Possibility of Liquid Bio-Fuels, Electric and Heat Energy Production from Biomass in Polish Agriculture

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Abstract

Poland is among those countries where there are possibilities to use renewable energy sources, and biomass in particular. Significant amounts of unused biomass are found in the form of waste materials: in public utilities, in industry, agriculture and forestry. Suitable management of any waste biomass and raw materials from agriculture create a huge potential for the production of liquid bio-fuel, electric energy and heat energy. The requirements to fulfill the EU directive constitute another incentive for activities oriented on the use of RES, particularly biomass.

Keywords: biomass, agriculture, bio-fuel, heat and power

Introduction

The power industry in Poland is 95% reliant on coal, including hard coal (60%) and brown coal (35%). This condition of the power industry causes serious problems of an ecological nature, as well as difficulties to meet the EU requirements concerning the emission of greenhouse gases, particularly CO_2.

Obsolete systems of power transmission grids, and also worn out thermal power stations, which are based on low-efficient combustion technologies, pose an opportunity and present a requirement to make radical investments in power engineering. Taking into consideration the pressure all over the world, and in particular the pressure on the part of the European Union concerning the common implementation of Renewable Energy Sources (RES), Poland has a unique opportunity to meet the requirements of the EU directives concerning the use of non-emission RES and at the same time to meet the state's economic requirements.

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Suitable management of any waste biomass and raw materials from agriculture creates a huge potential for production of electric energy, heat energy and liquid biofuels. The use of any waste for energy constitutes not only an opportunity, but also an economic and ecological requirement [1].

It is also possible to use part of arable lands (ca. 25%) for the production of annual energy crops (chiefly maize) in the production of biogas, from which electric and heat energy can be obtained in a highly efficient system: a co-generative system or liquid fuels (Fischer-Tropsch synthesis) [2]. It is also important to set up permanent energy crops (e.g. willow or Miscantus), and biomass produced from them should replace hard coal used at present in heat generating plants, especially in small towns. Creation of local power engineering centres will facilitate the use of biomass waste and agricultural production waste on the local level, and this will fulfil the local requirement for electric and heat energy [3]. In this way, we will avoid large transmission losses of electric energy, and also costly investments connected with the replacement of worn-out transmission grids.

There is both a requirement and a favourable climate for the diversification of the sources of electric and heat energy production in a spatially dispersed system.

Possibility of Polish Agriculture to Fulfil the Needs of Food and Renewable Energy

In a long-term strategy (up to the year 2030), efforts are to be made to ensure food self-sufficiency as well as an effective use of production surpluses and vegetable and animal waste for energy purposes [4]. As the basic level of feeding, a physiological minimum was accepted which ensures keeping a person alive (7.500 KJ per day); ca. 10,800 KJ was accepted as the level which ensures the normal functioning of a man. A complete safety of food provision which guarantees the total feeding demands of a resident of Poland was specified to be on the level of 12,700 KJ per day per resident. In the food taken, plant products are to supply 64%, and animal products 36% of energy (protein included in plant products should constitute 44%, and protein from animal products 56%).

According to the forecast by the Central Statistical Office 2008, the population of Poland will have reached 36.8 million people by the year 2030. To ensure the full safety of the food provision for Poland, total food demand was calculated [5]. In order to provide 10,000 KJ of energy in the form of food products, ca. 3.2 kg of biomass is to be supplied. Hence, the resulting demand in the year 2030 for food biomass is 53,955,000 tons.

Taking into account the risk of variable and unfavourable climatic conditions, this value needs to be increased by 10%. Considering lasting losses of lands for non-agricultural purposes, it can be assumed that in the year 2030, agricultural production will be realized on ca. 13.5 million hectares.

It can therefore be expected that the domestic supply of food will be similar to the volume of demand. It is to be supposed that a limited market will not allow any significant growth of production, or an increase of the prices of agricultural produce, or the earnings of farmers.

Considering only the food self-sufficiency by the year 2030, there should even be a slight decrease of production: ca. 0.3 dt corn units per hectare 2003-07 – 43.4 dt/ha. If we consider the demographic changes in Poland that will undoubtedly occur over this period, especially the ageing process of the population (the share of those aged over 65 will reach 24 percent and in 2007, 15.9 percent), then this will result in decreased consumption.

At present, there is a large regional diversification as regards commodity production. The justification of the present production level in farms with an integrated and eco-friendly production system (the EU support, an application of the interdependence principle: observation of the requirements concerning agents for plants, fertilization, taking care of the natural environment) will all be guaranteed by the EU agricultural and environmental programmes (observation of the norms and principles). A gradual exclusion of lands from agricultural food production will constitute an important aspect [6]. Considering the implementation of the sustained development concept, one needs to foresee an increase of the share of low-consumption plants, especially of those for energy purposes: both for the production of liquid biofuels and for the production of electric and heat energy [7].

