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## Agricultural biomass as a source of renewable energy

***Abstract:*** *This paper presents the role and importance of agricultural biomass in the production of renewable energy sources. A significant increase in the general public's interest in environmental protection and a possible future threat that natural sources of energy (petroleum, natural gas, coal) will be exhausted result in increasingly larger production and use of energy generated from agricultural, forest and municipal biomass. The paper shows the location conditions and environmental factors conducive to the establishment of an energy plantation as well as the prospects for the development of agricultural biomass production and utilisation. The aim of the present research was to analyse the methods of use and the importance of agricultural biomass in the production of renewable energy sources as well as to investigate related problems. Numerous scientific papers and studies presented in the literature were the basis for this analysis.*
*Key words: biomass, energy crops, biofuels, agricultural production.*

### Introduction

Nowadays, it is difficult to imagine life without using electrical energy, petroleum derivatives or natural gas. Existing scientific studies [Ramsay 2007, Roszkowski 2008] show the high probability of an energy crisis that may happen in the near future of 15-25 years. The studies of the International Energy Agency (IEA) estimate that the demand for energy will increase by 50% until 2030, which clearly exceeds the estimates made two years ago. The IEA estimates that the demand for energy will double in 2030, whereas the demand for petroleum-based products will rise by 37% [Ramsay 2007]. The rapidly increasing depletion of traditional sources of energy causes an increased interest in the use of renewable energy sources (RES), primarily biomass of agricultural origin.

Agricultural biomass is understood as a qualitatively balanced stream of organic matter originating directly or indirectly from agricultural crops [Dobrowolski et al. 2011]. According to the EU's Directive 2001/77/EC, biomass means the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste.

In the 1990's there was a significant increase of interest in renewable energy sources. The benefits arising from the use of such kind of energy for the society, regional development, increased energy security, the creation of new jobs, and environmental care cannot be overestimated. According to Denisiuk [2004], the continually growing level of energy consumption and petroleum extraction creates reasons for making intensive efforts to implement RES.

To protect the natural environment from a disaster and to provide energy security, three essential documents have been developed which contain the basic characteristics of renewable energy sources [Denisiuk 2006]:

zero contribution of exhaust emissions from biomass burning to the generation of greenhouse gases - $CO_2$ and $CH_4$ (burning of straw, tree branches, energy crops);

the possibility of meeting energy needs of a developed economy by using the potential of renewable energy sources;

the dispersed occurrence of these resources, which allows them to be used in local energy systems, in particular in rural areas and small towns.

In spite of the fact that an ever greater interest in energy crops has been observed in Poland for more than a dozen years and that the production and collection of biomass of quickly growing species are promoted as a direction of agricultural production, the development of this new agricultural activity, termed the agro-energy industry, is largely determined by economic factors.

## Agricultural biomass as raw material for the generation of electricity and heat

The importance of the role of biomass in the energy balance of our country markedly increased after Poland's accession to the EU. At that time, in seeking the possibility of meeting Poland's commitments concerning the share of energy generated from renewable sources, special attention was drawn to biomass. The high utilisation of biomass is a common solution in Sweden, Finland, Germany, France, the United States, and in other countries. In accordance with the EU standards, the share of biomass-generated energy should be 15% relative to coal-based energy in 2020 [Faber et al. 2009].

The main agricultural biomass material that can be processed for the needs of the energy industry is straw of cereals (wheat, rye, triticale) and oilseed rape [Dobrowolski et al. 2011]. Agricultural biomass has a huge potential in each country, but it is largely dispersed. It comprises waste from plant production (straw) and animal production (animal manure and slurry). In this aspect, forest and timber industry waste as well as municipal waste should also be included in agricultural biomass.

According to Faber and Kuś [2007] as well as Stuczyński et al. [2008], the basis for the possibility of biomass generation is the efficiency of converting solar energy into biomass, the availability and agroclimatic suitability of areas of the Earth for plant and forest production as well as net energy yields that can be obtained. In physico-chemical and energy terms, biomass can be considered to be a kind of universal semi-raw material, since all types of energy carriers, like heat and electrical energy, transport fuels, including hydrogen fuels which have a promising future, and a wide group of chemical products (polymers) can be produced from it [Roszkowski 2009].

