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Analysis of the profitability of solar energy implementation as a determinant of sustainable economy

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Abstract: *At the beginning of the new millennium, the consumption of the natural resources and the size of the worlds' population become inversely correlated. The motive of this research is to confirm the influence of solar energy in the direction of implementing the strategy of sustainable development of countries. The aim of research is to calculate the consumption share of the household budget and the profitability of investing in the installation of renewable resources for electricity supply in Serbia. The results of the research confirm a significant reduction of the funds allocated for the supply of electricity through the installation of solar panels, while ensuring the return on investment in the extrapolation period. The research concludes that the use of renewable energy sources is a key determinant of sustainable development and protection of the natural environment. Namely, the transition to renewable energy sources provides financial and environmental benefits for the entire society.*

Keywords: *Sustainable economy, Solar panels, Renewable sources, Environmental protection*.

Analiza isplativosti implementacije solarne energije kao determinante održive ekonomije

Apstrakt: *Početkom novog milenijuma, razvija se negativna korelisanost između korišćenja prirodnih resursa i veličine svetske populacije. Motiv ovog*

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istraživanja je potvrda značaja solarne energije u kontekstu implementacije strategije održivoj razvoja zemalja. Cilj rada je obračun smanjenja potrošnje dela kućnog budžeta i isplativosti investicija u ugradnju obnovljivih resursa, za snabdevanje domaćinstava električnom energijom na teritoriji Srbije. Rezultati istraživanja potvrđuju značajno umanjenje sredstava koja se izdvajaju za snabdevanje domaćinstva električnom energijom putem ugradnje solarnih panela, uz postizanje povrata investicija u periodu ekstrapolacije. U radu se zaključuje da upotreba obnovljivih izvora energije je ključna determinanta održivog razvoja i zaštite životne sredine. Naime, prelazak na obnovljive izvore energije, podrazumeva finansijske i ekološke benefit za društvo u celini.

***Ključne reči**: Održiva ekonomija, Solarna energija, Obnovljivi izvori, Zaštita okruženja.*

1. Introduction

The supply of electricity through non-renewable energy sources implies one of the basic problems of sustainable development of modern societies. Regardless of the mode of using conventional energy sources such as coal, oil and natural gas, it has been confirmed that their quantity is limited, i.e. prone to exploitation. The increased use of non-renewable resources implies one of the causes of the greenhouse effect, which is considered the main reason for climate change. At the current level of development of civilization, the consumption of conventional energy sources cannot be stopped, but their use can be reduced through rational consumption and a gradual transition to the use of renewable energy sources (Grgur, 2015).

The combined effects of the depletion of fossil fuels and the gradual development of awareness about environmental degradation influenced the use of renewable energy sources to become a priority, which intensified in the first decades of the 21st century (Chen et al., 2010). In their research, Evans et al. (2009) and Demirbas (2005) proved that energy produced from renewable sources is the most sustainable with minimal greenhouse gas emissions. Of all renewable sources, solar energy is considered extremely important due to its practically unlimited character, as well as the distinct potential of the mentioned resources in many developing countries (Holm & Arch, 2005). In the past decades, solar energy has been used for heating water and rooms, while supplying energy to an increasing number of households. Through the development of technology and the cheapening of solar photovoltaic panels, the sun's energy has been provided for the purpose of obtaining electricity.

