

CONSTRUCTION OF THE FIRST PHOTOVOLTAIC POWER PLANT WITHIN THE FRAMEWORK OF JSC ESM

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Abstract

To realize the green scenario, foreseen in the Energy Development Strategy in the Republic of North Macedonia until 2040, the existing coal-fired thermal power plants with an installed capacity of 800 MW should be successively closed in the coming period. For the same reason, the Republic of North Macedonia became a member of the PPCA Alliance (Powering Past Coal Alliance) and the first country from the Western Balkans that, together with Spain committed to abandon the production of electricity from coal by 2030.

Hence, the problem that has been elaborated is very relevant because it deals with the continuation of the existence of MPC "Oslomej" through energy transition, that is, the replacement of electricity production from coal, with the production from solar energy.

The analysis in this paper is focused and aims to address the importance of the further operation of MPC "Oslomej", with the construction and commissioning of the first photovoltaic plant PVPP Oslomej 1 of 10 MW. Afterward, MPC "Oslomej" will continue with the construction of PVPP Oslomej 2 of 10 MW and PVPP Oslomej 3 of 100 MW, which will completely replace the existing coal-fired thermal power plant TPP "Oslomej" of 120 MW. The construction of these photovoltaic power plants in the mine of the Oslomej plant, during the energy crisis is the first example in South-Eastern Europe, for which the European energy community reacted positively and expressed support to JSC ESM.

Keywords: photovoltaic power plants, thermal power plant, mine, energy transition.

1 Introduction

The photovoltaic power plant of JSC ESM built in the circle of MPC Oslomej with a power of 10 MW is the first example of energy transition in Southeast Europe in which electricity is produced from the sun through panels placed upon the old and exhausted/depleted coal mine. The planned investment of the project is 8,771 million euros. The output power of the PVPP is limited to a maximum of 10 MW due to compliance with the regulation of North Macedonia on renewable energy sources. It is planned to have an average annual electricity production of ~ 14.6 GWh. The photovoltaic power plant in Oslomej, which has been put into trial production, is the first in a series of power plants that should completely replace the current installed capacity of MPC Oslomej.

TABLE 1. BASIC DATA FOR PVPP OSLOMEJ 1

Power AC (MW)	Annual production (GWh)	Financing source
10	14 .6	5.9 Meur EBOR 2.871 Meur ESM

Source: (JSC ESM, 2022a)

According to the legal provisions, the concessionaire of the mining location has the obligation after its exhaustion to arrange and refine the space as well as return the land to its original state. The photovoltaic

power plant of JSC ESM built in the circle of MPC Oslomej in Kichevo is also the reclamation of the land, with an area of 19 hectares, on which coal was mined in the past.

The panels placed upon the old coal mine will produce "green" electricity will not pollute the air and the environment, and therefore the area around them will be planted with grass, which will simultaneously restore the eco-system and prevent dust from accumulating on the photovoltaic panels and reduce their effectiveness.

For those reasons, the photovoltaic power plant project in Oslomej is significant not only because of its energy values, but is also important from an environmental point of view for the near and far surroundings of MPC Oslomej (JSC ESM, 2022c).

Hence, the paper is composed of three parts. The first part will analyze the energy transition process of MPC Oslomej, which will completely replace 120 MW of the existing thermal power plant with photovoltaic power plants. In the second part, we will refer to the performance and technical characteristics of PVPP Oslomej 1 photovoltaic modules. In the third part, we will continue with the analysis of the production of green electricity during the trial operation of PVPP Oslomej 1, and in the end the paper is wrapped up with a conclusion.

2 Energy transition of MPC Oslomej

The total installed capacity of the planned capital projects by JSC "ESM" is 2018.8 MW, which is 508.6 MW more than the current total installed capacity of JSC "ESM", amounting to 1510.2 MW, that is, 79.19 MW less than the current total installed capacity of 2097.99 MW at the state level. The current total installed power of JSC "ESM" will be reduced by 800 MW by the end of 2030, which is the capacity of the thermal power plants. Therefore, with the implementation of the planned capital projects, the total installed capacity of JSC "ESM" will amount to 2729.0 MW.

The total installed capacity of the planned capital projects is mostly attributed to RES, i.e., 1718.8 MW or 85%, while the remaining part of 300 MW or 15% is attributed to gas power plants (Bitola and Energetika), for the production of base energy (JSC ESM, 2022a).

