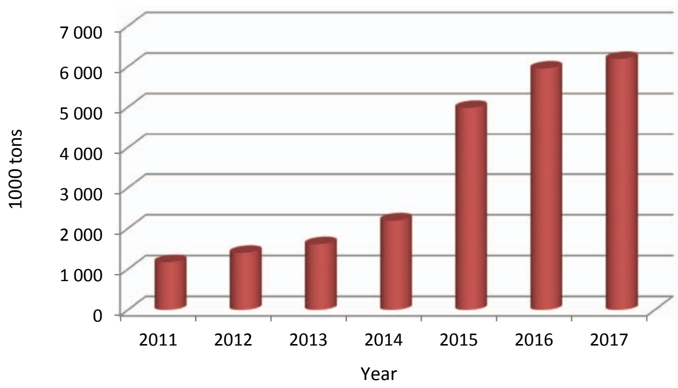

Fig. 3. Global biopolymer production capacity [4]

The "bio" prefix is frequently perceived as a synonym of something good for the environment or health. This prefix, if it accompanies lubricants, may be perceived by consumers as a confirmation of the products biodegradability. In other words, consumers may presume that "biolubricants" are biodegradable (decompose in the environment), which is necessary in the case of e.g. leaks or intended technical losses. Attention should be drawn to the fact that a product of biological origin may not necessarily be biodegradable and – to the contrary – also products of fossil origin may be biodegradable – examples are presented in table 1 [24].

Biodegradation of bioplastics was a subject of research performed by [3]. The research showed that depending on the type of bioplastic and conditions, biodegradability expressed in (%) can vary from 1 up to 100% and period of biodegradability (days) may reach 6–300 days. Similar researches were performed by [19]. However, in this case, biodegradation in soil of biolubricants, was assessed.

The use of bio-based raw materials is also favourable referring to two current problems: the depletion of fossil resources and climate change. So this sector of industry seems to have good development prospects. However, it is necessary to arrange the nomenclature in this field and to determine the rules for biological confirmation of raw materials origin, for the lubricants products and other operational liquids.

Table 1. Specification of selected products origin and biodegradability

Origin of material	Biodegradability	Example
Renewable	yes	rape oil, trimethylpropane trioleate (TMP-O)
Non-renewable	yes	diisotridecyl adipate (DITA)
Renewable	no	hydrocarbons from Biomass-to-Liquid (BtL) processes

Threats Related to the Use of Products of Biological Origin

Products of biological origin are now widely used as substitutes for fossil fuels, both in the energy and in the transport sector. If in the energy sector the renewable energy sources are diversified (e.g. the wind and solar energy, biomass), in the case of transport fuels, because of their type and chemical nature, the agricultural raw materials are the main resources for the production of energy carriers from renewable sources. Hence the threats related to this type of energy carrier, apply mainly to the area using the arable land for the biofuels production. In accordance with the European Union policy assumptions the share of biofuels in engine fuels will be increasing till 2020. It is necessary to draw attention to the fact, that the set targets apply to the percentage share and hence, if the demand for fuels will be increasing, the volume of biofuels sold will also grow, even if the biofuel target will be maintained at a permanent level. The impact of this phenomenon has been presented using the following example: to produce 1 MJ of FAME, 0.073 kg of rape seeds are necessary [13]. The POPiHN estimates that in Poland 755.000 m^3 of methyl esters were added to fuels in 2015. Assuming the calorific value for FAME given in the directive [23] we should state that 24.915 bn MJ FAME were introduced in 2015 to the fuel oil (excluding B100), so approx. 1.818 M tonnes of rapeseed were used for that. Assuming a yield from a hectare of around 3.1 tonne, raw materials for FAME production were grown on land covering 586.708 ha. Acc. to the statistics, 14.545.300 ha of arable land were registered in Poland in 2015 [11], which means that if the raw material to produce biodiesel integrated with the fuel oil would be acquired only from the territory of Poland, 4% of the arable land should be allocated to acquire the raw material. Considering also raw materials for the production of ethanol – being a component of engine petrol, and the growing biofuel targets – the use of land for the biofuel production raw materials may be significant on a European scale.

Of major concern is that with the expansion of cultivation for biofuels, in particular in those areas of the world, where the acquisition of agricultural raw materials is economically profitable, the natural environment may be degraded. To prevent possible adverse impact of the growing demand for agricultural raw materials on the natural wealth, the RED directive [23] introduced the sustainable development criteria, which must be met, to account for a given batch of biofuel in the national biofuel quota obligation. The fulfilment of such criteria must be confirmed by a certificate issued within the certification system approved by the European Commission. The only such Polish system is the KZR INiG System [7, 18].

