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BIOMASS AS A RENEWABLE SOURCE OF ENERGY

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A b s t r a c t

In this paper state of art on known and potential biomass sources is reviewed. The review will consider energy dedicated crops and waste types that are already applied for clean energy purposes as well as potential ones. The resources can be applied for biofuels, bioethanol, methane, hydrogen production by means of various processes (methane fermentation, pyrolysys etc). The environmental and economical benefits of biomass application as a renewable energy source are also described.

Introduction

Rapid industrial progress has caused sudden increase of energy consumption. This phenomenon is especially visible in developing countries. Traditional methods of energy production were based on fossil fuels (mostly oil and gas), which caused consequences in form of excess emission of greenhouse gasses (ZIEMIŃSKI, FRĄC 2012). Industrial revolution and civilization development led to burdensome climactic changes. According to scientific research the 2°C rise of average temperatures can lead to extinction of plants and animals. Climate warming causes many environmental problems such as: floods, hurricanes, drought, tropical cyclones, erosion of coast beaches, increase of sea level (which leads to submersion of islands and lowlands), and problems in drinking water

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supply for humans and animals (SHUIT et al. 2009). In order to decrease the above climactic problems, consumption of fossil fuels and increase energy efficiency two types of actions were undertaken – development of energy saving programs, and research on renewable energy sources. Energy from renewable sources although more expensive in production then conventional energy has many advantages. It leads to reduction of carbon emission to atmosphere, it is compatible with rules of balanced development, it reduces the dependence on fossil fuels and is not as dangerous as atomic energy (BANOS et al. 2011). According to SAYNIGH (2012) we distinguish following renewable energy sources: solar radiation, wind, water and ocean currents, biomass, biofuels, geothermal sources and hydrogen.

Poland as a member of European Union is obligated to adjust to European energy policy. Currently the use of renewable energy in relation to other countries is insufficient. In *Energy from renewable sources 2011* (http://www.stat.gov.pl) report the predictions are that energy produced from renewable sources should be 15% of overall energy consumption until 2020. On Figure 1 the percentage of renewable sources energy consumption to overall usage in UE and in Poland in 2002-2010 period. It visualizes how far Poland is in comparison to UE countries considering renewable energy development.

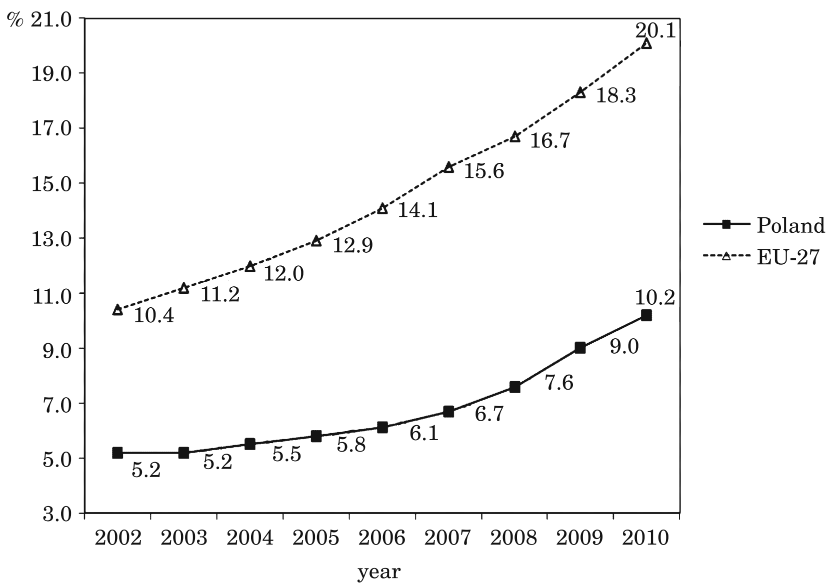

Fig. 1. Percent of energy obtained from renewable sources in UE and Poland in 2002–2010 period
Source: Główny Urząd Statystyczny. Portal Informacyjny, on line: http://www.stat.gov.pl/gus

Biomass as energy source

Biomass is one of the most promising alternative energy sources, because similar to that of carbon neutrality and availability from multiple sources (LIM et al. 2012). According article 2 of 25th of August 2006 law on biocomponents and liquid biofuels biomass consists of: solid or liquid substances of plant or animal origin, which undergo biodegradation from products, waste and left-overs of agricultural and forest production, and their products processing industry and parts of other wastes which undergo biodegradation, especially agricultural raw materials. According to DODIĆ et al. (2012) biomass after partial processing can be in solid state (briquettes, pellets), liquid (biodiesel, biomethanol and bioethanol) or gas (biogas, syngas and hydrogen). Since mastering fire biomass was used for energy production in burning process and has been used since then, especially in third world countries example: Tanzania or Ethiopia, where 90% of energy originates from biomass (KELLY-YONG et al 2007). The most favorable from the balanced development point of view is biomass processed to liquid fuels, because the highest energetic efficiency can be achieved this way (SUNTANA et al. 2009). Biomass can be processed by means of: thermo-chemical methods to liquid fuels, gasses (carbon oxides methane), or pyrolysis where hydrogen is the final product.

