The Possibilities of Using Renewable Sources of Energy in Podlaskie Province

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Abstract

This paper presents the possibilities of using renewable sources of energy in Podlaskie Province. It shows the structure of acquisition of renewable sources of energy in the European Union, Poland, and Podlaskie province. In Podlaskie, windpower can be developed in its northern part, while hydropower can be acquired across the region. However, the greatest opportunities are connected with biofuels. Since supply of solid biomass from the four national parks and food-and-agricultural processing is limited, it is necessary to foster cultivation of energy plants as well as to use municipal waste as a source of energy. In the future, Podlaskie province should become a region of innovative economy pursuant to the provisions of the Innovative Energy program. Energetic Agriculture, liquid biofuels will be gradually replaced by gas biofuels generated by biological methods.

Keywords: renewable sources of energy, solid biomass, liquid biofuels, biogas

Introduction

In Podlaskie Province the greatest potential of renewable energy lies in biomass, including the following sources [1]:
- oil plants and waste oils,
- sugar plants (sugar beet, fodder beet),
- starch plants (potatoes, maize),
- lignocellulose materials (trees, shrubs, fibre and energy plants, straws, municipal waste, waste from food-and-agricultural processing).

The Białystok Thermal-Electric Power Station has accomplished a conversion of one of the steam boilers into a fluidized bed boiler fed by biomass. The author of this paper took part in the realization of the conversion. The author of this paper also joined a group of researchers whose task was to examine what kind and how much solid biomass can be acquired in Podlaskie province on a permanent basis [2].

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Białystok Thermal-Electric Power Station and other distributed individual sources of heat are already acquiring and burning solid biomass of the following kinds: sedges, reeds and shrubs in the national parks (Biebrzański National Park, Narwiański National Park, Wigierski National Park and Białowieski National Park) [3], cellulose production waste, municipal waste and waste pulp obtained from processing potatoes in starch and potato flour production plants.

In the long run, Podlaskie province should become a region of innovative economy pursuant to the provisions of the program: Innovative Energy. Energetic Agriculture (IEEA) [4]. Innovation activities under the IEEA will contribute to the development of second generation biofuels.

Influence of Biofuel Production on Prices of Food Commodities

Over the last three years the prices of food commodities have risen. However, in comparison to the prices in the1970s, the real prices of agricultural raw materials are still relatively low (Fig. 1) [5].

Long-term analysis shows that food is becoming cheaper. The recent rise in its price has resulted from a quick increase in oil prices. The prices of all commodities have also gone up, even at a greater rate than the prices of food commodities. Prices of these products are strongly related to costs of energy (Fig. 2).

A comparison between maize price increase rates and oil price increase rates since 1949 shows that energy prices have been rising ten times more than the price of agricultural raw materials. LEI Wageningen and Research Center research confirms that energy prices have had twice as strong an influence on food price index increases as the prices of agricultural raw materials.

Despite various objections raised by some countries and international organizations such as the OECD, the FAO or the World Bank, the European Commission has not changed its stand. The share of biofuels in the transportation fuel sector is supposed to account for at least 10 percent.

Types of Renewable Resources of Energy and their Usage up to Date

Types of Renewable Resources of Energy

Currently, fossil fuel energy is being replaced by renewable energy from renewable and distributed sources such as: wind, water, sun, geothermic and geothermal energy, solid biomass, and biofuels [6]. Solid biomass and biofuels are the biggest reservoir of renewable energy.

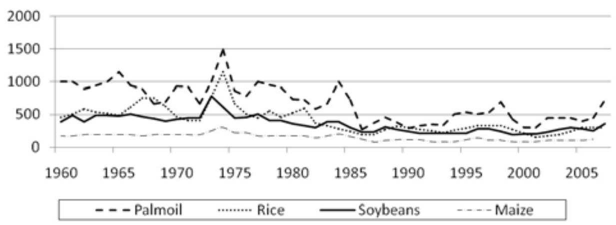

Fig. 1. The prices of agricultural raw materials in 1960-2007 [USD/t], in stable prices from 1990 [source: World Bank data base (2008)].