Photovoltaic and wind power plants in the section of electricity production from renewable sources in the Energy Development Strategy until 2040 (Government of the RNM, 2019) are predicted to be the fastest-growing technologies for electricity production in all scenarios (up to 1,400 MW PVPP and 750 MW wind). ESM as a socially responsible company and the largest state-owned company will have the most significant role in this process. In addition, in the Strategy, TPP Oslomej ceases to operate in all three scenarios and therefore it is recommended as one of the transformation solutions to build a PV power plant with an installed capacity of 80 MW to 120 MW.

The ultimate goal of this project is to replace the mining-energy plant, which has an installed capacity of 120 MW, with solar power plants having an equal installed capacity of 120 MW. The European Energy Community recommends this example to other countries in the region where the energy transition is being implemented (JSC ESM, 2022b).

Accordingly, North Macedonia became a member of the PPCA Alliance (Powering Past Coal Alliance) during the London Week for Climate Action. Together with Spain, by 2030, the country has committed to abandoning coal production energy (META.MK, 2021).

Hence, based on the Intervention Plan for Investments 2021-2027 in the value of 8.2 billion euros, of which 3.144 billion euros are planned in the energy sector, and of which 85 million euros are planned investments in MPC Oslomej (Government of the RNM, 2021).

All this with the aim of conducting the green scenario foreseen in the Strategy for the development of energy in RNM until 2040, and all this by RNM, as a candidate country for EU membership through the transformation of electricity production from conventional thermal sources (coal, oil, etc.) with production from RES (water, sun, wind, etc.)

Undoubtedly, with the termination of the operation of TPP Oslomej and the replacement of this production of electricity from conventional thermal sources with production from renewable energy sources through photovoltaic power plants, the production of electricity from these sources will significantly increase, and thus the participation of energy from RES in the consumption of final energy to achieve the target of 23% in the Republic of North Macedonia (Energy Community, 2018). For the same reason, the Government of the Republic of North Macedonia through the Law on Energy (Assembly of the Republic of Macedonia, 2018), enables investments in RES, of either public, private, or public-private nature.

In this context, MPC Oslomej within JSC ESM, apart from the construction of the first 10 MW photovoltaic power plant with the state's investment will be the first to realize and build the following power plant projects through the energy transition and the respective investment:

In addition, another 10 MW photovoltaic power plant will be built with the support of the EU and EIP from an investment fund for the Western Balkans, which is in the preparation stage of the documentation. It's time for projects to produce electricity from RES and in the future only such projects will be stimulated, promoted, and supported through loans from relevant European institutions.

Another capacity of 100 MW, i.e. two photovoltaic power plants of 50 MW each, an investment value of 70 million euros, will be built as part of MPC Oslomej through the principle of public-private partnership for which agreements with companies from Turkey "FORTIS ENERJI" and Bulgaria "SOLAR PRO" have already been signed (Agreement on PPP, 2021a, 2021b) and the companies are working in the building of the capacities. These investors of a 100 MW photovoltaic power plant must hire 1 employee per megawatt, that is, 100 employees from MPC Oslomej. From this investment, the state receives a profit from the energy sold at a price according to the HUPX regional stock exchange (Ministry of Finance, 2020) of 18% from one company and 18.5% from the other company, which exceeded all expectations and the Republic of North Macedonia has proven itself as an excellent destination for investments in photovoltaic power plants. These above-mentioned projects will use the same infrastructure (site and transmission network) and employees.

The construction of these photovoltaic power plants in the Oslomej Mine is of great economic, energy, social, and environmental importance, due to the use of RES, especially the investment in increasing the production of electricity from RES has a great impact on the economic development of the country, the sustainable development of the electricity system as a whole, the creation of new jobs, as well as the direct impact on the protection and preservation of the environment in general and the health of citizens in particular.

According to all relevant international organizations, North Macedonia is at the top of the list of countries in the region in terms of the growth of renewable energy sources. Last year alone, renewable energy production in the state increased to 827 megawatts, representing a growth of 10.1%.

The results of the energy transition of North Macedonia last year are a confirmation of the successful engagement of the Government and JSC ESM for investments in "green" energy, and environmental protection through a just transition (ESM Corporation, 2021).

Before the adoption of the Energy Development Strategy in RNM until 2040 (JSC ELEM, 2014, 2016a) an analysis was made for TPP Oslomej by the development and investment sector at JSC ELEM, as well as by the management of JSC ELEM, due to the lack of coal for TPP Oslomej and the need to modernize the technological process and its old equipment of over 35 years.

In the analysis, the option with a new CFB boiler is the most acceptable from a technical, economic, and environmental point of view, as well as the option for long-term supply of the modernized thermal power plant with imported coal of a high calorific value of 25MJ/kg, for which AF-Consult has prepared a Feasibility study (AF-Consult Switzerland Ltd, 2015). The same has been confirmed and given preference by the Working Group (JSC ELEM, 2018a) established by JSC ELEM. The same modernization is planned in JSC ELEM's plans for development and investments (JSC ELEM, 2016b, 2018b), to continue the operation of TPP Oslomej for an additional period of 30 years.