Biomass can be also processed by biotechnological means. Through fermentation of oily plants biodiesel is produced, which can be used in standard diesel

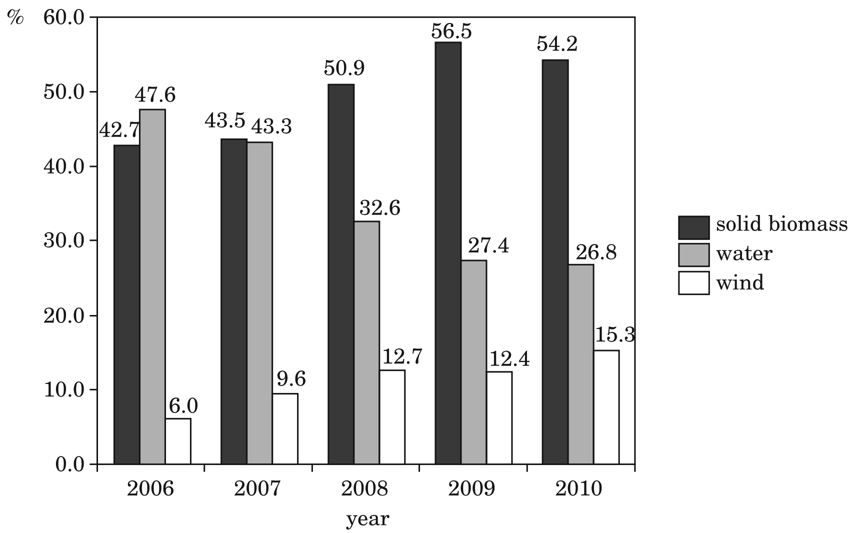

Fig. 2. The contribution of solid biomass, wind and water to electric energy in Poland in 2006–2010
Source: Główny Urząd Statystyczny. Portal Informacyjny, on line: http://www.stat.gov.pl/gus.

and gas engines, after minimal modifications. Through fermentation of municipal waste such as post breading waste exp. manure the biogas with relatively high content of methane can be obtained (ZAGORSKIS et al 2012). This proves high biomass potential as an energy source which can replace conventional fuels in the near future (DEMIRBAS 2008). Biomass is a clean renewable energy source, which can greatly improve the environment, economics and energetic security. Biomass application as an alternative energy source is beneficial for developing countries because of availability of local raw materials and employment of local labor for its production and processing (DEMIRBAS 2008).

In Poland biomass is getting more and more popular as electric energy source, and is dominant to water and wind energy (Figure 2).

Biomass main sources

Energy dedicated willow (*Salix viminalis*)

One of the more and more popular biomass types is energy dedicated willow. Two types are present in nature: tree type and bush type (more often used for energy production). It is characterized by high resistance to soil contaminations and quick growth (STOLARSKI 2003). Growth cycle of energy dedicated willow is 3 to 5 years, thanks to which it is considered a fast renewable source (TAHVANAINEN, RYTKONEN 1999). Its wood (unlike coal) does not emit green house gasses in burning process and is characterized by low emission of nitrogen, chlorine and sulfur to atmosphere. It has low accumulation of heavy metals from soil, which makes it ideal for energetic purposes (JAMA, NOWAK 2012). Application of energy dedicated willow for soil purification purposes is not an ideal solution. Though the elimination of excess nitrogen is satisfactory, the low soil purification in case of excess chlorine still remains a problem, especially in dry climate where concentration of this element may exceed toxic values (MARMIROLI et al. 2012).

