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SOLAR ENERGY POTENTIAL IN FREIBURG, GRAZ, MARIBOR, BANJA LUKA, NIŠ, AND ATHENS

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Abstract. *This paper presents a comparative analysis of solar energy potential for six different cities, in six different countries in Europe: Freiburg (Germany), Graz (Austria), Maribor (Slovenia), Banja Luka (Bosnia and Herzegovina), Niš (Serbia), and Athens (Greece). Data processed in this work are accessed from Photovoltaic Geographical Information System (PVGIS). Photovoltaic technology is crystalline silicon, and installed peak photovoltaic power is 5 kWp. The aim of the work is to find out whether there are statistically significant differences among the cities in relation to monthly energy production in regard to different types of photovoltaic system (fixed – free standing, fixed – building integrated, inclined, and two axis solar power plants). The work is based on four hypotheses. The estimation of solar energy production in different regions is very important for determination of potential regions suitable for generation of renewable and sustainable energy.*

Key words: *solar panels, photovoltaic technology, crystalline silicon, PVGIS*

1. INTRODUCTION

Different factors have impact on the amount of incoming solar radiation to the Earth. The most important factors are: geographical latitude, part of the year and day, atmosphere condition, cloud status, surface disposition, and orientation. These information are important for planning and installing of photovoltaic systems [1]. In this paper, solar energy potential for six different locations in Europe (Freiburg, Graz, Maribor, Banja Luka, Nis, and Athens) has been compared. Those six cities were selected in order to see the differences in the amount of produced electricity from photovoltaic systems. Cities like Freiburg, Graz, and Maribor have developed PV systems for electricity generation, while Banja Luka, Niš, and Athens, are on the ascending path in regard to application and use of solar energy. Different types of photovoltaic systems were used for this comparison: fixed – free standing, fixed – building integrated, inclined, and two-axis solar power plants.

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Freiburg and Graz have been green model cities from the late 1980s. Both cities are mid-sized, with less than 500 000 inhabitants, and both cities are administrative centers of their regions. Freiburg was ‘Germany’s Environmental Capital’ in 1992, for its ecological accomplishments. In 2010, Freiburg received another award, ‘Federal Capital of Climate Protection’, and in 2012, ‘Most Sustainable Large City of Germany’. Graz has been awarded many times for its achievements in field of ecology and sustainability (‘Greenpeace Climate Protection Award’ in 1993 and the ‘Sustainable Energy Europe Award’ in 2008). In 1996, Graz has received, as the fist city in Europe, the ‘International Sustainable City’ award by the European Union [2].

Freiburg is also called ‘Europe’s solar city’. Vauban is the neighborhood in Freiburg, which is one of the most sustainable city neighborhoods worldwide. In this city district, the majority of houses have solar energy generation on-site (mostly from the rooftop PV panels). The surplus electricity is sold to the municipal grid [3]. The international headship of Freiburg in urban sustainability began in the 1970s, after successful anti-nuclear protests in the city [4]. Federal state government has intended to build nuclear power plant in the rural area north of the city. Because of the strong resistance of the city’s citizens, the government plans have not been realized and therefore, Freiburg is called ‘birthplace’ of the environmental movement [5]. Freiburg is also one of the sunniest locations in Germany. City has incorporated many branches – community, business, energy, scientific comunity, education, construction, tourism with civil society together with the help from local and national levels to become a world leader in solar energy [4]. In Graz, in the first half of 1990s, many environmental proposals and projects were arranged (‘Ecocity 2000’, ‘Municipal Energy and Climate Concept’, ‘Eco-profit’, and ‘Eco-drive’). At the same time, Graz became the first Austrian representative of ‘Climate Alliance of European cities’, with the aim to reduce greenhouse gas emission for 50 per cent until 2010 (with 1987 as the baseline). Graz also embraced energy constricting plans for the renovation of buildings and the transition to district heating or renewable fuels. Also, city has set in motion a ‘solar initiative’ that supports the feeding-in of solar thermal energy into the district heating system during summer [2]. In Graz, the first Smart City community is being developed. In this district, new energy technologies for energy self-sufficient cities are established. The Smart City Graz Project is examining innovations like solar modules, solar cooling systems, solar power generation in urban areas, mini-CHP-facilities (Combined Heating and Power), integrated façade technologies and smart heat grids, with their application in demonstration buildings [6].

