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DO WE NEED ECONOMIC STIMULATION OF SOLAR ENERGY DEVELOPMENT IN HOUSEHOLDS? COMPARATIVE ANALYSIS OF UKRAINE AND LATVIA

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Introduction. Renewable energy (RE) is an integral part of energy development programs in many countries worldwide. In 2019, in the document "A European Green Deal," the European Union (EU) declared an ambitious goal to achieve carbon neutrality by member states by 2050. RE sector deployment was defined as one of the leading directions to reach this target [8]. Ukraine also seeks to contribute to achieving the goals of the Green Deal in the framework of European integration. To this end, the country has developed the Roadmap for Carbon Neutrality in the context of its international obligations. The tasks of the National Roadmap include an increase in the energy efficiency of buildings, the energy sector liberalization, green energy technologies dissemination, integration of the United Energy System of Ukraine with the EU market, etc. [3]. In addition to reforms in the energy and construction sectors, performing these tasks requires changes in households' energy supply and consumption, such as shifting to the predominant use of RE sources and the implementation of energy-efficient measures to ensure the population's livelihood.

The advantages of using green energy technologies in the residential sector are energy costs reduction, rising energy independence, energy source decentralization, increasing environmental friendliness of energy generation and consumption, the possibility of obtaining additional profits from selling energy surpluses, and others. The importance of energy-efficient changes in the housing sector is due to the fact that it consumes about 40% of all energy consumed by national economies [13].

Analysis of recent research sources and publications. Many scientists have studied the problems of RE development, including in the household sector. The use of data analysis tools in Scopus and Web of Science databases has revealed current research trends in this area. Figure 1 presents the quantitative analysis of publications on the keywords "renewable energy" and "household" in these databases for 2011-2020. As seen from the figure, the annual volume of articles on RE has grown steadily in the last ten years, especially in 2016-2019. It indicates an increasing interest of scientists in green energy issues and the relevance of research in this area.

The leading countries with the highest number of publications on the RE topic are the United States, Germany, China, India, and the United Kingdom. Figure 2 shows the distribution of articles by fields of knowledge according to the Scopus database. As shown in the figure, the share of economic publications during 2011-2020 was 5.8%, decreasing to 5.4% in 2016-2020. Over the last ten years, the largest number of studies concerned energy (28.0%), engineering (19.5%), and environmental sciences (14.1%). The share of economic articles on household RE issues is slightly higher, according to the Web of Science database. It amounted to 10.6% in 2011-2020 and 9.5% in 2016-2020. However, like in the Scopus database, energy, engineering, and environmental sciences remain the leading research areas on green energy in households.

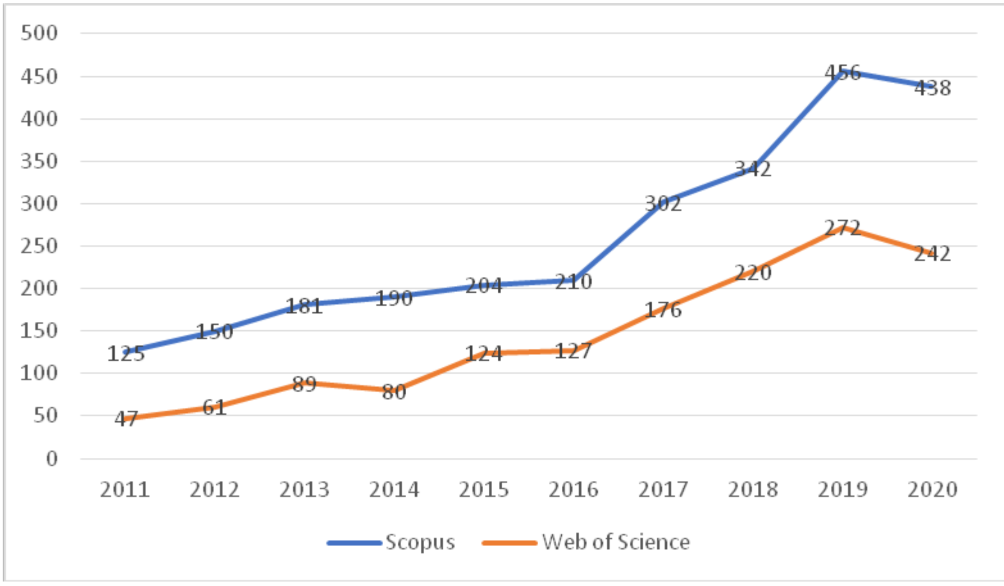

Fig. 1. Number of published articles on household RE issues in Scopus and Web of Science databases (compiled by the author according to Scopus and Web of Science databases)

