COST-EFFECTIVENESS ANALYSIS OF THE CONSTRUCTION OF A SOLAR POWER PLANT IN ASH AND SLAG LANDFILLS

Expert Paper
DOI: 10.5937/RGD240042A

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Abstract: *This paper gives an overview of the possibility of building a photovoltaic solar power plant on ash and slag landfills, an assessment of possible power, as well as investment and expected return on investment on the example of the ash and slag landfill SKO (Srednje Kostolačko Ostrvo). The results show that the investment is economically viable and can contribute to reducing CO_2 emissions into the atmosphere, as well as increasing energy independence. This is a good example for future solar power plant projects in similar locations, highlighting the advantages of unused and degraded spaces, which can be used to generate electricity from renewable sources.*

Key words: SOLAR POWER PLANT, ASH AND SLUG LANDFILL, PROFITABILITY, INVESTMENTS

INTRODUCTION

When producing electricity in coal-fired power plants, among other things, there is a problem of ash and slag disposal. For this purpose, landfills are planned, which occupy a large area, and which are designed for 20-30 years of operation. After this period, it is necessary to close such a space in an environmentally friendly way.

Landfills affect water pollution, and are also a surface source of air pollution with ash particles. Due to the unfavorable physico-chemical characteristics of ash and the existing method of ash disposal, aeolian ash erosion occurs in open landfills, in dry and windy weather. In accordance with the existing technology of transport and disposal of ash, in order to prevent aeolian erosion of ash from landfills, appropriate protection measures are applied [1]. The appropriate steps for this purpose are carried out through a process called remediation.

The implementation of measures for the remediation of the ash and slag landfill on the Srednje Kostolačko ostrvo (SKO) is aimed at [2]:

- Prevention of the dispersal of deposited ash and the spread of contamination under the influence of wind
- Protecting the underground from contamination of lithological formations under the landfill
- Protection of surface and groundwater from the effects of leachate of atmospheric water landfill after the cessation of ash disposal at this location
- Looking at the possibility of repurposing the landfill space for the construction of renewable energy after remediation.

With the permanent closure and application of measures for the remediation of the ash and slag landfill, new opportunities for the use of this space are created. Since the space occupied by the landfill is a degraded area, the construction of renewable energy sources (RES) can contribute to the use of such space, and in addition, it would improve the energy picture that Serbia needs to provide from RES.

The construction of PV power plants on degraded land created after the permanent closure and reclamation of landfills generated by mining and thermal power activities has become a positive practice in the world.

The Matra Thermal Power Plant in Hungary has built a PV power plant with an installed capacity of 16 MW on a permanently closed and recultivated landfill of thermogenic waste on an area of 25 hectares, shown in Figure 1 PV solar power plant at the landfill of thermogenic waste of TPP Matra.

Figure 1, PV solar power plant at the thermogenic waste landfill in TPP Matra

PV SOLAR POWER PLANT AT THE LOCATION OF THE ASH AND SLAG LANDFILL

According to the Spatial Plan of the Special Purpose Area of the Kostolac Coal Basin, (Official Gazette, No. 1/13, 20/18), space is reserved for a solar power plant in the spatial unit Landfill Srednje Kostolačko ostrvo. The possibility of building a solar power plant gives significant potential for the permanent arrangement of this area, which would be useful in terms of energy, and in ecological terms would be completely acceptable for both the population and the environment [3].

The SKO landfill is at the very end of the closure process, given that TPP Kostolac B, all the amount of ash and slag is disposed of at the OP Ćirikovac landfill, which is expected, in the near future, for TPP Kostolac A. It is located on the right bank of the Danube, and on the outskirts of Novi Kostolac (about 70 km downstream from Belgrade and about 11 km from Požarevac). The location of the SKO for the disposal of ash and slag was chosen in 1973, and after 1977 the landfill came to life as a facility, when the construction of the initial embankment at the height of 73 m above sea level began [2]. The area on which the solar panels would be located, as well as the accompanying equipment, is approximately 180 ha. There are no forests and vegetation on the ground itself, and there are no tall buildings that could affect the shading. Figure 2 shows the location of the landfill. The advantage of building a PV solar power plant in the area of ash and slag landfills, in addition to the environmental benefits, is certainly the use of the existing network for the transmission and distribution of electricity.