The ultimate aim of sustainable economic development refers to achieving greater economic development while protecting the living environment of countries. The legal articulation of the idea of investing in renewable sources, environmental protection and ecologically sustainable financial sector was created in London in 2008 (Green New Deal Group, 2008). During 2019, the resolution on the adoption of the "Green New Deal" was discussed at the session of the American Congress, which had identical aims in terms of environmental protection (Galvin and Healy, 2020). The European Commission adopts the "European Green Deal" (2020), which has clearly defined aims, to achieve climate neutrality of the European Union, ending with the year 2050 (Simon, 2019). Similar initiatives were adopted in the area of Asian countries. Namely, China is developing the Green Job Guarantee, which refers to the subsidization of population employment within the scope of environmental protection activities (Huang, 2022). Also, South Korea adopts the “Digital New Deal” (2020), with the intention of achieving zero greenhouse gas emissions by 2050. The aims of the adopted regulations are the transition to the production of electricity from renewable sources and the reduction of carbon dioxide emissions (Lee & Woo, 2020). With an installed capacity of 609,921 MW, China is the leading producer of electricity obtained mainly through solar energy, which represents 43% of the total world capacity. China is becoming the largest producer and exporter of solar equipment and energy in the world. On the other hand, Germany is the leading producer of solar energy in Europe. Almost 1/3 of the total solar energy produced in Europe is produced in Germany. China's rapid progress in this field is indicated by the fact that Germany was the dominant producer of solar energy in the world from 2005 to 2014, after which China took over the leading position (www.irena.org). However, Australia has the greatest potential for solar energy production. The reason for that is the high photovoltaic electric potential on the territory of Australia, which is above all other country in the world (www.solargis.com).

The production of solar energy and the use of renewable energy sources is recognized as an important topic in Serbia, only at the beginning of the new millennium. Legal regulations were adopted that define the rights related to the production of solar energy and provide subsidies, all with the aim of increasing the share of solar energy in the total production of electricity (Nikolic & Filipović, 2020). According to data from 2023, solar energy production capacities in Serbia amount to 137 MW (www.irena.org). The production of 137 MW constitutes only 4% of the total installed capacities for the production of electricity from renewable sources, such as hydropower (82%), wind energy (13%) and bioenergy (1%). With 137 MW, Serbia ranks on 96th place in terms of solar energy production. The observed data indicate less realized production compared to the potential for the production of solar energy in Serbia.

The energy potential of Serbia is higher by 30% compared to the countries of Central and Eastern Europe (www.solargis.com). Analysis of Serbia's potential for the production of renewable energy sources requires a comparison with solar energy producers in Europe (Reljić, Mihić & Cvijović, 2018). The average value of global radiation for the territory of Germany is about 1000 kWh/m2, while for Serbia that value is around 1400 kWh/m2 (Stamenić, 2009). The total annual insolation in the cities of Serbia is 1250 kWh/m2 in north-western part of Serbia, 1550 kWh/m2 in south-eastern part of Serbia and 1400 kWh/m2 in the central part of Serbia (Ilić & Lepotić, 2013). Insolation is the highest in cities such as: Peć, Priština, Vranje, Kuršumlija and the lowest insolation is in the Zlatibor district, the city of Požega (1226.35 kWh/m2).

In accordance with the green agenda of the European Union, Serbia adopts the "Integrated National Energy and Climate Plan" (INEKP) during 2024. Based on the INEKP, the target is that every second megawatt-hour of electricity should be produced from renewable sources, which refers to the period ending with 2030. The provisions of INEKP are aimed at decarbonization of the energy sector, with the reduction of the level of harmful gases with the greenhouse effect by 40.3%, compared to the values measured during 1990. The plan predicts that the share of renewable sources in the gross final consumption of electricity will reach the level of 29.8% by 2025, and then that the use of renewable energy sources will increase to 33.6% by 2030 ("Official Gazette of RS", No. 70/2024). According to the “Energy Sector Development Strategy of Serbia” until 2040, with projections until 2050, the focus is on sustainable development, i.e. environmental protection, which indicates the significant role of renewable energy sources. The International Agency for Renewable Energy Sources (IRENA) suggests that the use of solar energy has become an increasingly common source of household electricity. Namely, IRENA reports indicate that renewable energy production should be 25% (2025) of the total amount of electricity worldwide, but on the condition that the capacity of photovoltaic systems increases to 2840 GW by 2030 and 8519 GW by 2050 (Asmelash & Prakash, 2019). The use of solar energy through photovoltaic systems is implemented through installation on the roof surfaces of both industrial and residential buildings. The capacity of photovoltaic systems is from several to several hundreds kilowatts per hour, depending on the roof surface. With that, the profitability of installing photovoltaic systems will be analyzed as an altenative for energy production. The primary field of research is related to examine the cost-effectiveness of using solar energy, all with the aim of implementing sustainable development strategy. The profitability of the transition to photovoltaic systems for the production of electricity will be examined on the example of an individual household and a household with the Republic's average electricity consumption.

