Open Access Journal

**Journal of Power Technologies 95 (2) (2015) 143–157**

journal homepage:papers.itc.pw.edu.pl

# SWOT analysis of the renewable energy sector in Poland. Case study of Wielkopolskie region

Bartłomiej Igliński*, Roman Buczkowski, Anna Iglińska, Marcin Cichosz, Marta Plaskacz-Dziuba

*Nicolaus Copernicus University in Toruń, Faculty of Chemistry*

*Gagarina 7, 87-100 Toruń, Poland*

**Abstract**

This paper presents SWOT analyses of renewable energy in Wielkopolskie region, Poland. The current state, energy potential and future prospects for the development of renewable energy in the region are presented. The SWOT analysis led to the conclusion that the pace of development of the renewable energy sector in Poland depends largely on: the proposed legislation on renewable energy sources being adopted, legal regulations being made simpler, increased subsidies for development of the sector, introduction of guaranteed certificate prices, and educating the public, investors, developers and decision-makers..

*Keywords:* SWOT analysis, Poland, Wielkopolskie region, renewable energy, energy policy

## 1. Introduction

The limited amount of natural resources, rising prices of fossil fuels and environmental pollution are major reasons for expanding the use of renewable energy sources. Renewable energy resources cannot be exhausted, are locally available for each country and, thus, do not lead to any economic or military conflict [1, 2].

The development of renewable energy is of utmost importance to the implementation of Poland's Energy Policy until 2030 [3]. The increase in the use of renewable energy sources results in a greater independence from imported supplies. Promoting the use of renewable energy sources enables greater diversification of supply sources and creates conditions for the development of distributed energy based on locally available resources [1, 2].

Renewable energy usually consists of small production units located close to the consumer, which improves local energy security and reduces transmission losses. Renewable energy generation is characterized by small or zero pollution emissions, which can translate into a positive environmental impact. The development of renewable energy also fosters the growth of less developed regions (eastern and northern Poland) with abundant renewable energy resources. Currently, the greatest amount of renewable energy is generated by the following regions: Kujawsko-Pomorskie, Zachodniopomorskie, Pomorskie and Wielkopolskie (Fig. 1) [4–7].

## 2. SWOT analysis—methodology

Strategic planning is used widely in local and regional development and structuring. Cities, districts and regions have produced strategic plans on the basis of participation processes, which have driven the development of their areas [8–11]. A SWOT analysis is a structured planning method to evaluate the strengths, weaknesses, opportunities and threats involved in a project or business venture. The degree to which the internal environment of the entity matches the external environment is expressed by the concept of strategic fit (Fig. 2):

- **Strengths:** characteristics of the business/project that give it an advantage over others,

*Corresponding author
*Email address:* iglinski@chem.umk.pl (Bartłomiej Igliński*)

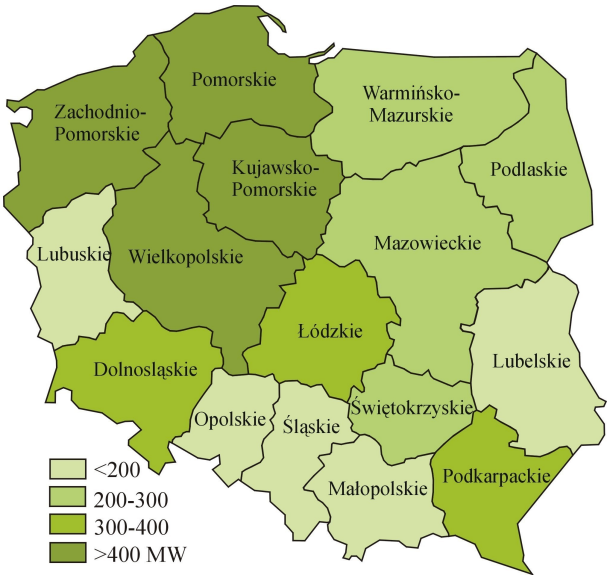


Figure 1: Distribution of renewable energy installations in Poland by power (authors' data based on [4])


Figure 2: Scheme of SWOT analysis

- **Weaknesses:** characteristics that place the business/project at a relative disadvantage,
- **Opportunities:** elements the project could use to its advantage,
- **Threats:** elements in the environment that could jeopardize the business/ project [8–11].

The SWOT analysis was conducted using information provided by renewable energy producers, literature sources data, the strategy for the development of renewable energy sources as well as legal acts and regulations. Recommendations on how to accelerate the development of a particular renewable energy sector are made in this paper [8–11].

No SWOT analysis has previously undertaken before for the renewable energy sector (RES) sector in Wielkopolskie region and Poland. The SWOT analysis in this paper reveals how the RES sector in Poland is currently developing and gives pointers to the future, while indicating the greatest problems of and threats to the RES sector in Wielkopolskie region and Poland. In "Our recommendations" the authors suggest what needs to be done to foster greater development of RES [8–11].

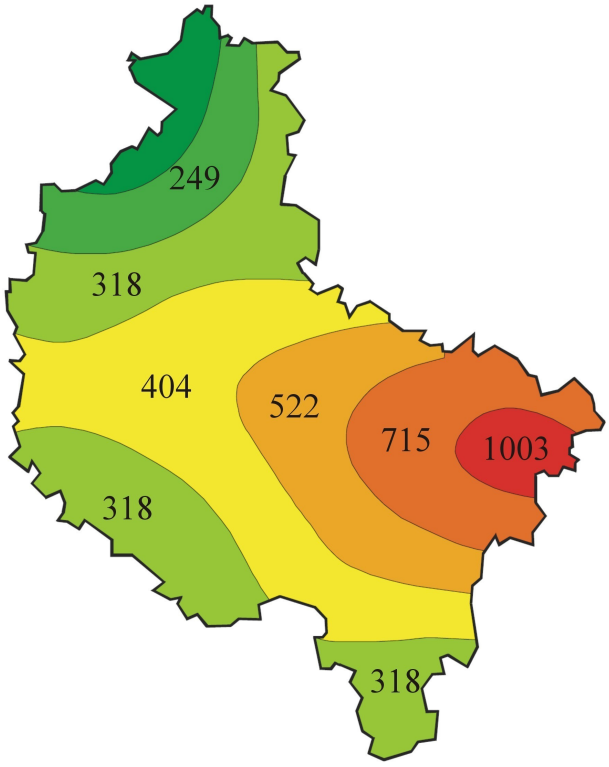


Figure 3: Technical potential of wind power in Wielkopolskie region at a height of 40 m, kWh/(year·m$^2$) (authors' data based on [12–15])

## 3. Wind power—current state, prospects and SWOT analysis

Poland mostly enjoys good or quite good wind conditions [12–14]. Detailed research indicates that the windiest season in Wielkopolskie region is winter, while summer is the least windy season. 24-hour wind speed analysis shows monomodal distribution with maximum speed around midday hours [12–15].