Table 1. The Structure of Polish Arable Lands in 2007.

Description	2007 in million hectares
The area of arable lands	16,177 ha
Croplands	11,869 ha
Grasslands	3,271 ha
Including meadows	2,497 ha
Grazing lands	0,774 ha
Orchards	0,337 ha
Remaining arable lands	0,700 ha
Fallow lands	0,413 ha
Forest areas	7,053 ha

Source: Central Statistic Office RP, 2008.

The use of all arable lands, including fallows and idle lands as well as grassland, creates an opportunity for the use of large power engineering potential.

Possibility of Production of Liquid Bio-Fuels

The basic biofuels from agriculture are ethyl spirit (bio-ethyl) and methyl esters (bio-diesel).

The structure of the use of agricultural materials in the production of low spirit changed depending of price relations, and the following were mainly used: potatoes, rye, wheat, triticale, maize and sugar beets.

Until now, a two-stage bio-ethanol production cycle has been dominating in Poland: the first one in distilleries (production of low spirits) and the other one in specialized plants (dehydration of low spirits). The low spirits dehydration process has been very much modernized in recent years, owing to which the energy consumption of the process has been reduced. The ethanol production technology is on a high level in Poland. The fulfilment of the EU directives concerning the fraction of bio-ethanol in leaded petrol are 5.75% by the year 2010, and 10.0% by the year 2020, should not constitute any problem; quite the opposite, Poland may become a significant exporter. It is also important that the possibility of the use of arable lands for the cultivation of plants for bio-ethanol production exists.

Therefore, in order to meet needs that fulfil the requirements of EU Directive no. 2003/30/WE: the use of bio-ethanol in 2020=806 thousand m^3 (568,000 tons), the area of lands for the cultivation of plants for the production of

Table 2. Foreseen area of crop lands for the production of renewable energy.

Description	Unit	Intended level of production and area of crop lands				Maximum variant
		2007	2008	2009	2010 5.75%	2020 10%
Area of energy rapeseed cultivation	thousand hectares	219	262	305	354	708
Average crop	dt	2.9	2.9	2.9	2.9	2.9
Harvest for bio-diesel production	thousand tons	613	760	896	1,027	2,053
Production of esters	thousand tons	245	304	358	411	821
Area of rye cultivation for bio-ethanol	thousand hectares	413	426	451	480	835
Average yield	tone/hectare	2.5	2.6	2.6	2.6	2.6
Rye crop for bio-ethanol production	tone/hectare	1,031	1,107	1,173	1,249	2,171
Bio-ethanol production	thousand m^3	313	336	355	378	658
Area of crop lands: bio-components for liquid fuels	thousand hectares	632	688	756	834	1,543

Source: Central Statistical Office 2008, Ministry of Agriculture and Rural Development, K. Żmuda [8, 9].

bio-ethanol should be 480,000 hectares in 2010, and 835,000 hectares in 2020 (Table 2). The areas required for this purpose should constitute, depending of the quality of soils, from 130,000 hectares of very good soils sown with sugar beets, to over 600,000 hectares of poor soils sown with rye. A more practical approach is required for the realization of the goal, i.e. particularly if a poorer quality seed is to be used, also with the use of GMO (which gives a higher yield, and does not necessarily fulfil the consumption requirements). Therefore, the use of ca. 500,000 hectares in 2010 and ca. 800,000 hectares in 2020 should not pose any problem without the consumption production exposed to the risk of being reduced.

It is also possible to adapt the production and processing of sugar beets into bio-ethanol by the use of financial compensation introduced by the EU in connection with the limitation of sugar production. According to the latest data released by the Ministry of Agriculture and Rural Development [8], in order to meet the demands of the National Index Goal as regards bio-ethanol in 2020, 805,750 cubic metres (an area of 500,000 hectares) is to be sown with corn, and for this purpose, the production of corn is to be on the level of 1.9 million tons [9].

Possibility of Production of Methyl Esters

As regards the production of methyl esters (bio-diesel), in order to fulfil the requirement of Directive No. 2003/30/WE, i.e. the area of rapeseed cultivation is to be increased in Poland from 797,000 hectares at present (2007) to 975,000 hectares in 2010 and 1.1 million hectares in 2020. Rapeseed production should be increased from 2,130,000 tons (2007) to 2,730,000 tons (2020), out of which 1.3 million tons will be for consumption.