Willow may find application in waste purification from small household waste water disposal facilities. Water purification is achieved through usage of nutrients from sewer sludge and simultaneous biomass for bioenergy production. Household wastewater is almost ideal nutrient for willow plantation fertilization. Part of the differences between plants need for nutrients and content of substances in wastes is neutralized by the soil. Household wastewater are more effective for fertilization because of lower concentration of heavy metals than in industrial wastewater, which can inhibit plant and soil microorganisms growth. Both of these processes lead to decrease of waste utilization. Research on application of *Salix viminalis* grown on hydroponic gravel for waste utilization published by MANT et al.(2003) had shown that effectiveness of utilization of gravel alone is: 90% for BOD, 45.7% for nitrogen, 85.8% for phosphorus, and 6.9% for potassium. The plant increases this effectiveness of 12% for nitrogen and 5% and 18% for phosphorus and potassium.

JAMA and NOWAK (2012) investigated the application of energy dedicated willow for utilization of sewage sludge. They are considered as wastes of high organic compounds and nutrients concentration, thus good fertilizer material. Sewage sludge are a inhomogeneous material, dependent on waste type, applied technology and season of the year. Before application it needs to be checked for the presence of pathogenic bacteria. When energy dedicated willow is being fertilized it accumulates 20% of phosphorus in the first year and this amount increases in time. The same goes for nitrogen but the amounts of accumulated element differ with carried out research and vary from 20% (and increase to 25% in following years) to 70% in the first year. Willow also accumulates calcium (3.1%), magnesium (0.81%) and sulfur.

Wastes of freshwater fish breeding ponds are a great problem for breeders. A huge amount of water is needed in order to minimize the concentration of ammonium, which dissolves impurities from excrements and non digested leftovers. Wastes are mostly waters with small concentration of contaminants. A simple and ecological solution for waste utilization is watering of energy dedicated willow and poplar plantations, because of a their higher water usage in comparison to other types of trees. Research carried out in Canada in 2005 proved that willow and poplar can be intensively watered with water from breeding ponds and decrease the sewage phosphorus income to natural ecosystem (FILLION et al 2009).

Sweet sorghum (*Sorghum Moenh*)

It is a very promising plant for energy application. High photosynthesis efficiency, high resistivity to water deficit, small fertilizer need, ease of climactic and soil accommodation and high surface efficiency are its benefits. The growth period is 3-5 months long in warm climate conditions (MATSAKAS, CHRISTAKOPOULOS 2013, MEKI et al. 2013). Sorghum is energy dedicated plant attractive for bioethanol production, because of high sugar concentration in its juices, which undergo fermentation processes with ease and are transformed to biofuel (WANG et al. 2013). Research published by REN et al. (2013) showed that plantation of this plant are more profitable then cotton and corn considering lower energy intake and higher energy production yield.

Giant miscanthus (*Miscanthus giganteus*)

It is a high multiyear grass, with stems similar to reed (KLUDZE et al 2012). Within a yearly time of plantation the plant grows 3.5 meters high. It is harvested from January to March. It resistant to low temperatures with maintenance of high CO_2 assimilation and harvest yield (COPELAND et al. 2012). It harvest is 20 to 26 tons from hectare of space during the year (PARK et al. 2012). Miscanthus production cycle is 15 years (VENTURI et al. 1999). The plant aside from energy purposes can be used for reclamation industrially degraded territories (HOWANIEC, SMOLIŃSKI 2011). Miscanthus is interesting as energy dedicated crop because of its ability to decrease of anthropogenic CO_2. It is caused by the fact that the amount of CO_2 which is brought to the atmosphere during biomass burning will not exceed the amount that was accumulated by the plant during photosynthesis. It needs very few nutrients, thus can be grown on low nutrient soils. High resistance to varmints allows planting without the need of pesticide use (ANGELINI 2009). Miscanthus can be used for burning for heat production, for cellulose production, and for furniture production as isolation material (ACAROGLU, AKSOY 2005).

Jerusalem artichokes (*Helianthus tuberosus*)

It is a multiyear bulbous plant of high energetic potential. It characterized by quick growth and plantations do not require large amounts of fertilizers, pesticides or water. It can be planted on soils of low agricultural usefulness. Its energy production use is based on biofuel production, mainly bioethanol (LU et al. 2011). Harvest is between 60 to 90 tons of fresh mass per hectare. Bulbous of Jerusalem artichokes contain about 80% water, 15% carbohydrates, 1–2% protein and small amount of fat. The main sugar of this plant is insulin, and in smaller amounts saccharose, glucoses and fructose (MATIAS et al. 2011).