The authors [15] used data from the Climate Atlas of Wielkopolskie region to calculate the technical potential of wind using the formula:

$$E = \frac{t \int_{w1}^{w2} [P(w) f(w)] dw}{F} \quad (1)$$

$E$—technical potential of wind power, kWh/(year·m$^2$)
$t$—time, s
$P$—power of a wind turbine at a wind speed $w$, kW
$F$—rotor surface, m$^2$
$w1$—cut-in speed, m/s

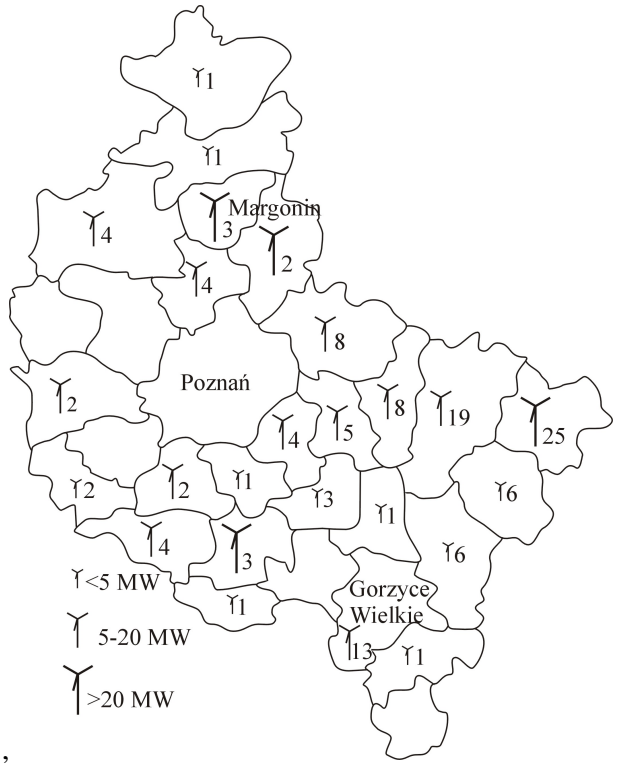


Figure 4: Power of installed wind power stations and number of installations in Wielkopolskie region (authors' data based on) [4])

*w*2—cut-out speed, m/s

Analyzing Fig. 3 it can be concluded that the best conditions for wind turbines are in the south-east while the worst conditions are in the west. Wind speed in the range 4-9 m/s occurs 4 times more frequently in the south-east. Apart from the wind farm in Margonin, there are no large wind farms in Wielkopolskie region. Wind installations (individual wind turbines or small farms) are located in 130 places (Fig. 4); the total aggregate power of all wind turbines in Wielkopolskie region is 460.5 MW [4].

One of the first wind turbines in Wielkopolskie region was constructed near to Gorzyce Wielkie in 2001 (Fig. 4). The mean annual wind speed in this area reaches 6 m/s at 30 m above the ground. The largest wind farm in Poland is located in Wielkopolskie region, in Margonin (Fig. 4). It consists of 60 wind turbines with total power of 120 MW, which is sufficient to meet the domestic demand of 90,000 households [16].

### *3.1. Prospects*

According to the data of the Institute for Renewable Energy [17], the economic potential of the wind power sector in Wielkopolskie region is 4 GW, which places it seventh among the 16 Polish regions. Taking into consideration the current political and market conditions, the greatest number of wind turbines in the period 2014-2020 will be located in the following regions: Zachodniopomorskie, Pomorskie, Wielkopolskie, Kujawsko-Pomorskie and Podlaskie. Large wind power plants will be erected in the south-east of the region, where the best wind conditions occur.

Wielkopolskie region has significant potential for the development of small wind power plants (below 100 kW), for individual use in households and small companies. It is estimated that 4200 small wind turbines will be commissioned in Wielkopolskie region, mainly on farms, before 2020. With regard to the costs and the support system, small wind power plants are one of the most promising technologies of distributed generation and micro generation [17].

### *3.2. SWOT analysis*

The SWOT analysis of wind power in Wielkopolskie region was prepared (Table 1) using information from companies developing wind power plants, the owners of wind turbines [18] and related documents [12–17, 19].

**Our recommendations:**

- simplification of the procedure to obtain a wind energy construction permit,
- higher subsidies for wind energy,
- appropriate locations for wind turbines,
- educating the public.

While Wielkopolskie region generally enjoys good wind conditions, very good conditions are found in the western part of the region. Wind energy is generating great interest among investors. The main reasons include: significant investment profits, following the example of other owners of wind turbines/farms as well as a desire to protect the environment. The investors make profit from selling electric power and from selling green certificates [12–19].

Another strength lies in the recent development of wind micro power stations. These are mainly commercial wind turbines with power of a few kW, installed on roofs or on a tower next to a house. Hybrid systems, combining wind turbines with other renewable energy sources, are used more often [20].

The weaknesses include the numerous obstacles facing investors, especially the long and complicated investment process. Most investors complain about the high investment costs. It is possible to obtain public funding to construct/connect a wind power plant in Poland, but it takes quite a long time. The National Fund for

Table 1: SWOT analysis of wind power in Wielkopolskie region [12–19]

| Strengths | Weaknesses |
|---|---|
| good wind conditions | complicated and time-consuming procedure to obtain a construction permit |
| established technology | high investment costs |
| micro power stations can be used in places not connected to the power grid | impact on the landscape |
| very high interest among investors | potential threat to fauna |
| funding support, including green certificates | |
| **Opportunities** | **Threats** |
| technological progress increasing the efficiency of wind power installations | opposition from local communities |
| development of energy storage technologies | difficulties with connection to the power grid |

Environmental Protection and Water Management subsidizes the construction/connection of a wind power plant as part of the Priority Programme "GIS—Green Investment Scheme". Funding is available from the regional administration in the shape of the region's Environmental Protection Fund, Marshal's Office, etc. In addition, in areas with a large number of operating wind turbines there are increasingly frequent problems getting connected to the power grid [12–19].

Badly located wind turbines—they are tall structures—can have a significant visual impact on the landscape. Environmental impact assessments (part of the permit process) typically impose requirements on investors to commission thorough investigations into the impact a given wind turbine/farm has on animals—birds and bats in particular.

Widespread use of wind power technologies has led to more efficient and quieter wind turbines. Nonetheless, ecological NGOs and local individuals affected typically raise concerns during the permit process for—and sometimes construction of—wind turbines. The close vicinity of wind turbines (regulatory minimum distances apply) and especially the flicker, noise and infrasounds generated by wind turbines may lead to an impact on health, which begins as soon as a wind turbine commences its operation. These ailments are sometimes described as "wind turbine syndrome" and include headaches, sleep disruption, balance problems, nausea, concentration problems and irritability. This problem can be mitigated by the appropriate setting of a wind turbine and early public consultations [12–19].