In Maribor, the Faculty of Energy of the University of Maribor is an important institution in the disciplines of thermo-energetics, hydropower, nuclear power, renewable and alternative energy sources. The emphasis of the research is on PV systems. The Institute of Energy Technology possess a park of renewable energy sources, which comprises nine tracking PV systems. This Renewable Resources Park aims to study various networking systems for examination of new elements that are components of a smart grid. PV systems in the Park are coupled to the distribution grid [7]. Another paper from Seme et al. [8] presented a overview of performance study of PV systems in Slovenia. Total of 91% of the PV systems in Slovenia have a peak power of 50 kW_p or less. This is because of the energy law that prevents installations of higher power [8]. However, in recent years in Slovenia, Feed-in Tariff has influenced the growth of the PV market, which triggered the lower prices of PV technologies [9]. Dravske Elektrane Maribor is the major renewable electricity manufacturer in Slovenia. It got a permit for segment five of the Zlatoličje solar power plant. This segment of the solar power plant will be installed on the left bank of the outflow canal of the biggest Slovenian hydro power plant Zlatoličje. A planned yearly production of 5 820 PV modules with a power of 2.7 MW_p will be 3 GWh [10].

The Republic of Srpska holds a huge potential for electricity production utilizing PV systems. The promotion of renewable energy is secured by Renewable Energy in May 2013 together with the decision of the Regulatory Commission for Energy of the Republic of Srpska on the charge level and premium prices. The Republic of Srpska gives a priority to grid connection for renewable energy source operators and proposes incentives for external investors. The Solar Energy Laboratory of the Academy of Sciences and Arts of the Republic of Srpska was developed in 2012, as an outcome of the scientific research projects on renewable energy sources – particularly solar energy. On one rooftop, in October 2012, fixed on-grid solar power plant (power 2.08 kW_p, monocrystalline silicon solar cells) was installed. The solar power plant is equipped with accompanying tools for supervising, acquisition, and data obtaining, and measuring. With the help of this PV power plant, the effects of solar radiation strength, air temperature, wind speed, and air humidity on the energy efficiency of the PV solar power plant in the Banja Luka region can be constantly observed. Two years later, in 2014, another solar system was installed additionally to the Solar Energy Laboratory – Solar Box, which comprises a metallic base with five PV solar modules made of polycrystalline silicon, with distinct power of 50 W. Three solar modules are placed vertically and positioned to the east, south, and west, respectively. The fourth solar module is placed horizontally, and the fifth is at an angle of 33° to the south. Additionally, in October 2017, a two-axes tracking PV system was appointed on the roof of the Academy of Sciences and Arts of Republic of Srpska. This system contains electronic, mechanic, and measuring subsystem. In 2020, in the Republic of Srpska, 42 electricity producers used PV systems of up to 250 kW [11]. Following papers [12,13,14,15,16] contain great amount of material on the solar potenitals to generate electricity from PV solar plants in the Republic of Srpska.

Serbia's solar centers are located in Niš, Zrenjanin, and Novi Sad. Faculty of Sciences and Mathematics (FSM) in Niš occupies a Solar Energy Laboratory that studies physical features of the flat-plate thermal and hybrid solar radiation collectors, solar cells and PV solar power plants. Also, in Niš, Faculty of Electronic Engineering possess contemporary laboratory for electronic exploring of rotational PV systems for optimum solar radiation incidence. Faculty of Technical Sciences in Novi Sad owns Renewable and Distributed Energy Sources Laboratory devoted to the investigation in the field of renewable energy, mostly in the wind and solar energy conversion and energy storing. In Zrenjanin, Faculty of Technical Sciences M. Pupin, has a Solar Energy Laboratory that focuses on flat-plate thermal and PV modules [17]. Studies [17 – 21] contain relevant information on solar energy in Serbia.

