The 56th International October Conference on Mining and Metallurgy
22-25 October 2025, Bor Lake, Bor, Serbia
www.ioc.tfbor.bg.ac.rs

DOI: 10.5937/IOC25106K Review paper

IMPLEMENTATION OF GROUND-MOUNTED AND FLOATING SOLAR PANELS IN MINES

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Abstract
The mining industry is one of the most difficult sectors to turn greener due to its significant environmental impact. Mines have high energy and water consumption due to the equipment, lighting, and ventilation required. The application of renewable energy in mines can contribute to clean energy production and a sustainable mining industry. This paper provides insights into solar projects in several active and abandoned mines worldwide and discusses potential benefits and challenges associated with this topic. Integrating renewable energy into the mining industry can reduce costs by 25% in mining operations and up to 50% for new mines. A great opportunity exists for the use of mine sites for hosting solar panels to recover the land, produce green energy, reduce greenhouse gas emissions, ensure energy independence, and create new jobs.

Keywords: *solar energy, mine, renewable*

1. INTRODUCTION

Solar energy helps achieve several Sustainable Development Goals (7-Affordable and Clean Energy, 13-Climate Action, and 9-Industry, Innovation and Infrastructure). Solar energy is one of the fastest-growing renewable energy in Europe and the world. Moreover, floating solar projects have attracted increased interest worldwide. Floating solar panels have higher efficiency than ground-mounted due to the water-cooling effect, light reflection from the water, and less dust deposition [1], [2]. Floating solar panels reduce water evaporation and excessive algae growth [3]. Attention should be paid to mitigating the environmental and ecological impact on the local communities after the closure of the mine. The mine reclamation implies land restoration and reuse of flooded areas or electrical facilities. Planning and development of solar power plants in mine areas can be a good way for the redevelopment of such areas. Surface coal mining usually causes the apparition of flooded areas (mining pit lakes) and coal waste heaps, while underground coal mining usually causes the apparition of flooded underground galleries with needs of dewatering pumps, abandoned buildings, infrastructure, and facilities to restore and also coal waste heaps [4]. Mine sites appear as suitable locations to deploy solar panels due to land use limitations and exiting power grid which reduces costs. The power grid in coal areas has usually high capacity, due to the existence of thermal power plants. The existing power network in such locations can accept new power generation from solar panels. The terrain in post-mining areas is slope, loose, and challenging for installation of traditional solar ground-mounted systems. Therefore, the geotechnical study of the terrain is necessary to obtain soil type, moisture content, and rock quality, which can affect the stability and performance of the mounting system panels [4]. Floating solar panels can be a viable solution in postmining areas where ponds can appear. Some best practice case examples of solar project installation in post-mining areas are shown below. The mining

industry has faced many challenges, such as rising demand, fluctuating energy prices, increasing energy consumption, and environmental concerns [5]. Power consumption in the mining industry generates 0.4 gigatons of CO_2 equivalent to greenhouse gas emissions each year [6]. Reducing greenhouse gases and carbon dioxide levels in mining areas due to renewable energy use improves the health of local communities [7]. Solar energy provides the mining industry with the opportunity to become more sustainable.

2. POTENTIAL IN SERBIA

Serbia added around 80 MW of solar in 2024, bringing total capacity above 200 MW, according to the Association of Renewable Energy Sources of Serbia. By 2028, the country plans to develop solar power plants of a total 1 GW across six locations. In the regions of "Kolubara" and the "Kostolac" coal basins the specific photovoltaic power output is 3.5 kWh/kWp while the global tilted irradiation is 4.3 kWh/m^2 [8]. The first solar power plant "Petka" will be built at the 15 ha of disposal side of the open pit mine "Ćirikovac" within the thermal power plant and coal basin "Kostolac". The installed power will be 9.75 MW, while the planned electricity production is 15.6 GWh annually. The 18,720 solar panels with individual power of 580 W and efficiency of 21% will be fixed under a 25° angle. The solar project includes 98 inverters and 10 transformers. This solar project will cost 8.5 million euros financed by Serbian state-owned energy producer "Elektroprivreda Srbije". In Serbia, the "Kostolac" wind farm with a power capacity of 66 MW is situated in coal mined-out areas and landfills. "Elektroprivreda Srbije" also plans to build two solar power plants (up to 9.9 MW each) on the coal ash dump sites of thermal power plants "Morava" and "Kolubara A". In 2029, it is planned to build a 150 MW solar power plant within the "Kostolac" mining basin at the ash and slag dump "Srednje kostolačko ostrvo" (270 ha) which will be closed in the future. Moreover, the construction of two solar power plants "Stiško Polje 1" and "Stiško Polje 2" (350 W and 500 MW) is planned. The Klenovnik location within "Kostolac" should host a 250 MW solar project.

