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MANAGEMENT OF SOLAR ENERGY

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Summary

The article addresses issues related to planning investments based on renewable energy resource, as exemplified by solar energy.
In the first part mean annual amounts of total solar irradiance in Poland are presented and legal conditions for development of this kind of technology with reference to the European Union regulations and to the Renewable Energy Resources Act of 20 February 2015.
In the next part of the paper a distribution model of direct solar irradiance for the town and community (gmina) of Jordanów has been constructed. Mountainous character of this area, located in the south part of the Małopolskie voivodeship, means there are very good as well as very bad conditions of insolation. The results obtained by using the model were assigned to building plots and plots intended for development and than they were analysed with the aim of choosing optimal areas for green investments based on solar energy.

Keywords

solar energy • solar radiation • GIS • spatial planning • investment planning • Renewable Energy Resources Act • renewable energy resources

1. Introduction

Uninterrupted and reliable power supply is fundamental for the economic and social development, and for the improvement of quality of life in every country. Due to undergoing global changes the increase of demand for energy is unavoidable. Today's demand for energy is met mainly by conventional fuels, such as hard coal, crude oil and natural gas.

In the natural world solar energy has always been a basis for maintaining all forms of life on the Earth. Whether this kind of energy is acquired efficiently depends largely on locations of solar systems [Myers 2013], and especially on latitude, altitude and local climate conditions as well as duration of solar irradiance. The level of environmental pollution is also important, because it impacts air transparency in an area.

Thanks to new technologies solar power can be used more and more efficiently to produce thermal energy for heating houses by solar thermal collectors and to produce electrical energy by photovoltaic systems. However the potential of these devices is used fully only if they are installed in proper locations. That is why the location for investments based on solar power should be taken into account already at the stage of preparing spatial developments plans.

2. Solar energy management in Europe and Poland

Thanks to the development of new technologies, adjusted to climate conditions and to types of energy load, acquiring solar energy for utility purposes is more and more efficient. Solar power is regarded today not only as a technical solution, but also as part of aesthetic and architectural concepts applied to designing buildings and their surroundings. Essentially, it is also, in a sense, a starting point for other renewable sources of energy, because it conditions the development of other aspects of life and is a cause of many changes in nature, such as water circulation (precipitation, evaporation) or thermal movements (wind, waves, sea currents).

For more than a decade, the attempts are made to maximize the potential of renewable energy resources for the economy. They can be observed especially in Europe in the way family housing is designed. Research on the design of passive houses was carried out already in 1980' in Germany. Passive housing is characterized by reducing or minimizing energy consumption during a building's operation and by very good insulation parameters of a building envelope. Thus the passive house requires even eight times less energy for heating than a conventional house that meets all construction standards. What is innovative about passive housing is that it focuses mainly on improving parameters of elements and systems that are present in every building rather than provides additional solutions. The heating demand in a passive house is met mainly by thermal gains from solar radiation and by heat emitted by household members and devices used inside.

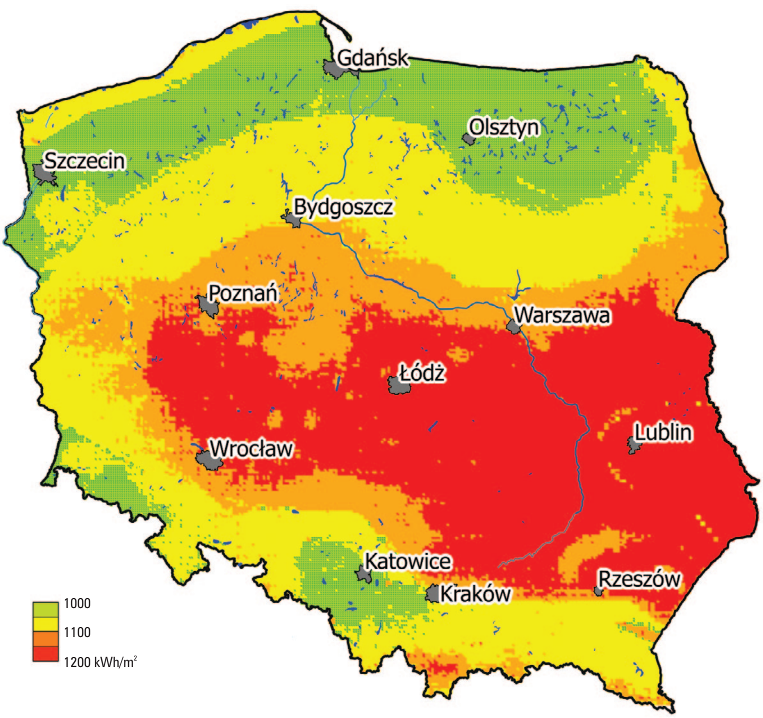
Passive and energy-efficient houses are gaining in popularity across Europe. The energy-saving construction industry has been developing quickly, backed up by legal regulations and government policies. The respective EU directives (2005/32/WE, 2006/32/WE, 96/61/WE) require member countries to implement clean energy policy. Poland also committed itself to join the EU renewable energy policy. Its major goals: improving energy security, increasing energy efficiency, better use of renewable energy resources, development of alternative fuel and energy sources and reducing environmental impact, are to be implemented by 2013.

