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ANALYSIS OF THE IMPLEMENTATION OF INDIVIDUAL PHOTOVOLTAIC SYSTEMS IN UKRAINE: TECHNOLOGIES, CHALLENGES AND PROSPECTS

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Abstract. *The article reviews modern technologies for increasing the integration of photovoltaic systems, prospects and challenges for owners of local photovoltaic plants. Examples of problems with reducing electricity generation due to limitations in the capacity of photovoltaic plants are given. Modern trends in the implementation of balcony photovoltaic systems in the European Union countries are analyzed in the context of climate policy and decentralized energy generation. The technical and economic advantages of such installations are considered, in particular, their growing popularity among the urban population and the relevance of auto-consumption in the context of decreasing "green" tariffs. The emphasis is on the need for regulatory and legal regulation of this segment in Ukraine, taking into account international experience. The feasibility of following the experience of European countries in attracting investments in the energy sector, the need for changes in legislation and new incentives for the population are demonstrated.*

Key words: *photovoltaic system, efficiency, power limitation, balcony photovoltaic stations, legislation, direct current.*

Introduction.

Historically, photovoltaic (PV) systems have been regarded as an attractive investment tool, primarily due to the opportunity to sell surplus electricity at feed-in tariffs. However, in recent years, feed-in tariff rates have significantly declined across the European Union, and in Ukraine, they have been effectively frozen. As a result, the focus has shifted toward self-consumption, as the cost of self-generated solar electricity currently amounts to only about one-third of the retail electricity price from conventional suppliers (approximately €0.10 per kWh). Consequently, maximizing the share of self-consumption has become a key factor in the economic viability of residential PV systems.

Main text.

The development of renewable energy sources is a strategic priority within the European Union as part of the implementation of the European Green Deal and long-term climate policy aimed at achieving carbon neutrality by 2050. In this context, Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (RED II) supports decentralized electricity production, particularly by encouraging microgeneration at the household level.

To enhance the integration of photovoltaic (PV) systems, researchers are exploring advanced technologies and innovations in PV system architecture, including the use of perovskite materials, tandem solar cells, quantum dots, bifacial modules, flexible PV elements, and transparent solar cells [1].

In [2], the authors present various classifications of innovation pathways in photovoltaics. These include decentralized systems, integration with other energy systems (such as grid-connected battery storage and electric vehicles), increased self-consumption of energy, the development of novel high-efficiency materials, building-integrated photovoltaic (BIPV) solutions, and the application of artificial intelligence for system operation and management.

Among the key barriers to further increasing the share of photovoltaic (PV) systems in power grids are the lack of large-scale energy storage capacity, high variability in generation, technical limitations on installed capacity, and the necessity for accurate forecasting of electricity production [3].

Large grid-connected solar power plants often face curtailment by system operators due to excess electricity generation in the network. Similarly, local hybrid PV systems equipped with batteries (operating without a generation permit from the grid operator) may experience limitations in generation once the battery reaches 100% charge. As an example of potentially low generation efficiency on certain days, we present generation/consumption graphs for a 30 kW hybrid photovoltaic system installed at a university. On weekends, when campus energy consumption is low, the PV system ceases generation after 12:00 PM, once the battery is fully charged, and no additional energy demand is present.