Figure 5: Power and number of hydropower stations in Wielkopolskie region (authors' data based on [4])

## 4. Hydropower—current state, prospects and SWOT analysis

Hydropower, along with wind power, is the most important type of renewable energy in Poland. At the beginning of 2015 the total power of hydropower plants in Poland was 978 MW [4]. In Wielkopolskie region there are 33 hydropower plants with total aggregate power of 12.2 MW (Fig. 5). Surface waters in Wielkopolskie region cover

an area of over 40,000 ha, of which 25% is taken up by standing waters. The total area of rivers including dykes and ditches is 7180 km [15, 19].

### *4.1. Prospects*

Wielkopolskie region is among the most water-deficient regions of Poland. The available water resources are on average 3754 million $m^3$, of which 1494 million $m^3$ is in the growing season. Thus, any form of water retention, contributing to either increasing the available resources or limiting drainage and raising the groundwater table is justified [19]. Consequently, the construction of small hydropower plants is beneficial for Wielkopolskie region, as they facilitate water retention and reduce the risk of flooding. History shows the potential for the construction of small hydropower stations, as there were more than 500 water mills operating in Wielkopolskie region in the $19^{th}$ century [15, 19].

A 330 kW hydropower plant recently went operational on the river Wełna in Oborniki Wielkopolskie. It has two RKT Kaplan hydro-turbines. The hydropower station generates 1450 MWh per annum, which is sufficient to supply power to about 500 households. The building has a fish ladder, which enables fish to swim freely towards the river's source and estuary. A new hydropower plant will be constructed on the river Noteć, in the vicinity of Wieleń, in the north-western part of Wielkopolskie region. It will be equipped with a screw turbine, which uses the principle of the Archimedean screw. This is an ideal solution for the rivers of the region, which have a low gradient and a small flow. Due to its construction and the very small rotations of the rotor, the turbine does not threaten the river fauna[19].

### *4.2. SWOT analysis*

The SWOT analysis of hydropower in Wielkopolskie region was prepared (Table 2) using information from the owners of hydropower [18] stations and related documents [15, 17, 19].

**Our recommendations:**

- promotion and development of small hydropower,
- use of existing hydrotechnical structures,
- building of fish ladders,
- simplification of legislation.

A strong aspect of hydropower in Wielkopolskie region is its lower price when compared with energy from combusting fossil fuels or nuclear power. In addition, the efficiency of power generation in water turbines is high and reaches even 90%.

Wielkopolskie region suffers the worst water deficit in Poland. Thus, increasing water retention capacity should be a policy priority for the regional authorities. In addition to power generation and flood prevention, damming rivers can deliver other economic benefits such as the development of water transportation, additional bridge crossings, higher crop yields due to the raised groundwater level and the development of tourism and recreation [15].

The weaknesses of hydropower include a necessity to put weirs on the river, which can have a negative impact on fish population [21]. Prolonged periods of drought in Wielkopolskie region can negatively influence the work of hydropower stations. As a result of convoluted regulations, private investors find it very difficult to enter the hydropower sector as they do not want to invest their capital in an uncertain market. Clear formal and legal regulations need to be introduced both at the whole country level and the region level.

## 5. Biomass—current state, prospects and SWOT analysis

The biomass market in the Wielkopolskie region and Poland is growing from a low base [22, 23]. Biomass, mainly waste wood, straw, pellets and briquettes, is being used on a greater scale in household boiler rooms as well as in combustion and co-combustion in large power plants. In July 2012 the concern running the Patnow-Adamow-Konin complex of power stations opened a new 55 MW unit in Konin power station, adjusted to burn 100% biomass (Fig. 6). The boiler burns 80% wood biomass and 20% agricultural biomass [22].

Bioethanol is also produced in Wielkopolskie region. In Leszno district 95 million $dm^3$of bioethanol is produced per year, in Murowana Goślina district: 13 million $dm^3$ per year, while in Niedźwiady district: 50 million $dm^3$ per year and in Oborniki Wielkopolskie: 150 million $dm^3$ per year (Fig. 5) [24].

In Wielkopolskie region biogas is also obtained for energy purposes. There are six biogas power plants that utilize biogas generated at municipal landfill sites, seven biogas power plants at sewage treatment works and six agricultural biogas power plants [25, 26].

Table 2: SWOT analysis of hydropower in Wielkopolskie region [15, 17–19]

| Strengths | Weaknesses |
|---|---|
| cheaper energy than from conventional sources | it is often necessary to put weirs on the river |
| well-controlled technology | negative impact on the fish population |
| increased retention of surface water and groundwater | unable to operate during a long-term drought |
| small hydropower stations can be constructed in many places, even on small water courses | |
| **Opportunities** | **Threats** |
| possibility to use water bodies for tourism and recreation | unclear legal regulations |
| development of fishing | limited interest from investors |
| possibility of using bodies of water for tourism and recreation purposes | |

### *5.1. Prospects*

The forest cover in Wielkopolskie region is 25.7%, which is lower than the average for Poland, at 29.3% [27]. Assuming that 15% of wood obtained directly from woodland could be used for energy purposes (parts of bark, slash, more chunky waste wood generated during logging), then 450,000 $m^3$ of waste wood could be obtained annually. The timber industry, including sawmills, furniture manufacturing plants, paper and pulp industry plants, creates a significant amount of waste wood in Wielkopolskie region (sawdust, woodshavings etc.). Used timber is another source of wood. It can be assumed that the amount of waste wood biomass obtained from industry and used timber is at least the same as the amount of waste wood obtained from woodland [28].

In 2013 Wielkopolskie region produced about 770,000 metric tons of wheat straw, 310 thousand metric tons of rye straw, 180,000 metric tons of barley straw, 330,000 metric tons of oat straw and 50,000 metric tons of triticale straw [29]. Around 30% of the straw could be used to generate energy. Currently, little of this potential is achieved.

The agricultural biogas which could be obtained in Wielkopolskie region is 39 million $m^3$, with 4 million $m^3$ from municipal waste and 7.3 million $m^3$ from municipal waste.

### *5.2. SWOT analysis*

SWOT analyses of biomass combustion and co-combustion in Wielkopolskie region (Table 3), liquid biofuel production in Wielkopolskie region (Table 4) and biogas generation in Wielkopolskie region were prepared (Table 5) using the information obtained [18] and related documents [15, 17, 22–26, 28–33].

**Our recommendations:**

- guaranteed prices of green certificates,
- education of farmers,
- guaranteed prices of biomass,
- implementation of Act on renewable energy sources.

Wielkopolskie region has the best developed agriculture in Poland. Consequently, it has a significant amount of agricultural waste biomass, which could be used for energy purposes. Solid biomass, mainly straw and energy crops biomass, is combusted or co-combusted in numerous boilers and in two power stations. The financial support in the form of green certificates means that co-combustion technology has been developing particularly well [15, 17, 18].