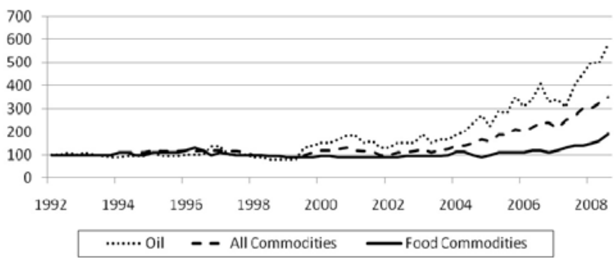

Fig. 2. Oil price index, food commodities price index and all commodities price index in 1992-2008 (January 1992=100) [source: International Monetary Fund: International Financial Statics].

The Structure of Acquisition of Renewable Sources of Energy

Fig. 3 presents the structure of acquisition of renewable sources of energy in Poland, while Fig. 4 gives the average value for the 25 EU countries.

Due to various geological and climatic factors, acquisition of energy from renewable sources varies from country to country. The most energy is acquired from solid biomass (91.4% in Poland and 51.3% in the EU). Next comes hydropower (3.5% in Poland and 21.4% in the EU). Significant sources of energy in the EU countries include: municipal waste, windpower, geothermal energy, liquid biofuels and biogas, while solar power is barely used. In Poland, except biomass and hydropower, biogas and liquid biofuels are used, while other renewable sources of energy are insignificant.

It needs to be emphasised that municipal waste is an important source of renewable energy in the EU (8.7%), while in Poland it is barely visible (0.3%). Municipal waste is a great source of renewable energy, with the function of both energy source and environmental protection [8].

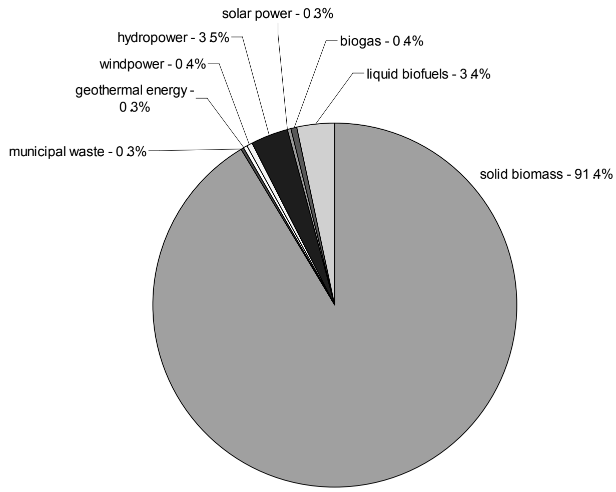

Fig. 3. The percentage structure of acquisition of renewable sources of energy in Poland in 2006 [7].

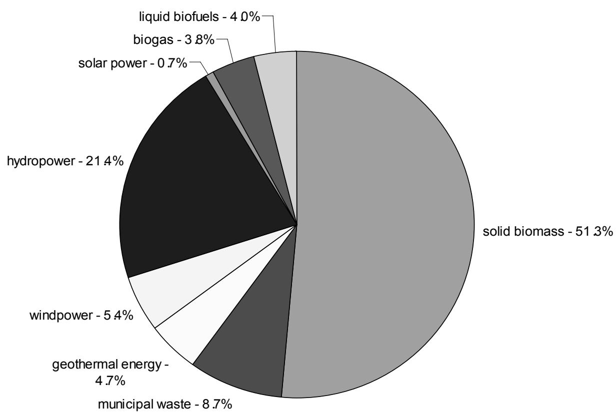

Fig. 4. The percentage structure of acquisition of renewable sources of energy in the 25 EU countries in 2006 [7].

Table 1. The protective areas of non-forest ecosystems in Biebrzański National Park [3].

