Photovoltaic potential of the City of Požarevac

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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.

Keywords: photovoltaic power plants; technical potential; degraded areas; brownfield location; Serbia

Abbreviations[1]

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

[1] **List of 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

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 1,400 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 1,390 kWh/m^2 to 1,460 kWh/m^2 of global radiation energy. The appropriate orientation of the receiving surface towards South and under the 30º 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 (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 (1,660 kWh), 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 Figure 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.

Fig. 1. Potential areas for development of photovoltaic power plants

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;
- the space between photovoltaic panel lines for cadmium-telluride cells is 4.267 m, and for polycrystalline cells of silicon is 7 m;
- the conventional supposition of the standard profile program for the efficiency of solar cells is 15.6% for cadmium telluride cells and 16.4% for silicon cells were kept;
- the proportion of direct and alternating current its set at the value of 1.17; and
- the price of electric energy was calculated based on the regulation of stimulation measures for privileged producers of electric energy, which is 9 c€/kWh for solar power plants on the ground [16].

Advanced mode of this program provided the possibility to import previously prepared KML files and to make the assessment. During the assessment of annual production of electric energy was not used data about global and diffusion radiation on the horizontal surface (Global Horizontal Irradiance (GHI) and Direct Horizontal Irradiance (DHI)) provided by Meteonorm software (Version 7.1). Laboratory for development of open source geospatial technologies – OSGL [17] made interactive maps of solar irradiation based on digital elevation model (DEM) with a resolution of 90 m over Serbia.

3. Results and Discussion

Based on new PV-GIS database from CM-SAF data [18] the annual energy of global solar radiation that reaches the square kilometer of the territory of City of Požarevac amounts averagely to 1,360 kWh/m^2. The highest values are in the northeast where the irradiation reaches approximately 1,389 kWh/m^2 (see Figure 2). Northern parts of the territory are recording the lowest value of about 1,320 kWh/m^2 (see Figure 2). This is opposite to previously established hypothesis that the most favorable surfaces for utilization of solar energy are at the East from the city settlement of Požarevac, as it is stated in the Spatial Plan of the City of Požarevac. However, the analysis of data of the total solar irradiation obtained by Luković et al. [19] shows that during the whole year the Eastern parts of the City of Požarevac receive a higher quantity of solar irradiation (see Figure 3). The Eastern parts of the cadastral municipalities Kličevac, Beranje, Bare, Popovac, Prugovo, Poljana received annually even up to 1,310 kWh/m^2 (see Figure 3). In this case are also suitable areas of open pit mines of Ćirkova and Klenovnik, which stopped the production, as well as, parts of the open pit mine “Drmno”. Within the former open pit mine of Ćirkovac locality, at which are presently, deposited slag and ash represent the favorable area for construction of PVPP, as the solar irradiation at this part is the highest, and by the realization of such project, numerous ecological and social problems would be solved.

A similar distribution of solar radiation as Luković et al. [19] was obtained from PV-GIS solar radiation database developed by Šúri et al. [20]. This database was created using the solar radiation model *r.sun* integrated into the GIS software GRASS and climate data collected from 566 ground meteorological stations in the period of 1981–1990. As Huld et al. [18] concluded one of the possible reasons for different spatial distribution of global solar radiation between old and new PV-GIS database and that is the change in aerosol load in the atmosphere over the European continent.

Fig. 2. Annual energy of global radiation on a horizontal surface in the territory of the City of Požarevac

Fig. 3. High-resolution grid of annual energy from global horizontal irradiance for the City of Požarevac

The total surface of all potential locations for the installment of PVPPs comes to 27.75 km^2 that is 5.7% of the surface of the City of Požarevac territory. In Table 1, the total production of energy during the first year of work of PVPPs is evaluated at 2,476.12 GWh at power plants which are using cadmium telluride solar cells made by First Solar company while 2,569.12 GWh was at those made of ordinary polycrystalline solar cells. This is about 43% of the electric energy produced by Public Enterprise "Thermal Power Plants and Open Pit Mines Kostolac" during the year 2015 (5,988 GWh [21]). The PVPPs installed on the terrain of the open pit mine of "Drmno" could contribute to the largest production of "green energy", around 43% (see Table 1). Energy capacity assessment tool [15] shows that inactive open pits "Ćirkovac" and "Klenovnik", the terrains of which are foreseen for recultivation by Spatial Plan of the City of Požarevac, represent another important potential for exploitation of solar energy with annually electric power generation between 620 and 644 GWh.