The weaknesses of combustion and co-combustion of biomass include variable prices of green certificates caused by their oversupply and concern regarding funding arrangements for future power units. Farmers lack knowledge about growing energy crops, which leads to mistakes during cultivation. In Wielkopolskie region there are many companies growing button mushrooms, for which they require a significant amount of straw. Equally, Wielkopolskie region has limited water resources and energy crop plantations require a significant amount of water [23].

The opportunities of combustion and co-combustion include a possibility of utilizing other waste streams

Table 3: The SWOT analysis of biomass combustion and co-combustion in Wielkopolskie region [15, 17, 18, 22, 23]

| Strengths | Weaknesses |
|---|---|
| great agricultural potential | variable price of green certificates |
| availability of biomass | farmers have limited knowledge about energy crops |
| known and simple to implement technology | in the case of straw, high competition from button mushroom producers |
| **Opportunities** | **Threats** |
| possibility to utilize waste types of biomass | variable prices of biomass |
| new workplaces in heat and power sector | difficulties ensuring stable supply |
| | Legislation on renewable energy sources not enacted (January 2015) |

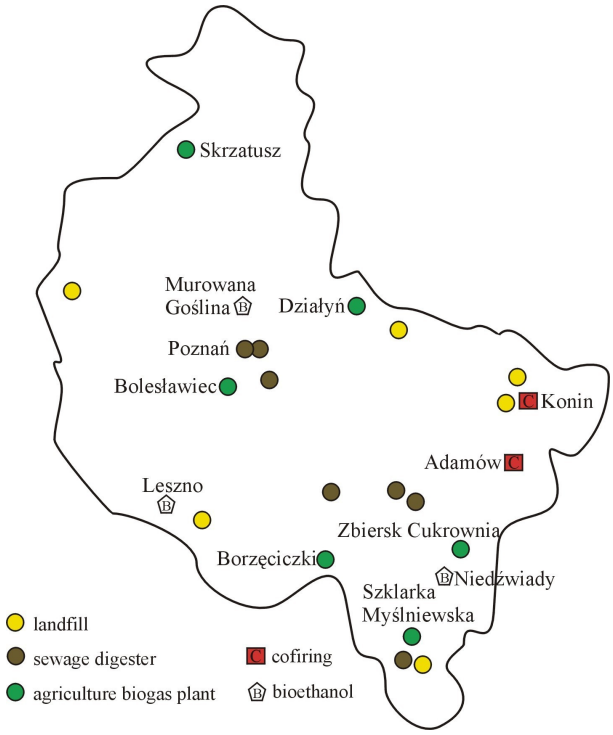


Figure 6: Bioenergy production in Wielkopolskie region (authors' data based on [4, 22–26])

of biomass; for example, from maintenance felling of Wielkopolskie region's numerous orchards. Energy generation based on biomass means new jobs, especially in rural areas, where unemployment is highest [23, 28].

The threats include variable biomass prices, dependent on supply and crop yield. Many boilers and heat and electricity power stations are struggling to ensure a continuous supply of biomass, necessitating major stockpiling. Biomass producers, in common with producers of other sources of renewable energy, are in a state of uncertainty caused by reports about adverse changes to regulations under the anticipated Act on Renewable Energy Sources [18].

**Our recommendations:**

- reduction in excise duty on biofuels,
- simplification of legislation,
- biofuel promotion in Poland,
- development of second-generation biofuels.

Wielkopolskie region leads the way in Poland in terms of growing rapeseed, a crop from which a great amount of biodiesel can be produced. Unfortunately, the import of biofuels from abroad as well as the low price of vegetable oil (and spirits) results in negligible profit for the producers, which in turn hinders the development of biofuels in Wielkopolskie region. The development is also thwarted by unclear legal regulations, which effectively discourage investors [21, 31].

Wielkopolskie region has huge potential for the production of second generation biofuels, which could be obtained from waste wood, straw or agricultural waste streams. First and second generation biofuels could be used as fuel for agricultural machinery in the region [23].

The threats to the development of biofuels in Wielkopolskie region are variable biomass prices and difficulties with ensuring stability of supplies. Despite more than 10 years of education about the benefits of using biofuels, many Polish drivers are reluctant to use biofuels. They are afraid that their vehicles will malfunction as a result of using biofuels. The opponents of biofuels stress

Table 4: SWOT analysis of the production of liquid biofuels in Wielkopolskie region [15, 17, 18, 24, 31, 33]

| Strengths | Weaknesses |
|---|---|
| great agricultural potential | competition from cheap biofuels from abroad |
| availability of biomass | unclear legal regulations |
| **Opportunities** | **Threats** |
| big acreage of rapeseed—a possibility of large-scale biodiesel production | variable prices of biomass |
| big potential for the production of second generation biofuels | difficulties ensuring stable supply reticence of Polish drivers to use biofuels |
| | rapeseed oil is a first generation biofuel |

Table 5: SWOT analysis of biogas production in Wielkopolskie region [15, 18, 22, 26, 30]

| Strengths | Weaknesses |
|---|---|
| well-developed agriculture | insufficient financial support for the investment implementation |
| significant experience of technology | high investment costs |
| waste deodorization treatment and disposal technology | long investment process |
| co-generation technology is most often applied | problems with utilizing heat |
| generated power can be used on site or transferred | |
| increase in employment (a high proportion of local companies participating in the construction of installations) | |
| increased crop yield due to use of post-fermentation pulp as a fertilizer | |
| **Opportunities** | **Threats** |
| fast development of biogas technology | variable prices of agricultural substrates |
| increased availability of biomass due to compulsory waste segregation for waste collection | unpredictable supply of feedstock in agricultural biogas plants |
| use of biogas as a fuel | |
| utilization of heat generated from biogas combustion to heat greenhouse crops | |

that biofuels are currently obtained from edible plants, which contributes to an increase in their price [23].

**Our recommendations:**

- higher subsidies for biogas plants,
- simplification of legislation,
- guaranteed prices of agricultural substrates,
- heat utilization (eg. floriculture).

Wielkopolskie region has a large biogas potential, mainly due to its well-developed agricultural sector. The fermentation process allows for waste deodorization. Electric power and heat are produced in co-generation in Wielkopolskie region. A small amount is used on site, with the rest being sold. In addition, a biogas power plant can co-operate with local heat networks and provide cheap energy for heating of public use buildings, houses or apartment blocks [18, 22, 26].

The development of biogas technology provides an opportunity for economic growth in the region and employment opportunities in companies constructing and operating biogas plants. Post-fermentation pulp is used to fertilize fields; research [34] shows that it significantly increases crop yield.

Investors looking to build biogas power plants complain about the bureaucracy, considerable investment costs and insufficient financial help during implementation of the investment. There are still problems getting connected to the power grid. In the case of biogas power plants located in rural areas, it is sometimes difficult to utilize heat from co-generation [22].