2. Method and data

Based on the previously set research topic, which relates to the analysis of the profitability of the application of solar energy and its role in promoting the sustainable development of countries, modelling of investment returns will be carried out through the calculation of economic flow, as an indicator of the economic efficiency of investments. For the empirical part of research, dynamic indicator will be applied, which take into account the time dimension of investments. The period of exploitation (T) of the installed capacity for electricity production and total own investments (Sv), along with the values of the discount rate (i_t) and internal rate of return (IRR) are used to calculate the net present value(NPV), the profitability index (PI) and the cumulative discounted net inflow (Npr) through different time units (t).

Obtaining the investment return period for the installation of infrastructure capacities for the production of solar energy is carried out by calculating the expected present discounted values. For this purpose, future values of economic variables will be discounted in relation to the time distance, through the calculation of discount rate (i_t). The calculation of the net present value involves correcting the net inflow by the discount factor $1/(1+i_t)$. The accumulation factor $(1+i_t)^n$ will be applied to obtain the discounted net inflow. Then, the cumulative net inflow will be determined in the business year in which the return on assets is realized, along with the number of days required for the return on investement. Additionally, the analysis will be expanded by determining the discounted investment payback period, with and without taking into account state subsidies, which are prescribed by law for subsidizing the construction of solar panels on the territory of Serbia (JP 2/21, 2023/2024).

The data for the methodological part of the research were taken from relevant and publicly available international databases. The database of the International Renewable Energy Agency (IRENA) and the global atlas and software “Solargis” were used for the analysis of the share of solar energy in the total supply of hausehold electricity. The robustness of the cost calculation is ensured by monitoring retail prices and collecting data using the survey method. Electricity consumption per household was determined using the “JP EPS” calculator and the “PVGIS 5.3” solar panel calculator. This research uses secondary data from databases of the European Commission and the

European Photovoltaic Industry Association (EPIA), which contain data on the level of solar energy radiation and measured photovoltaic production in different countries.

3. Results and Discussion

The production of electricity through the solar photovoltaic system is directly correlated with the geographic coordinates of the chosen household, where the solar panels are installed. Namely, the energy of sunlight radiation depends on the duration of insolation and the slope of the surface under which the rays of sunlight reach. The duration of insolation depends on the latitude and the season. Therefore, the calculation of solar photovoltaic energy production includes the following elements: total annual production of photovoltaic energy in kilowatt hours (kWh), annual amount of horizontal radiation per square meter (kWh/m^2), as well as the production of photovoltaic energy in kilowatt hours by different months. The results of the first part of the research refer to the profitability analysis of the installed solar panel, which is positioned on the roof of the building, with a power of 5kW, at an angle of 35 degrees. The analysis of the profitability of using solar energy was carried out on the example of a household with coordinates: 43.69 north latitude and 21.22 east longitude.

Using the "PVGIS 5.3" calculator, the total production of electricity through the solar panels of an individual household was determined, with an insight into savings through photovoltaic conversion from non-renewable to renewable sources. Dynamic indicators are used to calculate the economic efficiency of investing in renewable energy sources. The net present value (Npv)is calculated as the difference between the present value of the net inflow and the initial investment. The profitability index (IR) is calculated through the quotient of net present value and total investments. The internal rate of return (IRR) is obtained at the discount rate that equates the net present value to zero. The results of the payback period for the construction of solar panels are calculated below, using the example of a selected household in Rasina District of Serbia.