Table 1
Estimated results for potential location suitable for development ground mounted PVPPs

There are many good examples of prevention and sanation the negative influences of waste tips on the human environment. Some of them represent innovation solutions for landfill management, such as waste tip Tessman in San Antonio city, Malagrotta close to Rome, Lappa in the Municipality of Lindlar (Germany), or Solarberg Atzenhof in the city of Firt (Germany). By Spatial Plan of the Republic of Serbia and by National strategy of waste maintaining is defined the creation of a system of regional centers for establishing the waste control which would lead to the closure of some of the existing waste tips [22]. Locations of the regional centers will be selected upon the made research and assessment of the influence on human environment for potential locations given by spatial plans. One of the proposed locations for the construction of regional waste tip in the area of Braničevo region is at Rašanac village in Municipality of Petrovac na Mlavi.

At the closure of the existing waste tips, and by the obligation of forming a protection layer, which prevents penetrating of atmospheric water into waste tip body, the forming of flexible PV membrane represents an innovation solution. In this way, it is possible to establish the controlled outflow and collecting of atmospheric water and production of electric energy by photovoltaic cells with separation of biogas. If PV panels covered all waste tips at the territory of the City of Požarevac, the total annual production of the electric energy at those terrains would come to about 16% of the total PV potential at the territory of the City of Požarevac (value extracted from Table 1). The construction of PVPP on waste tips of slag and ash "Middle Kostolac Island", with estimated annually production up to 186 GWh, could fulfill the electric energy requirements for more than 44,000 households (based on the assumption that average household uses 350 kWh of electricity per month [23]). A large potential for construction of PVPP represents the inner landfill Ćirkovac where according to OSGL data [17] the global solar irradiation on a horizontal surface reaches 1,306 kWh/m^2. Besides, the ash at waste tips is contaminating neighboring airspace as it is easily lifted and after certain times period it falls to the ground. The ash contains large quantities of phosphate and sulphate that could get into the surface and underground waters, and it changes their ecosystem conditions [24].

Revitalization of brownfield locations represents a way to postpone the process of "dying" of certain parts of the settlements and establish an attractive and maintainable ambient that would bring the prosperity to the local community.

There are many examples in the world that relate to the renewal of such surfaces. The Municipality of Gavardo at the north of Italy can be proud of its educational park, which has for goal a promotion of renewable sources of energy. On the territory of abandoned turkey farm, the park was created. In the first phase of the renewal, 350,000 kg of the asbestos material was removed because of the risk of soil, water, and air contamination [8]. Then, the construction of new contents and elements of contemporary architecture was started. Photovoltaic panels are placed on the metal and wooden construction, so it wood blends with the natural outlook. Cycling and the educational path go through the park and visitors have the possibilities to enjoy the beautiful view from the watchtower, to access the laboratory and to use the recreation areas. This energy park of 5.5 MW capacity, delivers annually 5,801.796 kWh of electric energy into electrical network [8].

In the southern part of the Požarevac city settlement is situated the Centre for poultry at the area of about 80 ha [12] which at one site leans on the city bypass way and from the other side onto the urban zone. All brownfield locations represent a suitable place for mounting of PVPPs with total capacity up to 54.55 MW, which according to the assessments could reach approximately 58 GWh of annual electric energy production (see Table 1).

The military assets that are no longer in use can be also suitable for the development of sustainable projects, which can be seen in the energetic area of Morbah (Germany). Energy park was constructed at the place of the former warehouse of military ammunition which was abandoned in 1995 and today it represents the unique example of eclectic of various systems for exploitation of renewable energy (the wind, the sun, and biomass). From the year 2003, around 50,000 tourists from 113 countries visited this park [25].

The City of Požarevac has at its disposal six locations, which are presently placed in the List of properties for sale of the Ministry of Defence and Army of the Republic of Serbia [13] that could be of interest for the realization of PV projects.

The Military barrack Sopot in the northern part of the city settlement (urban part) of the city Požarevac has perspective for the use of solar energy as it is close to the users. The second important location for exploitation of solar energy is horse farm Ljubičevo, which at its disposal has sufficient space for the development of “small” (about 2 MW) utility-scale PVPP.