The development of biogas technologies contributes to the construction of new biogas power plants in Wielkopolskie region. An organic fraction from segregated municipal waste could supply an additional substrate for biogas generation. A possibility of using biogas (biomethane) to power vehicles is increasingly considered as an option. Moreover, heat surplus from biogas combustion could be used to heat greenhouse crops [18, 22, 26].

The threats to the development of biogas power plants include variable prices of agricultural substrates and unstable substrate supply.

## 6. Solar energy—current state, prospects and SWOT analysis

The solar collector market in Poland has been experiencing a significant growth in recent years compared to other European countries [35–37]. This is mainly due to the introduction of funding programs to support investment in solar installations. At the same time, market penetration levels in Poland are considerably lower than in many other Europeana countries [35].

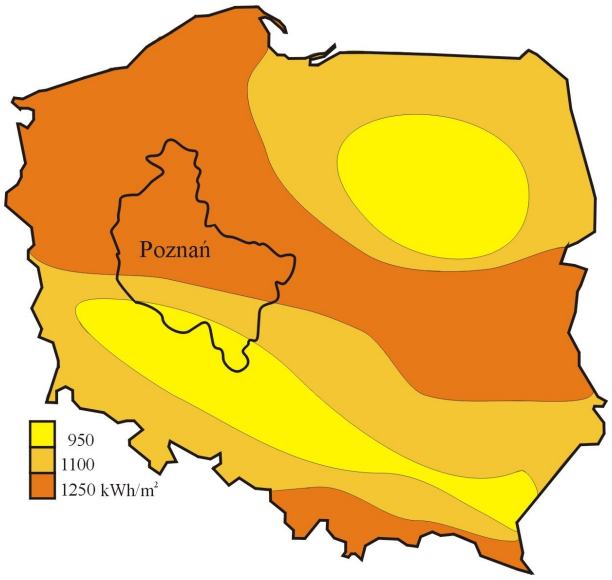


Figure 7: Solar radiation density in Wielkopolskie region compared to the rest of Poland (authors' data based on [15, 35])

The indicator of total installed area of solar collectors in Poland per number of inhabitants reached 31.4 $m^2$/1000 by the end of 2012. The annual density of solar radiation on a horizontal plane in Poland lies in the range 950-1250 kWh/$m^2$; in Wielkopolskie region it reaches about 1100 kWh/$m^2$ (Fig. 7). About 80% of the total annual insolation takes place during the six months of the spring-summer season, from early April to late September; the duration of solar operation increases to 16 hours per day in summer while in winter it falls to 8 hours per day [15].

Annual figures for insolation in Wielkopolskie region oscillate between 1250 and 2000 hours. The mean number of insolation hours throughout the year is about 1600 hours, which is similar to the average for Poland. Analysis of the annual insolation values for Poznań indicates that insolation is increasing by 11 hours per year on average, which is thought to be caused by changes to the local climate. While the annual insolation in some years falls below the long-term average, in the last 30 years there were only four years when the annual insolation sum fell below the mean value. It is worth adding that variations in the annual insolation sum are significantly greater than variations in the mean annual temperature [17].

The geographical location of Wielkopolskie region in mid latitudes results in a significant seasonal difference

between the amount of solar energy obtained in the spring-summer and autumn-winter periods [17]. Thus, Wielkopolskie region should be equipped with solar collectors adapted particularly for the spring-summer period. During the autumn-winter period the main source of heat needs to be a source independent of weather conditions. According to the Institute for Renewable Energy [17], solar collectors with a total aggregate area of 25 million m$^2$ were sold in Wielkopolskie region in the period 2008-2010.

### *6.1. Prospects*

In the near future the upward trend in harnessing solar energy for the purpose of providing hot domestic water in individual households and in the public sector (swimming pools, schools etc.) will continue. Photovoltaic cells will be used to a much smaller degree to power traffic lights, road signs and parking meters [33]. According to the Institute of Renewable Energy [17] the market potential of solar energy in Wielkopolskie region is 800 TJ until 2020, which is linked to the planned installation of 0.6 million m$^2$ of collectors.

### *6.2. SWOT analysis*

The SWOT analysis of solar energy in Wielkopolskie region was prepared (Table 6) using the obtained information [18] and documents [15, 17, 19, 35].

**Our recommendations:**

- higher subsidies for solar energy,
- support for micro sources and small sources of energy,
- promotion of solar energy,
- educating the public.

The strengths of solar energy in Wielkopolskie region include the capacity of a small solar installation to meet 90-100% of heat demand to provide hot domestic water during summer months (50..60% over a year). In Wielkopolskie region photovoltaic cells are increasingly used to power traffic lights, road signs and parking meters. Importantly, solar collectors and photovoltaic cells enjoy public support: they are considered to be safe and environmentally friendly sources of heat and electricity. The owners of solar collectors and photovoltaic cells stress that they are non-malfunctioning systems with little need for maintenance [15, 17–19, 35].

Among the weaknesses there is the high cost of solar installations, especially the photovoltaic ones, although

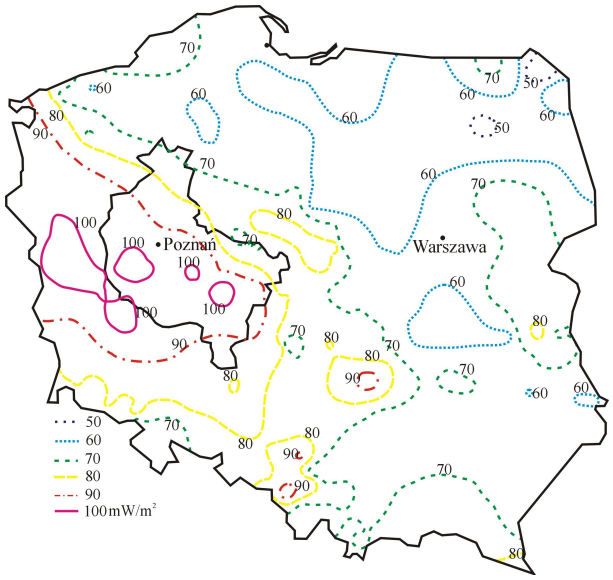


Figure 8: Map of terrestrial heat stream density for Poland, with Wielkopolskie region outlined (authors' data based on [38, 39])

prices are falling every year and generous funding attracts prospective investors. Poor insolation during the autumn and winter months necessitates the construction of another heat source. Solar energy technologies are a quickly developing branch of energy generation, which leads to the increased efficiency and lower price of solar systems—driving growing demand for solar installations in Wielkopolskie region [35].

The threat to the development of solar energy is the lack of support for micro and small power sources. An individual investor stands virtually no chances of securing funding for a solar installation [15, 17–19, 35].

## 7. Geothermal power—current state, prospects and SWOT analysis

The terrestrial heat stream density in Poland shows great differentiation, depending on the geological composition, and ranges from 50 mW/m$^2$ to 100 mW/m$^2$. In Wielkopolskie region the heat stream density reaches from 70 to 100 mW/m$^2$ (Fig. 8) [38, 39].