Oil palm (*Elaeis guineensis*)

This plant is no as common in Europe as those mentioned above, but is highly popular in Asia (exp Malaysia). It is a south African plant. It is used for production of edible oil from its fruits. The exploitation of the palm begins 3 years after its planting to 12–13 years maximum. In later periods the harvest decreases to 25^{th} year. Oil palms can be grown in all tropical countries, thus their availability for biomass production increases. Biomass of oil palm is mostly cellulose, hemicelluloses and lignin (KELLY-YONG et al. 2007, MOHAM-

MED et al. 2011). The palm fruit contains of a seed surrounded by oily mass. Oil is obtained in extraction process from cellulose mass of the fruit. Such oil can be used for edible purposes, but seed oil is used for soap production (SHUIT et al. 2009).

Agricultural wastes

In the process of agricultural production a lot of unused biomass is obtained. Agricultural wastes can be divided according to agriculture branches of their origin. Four basic groups can be outlined: wastes from field plantations, waste from food processing, breeding and slaughter wastes. It consists mainly of: manure, slurry, post slaughtering sediments leftovers from fruit and vegetables, straw, stems, whey, molasses, dairy production waste and others (CURKOWSKI et al. 2011). The problems with economically beneficial energy production from agricultural wastes is their high accumulation costs, and costs of transport from obtainment spot to utilization and storage point (DODIĆ et al. 2010).

Agricultural biomass can be used in industry for direct burning, for vaporization and fermentation. Vaporization process is very beneficial because of gas and liquid fuels shortage, and as means of heat production (DODIĆ et al. 2010). Utilization of agricultural biomass is possible not only in temperate climate but also in warmer countries. Malaysia is one of the largest producers of palm oil, which causes the need of production waste utilization. Waste are processed to animal fodder or fertilizer, but research are being done on biofuels utilization (bioethanol) and their processing to electric energy (SHUIT et al. 2009).

Wastes of food and agriculture industry

Rapidly developing food and agriculture industry generates large amounts of waste (peelings, seeds, mill cakes of juice and beer production, distillery stillage, whey, mushroom substrates, fish waste, slaughter waste and others) which are useful for renewable energy production (OLGUIN et al. 1995). This problem is the source of interest for Chair of Foundations of Safety from University of Warmia and Mazury in Olsztyn. At the moment the research on utilization of post beet pulp fermentation wastes from methane production are being conducted. In the last few years beet pulp from a desirable resource have become a troublesome waste. Work on utilizing them as fertilizers for energy dedicated willow are in progress.

Methane fermentation and biogas

Fermentation is a process of organic matter degradation by microorganisms in non oxygen environment. One of the fermentation products is biogas, which consists mainly of methane and carbon dioxide. In order to increase the production yield multisubstrate fermentation can be conducted (WU 2007). Fermentation processes are often utilized for stabilization of liquid and solid waste (LUSTRATO et al. 2012). Biogas production from agricultural wastes, animal excrements and municipal and industrial wastes is a potential alternative energy source for many countries. One cubic meter of biogas can produce 2.1 kWh electric and 2.9 kWh heat energy equivalent (ZIEMIŃSKI, FRĄC 2012). In 20th century 90's multiple benefits of biogas have been observed, as well as multitude of biomass sources, which could have been utilized for production of this resource (GUNASEELAN 1997). Such production is also one of utilization methods for food industry wastes, such as sugar wastewater (OLGUIN et al. 1995). Biogas is not only methane and CO_2, but also hydrogen. Hydrogen is more and more often described as the fuel of the future, and methods of its production are subject of many research. One of the sources of bio-hydrogen, considering its high concentration with relatively low nitrogen rate, are sugar industry and cellulose production wastes, as well as other wastes of high carbohydrates concentration. The wastes from plant watering are also worth consideration. Plants decrease the amounts of nitrogen, but wastes are still a rich hydrogen source (KAPDAN, KARGI 2006). A interesting solution is production of hydrogen from fermentation wastewater. Process is a two step fermentation, which leads to production of hydrogen in the first phase and production of methane in second phase. As substrate some of the algae like *Laminaria japonica* (JUNG et al. 2012) can be utilized, but also, what is more important from recycling point of view, food industry wastes (KIM et al. 2012).

Conclusions

With growing industrial development the need for energy increases. However because of growing environmental awareness in the society emphasis is being put on acquiring more amounts of energy from renewable resources then from not renewable ones. Biomass is an example of such energy sources. In light of presented studies a large variety of biomass and potential for its application for energy production purposes. It is possible to select energy dedicated crop for given climate and soil type as well as proper waste utilization. Considering this energy sources obtained during food – agricultural production processes are perspective for clean energy production. Because of Poland geographical location and need for energy sources diversification biomass energy seems to be especially beneficial for north-east regions of Poland.

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