Renewable and Sustainable Energy Reviews 73 (2017) 460–467

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Photovoltaic potential of the City of Požarevac

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ARTICLE INFO

Keywords:
Photovoltaic power plants
Technical potential
Degraded areas
Brownfield location
Serbia

ABSTRACT

Photovoltaic power plants represent a good solution concerning electric energy supply under the condition that there are sufficiently available and suitable areas for their mounting. This study supports an opinion hypothesis that the City of Požarevac has at its disposal a considerable potential for energy production by photovoltaic power plants at the degraded areas. The geographic information systems were used to identify and create polygons for degraded areas, and the Energy capacity assessment tool was used in order to estimate the solar potential for this areas. The results showed that it would be possible to generate about 43% of the electric energy produced by thermal power plants "Kostolac A" and "Kostolac B" by construction and work of photovoltaic power plants in proposed locations. For a long-term standpoint, this project would prevent the emission of over 30 million tons of CO_2 into the atmosphere. This study should contribute to the better understanding of local authorities regarding the potential for the use of solar energy, as well as, define of better principles, measures, instruments and policy to stimulate the application of solar energy to secure the requirements for electric energy.

1. Introduction

One of the basic starting points of conception of energy development in the Spatial Plan of the City of Požarevac [1] represents "gradual substitution of energy, from fossil fuel energy by renewable energy" which is in concordance with energetic strategy for Europe 2011–2020 (Energy 2020) and the other significant documents dealing with renewable energy use and environmental protection. In the Spatial Plan, it has pointed out that for the realization of longer use of the renewable energy sources is necessary to stimulate the further investigation of potential and the economic evaluation by contemporary technological solutions. A serious research was done in this region for wind energy, until now. The results of measuring in the surroundings of Ram and Bradarac have enabled the separation of 15 potential localities for the construction of wind parks [1]. The problem noticed so far is that the testing of possibilities for utilization of solar energy at present is being restricted only to the determination of theoretical potential without taking into consideration any of geographical or technical restrictions. The priority is given to active and passive systems for conversion of the Sun energy into heat energy, which is used for indoor heating and for getting warm sanitary water.

The Study of potential energy of Serbia for utilizing solar radiation and wind energy [2] shows that solar energy has the tendency to decrease from Northwest towards Southeast and that the average value of global radiation for Serbia is around 1400 kWh/m^2. Maps of an average daily energy global irradiation on the horizontal surface, as well as, the surfaces under different slopes that orientate towards South, done for January, July, and the whole year represent the results of this study. The maps show that the territory of the City of Požarevac belongs to the zone that at average annually receives from 1390 kWh/m^2 to 1460 kWh/m^2 of global radiation energy. The appropriate orientation of the receiving surface towards South and under the 30° angle gives higher values of average daily energy than the ones corresponding to the horizontal plane (> 6.6 kWh/m^2 vs. > 4.2 kWh/m^2) [3]. In the Energy Sector Development Strategy of the Republic of Serbia for the period by 2025 with projections by 2030 [4], a maximum technically usable capacity of solar power plants is 450 MW, i.e. their technically usable potential is 540 GWh/per year.

Pavlović et al. [5] dealt with the research of possibilities for the production of electric energy by use of photovoltaic power plants

Abbreviations: CdTe, Cadmium-telluride; CM-SAF, Climate Monitoring Satellite Application Facility; DEM, Digital Elevation Model; DHI, Direct Horizontal Irradiance; GHI, Global Horizontal Irradiance; GIS, Geographical Information System; KML, Keyhole Markup Language; Mtoe, Million tons of oil equivalent; OSGL, Laboratory for development of open source geospatial technologies; PV, Photovoltaic; PV-GIS, Photovoltaic Geographical Information System; PVPPs, Photovoltaic power plants; TPPs, Thermal power plants; Poly (x-Si), Polycrystalline silicon

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http://dx.doi.org/10.1016/j.rser.2017.01.154
Received 29 October 2016; Received in revised form 26 December 2016; Accepted 25 January 2017
Available online 01 February 2017
1364-0321/

(PVPPs) of 1 MW capacity in 23 locations in the territory of Serbia. By the aid of online software PV-GIS (Photovoltaic Geographical Information System) calculator that was developed by Joint Research Centre – JRC, the results were obtained that enabled comparison and showed that the best energetic income is realized by the PVPPs constructed of cadmium-telluride (CdTe) solar cells. Požarevac was one of the cities analyzed in the mentioned study. The best results were given by the systems that use double axis system of following the Sun and materials based on cadmium-telluride (1660 kW h), while the fixed systems based on monocrystalline silicon cells realized 32% less of the electric energy [5].