Protective procedures (ha)		Non-forest area (ha)
Removal of shrubs	Mowing	
4,064	21,250	21,250

Table 2. The amount of biomass possible to be obtained from Biebrzański National Park [3].

No.	Type of biomass	Amount (t)	Calorific value (GJ/t)
1	Green biomass – dry sedge, reeds, green plants, shrubs and tree bark	12,500	15
2	Chips after the first year	2,250	10-12
3	Chips in following years	4,020	10-12

The structure of acquisition of renewable sources of energy in Podlaskie province is presented in Fig. 5.

In comparison with the structure of acquisition of renewable energy sources, Podlaskie province is devoid of geothermal energy and energy from liquid biofuels. Hydropower and biogas enjoy greater popularity at 4.8% and 1.5% respectively, while windpower accounts for merely 0.9%. They are produced, however, for the facilities' own purposes, not for usage in supply networks. Solid biomass is a sole renewable fuel from processing where electric energy is used in general supply networks and thermal energy is used in detached houses, blocks of flats and public utility buildings in the Białystok agglomeration.

Acquisition of Renewable Sources of Energy in Podlaskie Province

Introductory Remarks

In Podlaskie, energy can be obtained from solid biomass, liquid fuels, biogas and municipal waste. Conditions for acquisition of hydropower and windpower are not very favourable, and those for obtaining geothermal energy are nonexistent. Wind energetic zones in the province cover a relatively small strip of land in the Suwalszczyzna region.

In Poland, geothermal resources can be used within 80% of its area [9]. Podlaskie province is located on the remaining 20% of land, which is devoid of geothermal sources. Thus, the acquisition of energy from renewable sources in Podlaskie province is limited to biofuels, which can successfully replace conventional energy.

Municipal heat producers (thermal power stations) together with municipal producers of heat and energy (Białystok Thermal-Electric Power Station) have started attempts to partially replace fossil fuels with biomass.

This paper considers four types of solid biomass [1, 2]:

- grass, sedges, reeds and shrubs in the national parks,
- organic waste from agricultural, food, and forestry processing as well as sorting out municipal waste,
- biomass from roadsides and waysides of railwaytracks,
- energy plants.

Acquisition of Biomass from Biebrzański National Park

Solid biomass can be acquired from Biebrzański National Park on a continuous basis by carrying out procedures that are necessary yet do not disturb the balance of ecosystems in the area.

Protective procedures set out in the Biebrzański National Park Protection Plan include: controlling and limiting the number of shrubs, acceptable mowing, twice-a-year mowing and acquiring biomass, yearly mowing and acquiring biomass, late-yearly mowing every 1-3 years, removal of shrubs and follow-up mowing every 1-3 years, and acquisition of biomass pursuant to the needs of particular plant species. Among the above-mentioned activities, the most extensive are mowing and removal of shrubs. Summary areas of non-forest ecosystems removal of shrubs and mowing are presented in Table 1.

The amount of biomass that can be obtained from Biebrzański National Park is presented in Table 2.

Acquisition of Biomass in Agricultural and Food Processing Plants

Acquisition of solid biomass in agricultural and food processing plants is analyzed in the example of the PEPEES food company in Łomża, a large operation where potatoes are processed into potato flour. A result of the technological process is a substantial amount of the so-called waste potato pulp, which has not been used so far but instead has been placed on landfills. Air-dried waste potato pulp (of 18% wetness) can be used as fuel. It is classic solid biomass. In 2007, 16,820 tonnes of waste potato