While determining the potential rapeseed cultivation area, one needs to take into account several factors at the same time, such as the soil fertility, freezing out, the agrarian structure and the share of rapeseed in the structure of cultivation. Basically, very good and good soils, which are fully suitable for the cultivation of rapeseed, constitute ca. 50 percent of the total resources of arable lands in Poland. In the structure of crops, the largest share of rapeseed is in the provinces of northwestern Poland, where rapeseed has taken up 12-19% of the best soils. With a high level of agriculture, rapeseed cultivation is also possible on poorer soils; however, the production risk increases in this case. It should also be emphasized that most rapeseed is grown by large-area farms (an area of >100 hectares). A serious barrier for the cultivation of rapeseed is constituted by the fragmentation of farms. In these farms, it is difficult to guarantee the proper production technology, which results in lower crops and small profitability. In large-area farms, where the share of cereal crops is large, rapeseed cultivation is recommended as it is connected with a good crop rotation and is a good forecrop for cereal crops.

Nevertheless, in coming years, an increase of the share of rapeseed in the area of crops will occur rather in the regions of its current concentration, i.e. in northwestern Poland. Rapeseed cultivation can be introduced in part in the areas of the present crops of wheat and sugar beets. Plant cultivation areas that are expected to fulfil EU Directive No. 2003/30/UE in 2020 cover ca. 835,000 hectares of rye for the production of bio-ethanol, and ca. 708,000 hectares of rapeseed for energy production. In Poland, a total of ca. 1.5 million hectares of crops (10 percent of arable lands) will be sufficient for the production of liquid biofuels to fulfil EU Directives in 2020 (Table 2).

Forecast of Biomass Utilization for the Production of Electric and Heat Energy

The use of biomass for the production of electric and heat energy in Poland is to be seen from various perspectives. The basic step for an effective use of biomass in the energy industry is the creation of local dispersed energy centres located in villages and small towns. Obtained biomass should come from local and nearby sources: agriculture, industrial waste, utility waste, sewage waste, waste from slaughter houses, the catering industry, plant and animal waste (both liquid and solid) [10]. As a rule, models should be used that have been tested on a large scale concerning the use of biomass for energy purposes in two different forms: effective biotechnology, i.e. fermentative gasification of energy plants with the addition of substrates in the form of waste biomass from plant production; and liquid manure, dung, plant remains, waste from slaughter houses, sewage waste, waste from agricultural and food industry, etc. As a result, biogas is obtained, which can be used directly in engines that drive power-generating units, most often of 200-1,000 KW power. At the same time, warm water from the cooling system, in a co-generative system, should be used to feed heating systems for public utilities, industry, etc.

Animal excrements constitute an important material for the production of biogas: one large item of livestock produces ca. 50 kg of liquid manure per day. The output of liquid manure as a substrate component in bio-gasworks is ca. 25 m^3 from 1 m^3 of liquid manure. It is estimated that in Polish farms, ca. 35 to 38 million of cubic meters are produced annually [11], out of which at least 30 percent can be used as a material in bio-gasworks. Also, slaughter waste amounts to ca. 661,000 tons yearly, and this constitutes an important substrate component in the production of biogas.

One should also consider the significant area of meadows that are not used in agricultural production (ca. 1 million hectares), from which material can be used in bio-gasworks to the amount from 1,139,900,000 cubic meters per year to 1,708,950,000 cubic meters per year.

The average power of fermentative bio-gasworks is accepted to be on the level of 1 MW (electric energy constitutes ca. 35 percent in the primary fuel balance, and heat constitutes 50 percent and 15 percent of the loss).

The potential in the co-generation system of fermentative bio-gasworks in Poland is assessed to be on the level of ca. 3,000 MW, which gives the possibility (the time of the use of the peak power being 6,000 h per year) of an annual use of ca. 44 TWH of renewable energy (18 TWH of electric energy and 26 TWH of heat energy, respectively [12]).

To cover the required share of renewable energy on the market of electric energy and on the market of heat (35 TWH and 50 TWH): 80 MWh/ha: 0.85=0.65 million hectares is required.