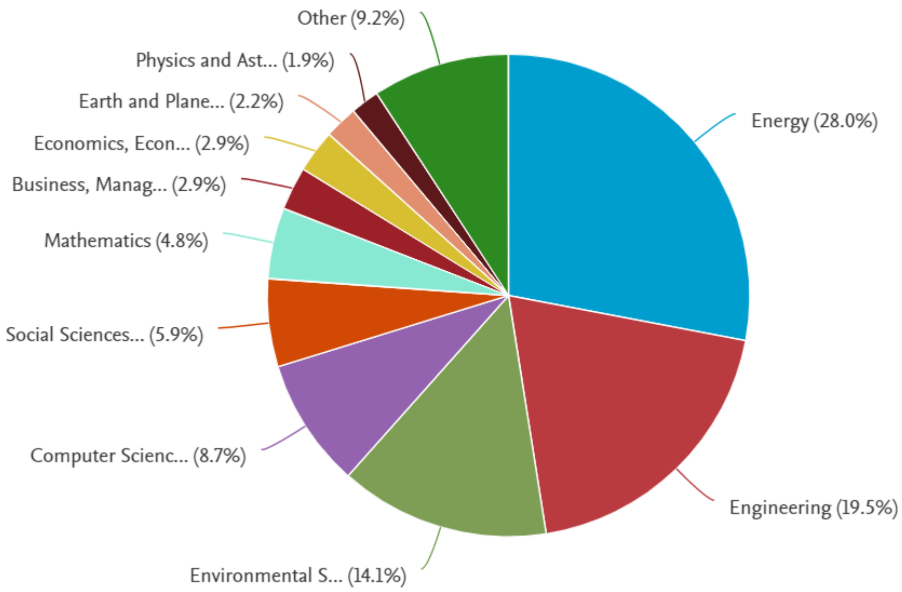

Fig. 2. Distribution of publications on RE issues in households by research areas in 2011-2020 (according to the Scopus database)

The need to create a technical base for implementing RE projects in the residential sector explains the predominant number of technical publications in the field. With the green energy technologies development, the issues of their implementation in business and household practices, effective management of these processes to ensure the decarbonization of national economies, and the energy independence growth are becoming more acute. Therefore, it is currently relevant to research the application of economic mechanisms to stimulate RE development in the housing sector.

Given the immaturity of most RE technologies, many countries worldwide introduce government support for the industry deployment. It helps make green energy competitive in the market and ensures the achievement of national targets for RE advancement. As a rule, the governments use feed-in tariffs in the initial stages of green energy development [5; 6; 14; 20; 27; 35]. As the RE capacity increases, the mechanisms of green auctions, green energy quotas, the formation of a market for green certificates, preferential investment in the RE, etc. are applied in the industry [1; 4; 11; 12; 17; 31; 34; 35]. Under favorable climatic conditions, countries usually install feed-in tariffs for solar (SPPs) and wind power plants (WPPs) of low capacity in the household sector. It is because these technologies set minimum requirements for installation, operation, and maintenance of power plants compared to other types of RE sources [10; 19; 21; 29; 30]. As the share of green energy increases, feed-in tariffs become a burden for the state budget and end-users, and there is a need to move to other mechanisms to stimulate RE [2; 6; 22; 23]. In addition, advances in green energy generation technologies, including solar and wind, significantly reduce its cost over time [16]. Therefore, questions about the feasibility of keeping the high feed-in tariffs and continuing to stimulate RE technologies in general require further research.

The purpose of the article is to substantiate the need for state support of households implementing RE projects, based on the analysis of experience and evaluation of the effectiveness of solar energy development in the residential sector of Ukraine and Latvia.

Research results. Even though Latvia is a northern country, it has solar energy potential, which allows successful deployment of this RE industry on a par with Ukraine. The average annual insolation for Latvia is 1000-1200 kWh/m^2, while for Ukraine is 1070-1400 kWh/m^2 [15; 24]. In Latvia, the photovoltaic panels provide the maximum electricity generation from April to September, while in Ukraine – from April to October. The advantage of the Latvian climate is cooler summer temperatures, which help avoid overheating of solar modules and increase electricity generation in summer.