The utilization of degraded surfaces for installation of PVPPs would drastically increase total PV capacity from present 9.95 MW [26] to 2,428.90 MW.

Table 2
Estimated energy production and avoided emission of CO_2 (25 years)

Based on OECD/IEA data [27] in 2015, Serbia reduced CO_2 emissions from fuel combustion since 1990 (62.0 Mt) for 38.5% mainly because of decay of heavy industry, but not because of measures against the climate change. Despite the pledge that Serbia will cut the emission of GHG (carbon dioxide, methane, and nitrogen oxide) for 9.8% by 2030, it is more evident that it will allow increasing the emission for 15.3% [28]. According to First biennial update report of the Republic of Serbia [29] in 2013, Serbia already reduced GHG emission for 25.1% compared to 1990. Table 2 shows some perspective about possible avoided emission of CO_2 that would help Serbia to fulfill ambitious goal of reducing GHG emission by 80-95% until 2050 if it becomes The Member States of the European Union. Avoided emission of CO_2 was calculated by multiplying of global average emission estimated by the First Solar Environmental Department (536 Mt) with electricity production for the period of 25 years [30]. The intensity of CO_2 derived from the table is 0.536 Mg/MWh and according to the values given by Hussy et at. [31] it is similar to those in a gas-fired power plant, but different from ones in a cold-fired power plant.

TPPs “Kostolac A” and “Kostolac B“ with a total available capacity of 921 MW, annually generate 5,989 GWh of electricity, which is almost 17% of the total electric power production in EPS's system [32]. Specific emission of carbon dioxide for “Kostolac A” amounts 1,274 g/kWh and 984 g/kWh for “Kostolac B” [33]. This information indicates that the Public Enterprise “Thermal Power Plants and Open Pit Mines Kostolac” is one of the biggest air polluters in Serbia.

The total expenses related to the realization of PV projects on suggested sites were roughly calculated on the basis of International Renewable Energy Agency (IRENA) estimation of global total installed costs for utility-scale projects (approx 2 USD/W) [34] and they are between 4.6 and 4.8 billion USD, depending on the type of solar energy. The estimated costs are real because they correspond to the cost of several finished PV projects, such as “Matarova” (2 MW) in the Municipality of Kuršumlija [35], “Prima Energy” (1 MW) in Tancoš near Beočin [36], “Sajan” (536 kW) in the Municipality of Kikinda [37], “Solaris 1” (1 MW) and “Solaris 2” (675 kW) near Kladovo [38], etc.

The expenses of PV projects are different in each country. The average expenses in 2010 for utility-scale PVsystem in Germany were among the lowest (3.64 USD/Wp for c-Si systems, respectively 3.61 USD/Wp for thin-film systems) at PV market, while the highest range of expenses were recorded at Italian market (from 2.89 USD/Wp to 6.67 USD/Wp) [39]. What is indicative for utility-scale PV projects around the world is the decrease of the total installing costs during the period from 2011 to 2014. The expenses for so-called “small” utility-scale PV projects (1-5 MW) have dropped for 37%, while for those that are larger (over 5 MW) the expenses dropped for 35% [34]. In Europe, the typical expenses for utility-scale PV systems, during 2013 and 2014 were in the range from 1.3 UDS/Wp to 3.75 USD/Wp [34]. Due to the PV systems price drop and the introduction of various support mechanisms in order to have the renewable energetic systems competitive with conventional systems, it led to the progress of large PV systems mounted on the terrain.

The justification for the high cost for the construction of PV systems on 54 proposed locations in the City of Požarevac is the fact that this is a long-term investment and can create more benefits than costs. Stretching costs for the period 2020-2050, the annual costs for PV systems correspond to 0.4% of gross domestic product in Serbia, based on the value of GDP of 39.46 billion USD [40]. Annual costs for the development of PV systems are much smaller in comparison with health costs resulting from the treatment of diseases caused by emissions from coal-fired power plants. Air pollution represents the biggest environmental risk to health [41]. Four of the ten largest emitters of SO_2 are located in Serbia, and one of them is TPP “Kostolac” located on the territory of the City of Požarevac [42]. According to statistics from the World Health Organization (WHO) [43], the region of Southeast Europe (SEE) has a loss of 19% of its GDP due to costs associated with cases of premature deaths from air pollution. In Serbia, the health costs associated with air pollution amount to 33.5% of GDP, while in Germany the leading market in the area of utility-scale PV systems is 4.5% [43]. In cooperation with WHO, EU and Serbian Ministry of Health, Alliance for Environment and Health (HEAL) [42] declared that health costs caused by air pollution are between 1.8 and 4.9 billion euros, or 680 euros per capita.