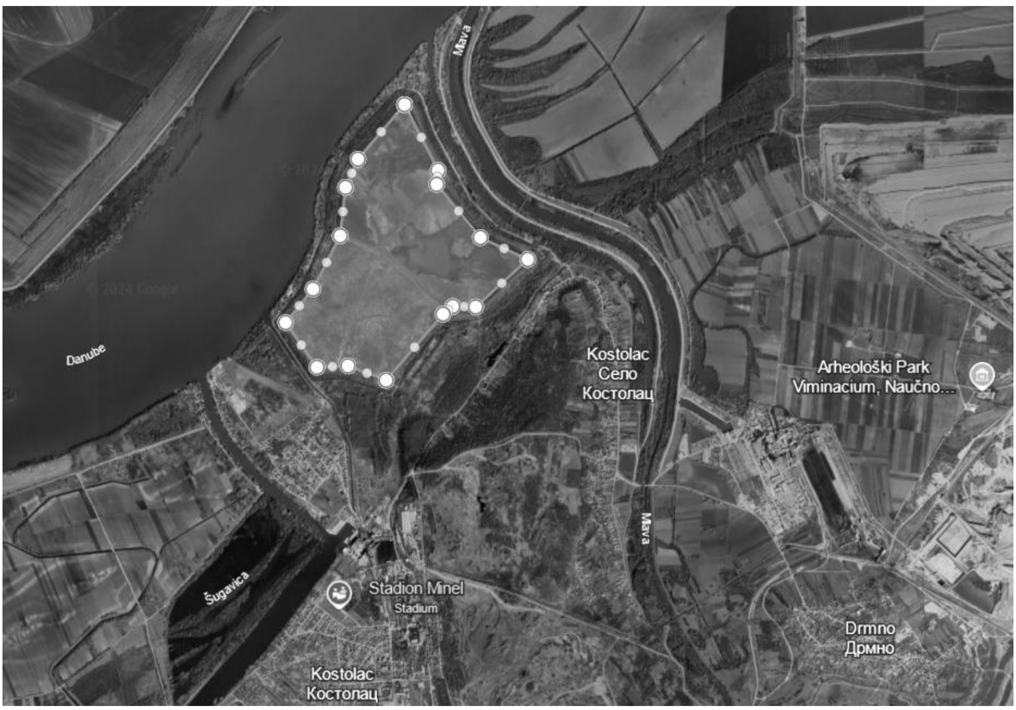

Figure 2, Location of the ash and slag dump [4]

The PV solar power plant would be modular and can be built in stages, depending on the financial resources provided, as well as the obtained permits (location, construction, use) for construction. The selection of module power within the power plant should be made according to the condition for the most flexible operation of the power plant and the optimal use of solar energy. The power plant should deliver all available energy produced depending on the current solar radiation, without the presence of an operator, i.e. to be built and equipped to operate in automatic mode.

A PV power plant consists of photovoltaic panels, which in turn consist of modules, sections of modules, and groups of sections. Supporting equipment includes inverter plants, compact substations, command and power building, connecting switchgear, battery storage.

When considering the ratio of the available landfill area and the potentially possible installed capacity of the PV power plant in the world, it is stated that power plants with panels based on crystalline silicon compounds require from 1.6 to 2.3 ha/MW. A proposal for the arrangement of solar panels on the surface of the landfill is shown in Figure 3, taken from [2].

Based on the available area of the reclaimed area of the SKO ash and slag landfill of 180 ha, the potential installed capacity of the photovoltaic power plant ranges from approximately 78 MW to 112 MW.