Latvia significantly depends on fossil fuels, importing up to 45% of the required energy resources (mainly natural gas) [7]. Ukraine also has energy problems, buying 50% of natural gas from its own needs abroad [26]. Both countries actively develop renewables through economic incentives, but Latvia prefers hydropower, biomass, and wind, while Ukraine focuses on advancing solar and wind, hydro, and bioenergy. As for the housing sector, both former Soviet republics have outdated and energy-inefficient housing stock, which mostly has not been renewed for decades due to lack of investment. Ukraine and Latvia are characterized by population energy poverty due to high utility prices, relatively low incomes, and energy-intensive housing. Therefore, improving energy efficiency and RE development in households is extremely important for both states.

Historically, both countries have initially chosen feed-in tariffs to stimulate the deployment of national green energy sectors. Latvia introduced feed-in tariffs for small hydropower plants in 1995. In 2010, they were extended to facilities generating electricity from hydropower, biomass, biogas, wind energy, and cogeneration technologies that included natural gas combustion. In 2019, the operation of the feed-in tariffs was temporarily suspended and canceled altogether for new installations. In 2020, the government introduced a new mechanism of the Mandatory Procurement Component. It provides funds for purchasing green energy from its producers by including green power in the electricity tariff structure [18].

During the whole period of RE development, solar energy in Latvia received almost no state support, and today its share in the total electricity mix is less than 0.05% (3 mln kWh in 2019) and less than 0.1% among other RE sources [7; 9]. The only weak incentive for households with photovoltaic SPPs is the possibility of selling green electricity surpluses to the local grid at a much lower price than the price of electricity for consumers. One more advantage is the exemption from paying part of the tariff for electricity consumed within the net metering system. Lately, Latvian society popularizes photovoltaic SPPs' installation in the residential sector to reduce household energy costs. These ideas are actively supported by engineering companies that supply SPPs' equipment, banking institutions that offer special loans for RE projects, and energy supply companies that, in addition to performing energy supply functions, provide consulting services in the energy efficiency field. However, given the high prices for SPPs' equipment imported to Latvia and the long payback period of the projects, the population is in no hurry to invest in solar energy.

Ukraine introduced feed-in tariffs for the business sector in 2009 and applied them to the electricity generated by solar, wind, small hydro, and biopower plants. In 2014, feed-in tariffs were extended to household photovoltaic SPPs and WPPs [32]. Today Ukrainian feed-in tariffs are the highest in Europe. They caused a boom in the RE industry of the country. As the most attractive tariffs are for SPPs, both the business and residential sectors accelerated building solar energy capacities [28; 29]. As of the end of 2019, the total number of photovoltaic SPPs in Ukrainian households was 21,968, while at the end of 2020 – 29,931 or 36% more. The installed capacity increased from 553 MW in 2019 to 779 MW in 2020, or 40.9%. The volume of electricity sold by household photovoltaic SPPs at feed-in tariffs increased from 282 mln kWh in 2019 to 733 mln Wh in 2020, or 2.6 times [25]. During 2016-2020, green electricity generation by household photovoltaic SPPs increased 244.3 times. These results indicate the effectiveness of the applied economic incentives for RE development in the residential sector.

However, several problems accompany such a rapid growth of green energy facilities in Ukraine. In 2020, with the 8%-share of green electricity in the total energy mix, feed-in tariff payments amounted to 26% of the national energy market money turnover [33]. As a result, the Ukrainian government has limited payments for feed-in tariffs and plans to reduce their rates in the coming years gradually. Feed-in tariffs should be brought in line with actual energy generation costs based on the global trends in the RE technologies' cost. In addition, the deployment of mainly SPPs causes disparities in the types of RE sources developing in the country. Moreover, it exacerbates the problems of improving energy infrastructure to increase grid capacity, raises the issue of creating balancing capacity to ensure the stable operation of the United Energy System of Ukraine, etc.

Thus, as follows from the above, the use or lack of economic incentives for the solar energy advancement in the residential sector has pros and cons. The SWOT analysis of the effectiveness of the household photovoltaic SPPs' development in Ukraine and Latvia is given in Tables 1 and 2.