The possibilities of biomass utilisation for energy generation depending on the conversion method are shown in Table 1.

Table 1.

Possibilities of biomass utilisation for energy generation.

| Biomass utilisation | | |
|---|---|---|
| Solid biofuels | gas biofuels | liquid biofuels |
| - agricultural residues (cereal and oilseed rape straw, potato waste);<br><br>- wood fuel, timber offcuts, bark, chips, sawdust;<br><br>- animal production waste;<br><br>- dewatered sewage sludge;<br><br>- wood and grass energy crops. | - agricultural biogas from the fermentation of slurry and agricultural waste;<br><br>- wood gas;<br><br>- landfill gas from the fermentation of municipal waste;<br><br>- biogas from the fermentation of sewage sludge;<br><br>- biogas from the fermentation of food processing waste. | - biodiesel (oilseed rape oil);<br><br>- ethanol;<br><br>- methanol,<br><br>- biooils;<br><br>- used cooking oil from food service establishments. |

Source: Prepared based on [Wojciechowski 2004].

The potential of agricultural biomass that can be used for energy generation purposes is dependent on the size and type of crops, primarily cereals and oilseed rape. The average straw yield per hectare of different cereal crops ranges from about 5 to 10 $t{\cdot}ha^{-1}$ [Małecka et al. 2012]. Hay dry matter yield harvested from meadows is more than 12 $t{\cdot}ha^{-1}$, whereas among native grasses the common reed produces the highest yields ranging 12 - 30 $t{\cdot}ha^{-1}$[Grzybek 2004]. On average, about 29 million tonnes of straw are produced in Poland per year. During the summer season, it can be frequently observed that straw or several-year-old haystacks are burnt directly in the field. Excess straw production is estimated at 9 million tonne·year$^{-1}$ and this surplus could be used entirely for energy generation purposes. Straw is a valuable energy carrier, since its calorific value is high, from ca. 13 MJ·kg$^{-1}$ (in the case of fresh straw) to ca. 18 MJ·kg$^{-1}$ (dry straw), whereas the calorific value of bituminous coal is about 25 MJ·kg$^{-1}$. When analysing the energy value of straw, it can be assumed that the amount of energy produced from 1 tonne of coal is comparable to the amount of energy generated from 1.5 tonne of straw. Moreover, compared to coal, straw contains only trace amounts of organic sulphur and nitrogen oxides, environmentally harmful substances. In biofuel production, about 1300 l of biodiesel can be obtained from one hectare of oilseed rape crops, about 3500 l of bioethanol from maize and wheat grain, 6000 l from sugar cane, and up to 9500 l of bioethanol from cellulose [Roszkowski 2008].

The area of fallow and underused agricultural land in Poland is estimated at about 1.5 million hectares. These are predominantly low-fertility soils, but if proper agronomic treatments and fertilization are used, they can be suitable for energy crops, producing satisfactory biomass yields. According to Budzyński and Bielski [2004], biomass-generated energy will determine for many years whether Poland will fulfil its commitments to increase the share of RES in the primary energy balance of our country. It is estimated that as much as 2.2% of arable land area should be used for the cultivation of energy crops until 2020. The supply of biomass in the energy market can be supplemented with biomass obtained from long-term plantations. In the opinion of Tworkowski et al. [2005], the production of biomass from such plants and its processing creates the possibility of utilising agriculturally poor soils. Given the above, perennial plants called energy crops are recommended as crops grown for energy purposes, in the case of which the period of use is at least 15-20 years, which has an effect on reducing cultivation costs. The term “energy crops” includes all species that accumulate relevant amounts of oil or carbohydrates as feedstocks for the production of energy carriers [Jeżowski 2001].

In the climatic conditions of Poland, the following plants are best suited for biomass cultivation: shrubs and trees that regrow easily after cutting (willow, poplar, and black locust), long-lived perennials (Virginia mallow and Jerusalem artichoke), and perennial grasses (miscanthus, prairie cordgrass, switchgrass, reed canarygrass, and big bluestem) (Figs. 1 and 2). The best energy crops should be characterized by high dry matter content; plants with low water consumption as well as resistant to diseases and adverse environmental conditions are preferred [Kowalik 1994, Jeżowski 2003].

The basis for location of plantations and environmental factors in the cultivation of energy crops

Fig. 1. Energy poplar and giant Chinese silver grass plantation.