Greece is considered to be very attractive country in terms of investing in solar photovoltaics [22]. Solar thermal market in Greece is well explained in the [23]. Starting in 2011, there were many policy attempts to promote solar investing. Those efforts positioned Greece at the leading position in global rankings for solar power share in electricity production, in just three years. But domestic PV market decreased in the time period from 2014 to 2017 to 1% of its 2013 range. This widespread closure of solar energy was directly in relationship with regulatory response to economic effects of the policy agenda - very plentiful twenty-year-feed-in-tariffs provided for great scale developments, remaining at high levels despite the fact that costs have dropped. Policy makers were forced to apply retroactive tariffs cuts. However, it could be fairly related to the energy-linked effects of political and economic insecurities, like the construction of new traditional power plants, and constant economic stagnation. Another barrier for advanced development of solar power in Greece can be contemporary immaturity of the economy, in terms of strategy and trade models, to motivate consumers to generate and accumulate clean energy locally [22]. Currenlty, Greece generates solar irradiation generally with flat plate collectors for low-temperature heating applications and with PV [24].

1.1. General information on selected cities

Geographical information on Freiburg, Graz, Maribor, Banja Luka, Niš, and Athens, are given in the following table (Tab. 1). Athens is at the same time the southernmost and easternmost city from the selected, Freiburg is the northernmost and westernmost city from the selected. More details are presented in the following table.

Table 1 Information on selected cities [29]

Parameter	Freiburg	Graz	Maribor	Banja Luka	Nis	Athens
Geografical latitude (˚)	48.0005	47.071	46.5621	44.772	43.3187	37.982
Geographical longitude (˚)	7.832	15.438	15.65	17.188	21.893	23.727
Optimal angle for fixed solar power plants (˚)	36	37	36	34	FS: 34* BI: 33*	FS: 32* BI: 31*
Optimal angle for inclined axis (˚)	38	39	38	36	36	34
Elevation (m)	263	364	275	167	198	84

* FS – freestanding solar power plants, BI – building integrated solar power plants, only Niš and Athens have different values for optimal angle for fixed FS and BI solar power plants, all the other cities have the same optimal angles for FS and BI solar power plants.

Given elevation is accessed from PVGIS and is related to free-standing solar power plants

Solar energy capacity and production of selected countries are presented in the following table (Tab. 2).

Table 2 Solar energy capacities and solar energy production in Germany, Austria, Slovenia, Bosnia and Herzegovina, Serbia, and Greece in 2019 [25]

Country	Solar energy capacity (MW)	Solar energy production (GWh)
Germany	49 047	46 392
Austria	1 702	1 702
Slovenia	264	303
Bosnia and Herzegovina	22	30
Serbia	23	14
Greece	2 834	4 429

As it can be seen from this table, Germany has the greatest solar energy capacity and the greatest solar energy production, whereas Serbia and Bosnia have the lowest solar energy capacity and the lowest solar energy production. Greater solar energy capacity of the country, means larger solar energy production.

2. Goals Materials and Methods

The goal of this work is to analyze differences in the projected solar energy production (kWh) between six cities. Also, the payback time for the installation of photovoltaic system (5 kW) is calculated for all six cities. [1] have studied solar radiation atlas for Banja Luka and it was concluded that there are no significant deviations of energy of global and direct solar radiation that fall on the horizontal and optimally positioned surface. In this work differences in solar energy potential were statistically analyzed between following cities: Freiburg, Graz, Maribor, Banja Luka, Niša, and Athens.

PVGIS was established at the Joint Research Centre (JRC) of the European Commission within its Renewable Energies Unit as a Geographical Information Systems (GIS) tool for the evaluation of performance solar PV systems in different geographical regions. It supplies data for technical, environmental, and socio-economic analysis of solar PV electricity generation [26,27]. The PVGIS data base [28] consists of satellite data from four different meteorological sources: Photovoltaic Geographical Information System on Climate Monitoring Satellite Application Facility – PVGIS-CMSAF, Surface Solar Radiation Data Set Heliostat - PVGIS-SARAH, Data produced by the European Center for Medium-range Weather Forecast – PVGIS-ERA5, and Consortium for Small Scale Modelling – PVGIS-COSMO. The CMSAF data are obtained in this work. The CMSAF solar surface irradiance retrieval is built on radiative transfer calculations, where satellite-derived parameters are used as input. It is the part of the European Organization for the Exploitation of Meteorological Satellites (EUMESTAT) ground segment and of the EUMESTAT network of Satellite Application Facilities. PVGIS-CMSAF aims to generate climate data records, which are time series of certain length, stability and excellence to discover climate variability and differentiations. Available data are from time period between 2007 and 2016 [29].