Industrial production of electric energy, by the so-called photovoltaic farms, is yet another group of solar energy applications. A distinctive feature of these "farms" is that they require a large area of lands. For example, power station of 2 MW in Ostrzeszów in the Wielkopolskie voivodeship takes up space of 3.3 ha. And in the south-east Poland, with its large land fragmentation, to get sufficient integrated area for that kind of investment requires implementing land consolidation procedures [Janus 2011].

As stated in the Communication from the Commission to the European Parliament and the Council on The European Energy Security Strategy (EESS): "New technologies can deliver efficient and cost-effective solutions to improve the efficiency of buildings and local heating systems, to provide new energy storage solutions and optimise the management of grids.

To achieve this, significant investments from the EU and Member States in energy research and innovation are required. Deployment of a broad range of new energy technologies will be crucial, in order to ensure that a sufficient number of them effectively reach the market, allowing Member States to meet their various energy mix choices" [COM/2014/0330 final].

The climate-energy policy adopted in all member states of the EU sets the development of energy sector as one of its main goals. The essential element of this policy is the implementation of the principle of sustainable development. This goal is achieved mainly by increasing the share of renewable energy resources in the fuel-energy balance, which would help to reach environmental objectives of reducing pollution emissions. These measures are also aimed at improving energy security by decentralizing energy production and using local energy resources. The member states accomplish this objective by adjusting their legal regulations to the EU requirements. The Polish Parliament in 2015 passed a new law on renewable energy resources (RES). The law takes into account normal development of green technologies in Poland and significantly changes the system of renewable resources management.



Source: author's private archives

Fig. 1. Irradiance distribution in Poland

According to Lewandowski [2001] mean monthly and annual amounts of total solar irradiance in Poland are highly diverse depending on the location. In Poland the highest number of sunny hours is on the Coast (1671 h · a^{-1}, Gdynia), slightly lower in Warsaw (1234 h · a^{-1}), and the lowest in Silesia (1234 h · a^{-1}, Katowice). For Poland, the norm of the annual total solar irradiance is 3600 MJ · m^{-2} ± 10% (1000 kWh · m^{-2}). The map of irradiance in Poland is presented in Figure 1.

An increasing number of Poles use alternative, green methods of energy production based on renewable energy resources. The systems using solar radiation for producing energy essential for functioning of a house grow in popularity. The roofs of new houses today are more and more frequently fitted with solar panels. In view of these changes, it seems highly justifiable that a degree of solar irradiance is taken into account in planning building investments and in choosing the right location for them.

3. Irradiance analysis in the town and community of Jordanów

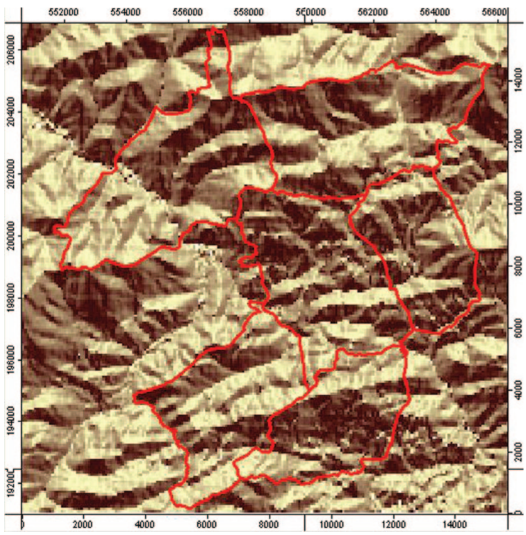
The possibilities of using solar energy, as I mentioned above, depend mainly on latitude and climate conditions, especially on the number of cloudless days. Sobolewski [1998] believes that Poland, due to its geographical position, has a potential for using of solar energy. Annual amount of energy from solar radiation ranges between 980 and 1100 kWh · m^{-2}. Mean annual irradiance is 1600 hours.

Source: author's study

Fig. 2. Villages in the commune Jordanów

The commune of Jordanów is situated in the south of Poland, in the area characterized by good insolation. The commune consists of five villages: Łętownia, Naprawa, Osielec, Toporzysko and Wysoka. The town of Jordanów is a separate administrative unit (Figure 2).