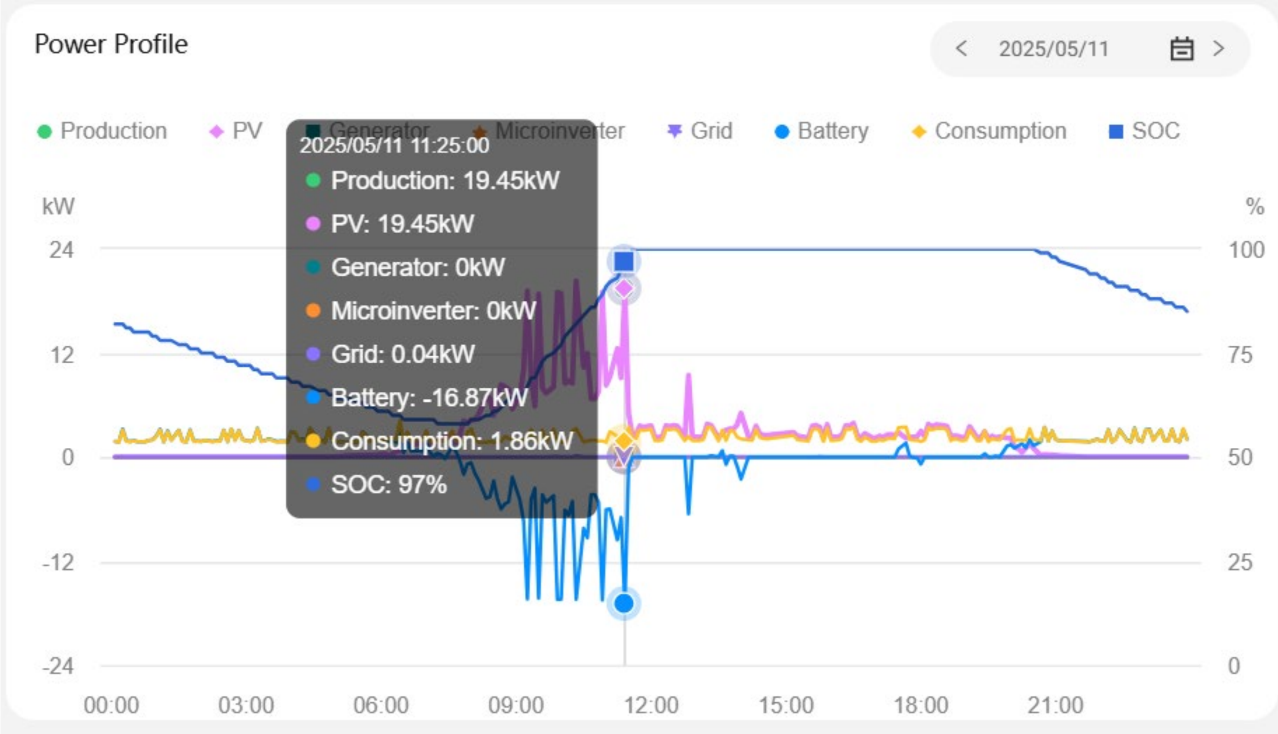

Figure 1 - Example of limiting electricity generation after battery charging

A source: Deye.Cloud https://www.deyecloud.com/

The further development of photovoltaic (PV) systems is not feasible without the integration of local power generation units, the implementation of direct current (DC) system architectures that eliminate the need for conventional inverters, and the widespread adoption of small-scale residential installations, particularly balcony solar systems [4].

The absence of legal and regulatory frameworks remains a major barrier in many countries. Ukrainian legislation, for instance, lacks definitions and provisions governing small-scale local generation sources such as balcony PV systems.

There is no clear mechanism for the registration or grid connection of such systems, nor are there simplified requirements for small generators similar to those established under the EU RED II Directive. In some cases, distribution companies have considered such connections as violations of network usage rules. Despite being technically feasible, this lack of regulatory clarity significantly hampers large-scale adoption.

In countries such as Germany, Austria, France, and Italy, it is permitted to install balcony photovoltaic systems with a capacity of up to 600–800 W without the need for formal permitting procedures. In most cases, it is sufficient to notify the grid operator or complete a simple online registration. Financial incentives such as subsidies and tax benefits are also available. These supportive measures have encouraged tens of thousands of households, including those in multi-apartment buildings, to install their own solar panels.

Given the high cost of electricity, balcony PV systems offer significant potential, particularly in urban areas. However, realizing this potential requires appropriate legal frameworks that recognize small-scale systems (up to 1 kW), permit straightforward connection to the internal electrical network without complex design approvals, and introduce simplified registration or voluntary reporting mechanisms. Additionally, government support through cost-sharing schemes or subsidies could further accelerate adoption.

Given the high cost of electricity, the deployment of balcony photovoltaic systems holds significant potential, particularly in urban areas. However, realizing this potential requires the legal recognition and regulation of small-scale systems (up to 1 kW), the allowance of simple plug-in connections to internal household networks without complex project documentation, the establishment of a streamlined registration or voluntary reporting mechanism, and consideration of financial incentives—such as partial cost compensation.

Balcony PV systems represent a realistic and cost-effective pathway toward energy independence for urban residents, especially in the context of rising electricity tariffs. Nonetheless, unlocking this potential necessitates urgent legislative action aligned with best practices and regulatory frameworks established in the European Union.

In response to the provisions of the directive, several EU Member States—including Germany, Austria, France, and the Netherlands—have adapted their national legislation to simplify the integration procedures for small photovoltaic (PV) installations into the grid, particularly for so-called "plug-and-play" balcony systems.

These balcony PV systems are experiencing rapid growth in popularity, driven by several key factors. First, they offer an affordable solution for residents of multi-apartment buildings who lack the option to install rooftop systems. Second, such installations are characterized by a high level of simplicity in deployment—they can be connected directly to the internal household grid without complex technical approvals, and in some cases, even without prior notification to the distribution system operator. Third, in the context of the ongoing energy crisis and rising electricity prices, an increasing number of consumers are seeking to enhance their energy autonomy and reduce electricity costs.

Figure 2 presents one of the tools available on the German market for estimating the performance of small PV systems.

Figure 2 - Input data for the grid-connected solar power system simulator

A source: https://solar.htw-berlin.de/rechner/stecker-solar-simulator/

To analyze the payback period of a balcony photovoltaic (PV) system under Ukrainian conditions, a basic model comprising two PV modules with a total capacity of 800 W is considered. The system's specifications are as follows: nominal capacity – 800 W (0.8 kW); average cost – approximately €500; exchange rate – ~47 UAH/€

(subject to change); average electricity price in Ukraine – 4.32 UAH/kWh.