However, with the adoption of the Strategy, the challenge for the modernization of TPP Oslomej was neglected and "fell into the water", and all this to realize the green scenario, foreseen in the Strategy, by the requirements of the EU and our status as a candidate country for EU membership. This version of the green scenario, i.e. the ceasing operations at TPP Oslomej and energy transition, is not foreseen in the Government's Work Program 2017-2020 (Government of the Republic of Macedonia, 2017), nor in the Development and Investment Plan of JSC ELEM for 2018-2022, but the same is foreseen in the Strategy prepared by MASA.

Also, the current trend is to terminate the operation of the existing coal-fired power plants. At the same time, the construction of new ones is stopped and therefore it is time to build energy facilities for electricity production from RES instead.

3 The photovoltaic modules of PVPP Oslomej 1

Photovoltaic power plant PVPP Oslomej 1 of 10 MW is located in the city of Kichevo, Republic of North Macedonia. The field coordinates are 41°34'10.69" North and 21°00'37.26" East. The altitude of the location of the power plant is 675 m above sea level. After quantifying the benefits of the project, the best slope/azimuth pair was decided to be 25°/0°.

Figure 1. Location of PVPP Oslomej 1 Source: (JSC ESM, 2022a)



Solar power plants harness energy from the sun, which is in abundance available, intermittent and yet cheap. This energy is further transformed into electricity using photovoltaic modules. These are one type of solar power plants. Simply, a number of modules are installed in an optimal configuration that use the energy from the sun and convert it into electricity which is entered into the grid. A photovoltaic module is an assembly of photovoltaic cells mounted in an installation frame. Photovoltaic cells use sunlight as an energy source and generate direct electricity. The photovoltaic panel used in the Oslomej PVPP project is AstroSemi 350 Wp.

Model from ASTROENERGY. The panel is a polycrystalline type, with external dimensions of 2000 x 992 x 40 mm.

The above image is derived from the module data sheet. According to that data sheet, the AstroSemi 350Wp PV module has a 12-year materials and workmanship warranty. A 25-year warranty is given for additional linear graph output power. According to that graph, AstroSemipanel's performance degrades linearly.

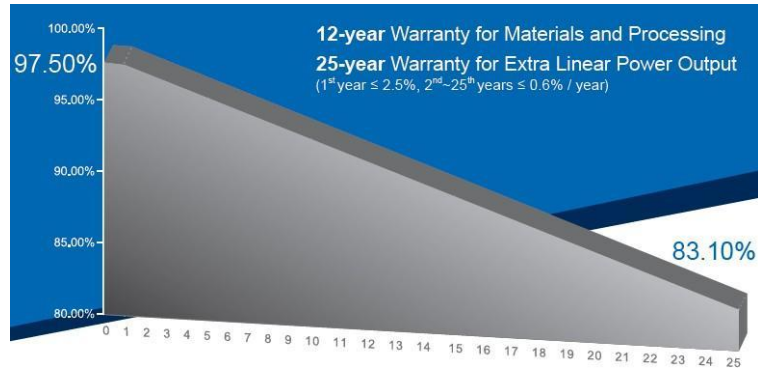


Figure 2: Linear power output of a photovoltaic panel
Source: (ZIM Skopje, 2021)

At the end of the first year, the module's performance drops to 97.5%, resulting in a maximum of 2.5% performance loss. From the beginning of the second year of use until the end of 25 years, the AstroSemi 350Wp photovoltaic module does not show a degradation greater than 0.6% per year and the manufacturer guarantees at least 83.10% of the performance at the end of 25 years. The AstroSemi module undergoes a TÜV Nord IEC / TS 62941 certification audit.