The best hydrogeological and thermal conditions in Wielkopolskie region are found in the Lower Jurassic deposits in the north-eastern part of the Fore-Sudetic Monocline and the western part of the Mogileńsko-Łódzka basin, where in the following boreholes (Polowica 1, Kaleje 5, Środa IG-2, Czeszewo IG-1—Fig. 9), at a depth of 600-1500 m, artesian flow was obtained with water temperature of up to 50°C and mineralization below 50 g/dm$^3$. It is estimated that the efficiency of the completed boreholes is 30-100 m$^3$/h [38, 39].

Table 6: SWOT analysis of solar energy in Wielkopolskie region [15, 17–19, 35]

| Strengths | Weaknesses |
|---|---|
| reduced heating costs | high cost—photovoltaic installations in particular |
| usable in locations not connected to the power grid (photovoltaics) | low solar irradiation of the region |
| high public support | long wait for break-even point |
| low operating costs of installations | |
| reliable, low maintenance | seasonal disparity between solar energy in spring-summer and autumn-winter |
| can be combined with other installations, e.g. a heat pump | |
| **Opportunities** | **Threats** |
| fast technological progress improving efficiency and reducing the cost of solar installations | no support for micro sources and small sources of energy |
| high demand for solar installations | |

The geothermal energy resources in Wielkopolskie region can be described as sufficiently significant to provide heat to dwelling buildings and public use buildings, drying facilities, greenhouses and also for the preparation of domestic hot water and for balneological and recreational purposes [39].

One of the biggest thermal aquaparks in Poland—Termy Maltańskie—is located in Poznań. The area of 6 hectares contains 18 swimming pools, including sports and recreational pools as well as brine pools with the thermal water of temperature of 40°C, extracted from a depth of 1300 m [38].

### *7.1. Prospects*

Wielkopolskie region is a prospective region for the exploitation of thermal waters. The feasibility of practical utilization depends on: high water temperature, general mineralization (<10 g/dm$^3$), suitable chemical composition of water, efficiency of exploratory boreholes (>20m$^3$/h). Thermal waters in Wielkopolskie region can be successfully used for heating as well as balneological and recreational purposes [39].

### *7.2. SWOT analysis*

The SWOT analysis of geothermal energy in Wielkopolskie region was prepared (Table 7) using the information [18] and papers obtained [15, 17, 19, 38, 39].
**Our recommendations:**

- higher subsidies for geothermal energy,
- green certificates for geothermal power,
- promotion of geothermal energy,
- educating the public.

Central Wielkopolskie region has good geothermal conditions, favoring the development of the thermal energy sector. The price of geothermal heat does not depend on unstable prices of conventional fuels, which is important. Geothermal plants are small installations and do not negatively impact the environment or landscape, which means there is huge public support for them. Hot geothermal water can be used for balneology and recreation purposes [15, 17–19, 38, 39].

The construction and start-up of a geothermal heat plant require substantial funding and determination, which effectively discourages prospective investors. Geothermal waters in Poland are characterized by high mineralization, which exacerbates the corrosion of machinery. In extreme cases there is a problem with pumping geothermal water back to the earth. The greatest problem faced by the Polish geothermal power sector is the lack of green certificates, which are available to other sources of renewable energy [39].

As with other renewable energy technologies, the geothermal power sector is experiencing technological progress, which will lower investment costs as well as geological risk. The thermal energy sector in Wielkopolskie region could use geothermal heat to solve the problem of high air pollution caused by "low emission" power plants as well as old coal-fired boilers. Many towns in Wielkopolskie region are considering the construction of thermal swimming pools [15].

The greatest threat to the geothermal energy sector in

Table 7: SWOT analysis of geothermal power in Wielkopolskie region [15, 17–19, 38, 39]

| Strengths | Weaknesses |
|---|---|
| good geothermal conditions, enabling heat production | high initial investment costs |
| stable production cost, not dependent on the prices of energy carriers | no green certificates for geothermal power |
| minimal environmental impact | frequent high mineralization of geothermal waters |
| very high public support | problems pumping used thermal waste |
| possibility of development of balneology and recreation | |
| **Opportunities** | **Threats** |
| technological progress leading to reduced investment costs and geological risk | lack of effective promotional policy towards geothermal energy |
| increased demand for balneology and recreation services | |

Poland is the lack of an effective promotional policy. An average Polish person does not even know that geothermal water could heat his or her house in an environmentally friendly way [15, 17–19, 38, 39].

## 8. Discussion

The renewable energy sector in Wielkopolskie region is developing well despite the many problems it faces, as described in the SWOT analysis. Importantly, the prospects for the near future are promising—the share of renewable energy in the energy balance looks set to increase. Nevertheless, formidable obstacles remain: the long-awaited Act on Renewable Energy Sources, high investment costs and numerous formal and legal barriers.

Despite intensive attempts in recent years, there is still inadequate access to expert knowledge, articles, training and know-how related to the renewable energy sector. It would be beneficial for the goal of accelerating the development of renewables, if leading stakeholders could make demonstration installations available. The education and information campaign should comprise three parts:

- educating the public—people generally lack in-depth knowledge about the benefits of and conditions for the construction of a renewable energy installation,
- educating investors and developers—they should know how to effectively deal with the local community so as to avoid conflict. The lack of communication with residents results in the local community being more receptive towards the arguments of the opponents of renewable energy. In addition, the lack of co-operation with local leaders and prospective partners can create ill-will.
- educating decision-makers—they often have to defend decisions made on behalf of the investor; thus, they need substantive arguments to do so. Even local authorities with the most favorable attitude can easily change their outlook when faced by a campaign against renewable energy sources.

The renewable energy sector in Poland faces similar problems to its counterparts in other parts of the world. Terrados and colleagues [9] carried out a SWOT analysis for the province of Jaén (south Spain). Among the weaknesses were: no individual awareness of renewable energy utilization, weakness of the renewable energy business and absence of financial mechanisms to encourage RES penetration.