2.1. PVGIS method – explanation

As it is described on the European Commission's science and knowledge service, the first stage in the calculation of solar radiation from satellite is the estimation of satellite images in order to see effects of clouds on the solar radiation, because they can reflect the arriving sunlight and so it comes to reduction of radiation that comes to the Earth's surface. Cloud reflectivity can be estimated, when the same satellite image pixel is observed at the identical time every day in a month. The darkest pixel during a month denotes the state of the clearest sky, which means there are no clouds. The cloud reflectivity of other days is estimated relative to the clear-sky day. The same is applied for all hours in one day. So, on that way, effective cloud albedo could be estimated [30].

The second step contains calculations of the solar radiation of clear-sky states, with the help of radiative transfer theory in the atmosphere, together with the information on atmosphere aerosols quantity and the amount of water vapor and ozone concentration, because water vapor and ozone do attract radiation at certain wavelengths. The overall solar radiation is estimated from the cloud albedo and the clear-sky irradiance. This method achieves good results, but may be neglect in some occasions, i.e., when snow covers the ground. The snow could seem like clouds in case that the method determines very low irradiance. The aerosol data used in the method is average over longer period of time, and sudden changes in aerosols (due volcanic eruptions or dust storms) are not took into account in this method [30].

Previously described method computes global and beam irradiance on a horizontal plane. But units and PV systems are placed at an inclined angle with respect to the flat plane or on tracking systems towards maximization of the incoming in-plane irradiance. In this case, the satellite-based values are not characteristic for the solar radiation obtained at the module surface, and it is crucial to evaluate the in-plane irradiance. For estimation of the values of the beam and diffuse constituents on sloped planes, the irradiance values on the horizontal plane of global and diffuse and/or beam irradiance components are needed. The addition of those gives the in-plane global irradiance on a sloped surface. Straight from the solar disc originates the beam irradiance, and its value on a sloped surface can be retrieved from the value on the horizontal plane when position of the sun in the sky and precise placement of the inclined surface is known. However, the estimation of the diffuse irradiance over sloped surfaces cannot be easily calculated, because it can be dispersed by the atmosphere. In this case, models for defining of diffuse component are classified into two categories, isotropic and anisotropic. The first category takes into account equal distribution of diffuse irradiance over the sky. Therefore, the diffuse irradiance on a sloped surface is same as the value on the horizontal plane scaled by the factor that depends only on the surface inclination and represents the portion of the sky, which can be seen from the plane's surface. But the diffuse irradiance is almost never isotropic. The estimation model used in PVGIS is anisotropic of two components, it can differentiate among clear and cloud-covered sky states and bright and shaded surfaces [30,31].

2.2. Statistical tests used for the calculations

Data and results are shown in tables and graphs. The analytical-statistical tool SPSS, version 24, was used for obtaining the data. Applied statistical tests were Kruskal Wallis test, which determines whether three or more samples do originate from the same population. Statistically significant differences were obtained by Mann-Whitney test that determines whether two samples originate from the same population [32].

The Wilcoxon Rank-Sum Test, also known as Mann-Whitney U Test, analyses the differences in population means, when the populations are not normally distributed. First assumption that is necessary is that the population must be continuous, and the second assumption that is necessary, their probability density functions need to have same shape and size [33]. The Mann-Whitney U Test calculates the statistic value U for each group. Mathematically, the Mann-Whitney U statistic for each group is expressed by next equations [34]:

$$U_x = n_x n_y + \left(\frac{(n_x(n_x+1))}{2}\right) - R_x \quad (1)$$

$$U_y = n_x n_y + \left(\frac{(n_y(n_y+1))}{2}\right) - R_y \quad (2)$$

where, n_x describes the number of observations or number of participants of the first group, n_y describes the number of observations or number of participants of the second group, R_x represents the ranks sum of the first group, and R_y is the sum of the ranks of the second group. Equations (1) and (2) can be seen as the number of times observation in one sample precede or follow observation in the other sample, after all the score from one group is placed in ascending order. The null hypothesis can be either rejected or accepted, after the calculation of U value and the appropriate statistical threshold (α) [34].