Photovoltaic parks do not only provide energy security and a healthy environment, they are also creating new jobs and local value creation. Places like these become new attractions for tourists who want to experience a new way of living, learn about technology and take some practical ideas home. The fact that supports the growing importance of green tourism in the tourist offer of the municipality is the increase of a total number of tourists who have seen Morbach energy landscape. The highest recorded visit in Morbach energy landscape is during the summer, especially in September. A guided tour lasts 2.5 hours, and it costs 50 € per group [25], or double if it is larger than 45 persons. One time in a month (every first Sunday) there is a special guided tour (called “Open tour”) not for groups but for individual persons, and the fee is 5 € per person [25]. Total revenue from the guided tour realized in the period 2003 to 2016 was estimated roughly at 78,000 € [44]. The regional added value by drinking coffee, going to a restaurant in Morbach, etc. was not calculated in this estimation.

Implementation of the proposed PV projects and individual solutions from the Spatial Plan, such as plantations of fast growing trees in the coastal areas of the rivers Danube and Velika Morava, biogas production on animal farms, as well as, building wind parks on potential locations will contribute to the development of sustainable tourism in the City of Pozarevac. Realization of the “Roman Emperors Route” and the archaeological locality Viminacium will increase the number of visitors and tourists overnights (300,000 tourists with an average residence time of 10 days [45]) causing the pressure on the environment and energy supply. PVPPs can provide clean energy, eventful tourist offer, and preservation of archaeological sites. Taking into account the above benefits, investments in PVPPs and other renewable energy systems can be regarded as economically justified.

4. Conclusion

The City of Požarevac belongs to the favorable zones for utilization of solar energy as an average annual value of energy of global irradiation amounts to 1,171.65 kWh/m^2 [17], and it has at its disposal sufficient adequate areas for installing the large PV systems. Expected energy production from suggested PVPPs in the City of Požarevac would be sufficient to supply 522,527 households in the whole region of Southern and Eastern Serbia [46], under the assumption that the average household uses 350 kWh of electricity monthly [23].

The analysis of 53 sites in the category of degraded areas and a greenfield location within the northern block of the industrial zone was estimated for the construction of PVPPs and the production of "green energy". Proposed projects include the construction of "small" (1-5 MW) and "large" (over 5 MW) utility-scale PV systems, among which stands out the project on the surface Open pit mine "Drmno" with the capacity of about 1 GW (see Table 1). Implementation of this and other large PV projects is predicted to be realized as one PVPP through the phase construction or as more individual PVPPs on suggested location. Estimated PV capacity of degraded areas reaches 2,428.90 MW and annual energy production of 2,569.12 GWh (see Table 1), and this amount is over 40% of the total electric energy produced in 2015 from TPPs "Kostolac A" and "Kostolac B" (1,743 GWh and 4,246 GWh [32]).

The total assessment of PV potential, which also includes residential PV systems, would give a true picture of the possibilities for the use of the solar energy in the electric energy production. This should be reason enough to give the priority to solar systems for conversion of solar into electric energy and to define more efficient and diversified support mechanisms in the Spatial Plan.

By analyzing the PV-GIS data about annual global irradiation on horizontal surfaces, it can be concluded that the most favorable locations in the City of Požarevac are in the Southern parts and not the spatial areas at the Eastern part of the Požarevac city settlement as it is stated in the spatial plan. The better quality data derived from digital elevation model (DEM) with the resolution of 90 m, show that the location of the Eastern boundaries of the City of Požarevac really has the largest values of solar irradiation.

If we take the irradiation as the only factor than the eastern parts of the territory are more favorable from the aspect of solar energy utilization. Taking into the consideration that PVPPs occupy a large area, which in the next 25 years cannot be used for other purposes, then one can rightfully say that, the northeastern parts of the territory have the most favorable locations for installing PVPPs.

