

Short Communication

Energy Autarky of Rural Municipality Created on the Basis of Renewable Energy Resources

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Abstract

The aim of this study was to assess the potential of meeting the energy needs of a rural community using renewable energy resources. The research was conducted in the municipality of Raków in the Świętokrzyskie Region. A new aspect of the research is an attempt to balance current and potential energy production from renewable sources. The studies included such resources as: solar, hydro, wind, and biogas derived from energetic and forestry plants. We divided renewable sources into existing, potential, and overall for a period until 2020. The assessment of the current state was based on a stocktaking of existing sources of energy, and prospective on the basis of potential and real opportunities, and trend analysis of the development of these energy sources. Currently, renewable sources cover only 2.2% of energy needs of the community, while electricity covers about 24% of the demand. The production of heat from renewable sources can now cover the needs of 120%, and has the potential to cover in 256%, including the biomass obtained on set-aside of 30%. The surplus of heat energy can be transferred to the outside.

Keywords: energy autarky, renewable power sources, biofuels

Introduction

Energy today is the foundation of human well-being, and its acquisition is an important element of economic and financial governance. Currently, the demand for energy is very high and continues to grow. Approximately 80% of the world's demand for energy is provided by fossil fuels, which are limited resources [1]. At the same time, we see that their negative impact on the environment is increasing continuously [2]. This determines an increasing interest in the societies of many countries in renewable energy resources, including biomass of different plants. In Poland,

the quest for the most effective methods of obtaining energy from renewable sources is an object of growing interest [3]. In recent years rural areas were characterized by dynamic transformations associated with changes in their function and the consequent redefinition of their objectives. In addition to the continuous adjustment of the basic functions of agriculture, which is food production, it is expected that rural areas should preserve environmental and cultural landscape elements while also becoming an important link in the process of obtaining energy from renewable sources. It is anticipated that agriculture will be one of the major suppliers of fossil fuels and will use the renewable energy produced across locations to a larger extent. This will allow us to transform agriculture from an energy con-

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sumer into energy producer, a function that was performed by agriculture prior to the intensive use of fossil fuels. Polish agriculture is seen as having one of the greatest potentials in the production of biomass for energy purposes and, particular emphasis should be placed on the development of fallow land as it is fairly common [4] for growing "energy crops" that are a valuable source of thermal energy. Rural areas also have favorable conditions for the location of other renewable energy solutions such as solar panels, wind turbines, and hydroelectric plants.

Our paper presents a description of Raków municipality, which has a large area of forests and smaller area of agricultural land – a high percentage of which is set aside. The ability to satisfy the energy needs of this community from renewable energy sources has been also assessed.

Responsible production and use of renewable energy sources contributes toward improving the environment by reducing pollutants emitted into the atmosphere, and helps in fulfilling commitments to reduce greenhouse gas emissions. [5] Investing in alternative energy also provides an opportunity for local development of rural areas [6, 7].

Methods

In addition to the possible sources of energy including the amount of energy that is available, an element crucial to the concept of energy autarky (efficient use of resources) is to estimate the demand for energy in rural communities. The studies included such resources as: solar, hydro, wind, biogas, and those derived from fast-growing plants and forestry resources. We divided renewable sources into existing, potential, and overall for the period until 2020. Assessment of the current situation was based on an inventory of existing energy sources and the analysis of reports. In addition, the prospective assessment of the state was based on the potential, real opportunities, analysis of policies, and an analysis of the trend of the development of these energy sources in the defined municipality.

The energy potential of the various energy sources were determined on the basis of scientific studies [8]. To assess the potential of solar energy in the studied community, we used maps drawn up for Poland of average annual totals of solar radiation and the annual number of hours of solar radiation [14, 21]. Wind energy resource assessment was based on data from the Institute of Meteorology and Water Management [9, 10], while the current status and prospects of hydropower were based on a detailed inventory of water-courses and small retention program data of Świętokrzyskie Voivodeship [11].