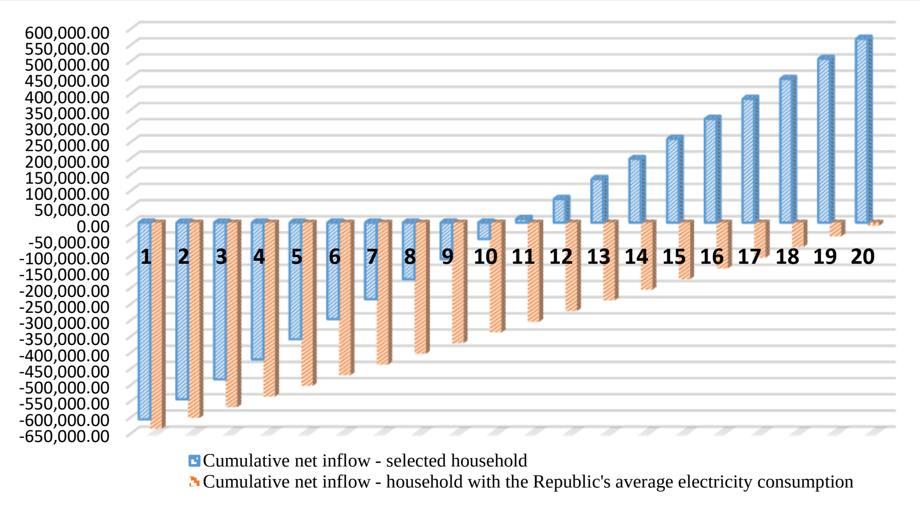
Table 1. Calculation of the return of investment period (selected household)

Calculation of the discounted investment return period	Without state subsidies	With state subsidies
Cumulative net inflow at the end of the year of investment return (RSD)	878.80 RSD	23,175.92 RSD
Duration of the year required for return on investment (%)	96.90%	47.29%
Number of days in the year of investment return	353.68 days	172.61 days
Discounted return period of total invested funds	15 years and 354 days	6 years i 173 days

** *according to the middle exchange rate prescribed by the National Bank of Serbia 1 RSD=0.117 EUR, which is defined in the public reports of the NBS (2025)*
Source: Authors' calculation

If the household doesn’t reach the criteria for the allocation of funds for co-financing of the energy supply of buildings through solar panels by the local self-government and the municipality (JP / 3/21), the installation of solar panels and accompanying installations will be provided from its own funds. Installing a 5kW solar system requires a total investment of 669.654 RSD (report "Flash-Power Led", Kruševac). The calculation of the discounted investment return period is carried out based on the exploitation period of the solar panels, discount rates and internal rates of return. The cumulative net inflow of the observed household without subsidies will be presented in Graph 1.

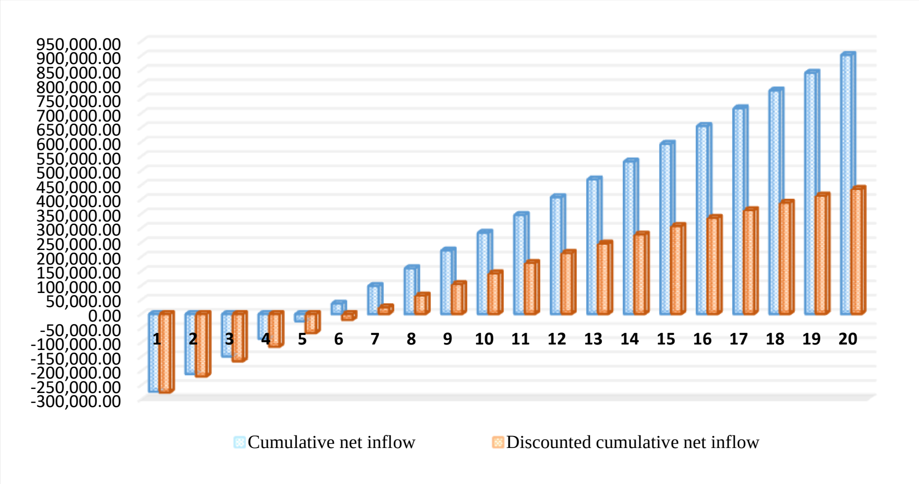
Graph 1. Cumulative net inflow of the selected household and the household with the Republic's average electricity consumption, without state subsidies



Source: Author's calculation

The research results indicate that the cumulative net inflow will amount to 878.80 RSD at the end of the year, in which the investment is returned. The duration of the investment return year is 353.68 days. Based on that, it is concluded that without the realized right to state subsidies, with a discount rate of 5% and an internal rate of return of 7%, the selected household would return the invested funds in 15 years and 354 days. The average annual rate of return on capital assets is 15.14%, which is realized on the present value of investments. Namely, the observed household would achieve savings in the amount of 101,382.95 RSD from the conversion to electricity supply through the installation of solar panels, i.e. renewable energy sources, which was measured over in a time interval of 20 years.