Table 1

SWOT analysis of the effectiveness of the households photovoltaic SPPs' development in Ukraine

Economic incentive type	*Feed-in tariff*
Strengths - rapid increase in electricity generation by small photovoltaic SPPs, the overall growth of the RE share in the country's energy mix; - generation of environmentally friendly energy; - fulfillment of Ukraine's international obligations to achieve the RE share in the energy mix and reduce the carbon intensity of the national economy; - increase in the RE sector employment; - independence of households from fluctuations in electricity prices; - energy independence growth of households and the country as a whole; - increase in incomes of citizens who are owners of small photovoltaic SPPs and decrease in their utilities' expenses due to selling green electricity at feed-in tariffs; - stimulation of the local economy's development by investing in small photovoltaic SPP projects; - growth of the housing stock market value.	***Opportunities*** - achievement of household energy autonomy due to the accumulator equipment installation or use of RE technologies combination; - development of energy supply decentralization processes, reduction of expenses for maintenance and construction of energy infrastructure; - achievement of the country's carbon neutrality in the future, increase in clean energy generation, environmental problems solution; - increase of investments in the national RE industry, employment growth in the sector; - energy poverty reduction; - adjustment of feed-in tariff rates to the actual costs of electricity generated by household photovoltaic SPPs while ensuring normal profits to green energy facilities' owners.
Weaknesses - instability of electricity generation from solar energy that worsens the balancing of the United Energy System of Ukraine; - increasing burden on the state budget and rising weighted average prices of electricity due to high feed-in tariffs; - deepening energy poverty since only wealthy households can afford investments in RE facilities; - lack of available lending programs for the small photovoltaic SPPs' construction at a low-interest rate; - disparities in solar energy development compared to other RE types; - reduction in feed-in tariff rates planned by the government that decreases the investment attractiveness of small photovoltaic SPPs; - the need for reconstruction and expansion of energy infrastructure to increase the power grid capacity and feed the green electricity to the grid; - long payback periods of RE projects in households.	***Threats*** - the emergence of a green electricity payments collapse while maintaining inadequately high feed-in tariff rates; - loss of investor trust due to the changes in state payments for the feed-in tariff, curtailment of RE projects in the country; - increase in the payback periods of small SPPs' projects due to the feed-in tariff reduction/cancellation; - high inflation and legislative risks; - deepening energy poverty of the population under the growth of the weighted average price of electricity caused by high feed-in tariffs and lack of accessible funds for investment in RE projects; - risks of accidents in the United Energy System of Ukraine due to deterioration of the capacities' balance and power grids overload; - worsening environmental situation due to involving maneuvering capacities of thermal power plants in balancing the United Energy System of Ukraine; - underdevelopment of other RE types due to the predominant solar energy deployment.

Table 2

SWOT analysis of the effectiveness of the households photovoltaic SPPs' development in Latvia

Economic incentive type	*net metering*
Strengths - decrease in household utilities' expenses due to the green electricity generation and subsequent consumption, the opportunity not to pay the tariff part for electricity consumed within the net metering system; - increase in incomes of citizens who are owners of small photovoltaic SPPs due to selling green electricity surpluses to the grid; - generation of environmentally friendly energy; - independence of households from fluctuations in electricity prices; - energy independence growth of households; - stability of the economic situation and electricity prices, which reduces the risks of small RE projects in the residential sector; - absence of financial burden on the state budget; - absence of local power grids' overload due to small volumes of green electricity fed by household photovoltaic SPPs to the grid; - availability of lending programs for the small photovoltaic SPPs' construction at a low-interest rate; - growth of the housing stock market value.	***Opportunities*** - slow development of energy supply decentralization processes, reduction of expenses for maintenance and construction of energy infrastructure; - energy poverty reduction, increasing energy independence of households; - slow increase in the share of household clean energy generation; - stimulation of the local economy's development by investing in small photovoltaic SPP projects; - slow solar energy market deployment in the country.
Weaknesses - insufficient use of the existing solar energy potential of the country; - lack of a significant contribution of household photovoltaic SPPs in fulfilling the country's obligations to achieve the RE share target and reduce the carbon intensity of the national economy; - sale of green electricity surpluses by households to the local grid at a much lower price than the purchase price of electricity; - long payback periods of SPPs' projects in households, lack of incentives to invest in solar energy facilities; - high investment costs for household photovoltaic SPPs compared to other EU countries; - the need to import equipment for small photovoltaic SPPs in the country.	***Threats*** - very slow implementation of the existing solar energy potential of the country, preservation and possible deepening of disparities in the solar energy development compared to other RE types; - risks of increasing the instability of the integrated power system due to local power grids' overload when connecting new household photovoltaic SPPs; - the need for reconstruction and expansion of energy infrastructure to increase the power grid capacity and feed the green electricity to the grid; - lack of equipment for small photovoltaic SPPs of domestic production; - almost invisible contribution to the achievement of national goals of the economy's decarbonization.