The analysis of energy from biogas was determined on the basis of an assessment of waste management and waste water treatment on the basis of the Municipal Office of Raków, and the waste management programme of this municipality [12, 13]. Assessment of the feasibility of obtaining energy from biofuels derived from agricultural crops is based on the analysis of the crop structure in the municipality, soil valuation classes, and relevant literature [14, 15]. The evaluation of the potential for growing ener-

gy crops was conducted through taking into consideration the small proportion of arable land to the large percentage of abandoned land and, through suggestions of local farmers, energy crops was limited to the set-aside land. With the help of satellite [16] images and fieldwork the locations and surface areas of abandoned parcels were established. Based on natural and organizational conditions and literature [17-20], even species of energy plants have been proposed, i.e. Sida, Miscanthus, black locust, willow and willow of the Eco-Salix, prairie cordgrass, and poplar. An analysis of the feasibility of using geothermal water was made on the basis of data from the marshal's office in Kielce, and Gebśka's work [21]. The assessment of energy resources from forest residues was based on data from the Municipal Office of Raków, the Forest Inspectorate of Staszów, and the literature [22, 23], and the evaluation of energy options with special regard to afforestation created with fast-growing trees was based on the provisions of the local development plan [24] and data of the Forest Inspectorate of Staszów.

The study was conducted in the municipality of Raków, in Świętokrzyskie Voivodeship, the Kielce region, on the request of the local government. This municipality consists of 28 villages, including: Dębno, Drogowle, Mędrów, Zalesie, Radostów, and Szumsko Kolonia, which was thoroughly studied.

Current and potential energy from renewable sources was compared with the needs of the community. Demand for energy is based on energy statistics from recent years [25].

Results and Discussion

The research showed that solar energy is not used for obtaining energy in the municipality. An installation of six solar collectors on public utility buildings in Raków was planned. This would give an average of 14,400 kWh (ca. 52 GJ) per year.

Small hydropower plants, which meet the energy demand of two households with 4-5 members, are located in Pułaczów and Jamno. We suggest the construction of a small hydroelectric turbine on the existing "Chańcza" Dam with a capacity of 160 kW. The amount of electricity produced in a year would be in average 1,100 MWh (3,960 GJ). In total it could produce approximately 1,250 MWh/year (4,500 GJ) of energy.

Decisive factors for the possible use of wind energy are wind speed, terrain, and coverage. Raków Municipality is in the favourable region (over 4.5 m/s) [26, 27]. One wind turbine currently operates within this community, and it is possible to build a wind farm on the area of approximately 300 hectares, with a total capacity of 1,500 kW, its location is included in the zoning plan. The total capacity of installed equipment would be 1,632 kW. Annual production is approximately 3,574,080 kWh (12,867 GJ).

Wood for energy purposes can be extracted from the forest, in the form of firewood, and waste from reprocessing and wood processing [28]. The waste material from the forest can be fully exploited for energy purposes. Established heating value waste of post harvesting is valued

Table 1. The power and amount of energy from existing and potential renewable sources in Raków municipality.

The types of renewable energy sources (OZE)	Existing OZE		Potential OZE		Total OZE	
	Power (kW)	Amount of energy (GJ/year)	Power (kW)	Amount of energy (GJ/year)	Power (kW)	Amount of energy (GJ/year)
Solar energy	-	-	-	52	-	52
Water energy	22	544	160	3,960	182	4,504
Wind energy	132	1,041	1,500	11,826	1,632	12,867
Wastes from forests	-	139,490	-	-	-	139,490
Energy plants	-	-	-	33,390.4	-	33,390.4
Wood	-	-	-	121,800	-	121,800
Biogas	-	-	-	1,800	-	1,800
Biogas from private farm plants	-	-	-	0.09	-	0.09
Total	154	141,075	1,66	172,828.49	1,814	313,903.49

Source: own study

for about 10 MJ/kg [29]. Raków community forest cover is 44.8%, the surface area is 8,560 ha, and the average level of timber harvesting is 232.8 m³/100 ha. Assuming such quantities for the analyzed area harvested timber volume should be 19,928 m³. This gives a total of 139,490 GJ of heat energy.