Graph 2. Cumulative net inflow and discounted cumulative net inflow of the selected household, with state subsidies



Source: Author's calculation

Graph 2 represents the values of the cumulative net inflow and the discounted cumulative net inflow of the observed household, whose installation of a solar panel is partially financed by state subsidies. At the end of the investment return year, the household provided a cumulative net inflow of 23,175 RSD. The duration of the investment return year is 172.61 days. The results indicate that with the realized right to subsidies provided by the state, with a discount rate of 5% and an internal rate of return of 18%, the observed household from the territory of the Rasina District would achieve a return on investment in 5 years and 150 days. After that time period, the selected household would ensure savings using renewable energy sources, which are produced through solar panels. Namely, the total savings of the chosen household from the transition to the use of solar energy would amount to 436,209.95 RSD, after the passage of a period of 20 years.

In the continuation of the methodological part of the paper, the cumulative net inflow of funds with state subsidies was calculated for a household with the Republic's average electricity consumption. Table 2 will present the calculated values of the discounted return period for the installation solar panels, i.e. renewable energy sources.

Table 2. Calculation of the return of investment period of a household with the Republic's average electricity consumption

Calculation of the discounted investment return period	Without state subsidies	With state subsidies
Cumulative net inflow at the end of the year of investment return (RSD)	-258,450.91 RSD	7,348.81 RSD
Duration of the year required for return on investment (%)	/	53.66%
Number of days in the year of investment return	/	195.85 days
Discounted return period of total invested funds	There is no return on investment	14 years i 196 days

**according to the middle exchange rate prescribed by the National Bank of Serbia 1 RSD=0.117 EUR, which is defined in the public reports of the NBS (2025)*

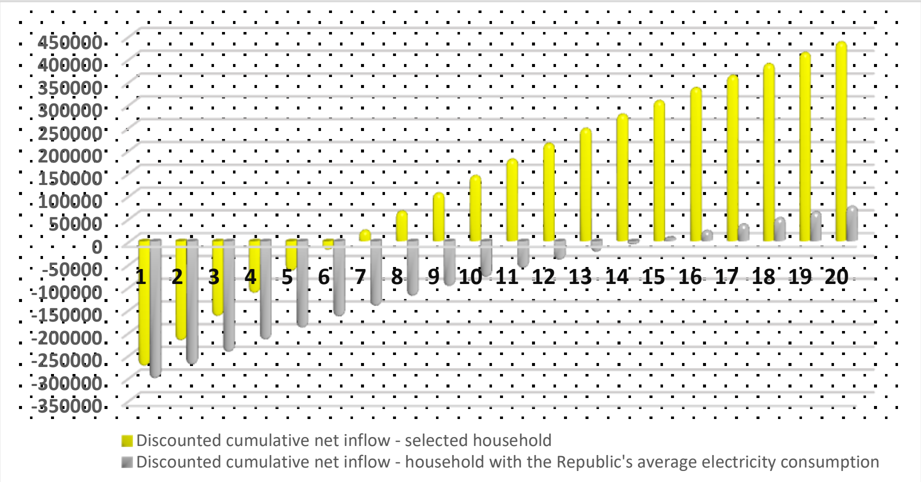
Source: Author's calculation

The results of the calculation of the cumulative net inflow of the household with the Republic's average electricity consumption indicate the complete unprofitability of investing in the installation of solar panels. On the other hand, due to the fulfillment of the criteria for obtaining state subsidies, households with the Republic's average consumption of electricity would ensure a sufficient level of profitability and the return od invested funds in the installation of a network of solar panels, which have a capacity of 5 kWh. Table 2 presents the calculated cumulative net inflows at the end of the year of return on investments in the amount of the 7,348.81 RSD, for households with the Republic's average electricity consumption. The duration of the investment return year is 195.85 days. Due to the fulfillment of the criteria for obtaining state subsidies, a discount rate of 5% and an internal rate of return of 8%, households with the Republic's average electricity consumption would achieve a return on invested funds for a period of 14 years and 196 days.