A corrected chart is presented comparing the monthly electricity generation of an 800 W balcony PV system with the average monthly electricity consumption of a typical Ukrainian apartment (ranging from 100 to 200 kWh/month). In the figure, green bars represent PV generation, the red dashed line denotes the average consumption level (~150 kWh/month), and the orange lines indicate the lower and upper bounds of typical consumption (100–200 kWh). As observed, the PV system does not fully cover household electricity needs; however, during the summer months, it can offset approximately 60–80% of average consumption.

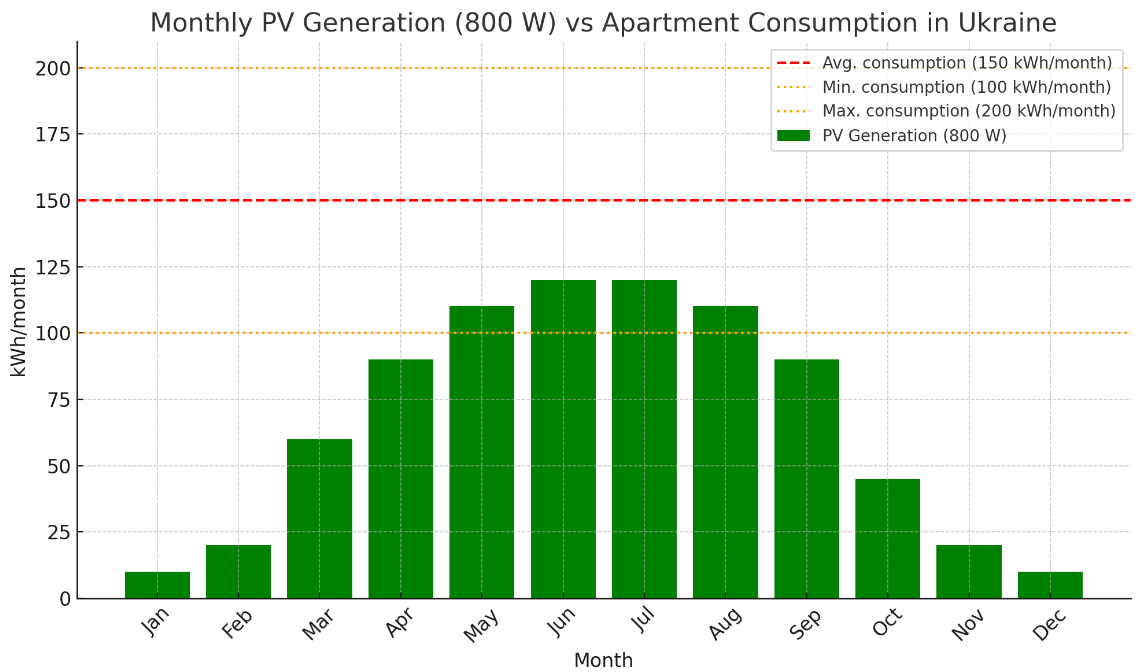

Figure 3 - Comparison of generation schedules of balcony PV plants and consumption by standard households in Ukraine

A source: Author's development

A balcony system with a capacity of 800 W is capable of generating ~816 kWh per year in Ukrainian conditions. Even at the current tariff (4.32 UAH/kWh), the payback period of a balcony system is only about 5 years. If the tariff increases, which is likely due to market liberalization or reduction of subsidies, the payback period may decrease to 3.5 or even 2.6 years. After that, the system generates net savings of more than 3–7 thousand UAH/year for another 15–20 years. connection to existing networks

Balcony PV systems (so-called plug-and-play or plug-in systems) are connected via a household outlet to the internal network of the apartment. This allows you to power devices without complex changes to the electrical system of the house. In Germany, for example, such systems up to 800 W are allowed to simply be registered without permits, and they automatically reduce consumption from the network. In Ukraine, this practice is not yet legally regulated.

The market share of balcony photovoltaic systems is expected to continue to grow, driven by technological improvements (including improved module efficiency and aesthetics), the gradual decline in equipment costs, and increased government support in the form of financial incentives, tax breaks, and simplified regulatory procedures. An additional incentive is increased public awareness of climate change and the need to transition to a low-carbon economy.

Summary and conclusions.

1. The study reviewed the current state of development of balcony photovoltaic systems in the European Union countries, taking into account legislative initiatives within the framework of the RED II Directive and the implementation of the European Green Deal. The technical and economic prerequisites for the spread of microgeneration, in particular in urban environments, were analyzed.

2. Based on current market data, the annual electricity generation of a balcony PV system with a capacity of 800 W for the climatic conditions of Ukraine was calculated and its payback period was determined at current and forecasted electricity tariffs. A comparative schedule of PV system electricity generation and average household consumption was constructed, which allowed assessing the potential for self-consumption. The main barriers to the implementation of such systems in Ukraine were outlined and the prospects for their development were formulated subject to the improvement of the regulatory framework.

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