Although the solar energy represents a clean, free, and practical endless source of energy, systems that enable the exploitation of this resource like PVPPs can have the influence on the human environment. It relates to the land possession, as it is restricted and valuable resource depending on the graphical position and type of chosen technology (its efficiency). Well-designed photovoltaic power plants of 1 MWp capacity should take the space between one and two hectares of land [6]. Less efficient power plants (CdTe thin-film solar cells) can take approximately 40 to 50% larger spaces than the power plants, which are using polycrystalline modules [6]. Hernandez et al. [7] in their study "Environmental impacts of utility-scale solar energy", give the survey of direct and indirect influence on biodiversity, the health of the population, water resources, soil, use of land, and changes of the soil surface. Project PVs in BLOOM identified the examples of good practice and methods by which the degraded surfaces (waste deposits, quarry, mines, abandoned military polygons, brownfield locations, as well as, other contaminated areas or other areas which are not cultivable), are reconstructed through PVPPs with capacity from 50 kWp to 2–3 MWp [8].

If we want to be resource efficient and energy independent in the future, we have to develop such system in a sustainable manner. This means a secure, competitive, and decarbonised energy system at which the renewable sources will play a significant part. According to the Energy roadmap [9] by the year 2050 the share of renewable energy sources in the final energy consumption could archive at less 55%, and between 64% and 97% in the electricity consumption, depending on the development of system energy storage.

In this study degraded areas were analyzed at the territory of the City of Požarevac that are suitable for installing PVPPs. The research included the excavation sites, metal and industrial raw materials, dumping pits of slag and ash, waste landfills, conventional power plants and heating plants, industrial areas, brownfield locations, and military property. With the help of on-line software of the First Solar company were calculated technically exploitable potential of solar energy and avoided emission of CO_2.

The main reason for writing this article is the lack of knowledge and assessment of the solar potential for electricity generation in the Spatial Plan of the City of Požarevac. It was mentioned previously, in the Spatial Plan that potential for wind energy, biomass, and solar thermal energy is recognized.

The goal of this study is to show that the construction of PVPPs in these areas could provide the half of electric energy, produced by thermal power plants (TPPs) "Kostolac A" and "Kostolac B" annually.

Based on the fundamental goal the following particular hypotheses were formed:

- The most suitable space for the use of solar energy is in the direction from the Požarevac city settlement towards East;
- Information and communication technologies could contribute to faster and better quality of evaluation of the potential for the construction of PVPPs;
- Spatial data about degraded areas are at disposal;
- Open pit mine "Drmno", communal waste pits, as well as dumping pits of slag, ash and coal represent the most favorable locations for development of PVPPs; and
- The City of Požarevac has at its disposal a considerable potential for production of electricity from solar energy.

The aim of this work is to provide a better assessment of the potential for the yield of solar energy at the territory of the City of Požarevac, as well as, the significance of degraded areas in the creation of a new energy mix. Based on identification and valorization on these terrains, it is possible to create a catalog of locations for an installment of PVPPs and to organize measurement instruments in more efficient and appropriate way.

2. Methods

The method used for assessment of the technical potential of solar energy that is, for the production of energy by PVPPs, and for their total installed power at the territory of the City of Požarevac, is comprised of three subsequent phases:

1. choice of suitable terrain for installation of PVPPs,
2. digitalization and geo-reference of potential terrains, and
3. assessment of the capacity of an annual production of energy.

Starting with goals defined in the Spatial Plan, in the first phase are chosen degraded terrains that required the sanation in order to stop the further devastation of the human environment. Selected sites include surfaces for the exploitation of energetic minerals is done (coal, lignite, bitumen rocks, oil, and gas), industrial and metallic raw material, coal waste, tip, slag, ash, communal waste deposit, conventional power plant, etc. (see Fig. 1). The data about surfaces used for exploitation of energetic, industrial, and metal raw materials was collected by WEB GIS of Ministry of Mining and Energy [10]. The Spatial Plan and its referral maps served as the secondary source of information, especially for conventional energetic plants and locations for depositing of coal, ash, and slag [1]. Database about waste tips which was formed by the Agency for the protection of the human environment was used for localization of waste tips where the waste is transported to and from in an organized manner, and for detection of illegal and old landfills [11].

When the potential locations were determined for installing PVPPs, brownfield and greenfield localities were taken into consideration which had been in the register of Agency for foreign investments and promotion of export of the Republic of Serbia [12]. Brownfields are especially interesting for the development of PVPPs as they are usually the abandoned or neglected localities in city, industrial, suburban or rural areas, which are considered as the source of pollution. Military polygon and structures can also be a good solution for development of the solar project, so the analysis included assets, which are on the sales list of the Ministry of Defense and Army of the Republic of Serbia [13]. The study also considered one greenfield location, as the part of the Northern block of the industrial zone defined by the General urbanism plan of the City of Požarevac.

For digitalization and geo-reference of chosen areas, was used the Google Earth program [14]. With the help of its Add polygon tool, digitalization of previously chosen areas was carried out, and then these polygons were transferred into files with KML (Keyhole Markup Language) extension. Many companies that are dealing with the planning and construction of PV systems have developed tools, which enable faster and easier assessment of system's performance for exploitation of solar energy. For capacity assessment and annual production of energy was used Energy capacity assessment tool (Version 6.0) of the First Solar Company [15]. Prior to this assessment, the initial adjustments were carrying out such as:

- for the beginning of construction the first quarter of 2016 was selected;
- the distance between photovoltaic field and the protective fence is 3 m;