UDK 633.17

PHOTOVOLTAIC POWER PLANTS IN AGRICULTURE

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An increase in greenhouse gas (GHG) emissions is a challenge for modern civilization [1]. World society increases the use of low carbon renewable energy to mitigate climate change. These kinds of energy show fast growth and absolute consumption [2]. However, currently, the transformation of world energy systems does not meet the requirements of the Paris Agreement [3].

The social-economic development expects an increase in second-generation biofuels and energy production from renewable energy, including solar power [4,5]. Annual power generated by solar photovoltaic (PV) needs to be in the range from 54 to 396 EJ to reach limiting warming (the 1.5 °C target by 2100) [5,6]. The development of bioenergy and PV requires the extent of land area. It can cause conflict with food production and, therefore, food security [7–8]. The solving of this problem requires using energy management planning. The use of abandoned cropland for creating renewable energy infrastructure is a promising solution to reduce competition for arable land.

Abandoned agricultural land can be used for ground-mounted PV panels. Due to a decline in specific installed PV system costs [2], solar power plants are expected to play a significant role in power supply systems. As to farmland, about 30% of its area is suitable for PV. There are a lot of studies concerning the utilization of land for solar energy.

This study hypothesizes that PV is more profitable and environmentally friendly compared to crop production in a semi-arid climate zone. The purpose of this study is an integral economic and environmental (carbon dioxide emissions) assessment of a PV power plant in farmland.

This study is based on the State Statistics Service of Ukraine, reports, research papers, actual prices, personal communication with stakeholders, etc. A semi-arid zone in the South of Ukraine (Mykolaiv province) is the subject of research.

The weather conditions in Mykolaiv region were as follows. Despite the significant fluctuation (from 240 to 750 mm), there was a drop in annual precipitation. Since 1970, it has decreased from 450 mm to around 380 mm in 2020 (or 12%). The average atmospheric temperature has increased from 9.6 °C to 11.25 °C. It constitutes 17%. These facts must be taken into account for PV projects.

Air temperature, solar irradiation, and wind speed are of significant fluctuation. These parameters impact the power generated by PV. In summer, the average daily air temperature did not exceed 30 °C. In winter, it dropped down to −17 °C. There is a significant fluctuation in sun irradiation due to weather conditions. It lowers the amount of power generated by PV. The average wind speed is less than 4 m/s. Therefore, wind cannot impact PV efficiency.

The global average levelized cost of electricity (LCOE) of PV power plants is decreasing. Since 2010, the average LCOE has decreased from USD 381/MWh to USD 57/MWh in 2020. In the same period, the global average LCOE of biomass-based electricity declined from USD 76/MWh in 2010 to USD 66/MWh in 2019. In 2020, India and China had the lowest LCOE (from USD 57/MWh to USD 60/MWh). The most expensive solar electricity is in Europe (USD 87/MWh) and North America USD 97/MWh.

In Ukraine (March 2021), the price for households was USD 62/MWh, and the price for businesses was USD 90/MWh. These prices were lower than the average prices in the world (USD 135/MWh and USD 124/MWh, respectively). The average leverized cost of electricity generated by Ukrainian power plants was as follows, USD/MWh: thermal power plants—79.4; nuclear power plants—21.0; hydropower—26.5. The feed-in tariff for solar power plants is EUR 109.7/MWh (since 2020 for the industry).

In Mykolaiv region, the solar field can reach a nominal capacity of 618 kWp/ha. Electricity generation is uneven during the year. The annual generation is around 769.8 MWh. The gross income from PV (82.37 thousand EUR/ha) exceeds one of crop production (up to USD1400/ha). Annual gross profit is around 63.8 thousand EUR/ha. The payback period exceeds 6 years. Its value has a strong dependence on the discount rate. Therefore, PV plants have higher profits compared to crop production.

The average emission factor of the Ukrainian power generation system is equal to 0.97 $kgCO_2$/kWh. Carbon dioxide emission for PV module production depends on its type. This value ranges from 170 $kgCO_2$/kWp (poly-crystalline) to 360 $kgCO_2$/kWp (mono-crystalline). In any case, the carbon dioxide payback period does not exceed one year. Crop production requires the use of fossil fuels, electricity, fertilizers, chemicals, etc. It results in carbon dioxide emissions. Its value depends on crop cultivar, practice, climate, etc. For most common crops, carbon dioxide emissions range from 500 to 3200 $kgCO_2$/ha. The figures reveal that sunflower growing has the smallest carbon dioxide footprint, and corn growing has the highest carbon dioxide emissions. Therefore, PV plants were less carbon dioxide footprints.

The sensitivity evaluation shows the following. If the discount rate is 0%, then the feed-in tariff has the greatest impact on the PI. Operational expenses have the lowest impact. An increase in the discount rate changes the situation drastically. Operational expenses remain the least sensitive variable. The feed-in tariff also has a significant influence on the PI.

Conclusions. Solar power generation may be an alternative for farmers. Currently, in Ukraine, a share of renewables and hydroelectricity is 10.7% of the total power generation. Solar power covers 29% of all renewables. Due to advanced technologies, there is a drop in the levelized costs of solar electricity. This fact and the growth of market electricity prices motivate a larger share of renewable power generation, including PV.

In Mykolaiv province, a solar field can have a capacity of 618 kWp and an annual generation of 794.87 MWh. Having sold green electricity (by feed-in tariff), stakeholders can get up to 82.37 thousand EUR/ha. It exceeds revenue from crop

cultivation. The profitability index ranges from 1.26 (if a discount rate is 10%) to 3.25 (if a discount rate is 0%). The payback period varies from 6 to 12 years. It depends on the discount rate.

Carbon dioxide footprints of crop production range from 500 to 3200 $kgCO_2$/ha. Corn cultivation has the most emissions. Unlike crop production, PV power plants do not emit greenhouse gases during their operation.

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