The Kruskal-Wallis Test represents a nonparametric statistical test, which considers differences of three or more independent groups on a single, and not normally distributed data [35]. The starting assumption is that we have k independent samples of volume $n_1, n_2, \ldots, n_k$, so that $n_1 + n_2 + \ldots + n_k = n$. After the ranking of samples, the sums of the ranks ($R_1, R_2, \ldots, R_k$) are obtained. Test statistics can be described with the following equation (Eq. 3) [36]:

$$R = \frac{12}{n(n+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(n+1) \quad (3)$$

The following four hypotheses have built this work:

H_{01}: There is no statistically significant difference in monthly solar energy production between the fixed solar panels (free-standing and building integrated) between the cities;

H_{02}: There is no statistically significant difference in monthly solar energy production of inclined photovoltaic system between the cities;

H_{03}: There is no statistically significant differences in monthly solar energy production between the cities in relation to two-axis solar power plant, and

H_{04}: There is no statistically significant differences in monthly solar energy production when all types of solar power plants were compared with each other among the cities.

The aim of the test is to reject one hypothesis and to accept the other hypothesis. The p stands for probability and it calculates the probability that difference between the groups is random. The p value can be between 0 and 1 [37]. Small p value, provides stronger evidence against H_0, and we are more certain that H_0 is not true. When the p value is large, H_0 becomes more possible, but we cannot be confident that H_0 is true. H_0 should be rejected, in case when $p \leq 0.05$ [33].

3. Results

Beforehand the results of statistical analysis, Table 3 represents yearly solar energy production (kWh) in selected six cities. Athens has the greatest yearly solar energy production among the selected cities, and Freiburg has the lowest yearly solar energy production. More details are provided in the table below.

Table 3 Yearly solar energy production (kWh)

Type of the PV technology	Freiburg (FR)	Graz (GR)	Maribor (MB)	Banja Luka (BL)	Nis (NI)	Athens (AT)
Fixed - Free standing	5316.05	5722.54	5851.62	5575.21	6302.62	8282.53
Fixed - Building integrated	5128.36	5514.94	5640.08	5366.03	6051.62	7952.83
Inclined	6661.49	7246.43	7541.29	7240.20	8216.33	11224.55
Two-axis	6813.87	7421.63	7725.29	7417.43	8415.07	11550.93

Testing the first hypothesis (H_{01}), statistically significant differences were found in testing fixed-free standing photovoltaic systems between the cities (p = .044) and in testing fixed-building integrated photovoltaic systems between the cities (p = .043). High statistically significant differences for both types of fixed photovoltaic systems were obtained in monthly solar energy production between Freiburg and Athens (p = .009), between Banja Luka and Athens (p = .009), between Maribor and Athens (p = .021), and between Graz and Athens (p = .018). High statistically significant difference was obtained between Niš and Athens (p = .0496) for fixed-free standing solar power plant, p = .043 for fixed-building integrated solar power plant).

For the inclined photovoltaic systems (H_{02}), statistically significant differences were obtained between Maribor and Athens (p = .028), between Freiburg and Athens (p = .011), between Graz and Athens (p = .021), and between Banja Luka and Athens (p = 0.018).

In testing of third hypothesis (H_{03}), high statistically significant difference resulted in testing of monthly solar energy production between Freiburg and Athens (p = .009). Statistically significant difference was obtained between Maribor and Athens (p = .028), Graz and Athens (p = .021), and between Banja Luka and Athens (p = .015). Results of testing H_{03} are presented in the Table 4.

Table 4 Results of testing of third hypothesis, monthly solar energy production by two-axis solar power plant between the cities

	Fixed – Free standing	Fixed – Building integrated	Inclined	Two-axis
All	**.044**†	**.043**†	.064†	.062†
MB & FR	.273‡	.273‡	.299‡	.299‡
MB & GR	.644‡	.644‡	.644‡	.644‡
MB & BL	.773‡	.773‡	.817‡	.817‡
MB & NI	.564‡	.603‡	.644‡	.603‡
MB & AT	**.021**‡	**.021**‡	**.028**‡	**.028**‡
FR & GR	.326‡	.326‡	.419‡	.419‡
FR & BL	.686‡	.686‡	.525‡	.564‡
FR & NI	.248‡	.248‡	.225‡	.273‡
FR & AT	**.009**‡	**.009**‡	**.011**‡	**.009**‡
GR & BL	.954‡	.954‡	1.000‡	.954‡
GR & NI	.488‡	.488‡	.525‡	.488‡
GR & AT	**.018**‡	**.018**‡	**.021**‡	**.021**‡
BL & NI	.386‡	.386‡	.419‡	.453‡
BL & AT	**.009**‡	**.009**‡	**.018**‡	**.015**‡
NI & AT	**.0496**‡	**.043**‡	.065‡	.065‡