The tests in Germany show that the solar parks have the positive influence effects on biodiversity of degraded and brownfield locations. The former polygon for military maneuvers in Lieberose in Brandenburg is a good example of protection and improvement of nature, as a part of the European bird's reservation. For construction and work of the solar park which take the area of 160 ha, it was necessary to clean 380 ha terrain from chemicals and military ammunition [47]. These, as well as, some other measures that were undertaken at this locality led to the long-term improvement of the quality of residence for some kinds of birds, which showed ten-year follow-up the program that established the existence of some very rare birds such as Steppe pipit, Forest lark, Hoopoe. In the town of Firt of the South of Germany within the solar park Atzenhof the shepherds twice yearly bring their sheep for grazing. Without mowing and regular grazing bushes and trees would disable the functioning of the solar plant. The investigations have been done during the year 2009 and have discovered a stunning diversity of flora. Totally was found 259 species of fern and flower plants and 30 types of moss, at which some are Red-listed [47].

Obtained results direct to the necessity of making a more detailed analysis of solar potential and to change the solutions in spatial planning where the priority would be given to the conversion of solar energy into heat energy. It is evident that the solar collectors and passive systems have become an accessible, reliable, and simple source of heat energy. But if we want in future to be more resourcefully efficient and to follow-up the goal of the EU, than we have to give priority to the degraded and brownfield locations for the development of photovoltaic parks in the function of production of "green" energy. This requires serious research and financial assessments that are based on contemporary information technologies such as GIS and various software tools for assessment of the efficiency of renewable energy systems. In this way, it is possible to easier and faster manipulate with the factors, which are of importance for the development of solar parks what enables better dynamics of realization of proposed projects and synchronized development of additional infrastructure such as long distance power lines, the transformer sub-stations, etc.

Independence of energy system and reliable supply of energy represent just one aspect of solar energy application, but the benefits are far greater. Realization of the project of PVPPs at degraded locations in the City of Požarevac would prevent the emission of over 30 million tons of CO_2 during their production period (25 years) as a result of decreased use of fossil fuels (see Table 2).

Total installation costs were estimated roughly between 4.6 and 4.8 billion USD. By looking them as long-term rather than "pay at once" investments, PV projects become more economically available. Adding the local value creation and healthy environment as the results from the installation PVPPs on degraded land, these projects could provide better opportunity for social prosperity and economic development of the City of Požarevac.

The manner for implementation the knowledge and results in this paper follow from the human need to integrate the PV system into their environment without negative consequences on the basic media of space (water, air, and land). The model presented in this paper will serve to local government to understand the potential for full and rational use of solar energy and thus to provide a range of economic, environmental and social benefits. Cadastre of potential PV location will allow more efficient auditing of remuneration for the production of energy from renewable sources by the set objectives, market situation, technological progress, and plans for the development of energy infrastructure, always guaranteed a reasonable rate of return.

Further research will focus on defining priority sites for the construction of PVPPs based on natural (climate, water, relief, soil structure, vegetation) and human made (transport availability, distance from infrastructure and places of energy consumption) conditions in the area. Previous studies have the aim to encourage a more detailed economic analysis in order to obtain the overall assessment of the feasibility of investing in these projects.