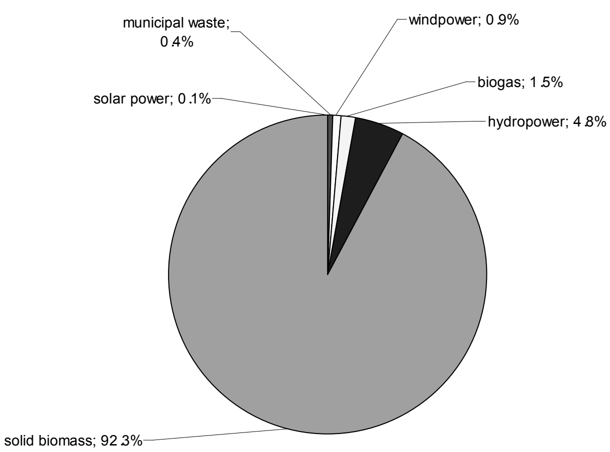

Fig. 5. The percentage structure of acquisition of renewable sources of energy in Podlaskie Province in 2006 [7].

Table 3. Combustion heat, caloric value and energy obtained from waste potato pulp [2].

No.	Wetness (%)	Combustion heat (GJ/t)	Caloric value (GJ/t)	Energy obtained (kWh/t)
1	15	13.927	12.788	3,478.1
2	18	13.436	12.241	3,277.3
3	30	11.470	10.092	2,736.4
4	50	8.194	6.510	1,741.4
5	85	2.461	0.241	66.9

Table 4. The amount of biomass that can be obtained from roadsides and waysides of railway tracks in Podlaskie Province [2].

No.	Item	Length (km)	Amount of solid biomass		Caloric value (GJ/t)
			t	m³	
1	Roadsides	8,563	35,718	119,060	10-12
2	Waysides of railwaytracks	-	1,472	4,907	10-12

Table 5. Biomass yield from energy willow and its production costs [1].

No.	Item	Cycle		
		1-year	2-year	3-year
1	Biomass yield (t/ha)	31.82	63.50	120.66
2	1 ton production costs (PLN)	37.46	40.27	35.47
3	Production costs (PLN/ha)	1,191.9	2,556.9	4,279.9
4	Chip price – 2002 (PLN/t)	80	80	80

pulp were produced. Table 3 shows combustion heat, calorific value and energy obtained from waste potato pulp.

Acquisition of Biomass from Roadsides and Waysides of Railwaytracks

In Podlaskie analysis has been conducted regarging acquisition of biomass from waysides of province, county, and commune roads, and waysides of railwaytracks [2].

Table 4 contains data concerning the amount of biomass that can be obtained from roadsides and waysides of railwaytracks in the province.

Acquisition of Biomass from Energy Plants

The inspiration to analyze and research the use of energy plants came from the managers of the Białystok Thermal-Electric Plant. It was planned to burn energy willow together with small coal. The Podlaski Centre of Agricultural Consultancy started to disseminate the idea of planting energy willows among farmers as potential planters [2]. In the first half of 2007, the Centre ran a training program for energy willow planters.

The basket willow Salix Viminalis, commonly referred to as 'energy willow', can be grown on soils of various classes, with pH ranging from 4.5 to 7.5. Among agricultural soils, the most convenient for energy willow cultivation are soils of class III, IV, and V, as well as temporarily wet ground. In particular communes, such soils account for 0.5-11% of their area. Considering the data gathered by all the 118 communes of Podlaskie province, this means more than 130,000 ha.

Energy willow is characterized by a huge mass increase and relatively high calorific value [10]. It is renewable and cheap fuel that does not emit pollution into the atmosphere. The energy willow plantation can sustain a period of 25-30 years.

Table 5 shows biomass yield from energy willow and its production costs. The 1 ton production costs are the lowest for a 3-year cycle because the annual biomass yield is the highest in the third year of a 3-year cycle.

Starting energy plantations is worthwhile for the following reasons:
- high caloric value of energy willow,
- very low contents of sulphur dioxide and other hazardous substances in exhaust fumes, especially chlorine Cl <0.06%,

Table 6. Caloric value and the cost of heat unit obtained from energy willow against coal and small coal [1].