3. CASE STUDIES

Solar energy is deployed in several abandoned mines in the USA, China, Finland, Poland, North Macedonia, and Germany as well as in several active mines in Australia, South Africa, Madagascar, Saudi Arabia, and Chile [5]. A 3 MW "Prapretno" solar power plant (Figure 1) was built in Slovenia in rehabilitated landfill that belonged to the shutdown coal-fired "Trbovlje" thermal power plant. The facility can be expanded to 13 MW. The 8.7 million tons of fly ash and slag from the thermal power plant were deposited on this site. The solar power plant has 6,748 solar panels. The power plant produces more than 3 GWh per year and can supply 800 households.

a) b)

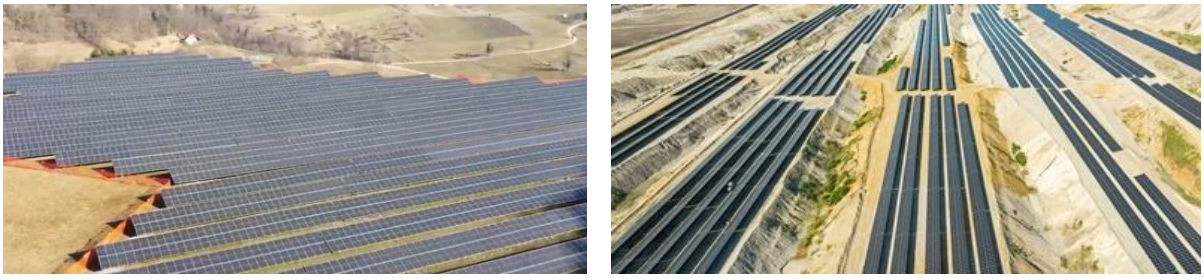

Figure 1. a) Solar plant in rehabilitated landfill of defunct coal-fired power plant (Slovenia) [9]

b) "RWE Neuland" solar power plant (German) [10]

In the North Rhine-Westphalia region in Germany, two solar power plants, one of which has an integrated battery storage system, were built at the shoreline of "Hambach" opencast mining lake (Figure 1). The power plant provides 12 MW of electricity while the battery storage is configured

for a two-hour charging and supply cycle of 4.1 MW. The 14,500 households can be supplied with green electricity. A 5.3MW solar power project was completed in the "Northern Star's Carosue Dam" gold mine in Australia (Figure 2). This power plant produces green energy for the mine reducing carbon emissions by displacing diesel and natural gas use. In this location were installed solar panels with an innovative "Maverick" mounting system from the Australian company "5B" pattern that creates alternating east and west-facing panels. Power plant produce 10,480 MWh per year and avoid emission of 6,686 tonnes of CO_2 per year.

a) b)

Figure 2. a) The Carosue Dam solar plant in mine (Australia) [11]

b) Floating solar plant (Grafenwörth, Austria) [12]

Floating solar plants can be installed on abandoned coal pits and mining ponds. In 2023, the fourth largest floating solar plant (Figure 2) in Europe is launched in Austria. A 24.5 MW floating solar plant is located on the 14 ha water surface created by former sand and gravel pits of two lakes. The 45,304 solar modules were installed. They produce 26.7 GWh of electricity per year and supply around 7,500 households. In Chile, in 2019 solar plant was built over a "Tórtolas" tailing pond of the "Los Bronces" copper mine. The project (Figure 3) consists of 256 solar panels with the capacity to generate 86 kW. This solar plant will produce 150,000 kWh of electricity per year, reduce CO_2 emissions by 58 tonnes, and reduce water evaporation by 80%. This water savings will be available for recirculation in the mining process.

a) b)

Figure 3. a) Floated solar panels in a pond of "Los Bronces" mining plant (Chile) [13]

b) Floating solar plant in flooded abandoned coal mine (China) [14]

A 70 MW floating solar power plant (Figure 3) was built on the lake of an abandoned coal mine in the Chinese province of Anhui in 2018. This region is recognized by its coal industry. The explosion caused the mine to collapse and a lake was formed. The 148.4 ha of flooded area hosts 13 floating islands with total a of 52,000 float elements and 194,731 solar panels. Solar power plants can generate 40 MW of power to supply 21,000 homes and decrease CO_2 emissions by 150,000 tonnes per year. The Fraunhofer Institute of Solar Energy Systems has estimated that the potential of floating solar panels on pit lakes in abandoned lignite mines in Germany is 56 GW [15]. The biggest diamond mine "Diavik" in Canada is the first of its kind that hosts 6,620 solar panels that generate 4.2 GWh of electricity. In Madagascar in 2023, a 20 MW solar power plant with an 8.25 MWh battery storage system was constructed to power the titanium and zircon mine.

This plant reduces mine CO_2 emissions by 26,000 tonnes yearly. Deployment of renewable energy can reduce operating costs by 25% in mining operations and up to 50% for new mines [16].

4. CONCLUSION

The mining industry is one of the most difficult sectors to turn greener. Due to their remote locations, mine sites worldwide are heavily dependent on power generated from fossil fuels which becoming more expensive. Deployment of renewable energy in mining areas can be an effective solution to reduce this problem. A large number of mines worldwide are abandoned or closed. Promotion policies and projects have been launched to achieve environmental restoration of abandoned mines. Solar energy provides the mining industry with the opportunity to become greener and more sustainable. A multicriteria analysis should be conducted to determine the best solar technology due to the different types and features of mine sites.

ACKNOWLEDGEMENTS

The research was funded by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant No. 451-03-136/2025-03/200017).

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