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Figure 1

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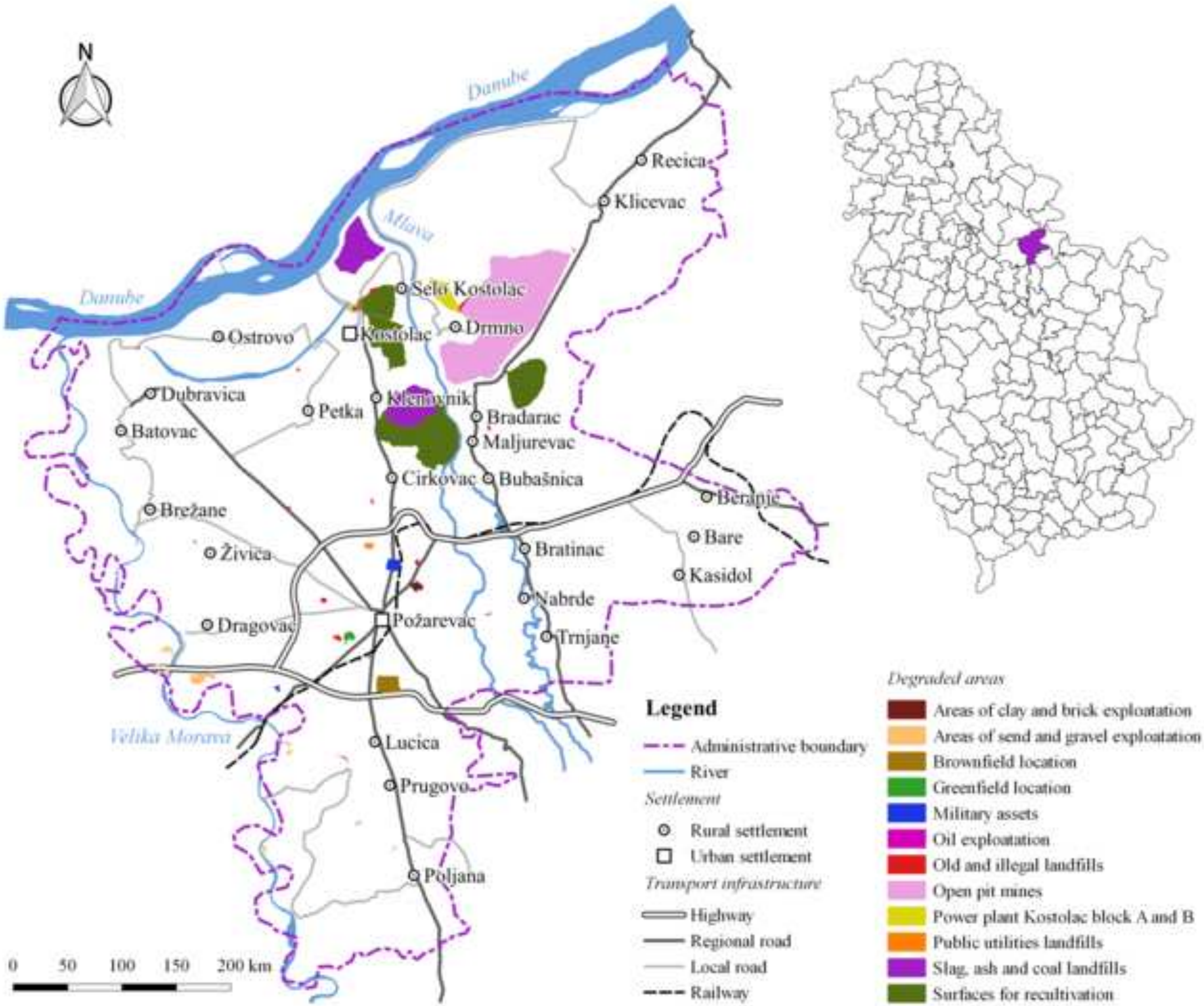