†Kruskal Wallis Test
‡ Mann-Whitney Test

Finally, for the fourth hypothesis (H_{04}), high statistically significant difference (p = .000) was obtained when fixed-building integrated, inclined, and two-axis solar power plants were compared with each other. Only in Athens is there a statistically significant difference (p = .029) in testing monthly solar energy production of fixed-building integrated, inclined, and two-axis solar power plants. In all the other cities, there is no statistically significant difference when those three systems were compared with each other. Results for testing of fourth hypothesis are presented in the Table 5.

Table 5 Monthly energy production - comparison between all types of installed solar power plants

Location	Fixed – Free standing & Fixed – Building integrated	Inclined & Two-axis	Fixed – Building integrated & Inclined & Two-axis
All	.415‡	.655‡	**.000**†
FR	.488‡	.603‡	.140†
GR	.419‡	.686‡	.135†
MB	.525‡	.644‡	.150†
BL	.644‡	.686‡	.143†
NI	.644‡	.729‡	.166†
AT	.564‡	.686‡	**.029**†

† Kruskal Wallis Test
‡ Mann-Whitney Test

In the following paragraphs, the payback time for installed fixed-building integrated photovoltaic system (5 kW_p) has been calculated. Also, information about annual incident solar energy (optimal angle), specific yearly electricity production, price of photovoltaic installation, and electricity prices in typical household (four members and yearly electricity demand 6 000 kWh) are shown in Table 6.

Table 6 Calculation of payback time for installed photovoltaic system, 5 kW, for one typical household with annual electricity demand of 6 000 kWh

Location	Yearly incident solar energy under optimal angle (kWh/m^2) [27]	Specific yearly electricity production (kWh/kW_p)	Electricity price that one household pays in one year (4 members, demand 6 000 kWh), country's average for March 2021*	Payback time for installed photovoltaic system, with power 5 kW
Freiburg	1331.72	992	1 920	2.60
Graz	1442.69	1145	1 260	3.97
Maribor	1472.76	1167	1 080	4.63
Banja Luka	1433.46	1096	552	9.06
Nis	1662.62	1239	480	10.41
Athens	2108.31	1557	1 140	4.38

Installation prices for photovoltaic system 'key in hand' for the selected cities are approximately the same (1 000 €/kW_P), because of the bounded components. This is related to the systems with the power to 10 kW, which are mostly used in households for the own energy consumption.
* Country's average electricity price as for March 2021, according to [38]: Germany 0.32 €/kWh, Austria 0.21 €/kWh, Slovenia 0.18 €/kWh, Bosnia and Herzegovina 0.092 €/kWh, Serbia 0.080 €/kWh, and Greece 0.190 €/kWh.

Investment payback time is the shortest for the countries where the electricity price is the highest. The payback time is calculated by dividing investment costs with electricity price that one household pays in one year.

4. CONCLUSION

Based on the presented research, following conclusions can be made:

i. Germany has the largest solar energy capacity and solar energy production;
ii. Between Freiburg and Athens, between Banja Luka and Athens, between Maribor and Athens, Graz and Athens, and between Niš and Athens, there is a high statistically significant difference when the energy production of fixed-free standing and fixed-building integrated photovoltaic systems were tested;
iii. Statistically significant differences were obtained in testing of inclined photovoltaic system between following cities: Maribor and Athens, between Freiburg and Athens, between Graz and Athens, and between Banja Luka and Athens;
iv. In testing of produced energy amount by two-axis solar power plant, following results were obtained: high statistically significant difference between Freiburg and Athens, statistically significant difference between Maribor and Athens, Graz and Athens, and Banja Luka and Athens;
v. In Athens, there is a statistically significant difference when monthly solar energy production was tested between three types of solar power plants (fixed-building integrated, inclined, and two-axis solar power plants), and
vi. Germany has the highest electricity price, and Serbia the lowest electricity price. Accordingly, in Germany the payback time for installed photovoltaic system of 5 kW is the shortest, and in Serbia the longest.

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