In Turkey, Celiktas and Kocar [40] conducted a SWOT analysis for renewables, while Dinçer [41] did it for the photovoltaic sector. Interestingly, many aspects of the analyses are similar to the SWOT analysis for Poland. Among the strengths the authors included: geostrategic location (Poland also has a geostrategic location), reliable resources, price and purchase guarantees, creating technological platforms, preventing immigration. Among the weaknesses the authors listed: weak technical infrastructure, lack of energy investment policy, high costs, lack of transparent regulations and little government support. The opportunities for developing renewable energy sources in Turkey include among others: sustainable development, creating new sectors, exploiting new market segments and using potential resources efficiently. Among the threats to the development of renewables in Turkey are: nuclear energy investment, political instability, lack of knowledge, lack of experience. It is worth mentioning that there are plans to create a nuclear power sector in Poland, initially with just one plant, which is unlikely to hinder the devel-

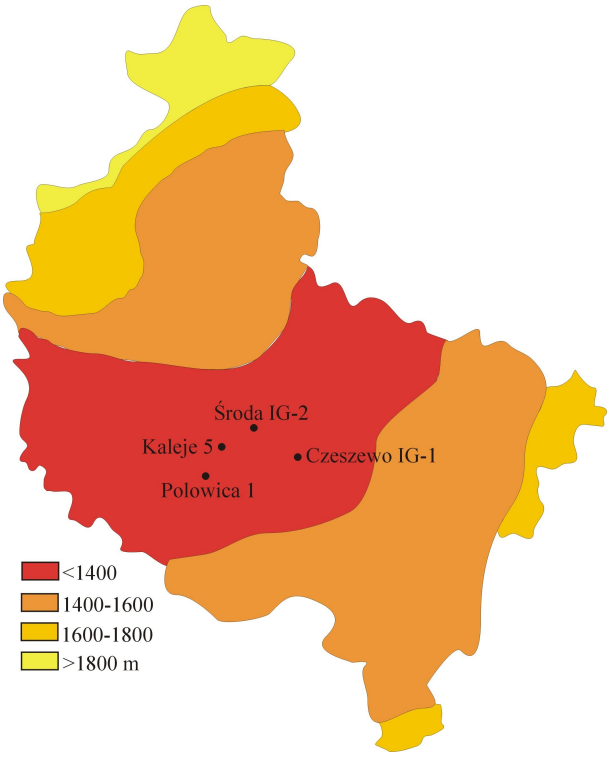


Figure 9: Map of geothermal conditions in Wielkopolskie region—depth where water temperature of at least 50°C was found (authors' data based on [15, 38, 39])

opment of renewable energy sources even in the medium term.

Liou [42] carried out a SWOT analysis for the photovoltaic sector in Taiwan. Taiwan has greater potential than Poland for the development of the photovoltaic sector. Among the reasons are: a well-developed electronic industry in Taiwan, great knowledge of designers and producers and the fact that the PV cluster effect has already formed gradually under the guidance of government policies.

As stressed by Chen and colleagues [11] in their SWOT analysis, the disaster in the nuclear power plant in Fukushima spurred the development of renewable energy sources in Japan. On the other hand, huge deposits of shale gas in South Korea could restrict the development of the renewable energy sector. Shale deposits have also been discovered in Poland, but initial euphoria as to their extent seems to have been misplaced. The optimal solution for Poland would be to add Polish-sourced shale gas and biogas to its energy mix, thereby significantly reducing its natural gas imports.

Despite the many problems it faces, the renewable energy sector in Poland is developing well. The share of renewables in the energy balance will continue to grow over the next few years. The SWOT analysis of renewable energy sources in Poland leads to the following conclusions:

- Poland has significant potential to develop renewable energy sources and improve energy efficiency,
- the potential of particular energy sources varies greatly across Poland, due to local conditions,
- strategic planning is required at the local level, based on detailed analysis of the local potential,
- educational action and information/promotion campaigns aimed at the general public and local authorities could eliminate many weaknesses and threats that are not caused by external factors,
- efficient, well-framed legislation is need to support the development of renewable energy sources in Poland, especially on the Act on Renewable Energy Sources.

The potential of renewable energy sources in Poland is many times greater than the current energy demand, or indeed the energy demand for the foreseeable long-term. Each type of renewable energy needs to be developed to ensure balanced development. Given the right political will, an energy system based on renewable energy sources would be quick to build, because would unlock funding, encourage individual and local authority initiatives, deliver energy security, create tens of thousands of jobs at the local level and would be environmentally friendly.

## 9. Conclusions

The renewable energy sector in both Wielkopolskie region and Poland is still in its infancy. Despite this, among its strengths is the fact that renewable energy technology is already well controlled. Every year the number of investors investing their money in the renewable energy sector is rising. Wielkopolskie region—and Poland in general—has a large renewable energy potential, mainly from biomass.

The weaknesses include: fluctuating green certificate prices, long investment period and unclear legal regulations. Among the opportunities of the sector, development of renewable energy technologies is leading to increasingly more efficient energy generation at lower prices. In addition, the development of the renewable energy sector is creating more jobs. Among the threats there are: the long-awaited Act on renewable energy sources and little promotion of renewable energy sources.

The SWOT analysis reported in this paper leads to the conclusion that the pace of development of the renewable energy sector in Poland strongly depends on:

- the proposed Act on renewable energy sources being adopted,
- legal regulations being made simpler,
- increased subsidies for sector development,
- introduction of guaranteed certificate prices,
- educating the public, investors and developers and decision-makers.

The increased use of renewable energy sources will improve the energy security of Poland, create new jobs and reduce emissions. The transition from coal to low-carbon is a long process, requiring an enlightened political and economic strategy as well as appropriate legal grounding, funding sources and operating resources. Above all, it is important not to focus on one selected renewable energy technology, but to establish a balanced structure of renewable energy sources that harness local potential.

## References


[1] F. Manzano-Agugliaro, A. Alcayde, F. Montoya, A. Zapata-Sierra, C. Gil, Scientific production of renewable energies worldwide: an overview, Renewable and Sustainable Energy Reviews 18 (2013) 134–143.

[2] W. M. Budzianowski, J. F. Gomes, Perspectives for low-carbon electricity production until 2030: Lessons learned from the comparison of local contexts in poland and portugal, Energy Sources, Part B: Economics, Planning, and Policy 10.

[3] Polityka energetyczna polski do 2030.
URL http://www.mg.gov.pl/files/upload/8134/Polityka %20energetyczna% 20ost.pdf (accessed 11.01.15)

[4] Mapa odnawialnych źródeł energii.
URL http://www.ure.gov.pl/uremapoze /mapa.html (accessed 12.01.15)

[5] B. Igliński, W. Kujawski, R. Buczkowski, M. Cichosz, Renewable energy in the kujawsko-pomorskie voivodeship (poland), Renewable and Sustainable Energy Reviews 14 (4) (2010) 1336–1341.

[6] W. M. Budzianowski, Sustainable biogas energy in poland: prospects and challenges, Renewable and Sustainable Energy Reviews 16 (1) (2012) 342–349.

[7] B. Igliński, R. Buczkowski, M. Cichosz, G. Piechota, W. Kujawski, M. Plaskacz, Renewable energy production in the zachodniopomorskie voivodeship (poland), Renewable and Sustainable Energy Reviews 27 (2013) 768–777.

[8] T. J. Chermack, B. K. Kasshanna, The use and misuse of swot analysis and implications for hrd professionals, Human Resource Development International 10 (4) (2007) 383–399.

[9] J. Terrados, G. Almonacid, L. Hontoria, Regional energy planning through swot analysis and strategic planning tools.: Impact on renewables development, Renewable and Sustainable Energy Reviews 11 (6) (2007) 1275–1287.