No.	Type of fuel	Caloric value, fuel unit cost, heat unit cost (with production efficiency)		
		GJ/t	PLN/t	PLN/GJ
1	Willow chips (30% wetness)	12.0	160	16.66
2	Coal	24.0	430	29.87
3	Small coal	19.0	340	29.82

- low contents of ash,
- the possibility of combustion in different types of boilers,
- fully renewable source of energy,
- job creation in rural areas.

Table 6 presents caloric value and the cost of heat unit obtained from energy willow versus coal and small coal.

Liquid and Gas Biofuels

Introductory Remarks

Podlaskie province has great reserves for growing plants both for food and energy production. These include uncultivated land, comprising over 300,000 ha, and 130,000 ha of waste land. These areas can be planted with food and energy plants. Biomass acquired from these plants together with municipal waste can be used to start production of second generation biofuels (incl. bioethanol and agricultural biogas).

Using municipal waste to produce liquid biofuels and biogas in Poland is at a preparatory stage. However, in the 25 EU countries it already accounts for 8.7% of renewable energy (data from 2006) [7].

Gas Biofuels

In Podlaskie province, the greatest potential for development is on the part of agricultural biogas plants. The gas production conducted there uses organic matter i.e. waste from concentrated animal farming (liquid and stable manure) and any waste of herbal origin. Methane obtained from biomass decomposition can be used as gas fuel for production of electric energy and heat. As a result of methane combustion, CO_2 is released into the atmosphere [11].

Fig. 6 presents the CO_2-free production of heat and energy in an agricultural biogas plant. In agricultural biogas plants, CO_2 is released to the atmosphere as a result of methane combustion. However, due to the closed cycle of biomass, energy production is emission-free. CO_2 released in the process is again sequestered by biomass from energy plants that are grown specifically for this purpose, by plants that are fodder for animals producing animal feedstock, or by waste biomass from food-and-agricultural processing (Fig. 6).

In agricultural biogas plants, electricity is produced during combustion of methane contained in biogas in highly efficient combustion aggregates; yet all the heat produced is actually the heat that is generated by aggregates during their operation. This heat can be used for heating buildings, producing hot usable water, and technological steam. Highly efficient co-generation allows for as much as 87% efficiency of processing energy from biogas. The total energy produced in big thermal-electric power stations, both electricity and heat, accounts for approximately 80% of original energy contained in the fuel.

Raw biogas contains a lot of methane (55 to 75%) and carbon dioxide (25 to 45%) [13], while natural gas (group E) has huge amounts of methane (97.4%) and traces of carbon dioxide (0.07%). Upgrading the biogas is based on the process of changeable pressure adsorption and desorption of pollution on molecular sieves based on active coal [12].

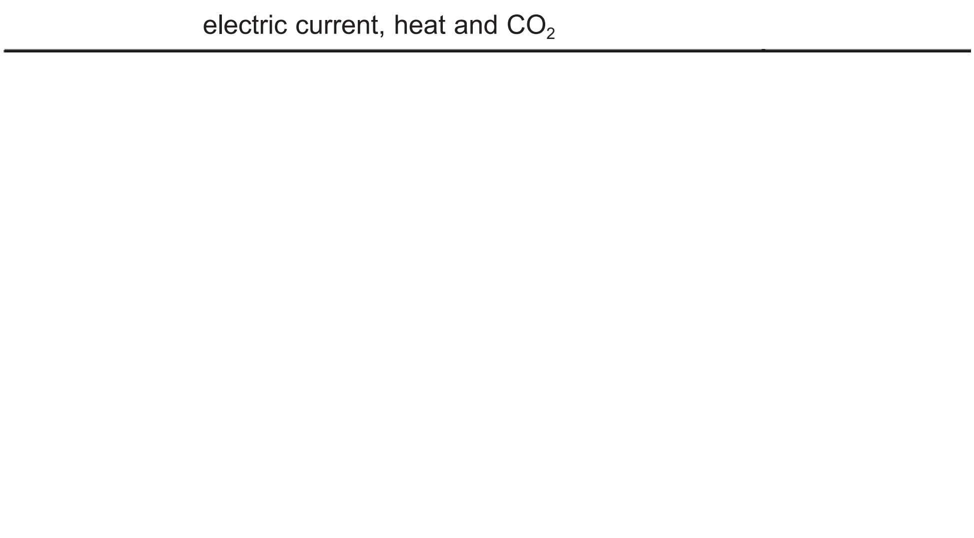

Fig. 6. CO_2-free energy production in agricultural biogas plant [12].