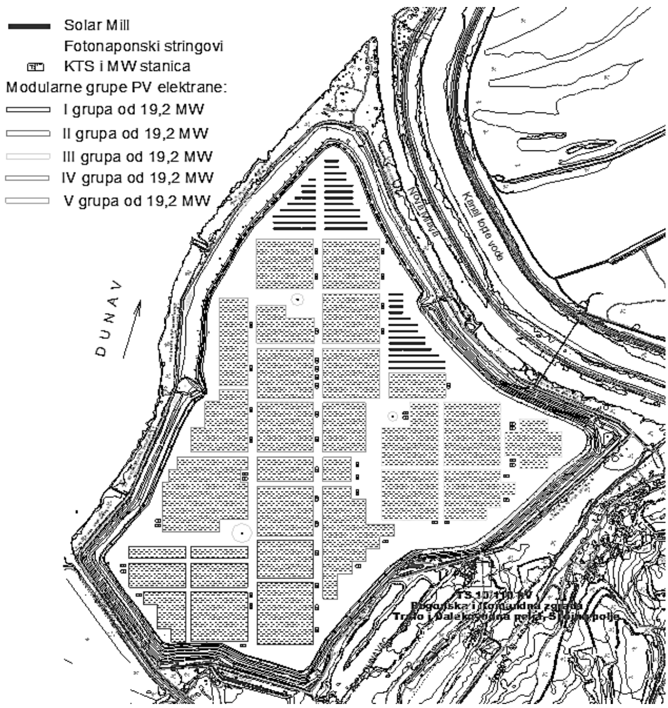

Figure 3, Proposal for the arrangement of PV solar panels at the SKO landfill according to [2]

TOTAL ANNUAL ENERGY PRODUCTION AND ECONOMIC VIABILITY

Earlier feasibility studies with the conceptual design for the implementation of remediation measures for the ash and slag landfill SKO from 2015, the estimated value of the investment in the 100 MW solar power plant amounted to € 196,000,000.00 [2]. In the last ten years, investments in solar power plants have been on a downward trend, primarily due to the decreasing prices of solar panels and the decreasing prices of accompanying equipment, as can be seen in Figure 4, taken from [5].

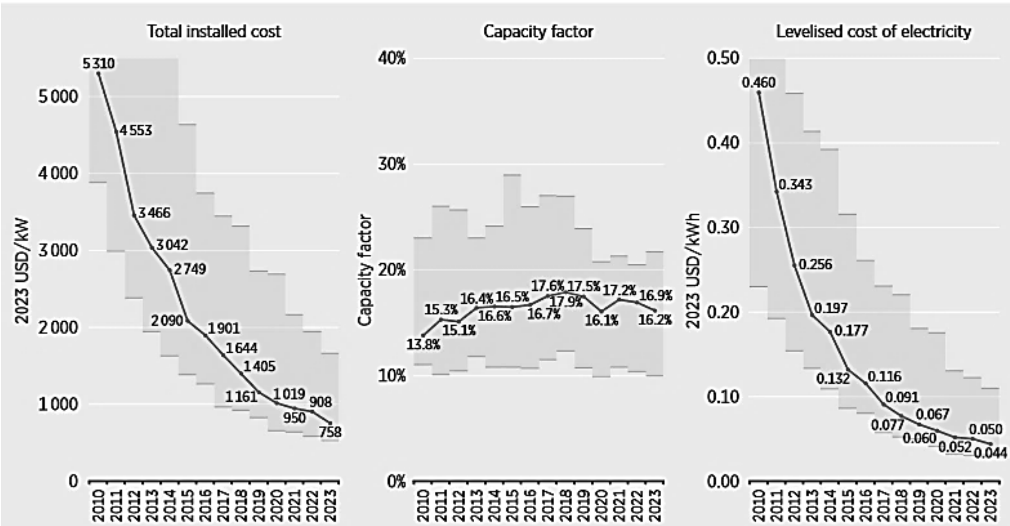

Figure 4, Global weighted average value and range of total installation costs, capacity factors, and LCOE for high-capacity solar photovoltaic systems, 2010-2023 [5]

At the moment, the estimated value for the construction of a 100 MW PV solar power plant is €110,000,000.00. This value includes investments for: foundation on piles, service roads, steel structure, solar panels with inverter stations, substation and other equipment. The Law on Amendments to the Law on the Use of Renewable Energy Sources, which came into force in 2023, determines the price of electricity through auctions for market premiums. The new law defines a period of 15 years during which premiums are paid to the producer of electricity from RES.

The following tables provide a calculation of the annual electricity production at current prices at secondary auctions of 9 c€/kWh. The data were obtained using the PVGIS-5 web application [6].

The input data for the calculation are:

- Latitude and longitude: 44.741, 21.175
- Database: PVGIS-SARAH3
- PV panel technology: Crystalline silicon

- PV installed power: 100000 kWp
- Loss in the system: 14%
- Panel inclination to the surface: 35º
- Azimuth: 0º

The results of the calculation are presented graphically in Figure 5.