TABLE 2. TECHNICAL SPECIFICATION OF THE PHOTOVOLTAIC MODULE

ELECTRICAL SPECIFICATIONS					
STC rated output (P_{mpp})*	345 Wp	350 Wp	355 Wp	360 Wp	365 Wp
Rated voltage (V_{mpp}) at STC	37.71 V	37.78 V	37.87 V	37.94 V	38.02 V
Rated current (I_{mpp}) at STC	9.15 A	9.26 A	9.37 A	9.49 A	9.60 A
Open circuit voltage (V_{oc}) at STC	46.04 V	46.25 V	46.45 V	46.65 V	46.84 V
Short circuit current (I_{sc}) at STC	9.57 A	9.65 A	9.74 A	9.83 A	9.92 A
Module efficiency	17.4%	17.6%	17.9%	18.1%	18.4%
Rated output (P_{mpp}) at NMOT	256.7 Wp	260.4 Wp	264.2 Wp	267.9 Wp	271.6 Wp
Rated voltage (V_{mpp}) at NMOT	35.01 V	35.09 V	35.18 V	35.24 V	35.30 V
Rated current (I_{mpp}) at NMOT	7.33 A	7.42 A	7.51 A	7.60 A	7.69 A
Open circuit voltage (V_{oc}) at NMOT	43.19 V	43.39 V	43.58 V	43.76 V	43.94 V
Short circuit current (I_{sc}) at NMOT	7.72 A	7.78 A	7.85 A	7.93 A	8.00 A
Temperature coefficient (P_{mpp})	- 0.3599%/°C				
Temperature coefficient (I_{sc})	+0.0430%/°C				
Temperature coefficient (V_{oc})	- 0.2765%/°C				
Nominal module operating temperature (NMOT)	44±2°C				
Maximum system voltage (IEC/UL)	1500V _{DC}				
Number of diodes	3				
Junction box IP rating	IP 67				
Maximum series fuse rating	15 A(≤345W), 20 A(≥350W)				

Source: (ZIM Skopje, 2021)

When it comes to the electrical specifications of the AstroSemi 350 Wp module, the above table is derived from the module datasheet. As indicated in the table above, the maximum power point (P_{mpp}) in the AstroSemi 350Wp photovoltaic module is 350 Wp, V_{mpp} 37.78 V, and I_{mpp} is 9.26 A. These values can be seen in the current-voltage and power-voltage curves below.

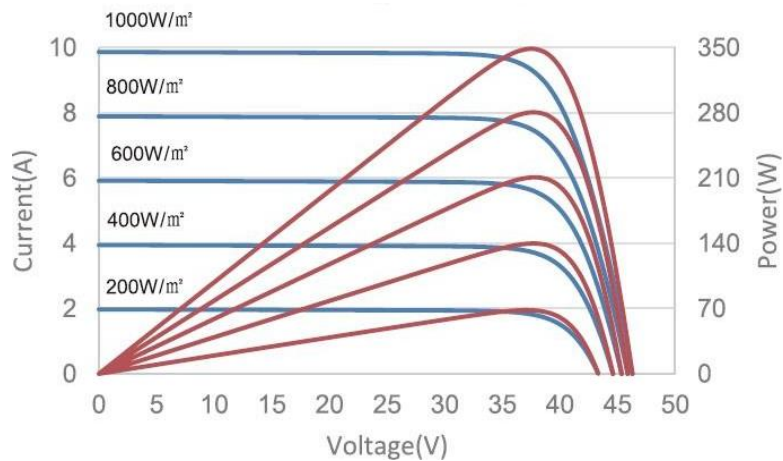


Diagram 1. Current-Voltage and Power-Voltage curves (355W)
Source: (JSC ZIM Skopje, 2021)

4 Trial operation of PVPP Oslomej 1

As of April 6, 2022, Photovoltaic power plant Oslomej 1 already started providing the first kilowatt-hours of electricity in the system, with which JSC ESM has officially expanded its portfolio of renewable sources, and now produces electricity from the sun in addition to wind energy.

The photovoltaic power plant is currently functional, it already uses the sun, which is abundant in this climate and contributes to the total daily production of JSC ESM.



Figure 3. View of PVPP Oslomej 1 with 10 MW installed capacity
Source: (JSC ESM, 2022b)

The total annual production of PVPP Oslomej 1 will amount to 15-17 GWh, enough for the needs of around 2800 households. PVPP Oslomej 1 is fully owned by JSC ESM. The construction of the power plant cost 7 million euros, part of which was own funds, and part of which was a credit line from the European Bank for Reconstruction and Development, which supports investments in renewable sources with favorable conditions (JSC ESM, 2022b).

For the period from 18.09.2022 until April 05, 2023 the production of electricity by PVPP Oslomej 1 in trial operation amounts to 5453651 kWh or 5.45 GWh (diagram 1). It is noticeable from the diagram that greater production was achieved in the period from 19.01.2023 until 18.02.2023 (1015455 kWh) as well as from 19.02.2023 until 18.03.2023 (1014988 kWh), while smaller production was achieved in the period from 19.11.2022 until 18.12.2022 (294499 kWh). The highest daily production was achieved on 01.02.2023 and amounts to 89751 kWh or 89.75 MWh, ie 0.089 GWh.