Figure 2
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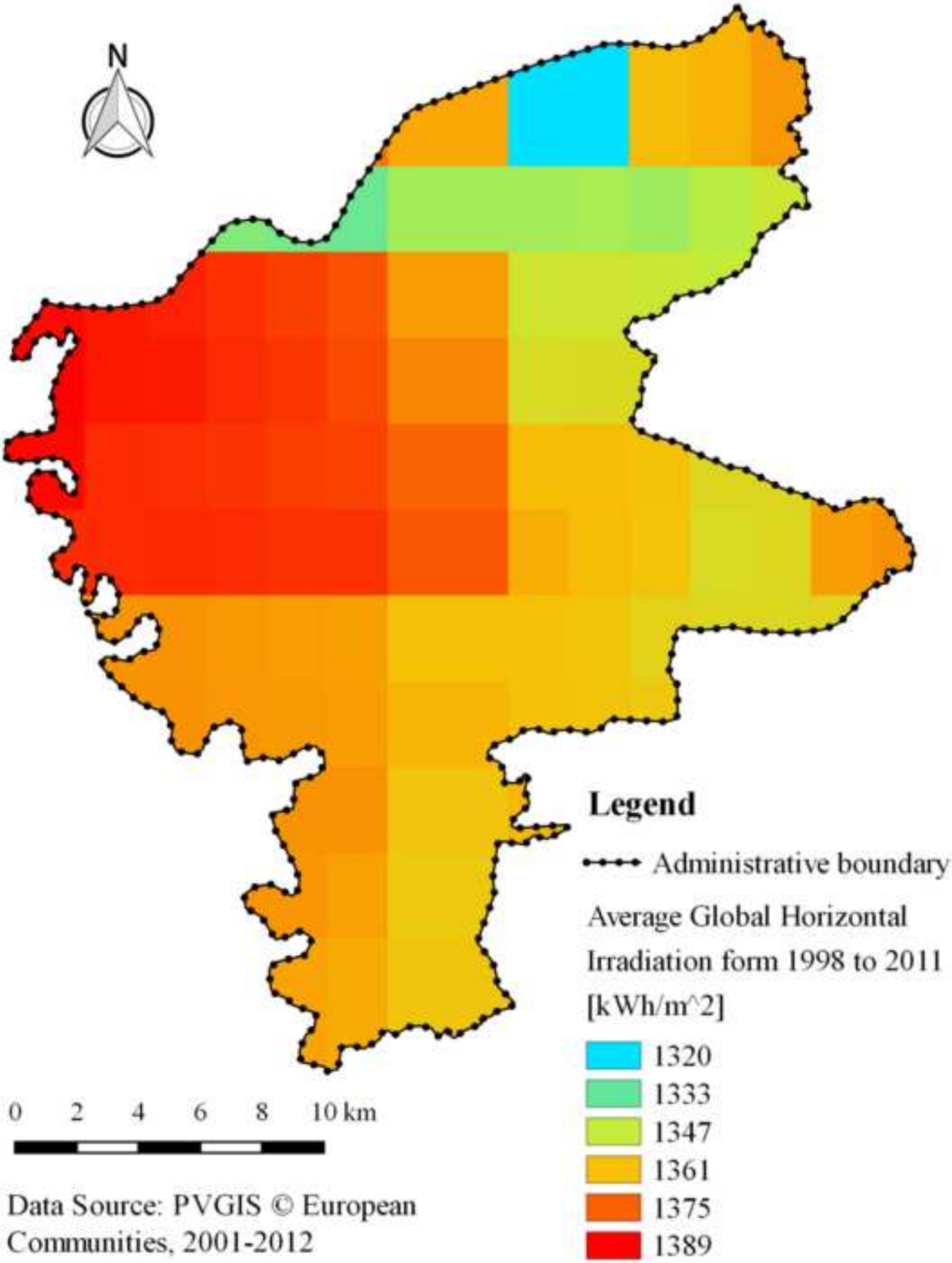

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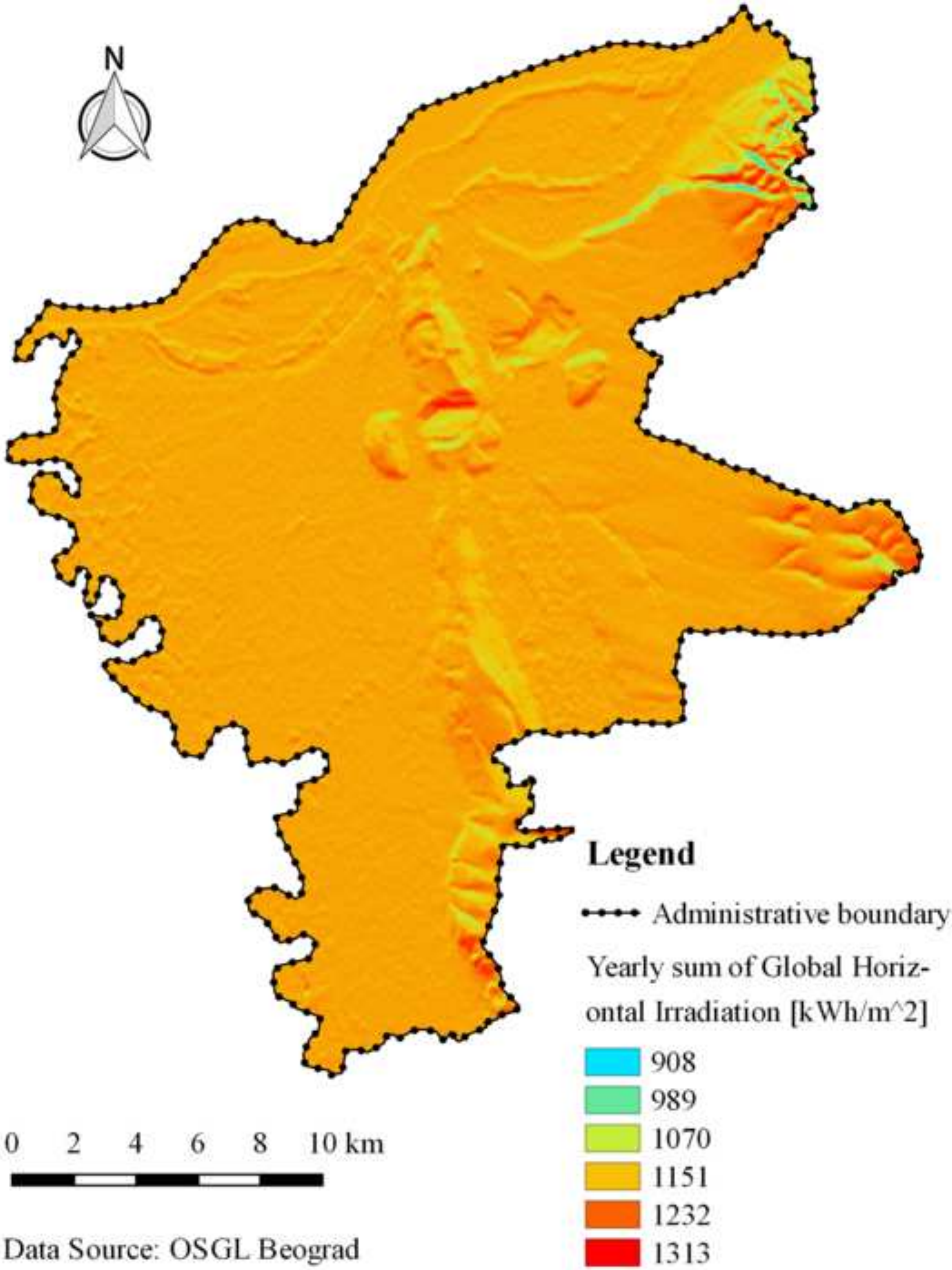