Mean annual density of solar irradiance in this area of Poland is above 1000 kWh · m^{-2}. Conditions of solar exposure in the commune, due to its mountainous character, are highly diverse. They are very good on southern slopes and very unfavourable on northern slopes. Solar exposure of slope equals an angle between a direction of maximal gradient of the terrain and a northern direction. The value of the angle determines the exposure of slopes. The map of slope directions compared to the north in the commune of Jordanów was created in SAGA GIS software (Figure 3).

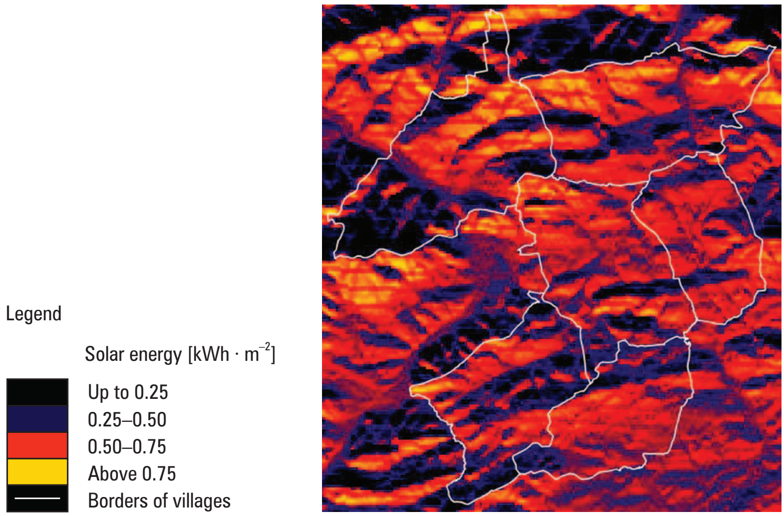


Source: author's study

Fig. 3. Map of directions of slope angles in the commune of Jordanów

The general model of irradiance taking into account the sun exposure of slopes in the whole commune of Jordanów (Figure 4) was built by using a digital terrain model. In this study Shuttle Radar Topography Mission (SRTM) was used. The terrain model describing the height of the points on the surface of the Earth was created using interferometric measurements techniques. The SRTM digital terrain model was developed in a form of a regular grid of 3″ × 3″ (around 30 × 90 m), with mean absolute height error, with 90% probability, less than 16 m. Thanks to calibration of a measuring system this error for Eurasia was 6.2 m [Rodrigues 2006].

In the next step in the Jordanów commune land plots were selected for further analysis. Among them were built-up plots and plots intended for development in the local development plans. Then from the general model for the Jordanów commune irradiance values were assigned to every plot chosen for the analysis.



Source: author's study

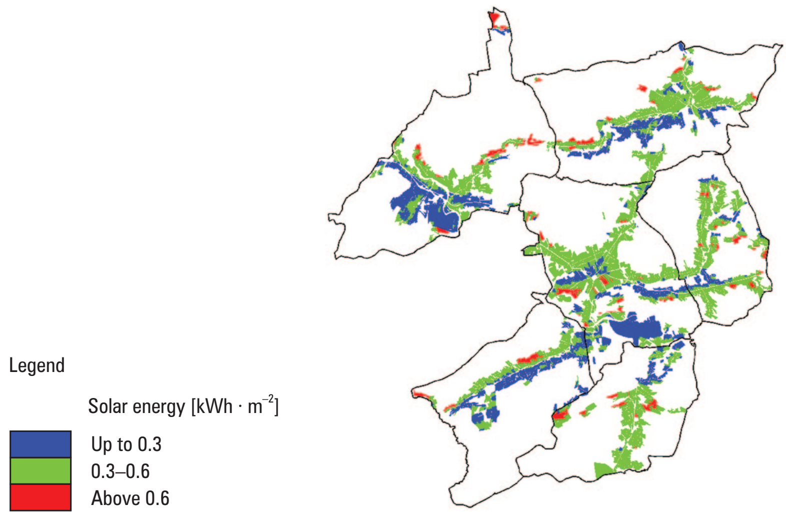
Fig. 4. Model of distribution of irradiance in the Jordanów commune

Simulation of direct solar irradiance distribution was made on 22 December (winter solstice), with a cloudless sky. The date was chosen because it has the worst insolation value and simultaneously the greatest demand for this kind of energy. The distribution of solar irradiance is described in kilowatt-hours per square metre.