Table 7. Differences in the contents of biogenic elements in digestate depending on the kind of feedstock used in the process [12].

Digestate from biogas plant on the basis of:	N (nitrogen)	P (phosphorus)	K (potassium)
	% of digestate		
Maize chaff	0.43	0.18	0.42
Wheat spent wash	0.35	0.07	0.06
Animal and herbal waste	0.9	0.40	0.40

While pressured gas flows through a molecular sieve, CO_2, N_2, H_2O, H_2S and other molecules are adsorbed on the surface of the absorbent (Fig. 7).

After having used its entire active surface, the reactor separates itself from the cycle and regenerates absorbent in normal pressure, in which the above-mentioned particles are released and removed from the system. With several adsorption installations, the process of increasing the quality of raw gas can be conducted continuously. After upgrading, gas is delivered to supply networks or stored in tanks. It can also be compressed and sold to vehicle owners.

CO_2-Free Fertilizer as a by-Product of Gas Production

During gas production, a lot of fermented biomass is produced as liquid organic fertilizer. It is a rich source of biogenic elements. The fertilizer leaves the biogas plant ready to use on fields in agriculture. Such fertilizer is characterized by mineralization 95% higher than initial substrates, dry mass content 50% lower and a reduced amount of substances that are detrimental to agriculture, especially those causing plant diseases and responsible for the stench of organic acids [12]. Heightened mineralization and the contents of compounds soluble in water facilitate the accessibility of elements to plants, which influences efficiency of fertilizing. Properly lengthened fermentation time prevents contamination of ground waters with dangerous bacteria [14], while controlled fertilization stops the flow of fertilizer to surface waters and their eutrophication. Fertilizer contents depend on the composition of co-substrates of the process (Table 7).

Innovative Energy. Energetic Agriculture – Development Prospects for Renewable Sources of Energy in Podlaskie Province

Introductory Remarks

The analysis of renewable sources of energy in Podlaskie Province proves that:

- the resources of biomass in its original form are too scarce to replace fossil fuels to a significant extent,
- Podlaskie Province has huge reserves of cultivating plants which, together with municipal waste, can be used to start production of first generation biofuels (plant oil biodiesel, sugar plant bioethanol) and second generation biofuels (cellulose ethanol, BtL – biomass to liquid technologies) and to prepare (distributed) power infrastructure.

Development of distributed power engineering can positively affect the environment.

It results from the requirements of waste utilization in agricultural production and food-and-agricultural processing, in which the technologies of biological gasification of biomass can be used. The significance of this idea is based on the fact that investors gain the rudimentary knowledge of the energy market and thus are prepared to pursue activities in power engineering based on biogas such as produc-

Fig. 7. The structure of adsorption installation for increasing the raw biogas quality to the quality of natural gas [12].

tion of electric energy and heat from cultivating biomass (co-generation). Considering this, it is possible to plan production of biomethane to be used in gas supply networks or for transportation with the use of LNG and CNG technologies [4]. This will result in the development of energetic agriculture.

Development Prospects for Energetic Agriculture

In the long run, the development of energetic agriculture may ensure permanent profitability of agricultural production by extending its sales into two independent markets: food and energy.

Restructuring Polish agriculture toward the development of mass production of profitable energy crops may lead to a situation in which about 300,000 hectares of arable land and 130,000 hectares of waste land may be used for these kinds of crops. This may result in total farmers' profits of about PLN 1 billion (2008 prices).