Conclusion. Feed-in tariff in Ukraine allowed ensuring a significant increase in the RE share in the country's energy mix, involving households photovoltaic SPPs. However, its application has significant drawbacks, which question the feasibility of using this instrument in its current form and in the future (see Table 1). In contrast, the net metering system operating in the Latvian residential sector does not have a noticeable positive impact on implementing the existing solar energy potential (see Table 2). It indicates the inefficiency of the applied economic lever. Therefore, both countries need to improve the state support mechanisms for the industry.

In particular, to interest the population in SPPs' construction, Latvia should exempt households from paying part of the tariff for consumed electricity, which is currently used within the net metering system, and include solar energy in the Mandatory Procurement Component. It will strengthen the economic incentives for the small photovoltaic SPPs' development and create a financial base to increase the households' income from green electricity surpluses fed to the grid. However, the tariff growth for supplied green energy and including SPPs in the Mandatory Procurement Component must be justified so as not to significantly raise the final weighted average electricity price in the country. On the one hand, the increase in tariffs should be sufficient to reduce the payback periods of small photovoltaic SPPs to an acceptable 5-7 years. On the other hand, it should interest the owners of green energy facilities in decreasing their energy expenses, rather than selling generated electricity for profit. Another way to increase the RE projects' attractiveness is to introduce a favorable investment policy. The latter will ensure the reduction of prices for SPPs' equipment in the domestic market by cutting import duties and encouraging the development of such equipment domestic production. It will decrease the household investment costs while shortening the payback period of projects. An important measure is a state preferential financing of RE projects using subsidies that partially compensate the investment costs of households. Given that solar energy is not a priority for Latvia, no one can expect a rapid boom in the photovoltaic SPPs' construction under the implementation of the provided recommendations. However, these measures can contribute to the growing public interest in small SPPs' investing and changes in energy consumption structure in households while turning them into prosumers. At the same time, it is possible to avoid financial and energy system problems due to high feed-in tariffs like in Ukraine.

Regarding Ukraine, in our opinion, the feed-in tariffs' revision is the first step towards improving the state policy in the national RE sector. It is necessary to bring tariffs in line with the actual price of energy generation based on global trends of RE technologies' cost reduction and normal investor profit. For keeping investors' trust, it is advisable to apply new feed-in tariffs only to new RE projects and preserve high feed-in tariffs for operating facilities since they previously received the tariff frozen until the end of 2029. On the one hand, doing this will be quite expensive for the state. On the other hand, it will ensure social justice in society and trust in government actions. In the future, given the steady trend of cheapening green energy, it is necessary to make a gradual transition from feed-in tariff policy to other support mechanisms. Like in Latvia, one of the key problems of the population is the lack of accessible funds to invest in SPPs. Therefore, the government should introduce preferential financing for investments in household photovoltaic SPPs by providing state compensation for small solar energy projects on the model of the popular Ukrainian "warm" loans program. Due to disparities in the solar energy advancement in the country's residential sector, greater financial support should be given to small RE projects involving wind farms. Moreover, household bioenergy facilities should be added to the list of RE technologies supported by the state. A significant advantage of Latvia is economic stability, which reduces the risks of implementing RE projects in the housing sector. Therefore, Ukraine should develop and steadily implement anti-crisis measures in the national economy. Consistent implementation of the provided recommendations will ensure the balanced deployment of RE technologies in the residential sector and help solve industry's systemic problems.