Fig. 2. Energy willow and Virginia mallow plantation.
*Source: www.google.pl/plantacjeenergetyczne*

The establishment of new plantations of energy crops should be preceded by a detailed analysis of a particular farm in terms of the quality of its soils, the crop species to be cultivated, the farm's technical equipment, and economic factors, i.e. the cost of transport and planting material as well as raw material prices. The largest investment is made in the first year of cultivation, but this expenditure is spread over all years of plantation maintenance. In the conditions of our country, such plantations should not be established on good and very good soils, since such soils should only be used for food and animal feed production. The current level of agricultural production, limited by the availability of agriculturally suitable land and water, shows that there are no trends towards the development of energy farming in the existing conventional meaning [Lewandowski 2006]. The industrial nature of energy crops, in particular annual ones, can be the cause of accelerated soil degradation in terms of nutrient availability and biological activity. On the other hand, an advantage of annual species is the possibility of maintaining proper crop rotation, easier adaptation to market conditions, and the use of existing machinery, equipment and buildings. Unfortunately, it often happens that the energy efficiency in the cultivation of annual species is lower than in the case of perennial crops. Perennial species are characterized by higher costs of plantation establishment and closure. Over the full period of use, however, investment is usually lower as well as the energy balance and the energy efficiency indices are more favourable than in the case of growing annual plants. The cultivation of energy crops should include many species which are adapted to diverse soil and climatic conditions and the technical capacity of farms. Biological diversity is the best method for reducing the risk of spreading diseases and pests. It also allows us to reduce the risk of losses in the event that some cultivated species is destroyed, including damage caused by game. Energy plantations offer the possibility of using low-fertility soils (Table 2) or contaminated soils, thereby creating an opportunity for implementing alternative agricultural production in degraded and low production lands.

Table 2.

Conditions for location of energy crop plantations in Poland.

| Environmental conditions | Soil complexes and soil quality classes |
|---|---|
| - areas with annual total rainfall > 500 mm;<br>- areas with an altitude of less than 350 m a. s. l.;<br>- with a slope gradient of less than 12°;<br>- undrained fields to grow willow and poplar trees;<br>- unused permanent grasslands*;<br>- plantations established only under no-tillage system “Eko-Salix”. | - good rye soil complex (5), class IVa and IVb;<br>- poor rye soil complex (6), class IVb and V;<br>- strong cereal-fodder soil complex (8), class IIIb, IVa and IVb;<br>- poor cereal-fodder soil complex (9), class IVb and V;<br>- medium quality grassland (2z), class III and IV;<br>- poor grassland (3z), class V and VI. |

*Plantations cannot be established in permanent grasslands with great biodiversity.

*Source: Preepared based on Kuś and Matyka [2010].*

Renewable energy sources (in particular biomass) can have a significant impact on the energy balance of particular municipalities or even whole regions (Fig. 3).

They can also contribute to increased energy security of a region, in particular to improved electricity supply to areas with more poorly developed energy infrastructure. Agriculture itself as well as housing and transport can be potentially the largest consumers of renewable energy.