In the long-term perspective, the development of energetic agriculture may be viewed as an active participation in the process of abandoning common agricultural policy in the EU for the benefit of both Poland and the EU. After 2012, the EU is planning to transform food agriculture into energetic agriculture, which will change common agricultural policy.

Energetic agriculture is a chance for Polish countryside to join the global innovation of the economy. The Polish countryside may become subject to the issue of electrical energy and thermal energy. Energetic agriculture will influence the development of fuels for transportation as a source for the liquid biofuel industry.

Advantages and Conditions of Innovative Energy Based on Agriculture

"The Innovative Energy. Energetic Agriculture Program refers to the development of technological innovation in American power engineering to create the hydrogen society in the USA and to the developmental strategy for innovative power engineering and establishing an emission-free society in the European Union" [4].

The IEEA Program [4] suggests that the fastest improvement in the energy sector in Poland can be achieved by developing distributed power engineering and energetic agriculture. Moreover, it shows that RSE-based power engineering is competitive with coal-based power engineering.

Apart from biotechnological-energetic-environmental-tax effectiveness, the innovative energy sector is characterized by architectural and urban-planning effectiveness. It means that spatial development of communes should consider the following factors:

- plans to develop energy crops in communes,
- studies of conditions and directions of spatial development with ideas of how to use local resources of renewable energy,
- setting up biogas plants and second generation liquid fuel production plants.

Advantages and benefits of innovative power engineering based on energetic agriculture are:

1. Establishing a new sector in the economy that is based on energetic agriculture. This sector takes into consideration energy security, ecological safety and is part of the sustainable development plan.
2. Stable energy security based on using energetic agriculture resources and innovative biogas technologies as well as second generation liquid biofuels.
3. Improved ecological safety based on utilization of waste from agricultural production and food-and-agricultural processing, which mainly means a significant reduction in CO_2 emissions during production of electric energy, heat, and fuels for transportation.
4. The opportunity to alleviate the problem of over-employment in rural populations.
5. Innovative power engineering based on energetic agriculture will foster the development of second generation biofuels. Liquid biofuels will possibly be replaced by much more effective gaseous biofuels produced by biological methods, including fermentation-gasification of energy plants, mostly with waste biomass substrates.
6. Much more effective biotechnologies will be commercially implemented, e.g. into the process of green cellulose gasification or immediate production of biomass from hydrogen.
7. New gaseous technologies will develop, including the technology of delivering biogas into natural gas supply networks, biogas purification, CNG and LNG road transport, and CNG vehicles. These technologies will introduce the use of second generation fuels as a product of coal and biomass processing.

Conclusions

This paper presents possibilities of using renewable energy sources available in Podlaskie Province. As the Białystok Thermal-Electric Power Station converted its fine coal-fired steam boiler into a biomass-fired one, interest in the acquisition of biomass has risen.

The paper lists possibilities of obtaining biomass from Biebrzański National Park, roadsides, waysides of railwaytracks of Polish State Railways, potato processing plants (potato waste pulp), and energy willow plantations. Other described factors include the net calorific value of biomass, and the quantity and cost of its energy yield compared to the cost of energy obtained from hard and fine coal.

Development of power engineering based on renewable energy sources in Podlaskie, where 40% of NATURE 2000 areas are located, may contribute to its economic growth. However, generating heat and electricity exclusively from biomass obtained in the manner that has been resorted to so far is highly insufficient in comparison to the potential possibilities and needs.

It is therefore necessary to:

1. Start building agricultural biogas plants (according to the government program, “Power Policy of Poland up to 2030” – one biogas plant in each commune).
   This requires:
   – utilizing waste in farm production and the agri-food industry, which may involve using biological gasification technology;
   – transferring and developing technologies that utilize municipal waste;
   – developing energy-crop growing techniques.
2. Once at least 118 biogas plants (the number of communes in the province) are in place, upgrade the power transmission and reception grid so that dispersed energy sources (biogas plants) could supply to that grid and consume it where necessary.

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