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Сотник Ірина Миколаївна, доктор економічних наук, професор. Сумський державний університет. **Чи потрібне економічне стимулювання розвитку сонячної енергетики у домогосподарствах? Порівняльний аналіз України та Латвії. О**бгрунтовано доцільність державної підтримки домогосподарств, що реалізують проєкти з відновлюваної енергетики. Проаналізовано досвід і результати застосування «зеленого» тарифу для розвитку сонячної енергетики у домогосподарствах України. Для порівняння оцінено результативність розбудови геліоенергетики у житловому секторі Латвії, яка має схожий потенціал галузі й застосовує систему чистого вимірювання як механізм економічного стимулювання. Виявлено, що використання високих ставок «зеленого» тарифу в Україні забезпечило стрімке зростання сонячних енергопотужностей у домогосподарствах. Так, за 2016–2020 роки виробництво «зеленої» електроенергії сонячними фотогальванічними електростанціями у житловому секторі зросло у 244,3 раза. Водночас, система чистого вимірювання не здійснює помітного впливу на розбудову геліоенергетики в латвійських домогосподарствах. У 2019 році частка електрики з енергії сонця в загальному електробалансі балтійської країни складала менше 0,05% та менше 0,1% серед інших «зелених» енергоджерел. Система чистого вимірювання в Латвії передбачає можливість збуту надлишково виробленої й не спожитої домогосподарством «зеленої» енергії в локальну електромережу за набагато нижчим тарифом, ніж середня ціна електроенергії для населення. Це збільшує строки окупності малих сонячних електростанцій до 20 років, демотивуючи домогосподарства до інвестування у відновлювану енергетику. Незважаючи на вражаючі результати зростання малих «зелених» енергопотужностей, щедрий «зелений» тариф в Україні створив непомірне фінансове навантаження на державний бюджет, загострив проблеми балансування енергопотужностей та збільшення пропускної здатності електромереж, диспропорції у розвитку різних видів відновлювальних енергоджерел. Натомість система чистого вимірювання, не забезпечуючи значного зростання потужностей геліоенергетики в домогосподарствах, дозволила уникнути проблем, характерних для України. На основі проведеного SWOT-аналізу двох розглянутих інструментів економічного стимулювання розроблено рекомендації для коригування механізмів державної підтримки з метою збалансованого розвитку малої сонячної енергетики у житловому секторі обох держав.

Ключові слова: відновлювані джерела енергії, домогосподарство, SWOT-аналіз, «зелений» тариф, система чистого вимірювання, ефективність, сонячна енергетика.

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Iryna Sotnyk, D.Sc. (Economics), Professor. Sumy State University. **Do We Need Economic Stimulation of Solar Energy Development in Households? Comparative Analysis of Ukraine and Latvia**. The article substantiates the expediency of state support for households implementing renewable energy projects. The experience and results of the feed-in tariff application for the solar energy development in Ukrainian households are analyzed. For comparison, the effectiveness of the solar energy deployment in the residential sector of Latvia, which has a similar potential of the industry and uses net metering as an economic incentive, is estimated. It was found that the use of high feed-in tariffs in Ukraine has provided a rapid increase in household solar energy facilities. In 2016-2020, the green electricity generation by photovoltaic solar power plants in the residential sector increased 244.3 times. At the same time, the net metering system does not have a significant impact on solar energy advancement in Latvian households. In 2019, the share of electricity from solar energy in the total electricity mix of the Baltic country was less than 0.05% and less than 0.1% among other green energy sources. Net metering in Latvia provides for the possibility of selling household green energy surpluses to the local grid at a much lower price than the average price of electricity for the population. It increases the payback period of small photovoltaic solar power plants up to 20 years and more, discouraging households from investing in renewable energy. Despite the impressive growth of small green energy capacities, the generous feed-in tariffs in Ukraine have created an excessive financial burden on the state budget, exacerbated the problems of balancing national energy system and increasing the power grid capacity, sharpened disparities in the development of various types of renewable energy sources. Instead, the Latvian net metering system, without providing a significant increase in household solar energy capacity, avoided the problems typical for Ukraine. Based on the SWOT analysis of the two national economic instrument sets for solar energy deployment, the article develops recommendations for adjusting the state support mechanisms for the effective advancement of small solar energy facilities in the housing sector of both countries.

Keywords: renewable energy, household, SWOT analysis, feed-in tariff, net metering, efficiency, solar energy.