As a result of the analysis three group of plots have been singled out. They were grouped according to amount of insolation. The comparison was made based on the following scheme:

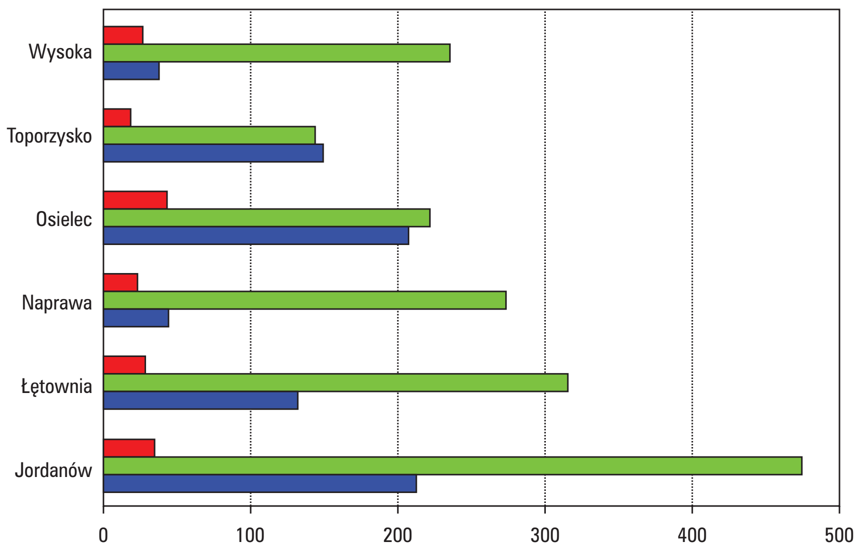
- first group: land plots characterized by very favourable conditions of solar exposure, with the value of direct solar irradiance above 0.6 kWh · m^{-2},
- second group: land plots on which average conditions of solar exposure prevailed, with the value of direct solar irradiance ranging between 0.3 kWh · m^{-2} and 0.6 kWh · m^{-2},
- third group: land plots characterized by unfavourable conditions of solar exposure, with the value of direct solar irradiance below 0.3 kWh · m^{-2}.

The comparison of land plots for particular villages is presented in Table 1 and the graphic depiction of the results of the analysis is demonstrated in Figure 5. The percentage share of each group of land plots is shown in Figure 6.



Source: author's study

Fig. 5. The analysis of solar irradiance for land plots intended for development in the Jordanów commune



Source: author's study

Fig. 6. Distribution of land plots according to solar irradiance in villages of the Jordanów commune

Table 1. Comparison of land plot areas according to amount of solar irradiance in villages of the Jordanów commune

Village	Land plot areas			Total area in a village [ha]
	Irradiance above 0.6 kWh · m^{-2} [ha]	Irradiance 0.3–0.6 kWh · m^{-2} [ha]	Irradiance up to 0.3 kWh · m^{-2} [ha]	
Jordanów	35	475	214	724
Łętownia	28	315	132	475
Naprawa	23	273	44	340
Osielec	43	221	207	471
Toporzysko	18	144	149	311
Wysoka	27	234	38	299
Total area in a village	174	1662	784	2620

Source: author's study

The group of land plots characterized by very favourable solar irradiance conditions, with the irradiance value above 0.6 kWh · m^{-2}, takes up the smallest area in the analysed region. The total area of this group of land plots in the Jordanów commune is 174 ha or 7% of the studied area. The largest amount of lands with favourable irradiance conditions is located in Osielec (43 ha), and the smallest – in Toporzysko (18 ha).

The value of irradiance for plots with average conditions of solar exposure ranges between 0.3 and 0.6 kWh · m^{-2}. The plots of this group take up 1662 ha in total, which is 63% of the whole studied area. The plots with average insolation are the biggest group in all villages, with the exception of Toporzysko.

The total are of plots with unfavourable irradiance conditions is 784 ha, which is 30% of the studied area. The largest area of this group of land plots is localized in Jordanów (214 ha) and Osielec (207 ha).

4. Conclusions

Assigning to land plots such attributes like: the slope of the area where a land plot is situated, defining the solar exposure of slopes and the amount of solar irradiance, opens up new possibilities for analysis related the spatial planning. From this perspective the plots can add precious information on the parameters of the area. Investment planning that takes into account environmental and scenic values of an area through linking them with land plots attributes can bring notable economic benefits. Ignoring these factors may eliminate the possibility of adopting environment-friendly solutions, such as solar systems. The essential role in modern techniques of analysis and interpretations of phenomena in the surrounding world is played by constant improvement of specialist computer programmes – including software like GIS used to statistical analysis or mathematical calculations.

As the software develops and spatial database systems become more diverse, it is quite probable that any future action affecting the surroundings will be carried out in accordance with the principle of sustainable development. And in light of Environmental Law, sustainable development is based on integration of political, economic and social measures, while preserving natural balance and permanence of basic natural processes, to ensure that the basic needs of communities or citizens of present and future generations are met.

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