The sustainable development criteria is comprised of requirements with respect to the land, on which raw materials for the biofuels production are cultivated, and set a condition to ensure an appropriate level of GHG emission reduction, during the life cycle, in relation to a fossil equivalent. Both, the issues related to land use and the methodology for GHG emission calculation do not consider the fact, that the management of arable land for the production of biofuel raw materials may result in transformation of the land, which so far has not been used for farming. However, with the expansion of the land for biofuel objectives, a situation may occur, that to satisfy mankind's need for food, the land not used for cultivation will be transformed into arable land. This phenomenon is referred to as the indirect land use change (ILUC) and it should be also considered when approving raw materials for biofuels production.

To take into account the effect of farming, land expansion resulting from the demand for biofuels and to introduce mechanisms encouraging the use of non-food raw materials for biofuels production, the European Commission in September 2015 issued directive 2015/1513/EC [22], referred to as the ILUC directive. It imposes an upper limit, 7%, on the biofuels content produced from raw materials competing with food; it provides also a list of biofuels and raw materials for their production, which share should be doubly calculated. The directive includes also GHG emission indices for individual raw material groups, resulting from the indirect land use change. Furthermore, to promote non-crop renewable sources, the ILUC Directive laid down a list of feedstocks which are double counted. These are:

a) algae if cultivated on land in ponds or photobioreactors,
b) biomass fraction of mixed municipal waste, but not separated household waste subject to recycling targets under point (a) of Article 11(2) of Directive 2008/98/EC,
c) bio-waste as defined in Article 3(4) of Directive 2008/98/EC from private households subject to separate collection as defined in Article 3(11) of that Directive,
d) biomass fraction of industrial waste not fit for use in the food or feed chain, including material from retail, and wholesale, and the agro-food, and fish and aquaculture industry, and excluding feedstocks listed in part B of this Annex,
e) straw,
f) animal manure and sewage sludge,
g) palm oil mill effluent and empty palm fruit bunches,
h) tall oil pitch,
i) crude glycerine,
j) bagasse,
k) grape marcs and wine lees,
l) nut shells,
m) husks,
n) cobs cleaned of kernels of corn,
o) biomass fraction of wastes and residues from forestry and forest-based industries, i.e. bark, branches, pre- commercial thinnings, leaves, needles, tree tops, saw dust, cutter shavings, black liquor, brown liquor, fibre sludge, lignin and tall oil,
p) other non-food cellulosic material as defined in point (s) of the second paragraph of Article 2 of ILUC directive [22],
q) other ligno-cellulosic material as defined in point (r) of the second paragraph of Article 2 except saw logs and veneer logs,
r) renewable liquid and gaseous transport fuels of non-biological origin,
s) carbon capture and utilisation for transport purposes, if the energy source is renewable in accordance with point (a) of the second paragraph of Article 2,
t) bacteria, if the energy source is renewable in accordance with point (a) of the second paragraph of Article 2.

Thus, one can foresee, that the raw materials listed above will gain value.

Biomass for the Generation of Energy, Heat and Cold

It might seem that similar problems will occur in the case of biomass use for the generation of electricity, heat and cold, because in this case producers are also obliged to utilise renewable energy sources. However, there is no defined obligation to apply sustainable development criteria for solid biomass – this issue was analyzed by the European Commission [25]. Directive [23], setting the target of generating 20% of energy from renewable sources in 2020, gave the impetus to develop this sector of the industry. The forecasts included in the Road Map [21] for renewable energy published in January 2007 were implying that the biomass use should increase twofold and it should account for around a half of energy from renewable sources, contributing thereby to accomplishing the 20% target by 2020. A growing demand for solid biomass has caused a substantial amount of it to be imported to the EU; in the Netherlands approx. 30% of the biomass used, is delivered from North America and 20% from Asia [1].

According to the information provided in the Report [25], in certain regions of Italy financial support is limited to power plants using to a significant extent (50÷70%) local biomass, that is produced within 50 km of the power plant.