This assumption according to [8] is consistent with the data concerning the functioning bio-gasworks, especially those in Germany, of the power to <1.0 MW, which require on average maize crops on the area of ca. 200 ha and other additional substrate components. Hence, 3,000 bio-gasworks in Poland (in Germany, there are ca. 4 thousand operating bio-gasworks) x 200 ha = 600,000 ha. Maize grows well on very good, good and average soils and thus this area should not constitute any problem for food economy. The location of fermentative bio-gasworks is an obvious issue: chiefly near cattle and swine breeding farms. However, this can also be a network of farms connected with a pipeline where liquid animal excrements are pumped. It is important for it to be a co-generative system, i.e. one that guarantees the collection of heat in order to obtain high efficiency [13]. Post-fermentative sediment constitutes a semi-fluid fertilizer that can be used in agriculture. It has a relatively low smell effect. The development of bio-gasworks in Poland is one of the priority actions supported by the Ministry of Agriculture and Rural Development in the coming next years.

Another important formula of the use of agricultural biomass is setting up energy cultivation farms, such as willow (Salix vim), Miscantus, mallow, topinambour or poplar. In particular, there is a large potential as regards cultivation of willow [1, 4, 6], whose low requirements make it possible to grow on relatively poor soils, including idle lands fed with precipitation waters. On the basis of local crops, there are large possibilities to create local dispersed energy centres situated in small towns: to replace the present central public utilities heating based chiefly on hard coal. The use of lignocelluloses (2nd generation) would be most recommended together with the use of bio-gas for a gas engine to drive an electric generator, and water from the cooling system is used in local heating systems for flats, social institutions, swimming pools, etc. Biomass can also be used by being burnt directly in highly efficient boilers, where a co-generation system is used, as well. The creation of a system for the local use of biomass (electric energy + heat energy) is very economical (90% efficiency) [14]. It is fully ecological and it contributes to the activation of rural areas: by the creation of new jobs, a full use of lands and capital turnover in a local system, which drives the local economy. Taking into account the fact that heat will not be used all the year round, we could assume an average figure of 50 to 60% efficiency. With biomass used on a large scale: in local energy centres, the most justifiable form (concerning economic reasons) is unprocessed biomass that is transported on short distances (up to 50 km) considering the costs. Unprocessed biomass in the form of chips has a relatively low energy value depending on humidity (6MJ/kg-19 MJ/kg), a low bulk density (m^3) indicates that there is no justification due to high transportation costs and their negative ecological effect. These are merely pretended activities of a large energy industry towards the fulfilment of the CO_2 emission norms [15].

Another important form of activities concerning the use of biomass is its processing to the form of pellets and briquettes (humidity <10%) with a high energy value (17-20 MJ/kg). Pellets are especially good for the purpose of heating of single houses with their own heating systems (with the use of complete automatics and bins for pellets or chips).

In the conditions of the Polish agro-climate, there are adequate conditions for the cultivation of the willow and poplar in the area of ca. 1.6 million hectares. If we assume an average crop on poor soils to be ca. 10 tons of dry matter per year, then we have the possibility to obtain ca. 16 million tons of dry matter per year, with the dry matter energy value of ca. 20 GJ/t: it is possible to obtain ca. 320 million GJ per year. To compare, as a result of hard coal burning, Poland currently obtains 888 million GJ, and 514 million GJ from brown coal.

Conclusions

1. In a long-term strategy, Poland can provide and ensure high quality food for it inhabitants, as well as energy biomass sources through an efficient use of the arable land and various biomass wastes.
2. The requirement to fulfil the EU directive constitutes another incentive for activities oriented toward the use of renewable sources of energy, including biomass.
3. Poland is among those EU Member States that have a high potential of biomass, especially biomass from agriculture.
4. To fulfil EU Directives in the year 2020, the following structure of arable land should be used in Poland:
   - 1.5 million hectares for liquid biofuels;
   - 0.6 million hectares for biogas (maize);
   - 1.6 million hectares for willow + poplar.
5. The creation of a system for the local use of biomass (electric energy + heat energy) is very economic. Taking into account the fact that heat will not be used all the year round, we could assume an average figure of 50 to 60% efficiency.
6. The development of bio-gasworks in Poland is one of the priorities supported by the Ministry of Agriculture and Rural Development in the coming years.
7. The development of bio-gasworks in Poland is desirable and should be supported by the government, including willow and poplar plantation areas. Poland has very favourable conditions to produce biogas and to grow willow, poplar and Miscantus for biomass.
8. Poland is in the state of possible changes of the power industry system: a transformation of the central large industry into a dispersed local industry, considering the high depreciation of power grids as well as combined heat and power plants.
9. There is opportunity for diversification of energy sources and their dispersion; this makes it possible to create an energy safety system.
10. The use of biomass offers an opportunity to get rid of a lot of unusable waste and to obtain valuable forms of energy.
11. The diversification of agricultural production does not involve any risk in agriculture but contributes to an activation of rural areas.
12. The dispersed power industry system is favourable to the sustained development of regions.

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