Maintenance costs for solar panels are negligible due to minimal effort required to maintain the system and long-term warranties against potential demage. Manufacturers provide warranty contracts of up to 25 years (80% of nominal power) with a degradation of 0.6% to 0.7% per year, which is significantly longer than the predicted investment return period (Mitrašinović & Radosavljević, 2022). Namely, the manufacturers provide an equipment warranty (physical aspects and component quality), assembly and installation warrancy and performance warrancy (maintenance of efficiency and capacity). The calculated savings of funds by a household with the Republic's average consumption of electricity would amount to 76,002 RSD, after the passage of a period of 20 years. Therefore, the installation of solar panels with a power of 5kWh would have a significant impact on the reduction of allocated funds for the supply of electricity to households with the Republic's average electricity consumption.

In the further empirical part, a comparative analysis of the profitability of the investment is carried out between the selected household in the territory of Serbia and the household with the Republic's average electricity consumption. The calculation of the investment return period and the value of the discounted cumulative net inflows are used for comparative analysis, depending on the type of household, which implements the conversion to renewable energy sources, i.e. installation of solar panels. The difference appears due to the geographical location of households, the intensity of insolation, the change in land size, as well as the total consumption of electricity, which is measured on an annual basis.

Graph 3. Comparative analysis of the selected household and the household with average electricity consumption based on the discounted net inflow



Source: Author's calculation.

Based on the calculation of the discounted cumulative net inflow of funds through different time units, the return of invested funds within the extrapolation period was confirmed for the selected household (6 years and 173 days) and for the household with the Republic's average electricity consumption (14 years and 196 days). Therefore, an individual household would return the invested funds in a shorter time interval (8 years and 23 days), compared to a household with the Republic's average consumption of electricity. Namely, fulfilling the criteria for obtaining state subsidies for the installation of solar panels, the selected individual household would provide 360,207 RSD more profitability investment compared to households with the

Republic's average consumption of electricity, observed in a time interval of 20 years.

5. Conclusion

The process of harmonizing social, economic and environmental protection factors are becoming the basic postulates of sustainable development, which most modern economies strive for. Compared to Central European countries, Serbia's energy potential is about a third higher in terms of solar energy production and distribution. With the adoption of new laws in Serbia, especially the Law on Renewable Energy Sources, obstacles to installing solar panels in households have been overcome. The introduction of subsidies significantly reduces the return period of investments in the installation of solar panels. The implementation of renewable energy sources as a type of household electricity supply is an important determinant of economic development, within the framework of environmental protection. The conclusion about the cost-effectiveness of installing photovoltaic system for electricity supply is based on the example of a selected household and a household with the Republic's average electricity consumption. With that, the research confirmed that there is a significant cost-effectiveness for the construction of a solar system for individual households and conversion to the use of renewable energy sources.

Numerous reasons have been derived for the use of solar energy as one of the significant sources for supplying households with electricity. Namely, solar energy hasn't location restrictions and losses caused by transportation from the place of production to the place of consumption. Solar energy is approved by the majority of the population, which is partly caused by its positive effect on the natural environment. Then, practice confirms the thesis that the installation of photovoltaic systems implies a simple process and lower installation costs, considered at the level of an individual example or a household with the Republic's average electricity consumption. Due to the development and implementation of technical and technological innovations, the installation of capacities for the production of solar energy becomes more competitive in price compared to other available renewable energy sources. The conclusion refers to the thesis that the use of solar energy as a type of renewable energy source implies a significant instrument for savings financial resources, i.e. part of the household budget throughout the territory of Serbia. The use of renewable energy sources is an important issue within the strategy of sustainable development, as well as the adoption of environmental policy measures in the direction of protecting the natural environment. The motivation for the transition to renewable energy sources is derived from proving the profitability of implementing solar energy and other renewable energy sources, while raising the environmental awareness of both individuals and the entire population.

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