Contrary to farming for biofuel objectives, biomass waste and recycling waste are not produced on purpose to use in the energy sector, but result from business activities. This is the case of e.g. sawmills, which sell sawdust to pellet producers, while dung is used in the biogas production via anaerobic decay. If this system is maintained, biomass use for energy production can increase in the EU, parallel to growing afforested areas in Europe, an increase in resources will remain at a constant level. The implementation of sustainable development standards shall also again protect the phenomenon of excessive production of waste and residues for energy purposes. On the other hand an increase in the demand for forestry and agriculture waste and residues may result in reducing resources of elemental carbon in the soil. Substantial amounts of this element exist in the organic matter of the soil, which may grow or fall depending on the planted crops or trees and on the management system, e.g. on the use of fertilisers, and hence its excessive removal, leads to reducing carbon resources in the soil, which converts into a higher GHG emission. Emissions originating from the land use, land-use change and forestry (LULUCF) are subject to the obligation of reporting by all countries, as specified in Annex I pursuant to the United Nations Framework Convention on Climate Change (UNFCCC), including the EU Member States, Russia, Canada, and the United States. The estimates [10, 14, 25] show that the biomass use, depending on its production path, results in even more than a 90% reduction of GHG emission as against fossil equivalents. So sustainable use of natural resources can contribute to GHG emission reduction on the Earth. Because of high GHG emission reduction indices this path seems to be more effective than the use of transport biofuels. According to [25] higher GHG emissions can occur only in the case of farming for energy purposes and to some extent in the case of short rotation groves, due to the use in farming of fertilisers, which are usually not used in forestry. In view of the possibility to use wastes and residues, a favourable path of production of eco-energy is a biogas plant. What is more, research has shown that a mixture containing fossil gas (LNG, LPG) and biogas can be burned in current devices, without the need for additional modification [8].

In the case of using tropical and subtropical raw materials, in particular products that require a higher energy input (e.g. charcoal), the GHG emissions are usually higher, because the energy from fossil sources is frequently used to process such raw materials and (to a smaller extent) due to the emissions related to transportation to the EU.

High fragmentation of the biomass sector is an important barrier to the introduction of sustainable development criteria systems. Because of that, the European Commission recommends applying sustainable development systems only to larger energy producers, whose generating capacity is at least 1 MW of heat or electricity. Imposing on small producers the requirement to prove a sustainable production would create an excessive administrative burden, although they should be encouraged to achieve higher efficiency and productivity.

According to [25], the suggestion of a harmonised system for sustainable development criteria, assessment makes it difficult for the diversification of biomass raw materials for energy purposes. Various raw materials – both of forest and agricultural origin – set different challenges with respect to sustainable production, GHG emission or efficiency of energy conversion. However, the risk related to the disturbance to sustainable production of biomass from waste as well as from farming and forest residues, at the lack of land use change, is now considered small. Therefore the European Commission has not implemented uniform legislation in this field at the EU level, presenting at the same time recommendations to Member States related to the development of sustainable development systems. In report [25] the Commission recommends that the Member States, which have introduced or are introducing national sustainable development systems related to solid and gaseous biomass used in the generation of electricity, heat and cold, should ensure equivalence of those systems with provisions of the renewable energy directive (directive 2009/28/EC) in nearly all aspects. That would allow to maintain a higher consistency and to avoid unnecessary discrimination in raw materials use, subject to certain differences resulting from the nature of specific renewable raw material. Thresholds determined for GHG emission reduction for liquid biofuels are the first difference. It is not easy to introduce standard emission values for those gases for a wide range of possible raw materials – such as waste, or common standard values comprising similar raw materials or their combinations. Equally difficult, is to justify imposing obligations and additional costs related to proving the meeting of GHG emission criteria for sectors, which routinely achieve a high reduction of such gases by e.g. the use of waste. However, acc. to the EC opinion it is not advisable to give up the criterion related to GHG emission reduction and in Annex I to [25] it provides the methodology to calculate GHG emission in the solid biomass life cycle.

Summary

An uncritical use of raw materials from renewable sources cannot be now unconditionally treated as a pro-ecological activity. The high environmental awareness of developed countries societies makes, that attention is paid to the fact, whether the use of a specific raw material of biological origin would not result in adverse changes in the natural environment. This applies both to the impact on ecosystems and the natural wealth as well as on the GHG emission.

Those issues have been clearly implemented to the assessment of biofuels used in liquid fuels. On the other hand, in the case of biobases application for lubricants production, they are only in the development phase.

The confirmation of solid biofuels origin is a strongly developing area. However, a single systemic approach to the verification of solid biomass origin is missing. The European Commission issued guidelines in this field, including mainly recommendations for consistency of national legislations with the RED directive requirements, in particular related to the confirmation of the sustainable development criteria and the methodology for GHG emission determination in the solid biofuels life cycle. Standard methods owned by private commercial certification systems are developing in parallel. One should pay attention to the fact, that the draft of the RED II introduces the obligation of sustainability certification also for solid biomass.

Moreover, the same group of raw materials will be desired by a few sectors (agriculture, power engineering, biofuel and maybe also bioplastics producers), which may compete for it.

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