Table 1

Types of locations	Area [ha]	Installed capacity		First year energy production	
		FSLR (CdTe) [MW_{dc}]	Poly (x-Si) [MW_{dc}]	FSLR (CdTe) [GWh]	Poly (x-Si) [GWh]
Public utilities landfills	6.00	5.10	5.34	5.50	5.70
Old and illegal landfills	36.83	28.19	29.27	30.00	30.80
Slag, ash, and coal landfills	407.00	338.88	356.17	368.10	382.00
Open pit mines “Drmno”	1,195.00	999.90	1,051.13	1,070.00	1,110.60
Surfaces for recultivation	892.00	743.14	781.23	792.30	822.20
Thermal power plants Kostolac A & B	78.00	63.88	67.07	68.20	70.60
Areas of clay & brick exploitation	13.00	10.21	10.69	11.00	11.40
Areas of sand & gravel exploitation	47.00	38.35	40.21	41.30	42.70
Oil exploitation	2.00	1.32	1.41	1.40	1.50
Brownfield location	63.23	51.92	54.55	55.81	57.91
Greenfield location	11.00	9.17	9.62	9.90	10.20
Military assets	27.12	21.15	22.21	22.61	23.51
TOTAL	2,778.18	2,311.21	2,428.90	2,476.12	2,569.12

Table 2

Types of locations	25 years energy production		Avoided emission of CO_2 for 25 years	
	FSLR (CdTe) [GWh]	Poly (x-Si) [GWh]	FSLR (CdTe) [Mg]	Poly (x-Si) [Mg]
Public utilities landfills	130.00	134.00	69,680.00	71,824.00
Old and illegal landfills	713.00	726.00	382,168.00	389,136.00
Slag, ash, and coal landfills	8,649.00	8,975.00	4,635,864.00	4,810,600.00
Open pit mines “Drmno”	25,146.00	26,099.00	13,478,256.00	13,989,064.00
Surfaces for recultivation	18,617.00	19,350.00	9,978,712.00	10,371,600.00
Thermal power plants Kostolac A & B	1,603.00	1,661.00	859,208.00	890,296.00
Areas of clay & brick exploitation	259.00	268.00	138,824.00	143,648.00
Areas of sand & gravel exploitation	973.00	1,007.00	521,528.00	539,752.00
Oil exploitation	33.00	35.00	17,688.00	18,760.00
Brownfield location	1,313.25	1,361.25	703,902.00	729,630.00
Greenfield location	232.00	240.00	124,352.00	128,640.00
Military assets	533.25	553.25	285,822.00	296,542.00
TOTAL	58,201.50	60,409.50	31,196,004.00	32,379,492.00