For six selected villages [14] there are a total of 213.73 hectares of abandoned land, which in terms of the entire municipality gives about 1,000 ha. on average. An area of different types of energy crops is suggested on set-aside land: virginia mallow (*Sida hermaphrodita*) – 97.40 ha, giant miscanthus (*Miscanthus giganteus*) – 15.70 ha, robin locust (*Robinia pseudacacia* L.) – 62.90 ha, poplar (*Populus* L.) – 22.1 ha, shrubby willow (*Salix viminalis*) – 7.74 ha, willow in the Eco-Salix system – 0.65 ha, and prairie spartina (*Spartina pectinata*) – 7.24 ha.

The average calorific value of wilted biomass of energetic plants is about 16 MJ/kg [30]. In the six villages of the municipality potential alternative crops would allow for the acquisition of energy in the volume of 33,390 GJ/year.

The territory of Raków includes farmlands with afforestation possibilities, provided in the development plan (5,220 ha) [7, 24]. The area of 522 ha (10%) was taken into consideration. If one third of the area (174 ha) is allocated for the cultivation of fast-growing trees (poplar, willow), with a minimum yield of 7 t/ha, this would give a total of 1,218 tonnes per year, equivalent to 121,800 GJ. The first results could be obtained only after a planned time perspective, i.e. around 2025.

Raków has two small sewage treatment plants, which can acquire around 100,000 m³ of green gas, which gives 500,000 kWh (1,800 GJ). Farmers can produce a small amount of biogas at home from available substrates (e.g. grass).

Poland is a country with high potential capabilities of geothermal energy generation [21]. 80% of the country's area has some geothermal resources, 40% of resources are economically viable. However, in the present study the

municipal deposits are of dubious value, hence the government withdrawal from the opportunity to use them.

Raków municipality has a population of approximately 6,000. The data of energy statistics [25] showed an average electricity consumption of 12.3 GJ/person/year, and 58 GJ – the annual consumption of heat for the house for 3 people. Thus, in order to meet the energy needs of the residents of Raków municipality from renewable energy sources, they need to produce about 73,640 GJ per year, and 115,749 GJ of heat energy per year. Altogether, the level of demand is 189,389 GJ per year.

Around 1,585 GJ of electricity from renewable sources is produced in Raków municipality, which covers only approximately 2.2% of the energy demand. However, the potential sources could give 15,838 GJ of electricity, which is 21.5% of the demand for electricity, and in total 17,423 GJ of electricity, i.e. approximately 24% of local demand (Table 1).

The amount of thermal energy stands at 139,490 kWh, which may cover 120% of the demand for energy from renewable sources in Raków municipality. The potential total amount of heat energy can be produced at approximately 296,500 GJ/year, i.e. 256%, including the biomass obtained on set-aside of 30%. Surplus heat can then be transferred to external needs.

Conclusions

In rural areas there are the possibilities of various sources of energy generation from renewable resources. Indeed, in this situation the surplus of energy can be obtained for local demand, which would enable the rural areas to obtain additional benefits.

On the basis of detailed studies in the community of Raków the following conclusions have been reached:

1. The greatest potential to meet the energy demands of residents of the municipality include collecting wood

- wastes from forests, less potential gives timber from possible afforestation areas and energy crops.
- Solar and water energy should be used for electricity production to the highest possible extent, using this for the production of electricity as often as possible.
 - Currently, the level of demand for heat from renewable sources can be balanced on the level of 120% and in the long run at about 256%, including biomass obtained on set aside land (about 30%).
 - Current electricity production from alternative sources shapes the demand for this kind of energy on the level of about 2.2%, and in the long run for approximately 24%. The amount of produced electricity may be potentially greater.
 - Due to the high rate of set-aside land (17.7%.) the main emphasis should be placed on the cultivation of energy crops on land currently not cultivated, which could further reduce the scale of abandonment in the analyzed community.
 - In conclusion, from performed tests and analysis it can be stated that rural communities in Poland can run almost entirely on energy from renewable sources.

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