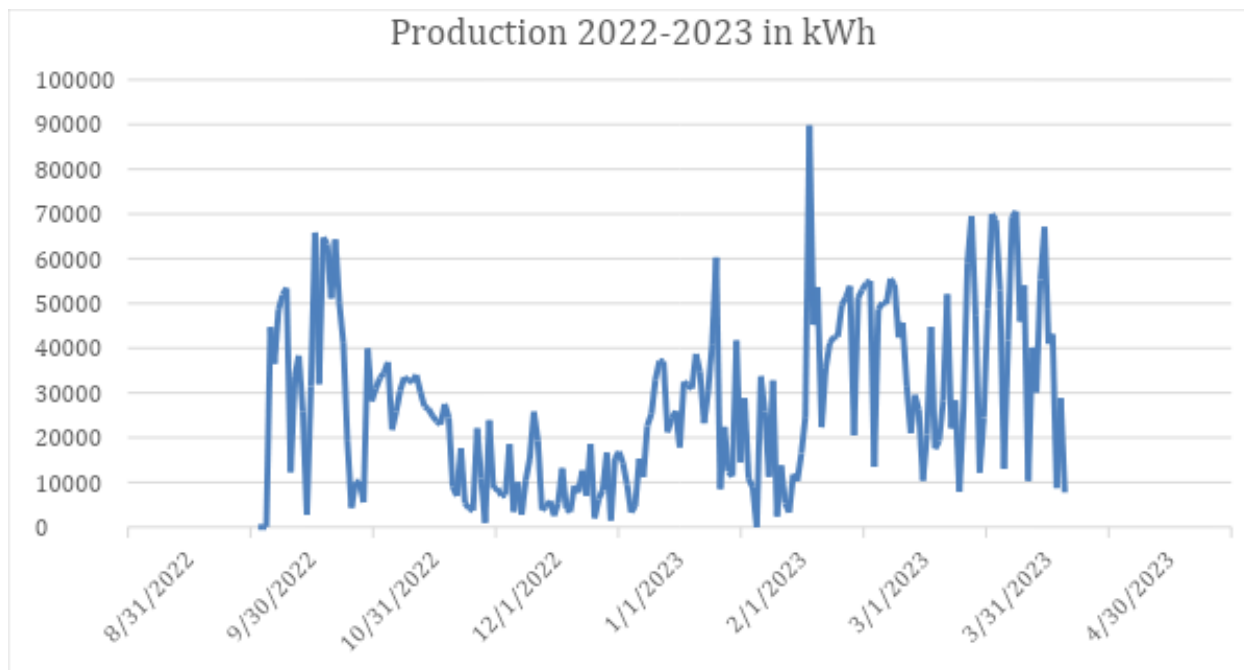


Diagram 2. Production 2022-2023 of PVPP Oslomej 1 [kWh]
Source: (PVPP Oslomej 1, 2023)

Conclusion

The paper is of great importance, because it deals with both the construction, as well as the trial operation of the first photovoltaic power plant PVPP Oslomej 1 with an installed power of 10 MW built in the Oslomej Mine, on the surface of the depleted coal. This photovoltaic power plant (PVPP) is the first state-owned power plant within JSC ESM and it represents the first example of energy transition in Southeastern Europe. This photovoltaic power plant is of great importance mainly for MPC Oslomej and for JSC ESM as a state-owned company that is a leader in the production of electricity in RNM, as well as a socially responsible company that follows the strategy for the development of energy in RNM until 2040.

This photovoltaic power plant (PVPP), which is already in trial operation, together with the other photovoltaic power plants that are under construction in MPC Oslomej, is of great and significant public interest, which consists of reducing local pollution, reducing greenhouse emissions gases, creation of green job opportunities, fair transition, increased production from renewable energy sources, meeting the goals for the participation of renewable energy sources in the gross final energy consumption, the electricity system as a whole, etc.

In this sense, of huge importance are also the other planned energy capacities from renewable energy sources (RES) in the ambitious investment program of JSC ESM, with which through investing in green energy we are getting closer to the technologically developed European countries and as a candidate country one step closer to integration in the European Union.

Nomenclature

EBRD-European Bank for Reconstruction and Development

GWh-Giga Watt Hour

JSC ELEM-Joint Stock Company Power Plants of North Macedonia

JSC ESM-Joint Stock Company Power Plants of North Macedonia

kWh-kilo Watt hour

MASA- Macedonian Academy of Sciences and Arts

MPC-Mining Power Combine

MWh-Mega Watt hour

MW-Mega Watt

PPCA-Powering Past Coal Alliance

PPP- Public Private Partnership

PVPP-Photovoltaic Power Plant

RES-Renewable Energy Sources

RNM- Republic of North Macedonia

TPP-Thermal Power Plant

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