[10] N. Pahl, A. Richter, Swot analysis. idea, methodology and a practical approach.

[11] W.-M. Chen, H. Kim, H. Yamaguchi, Renewable energy in eastern asia: Renewable energy policy review and comparative swot analysis for promoting renewable energy in japan, south korea, and taiwan, Energy Policy 74 (2014) 319–329.

[12] H. Lorenc, Struktura i zasoby energetyczne wiatru w Polsce, IMiGW, 1996.

[13] P. Michalak, J. Zimny, Wind energy development in the world, europe and poland from 1995 to 2009; current status and future perspectives, Renewable and Sustainable Energy Reviews 15 (5) (2011) 2330–2341.

[14] A. Brzezińska-Rawa, J. Goździewicz-Biechońska, Recent developments in the wind energy sector in poland, Renewable and Sustainable Energy Reviews 38 (2014) 79–87.

[15] C. Przybyła, R. Wojtkowiak, S. Gładysiak, J. Lesny, R. Schefke, K. Mrozik, Przegląd zasobów odnawialnych źródeł energii w województwie wielkopolskim, Poznań, Urząd Marszałkowski Województwa Wielkopolskiego (2007).

[16] Farma wiatrowa margonin.
URL http://pl.wikipedia.org/wiki/Farma_wiatrowa_ w_Margoninie (accessed 08.01.15)

[17] G. Wiśniewski, Określenie potencjału energetycznego regionów Polski w zakresie odnawialnych źródeł energii – wnioski dla regionalnych Programów Operacyjnych na okres programowania 2014-2020, Warszawa: Departament Koordynacji i Wdrażania Programów regionalnych (2011).

[18] Information directly obtained from renewable energy producers in the Wielkopolskie Voivodship (surveys, 2014).

[19] J. Lewandowski, Strategia wzrostu efektywności energetycznej i rozwoju odnawialnych źródeł energii w wielkopolsce na lata 2012-2020 (2012).
URL http://waze.pl/documents/dopobrania/Strategia_EE_i _OZE_w_Wielkopolsce.pdf (accessed 20.12.14)

[20] G. J. Herbert, S. Iniyan, D. Amutha, A review of technical issues on the development of wind farms, Renewable and Sustainable Energy Reviews 32 (2014) 619–641.

[21] C. G. De Leaniz, Weir removal in salmonid streams: implications, challenges and practicalities, Hydrobiologia 609 (1) (2008) 83–96.

[22] B. Igliński, A. Iglińska, W. Kujawski, R. Buczkowski, M. Cichosz, Bioenergy in poland, Renewable and Sustainable Energy Reviews 15 (6) (2011) 2999–3007.

[23] B. Igliński, G. Piechota, R. Buczkowski, Development of biomass in polish energy sector: an overview, Clean Technologies and Environmental Policy 17 (2) (2014) 317–329.

[24] Rejestr producentów biopaliw i biokomponentów.
URL http://www.arr.gov.pl /data/01670/rejestr_wytworcow_bio_2014.pdf (accessed 12.01.15)

[25] Rejestr biogazowni rolniczych.
URL http://www.arr.gov.pl/data/02004/rejestr_biogazowni _rolniczych_23042014.pdf (accessed 13.01.15)

[26] W. M. Budzianowski, I. Chasiak, The expansion of biogas fuelled power plants in germany during the 2001-2010 decade: Main sustainable conclusions for poland, Journal of Power Tech-

nologies 91 (2) (2011) 102–113.
[27] Główny urząd statystyczny, powierzchnia i ludność w profilu terytorialnego w roku 2013 (2013).
URL http://stat.gov.pl/cps/rde/xbcr/gus/l_powierzchnia_i _ludnosc_przekroj_terytorialny_2013.pdf (accessed 16.01.15)
[28] M. Jasiulewicz, Potencjał biomasy w polsce, Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu 12 (1) (2010) 70–74.
[29] Główny urząd statystyczny, rocznik statystyczny województw 2013 (2013).
URL http://stat.gov.pl/obszary-tematyczne/roczniki-statystyczne/roczniki-statystyczne/rocznik-statystyczny -wojewodztw-2013,4,8.html (accessed on 16.12.14)
[30] W. M. Budzianowski, Low-carbon power generation cycles: the feasibility of co2 capture and opportunities for integration, Journal of Power Technologies 91 (1) (2011) 6–13.
[31] J. Milewski, J. Lewandoski, Biofuels as fuels for high temperature fuel cells, Journal of Power Technologies 93 (5) (2013) 347–353.
[32] K. J. Mościcki, Ł. Niedźwiecki, P. Owczarek, M. Wnukowski, Commoditization of biomass: dry torrefaction and pelletization-a review, Journal of Power Technologies 94 (4) (2014) 233–249.
[33] N. R. Banapurmath, W. M. Budzianowski, Y. Basavarajappa, R. Hosmath, V. Yaliwal, P. Tewari, Effects of compression ratio, swirl augmentation techniques and ethanol addition on the combustion of cng–biodiesel in a dual-fuel engine, International Journal of Sustainable Engineering 7 (1) (2014) 55–70.
[34] R. Nkoa, Agricultural benefits and environmental risks of soil fertilization with anaerobic digestates: a review, Agronomy for Sustainable Development 34 (2) (2014) 473–492.
[35] B. Igliński, R. Buczkowski, M. Cichosz, G. Plaskacz-Dziuba, Marta ane Piechota, Technologie helioenergetyczne, Wydawnictwo Uniwersytetu Mikołaja Kopernika, Toruń, 2013.
[36] J. Milewski, M. Wolowicz, W. Bujalski, Methodology for choosing the optimum architecture of a stes system, Journal of Power Technologies 94 (3) (2014) 153–164.
[37] R. D. Tapakis, A. G. Charalambides, Performance evaluation of a photovoltaic park in cyprus using irradiance sensors, Journal of Power Technologies 94 (4) (2014) 296–305.
[38] J. Szewczyk, D. Gientka, Terrestrial heat flow density in poland-a new approach, Geological Quarterly 53 (1) (2010) 125–140.
[39] B. Igliński, R. Buczkowski, W. Kujawski, M. Cichosz, G. Piechota, Geoenergy in poland, Renewable and Sustainable Energy Reviews 16 (5) (2012) 2545–2557.
[40] M. S. Celiktas, G. Kocar, A quadratic helix approach to evaluate the turkish renewable energies, Energy Policy 37 (11) (2009) 4959–4965.
[41] F. Dinçer, Overview of the photovoltaic technology status and perspective in turkey, Renewable and Sustainable Energy Reviews 15 (8) (2011) 3768–3779.
[42] H. M. Liou, Overview of the photovoltaic technology status and perspective in taiwan, Renewable and Sustainable Energy Reviews 14 (4) (2010) 1202–1215.