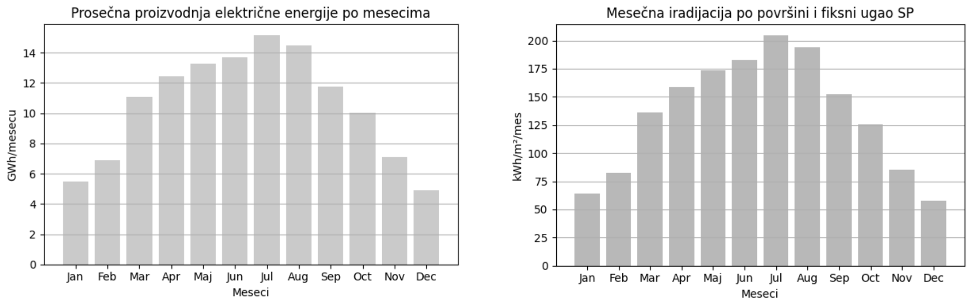

Figure 5, Calculation results of the average electricity production from a 100 MW PV solar power plant

The estimated annual income is shown in Table 1 and amounts to €11,365,788. Given that the total estimated investment is €110,000,000, the return on equity period can be determined, and it is approximately 10 years. Bearing in mind that after 10 years the efficiency of the module will decrease, we can then calculate the total annual electricity produced from: 0.92x126,286,536 = 116,183,613 kWh, i.e. 116,18 GWh. The five-year income after the reduction in efficiency would be 5x10,456,525 € = 52,282,626 €. If a market price of 6 c€/kWh were assumed for a period of 15 to 25 years of operation of the plant, the total revenue in that period would be € 65,921,572. By the end of its service life, which is 25 years, the performance of a solar power plant will decline, but not below 82% of its nominal power.

Table 1, Annual electricity production from SE and revenue with a feed-in tariff of 9 c€/kWh

Month	Power generation (kWh)	Revenue (EUR)
January	5,484,239,00	493,582,00
February	6,924,848,00	623,236,00
March	11,057,020,00	995,132,00
April	12,445,439,00	1,120,089,00
May	13,284,728,00	1,195,626,00
June	13,688,901,00	1,232,001,00
July	15,145,294,00	1,363,077,00
August	14,463,489,00	1,301,714,00
September	11,736,873,00	1,056,319,00

Month	Power generation (kWh)	Revenue (EUR)
Octobar	10,058,841,00	905,296,00
November	7,120,739,00	640,867,00
December	4,876,124,00	438,851,00
Total per year	**126,286,536,00**	**11,365,788,00**

If it is assumed that the electricity produced from a solar power plant replaces the electricity produced in thermal power plants on domestic lignite, the avoided carbon dioxide emissions can be determined by the implementation of this project. If the carbon dioxide emissions from coal-fired plants of 1 kg CO_2/kWh are taken into account, and the annual electricity production in Table 1, the avoided emissions determined are 126.287 t CO_2 per year.

CONCLUSION

On the ash and slag landfill SKO, on its flat area of 180 ha, the construction of a solar photovoltaic power plant with a capacity of 100 MW was considered. The investment value of the plant is shown, as well as the repayment period and the total income of the potential plant.

With the passage of the 2023 Renewable Energy Act, the payback period has increased even though investments in solar panels and equipment have decreased. This fact is contributed by the transition to a system of auctions instead of the previous feed-in tariffs, where the prices of electricity purchase from RES have almost halved.

The analysis showed that the payback period of the investment is 10 years, and counting on the operating life of the PV solar power plant of 25 years, it is possible to generate additional income.

On the other hand, the construction of a PV solar power plant does not occupy a large arable and usable part of the surface of a land, which is required for the installed power of this value, but a part of the degraded area that could not be better used was used for this purpose.

The PV solar power plant does not produce pollution in terms of unacceptable amounts of waste emissions into the air, water and soil, and there are no negative impacts on the surrounding environment, which would require additional protection measures.

With the construction of such a plant, Serbia would get closer to the planned plan, which refers to the provision of final energy from renewable energy sources.

And finally, a significant step is being taken towards what can be called a change in traditional ways of obtaining electricity.

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