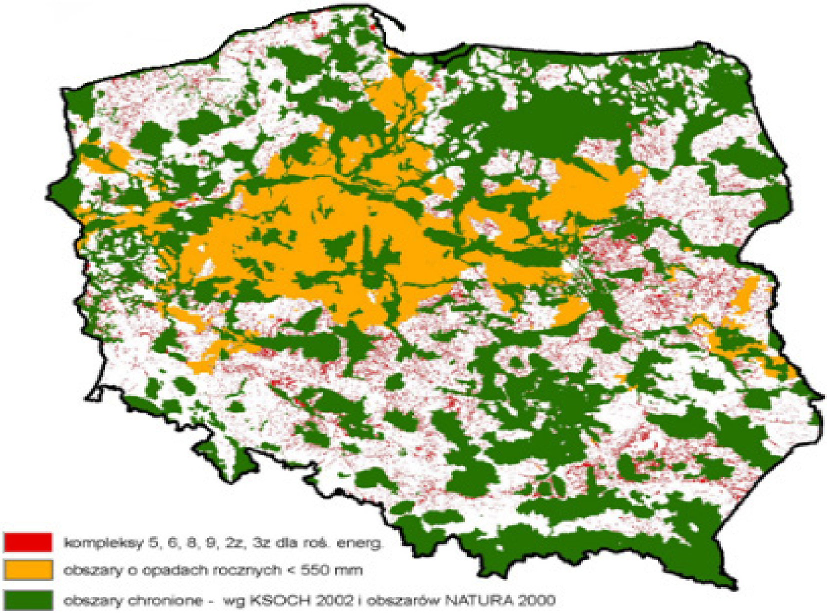


Fig. 3. Soils on which long-term energy crop plantations can be located (red colour) and areas in which such plantations should not be located (orange and green colours).
*Source: Pudełko and Faber [2010].*

The increased utilisation of biomass generated from energy crops requires the creation of an entire system that will include biomass production, distribution and utilisation. Therefore, such efforts should be oriented not only towards the establishment of plantations, but also towards organising a biomass storage and distribution system and ensuring effective biomass utilisation. Biomass originating from energy crop plantations can be used for the generation of electrical or heat energy as well as for the production of liquid or gas biofuels. Only a concurrent development of all elements of the biomass-based system can bring success. The cultivation of energy crops can contribute to the creation of new jobs and local independent energy markets in individual municipalities.

To sum up, it should be stressed that the power industry is interested in biomass burning due to the need to achieve the target share of RES relative to conventional fuels. A major obstacle is the lack of large area plantations and specialist machinery to harvest energy crops as well as the uncertainty of supplies. Generally, plantations are set up too slowly.

## Conclusions

The present and future development of the production of agricultural biomass for energy purposes must be pursued in line with sustainable development determined by three factors which include economy, ecology and social acceptance.

Biomass production can be an additional source of income for farmers and power generation companies. The development of energy farming can be an alternative solution for agriculturally unused land (soil class V and VI, degraded and low production soils).

The high probability of an energy crisis caused by a limited amount of natural resources as well as the high environmental pollution form the basis for accelerating the work and efforts designed to reduce the use of fossil energy carriers by replacing them with renewable energy sources.

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**Сільськогосподарська біомаса як джерело відновлюваної енергії**

*У статті розглядаються роль і значення сільськогосподарської біомаси у виробництві поновлюваних джерел енергії. Значне збільшення в загальному інтересу широкої громадськості до охорони навколишнього середовища і можлива майбутня загроза того, що природні джерела енергії (нафта, природний газ, вугілля) будуть вичерпані і збільшення виробництва можна буде отримати в* *результаті використання енергії, що виробляється з сільськогосподарської, лісової і муніципальної біомаси. У роботі показані умови розташування та екологічні фактори, що сприяють створенню енергетичної плантації, а також перспективи розвитку виробництва і використання сільськогосподарської біомаси. Метою цього дослідження було проаналізувати методи використання сільськогосподарської біомаси та її важливість у виробництві поновлюваних джерел енергії, а також дослідити пов'язані з цим проблеми. Численні наукові роботи і дослідження, представлені в літературі, стали основою для цього аналізу.*

***Ключові слова:*** *біомаса, енергетичні культури, біопаливо, виробництво сільськогосподарської продукції.*

*Мазяж Петр, Гарасим Эльжбета*

## Сельскохозяйственная биомасса как источник возобновляемой энергии

*В статье рассматриваются роль и значение сельскохозяйственной биомассы в производстве возобновляемых источников энергии. Значительное увеличение в общем интереса широкой общественности в охране окружающей среды и возможная будущая угроза того, что природные источники энергии (нефть, природный газ, уголь) будет исчерпаны и увеличение производства можно получить в результате использования энергии, вырабатываемой из сельскохозяйственной, лесной и муниципальной биомассы. В работе показаны условия расположения и экологические факторы, способствующие созданию энергетической плантации, а также перспективы развития производства и использовании сельскохозяйственной биомассы. Целью настоящего исследования было проанализировать методы использования сельскохозяйственной биомассы и ее важность в производстве возобновляемых источников энергии, а также исследовать связанные с этим проблемы. Многочисленные научные работы и исследования, представленные в литературе, стали основой для этого анализа.*

***Ключевые слова:*** *биомасса, энергетические культуры, биотопливо, производство сельскохозяйственной продукции.*