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PROSPECTS OF INVESTMENT IN GREEN ENERGY PROJECTS IN UKRAINIAN HOUSEHOLDS[1]

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Introduction. Renewable energy (RE) is a modern promising direction for the development of national energy complexes, decarbonization of economies, the growth of the energy security of countries as well as the creation of new jobs. This industry is extremely attractive for investment on a global scale and today it is experiencing a real investment boom in rapidly developing countries. Thus, in 2017 according to [1] 157 GW of new green power capacities were put into operation in the world, compared to 70 GW, based on burning fossil fuels, that is, 2.24 times more. Thanks to the generation of electricity based on renewable energy sources (RES), it was possible to reduce global CO_2 emissions by 1.8 Gtons in the same year. In 2017, investment on a global scale amounted to 279.8 billion USD and 45.2% of them were invested by China.

Since 2015 there has been a steady downward trend in financial flows into the RE sector in developed countries and their growth in developing economies. In particular, in 2017 the share of investments of developed countries into RE was 37% against 63% of developing countries. As in previous years, in 2017, the prices for equipment for RE facilities continued to fall. For example, in the sector of solar power, the cost of generating 1 MWh decreased by 15% compared with 2016, and compared with 2009 - by 72%, which was due to both a decrease in capital costs and an increase in the efficiency of solar installations. 10.3 million people were employed in the global green energy sector, which is 5.3% more than in 2016 [1, 2]. These dynamic indicators of RE development show that this industry is gradually becoming an important sector of national economies, acquiring strategic importance. In addition, solar energy occupies a leading position in most countries of the world.

[1] The publication contains the results of research carried out within the framework of research works of the Ministry of Education and Science of Ukraine "Organizational and economic mechanisms for stimulating renewable energy development in Ukraine" (No. 0117U002254) and "Innovation management of energy efficient and resource saving technologies in Ukraine" (No. 0118U003571).

For Ukraine, the issue of RE development is extremely relevant in view of energy (increase in energy independence), economic (reduction of energy resources import costs), environmental (reduction of environmental pollution) and social (improvement of energy supply, increase in income of the population) problems that can be solved at its expense. In addition, the presence of significant own untapped potential of RE [3] and the country's international commitments concerning the achievement of the share of RES at the level of 11% in the total electricity balance until 2020 [4] pushed the Ukrainian government to stimulate the processes of RE development through the use of, first of all, economic levers (feed-in tariff (FIT), tax and customs benefits, etc.). However, the current results of management of this sector development are unsatisfactory. As of the beginning of 2019, the RE share in the country's electricity balance was more than 5.7 times less in comparison with the benchmark for 2020, which casts doubt on the timely achievement of planned country's indicators. This raises the question of assessing the effectiveness of current economic mechanisms to support the RE development in the business sector and households and the prospects for the development of the domestic green energy market with their help.

Review of the recent research and publications sources. The issues of RE development management are the object of the research by foreign scholars (S. Abolhosseini, A. Heshmati [5], Y. Deng, W. Guo [6], A. Donastorg, S. Renukappa [7], S. Griffith-Jones, J. A. Ocampo, S. Spratt [8], D. Jacobs, B. Sovacool [9], M. Veiga [10]) as well as Ukrainian ones (O. Cherniak [11], H. Heletukha, T. Zheliezna [12], A. Kasych [13], I. Klopov [14], T. Kurbatova [15], A. Prokip [16], N. Riazanova [17], Ye. Savchuk [18] and others). Most of researchers deal with the issues of stimulating the development of green energy capacities in the business sector. On the other hand, less attention is paid to the RE deployment in households due to the small scale of private power facilities and the low financial projects returns compared to the business sector. For Ukraine, the insufficient study of the issues of managing the RE development in households is explained, firstly, by the short period of attracting households to the RE expanding processes (since 2015), and, secondly, by the insignificant power capacities of such facilities, which should not exceed 50 kW according to the current legislation [19]. The small energy capacity of green power plants causes their low profitability and long payback periods that discourage investors. It also causes the slower growth, compared with the business sector, of construction of RE facilities. In addition, unsatisfactory financial mechanisms on supporting green energy initiatives of households and a drop in FIT rates, planned by the government for coming years, are important factors hindering these processes.

Task statement. The objectives of the article are: 1) the economic justification of the feasibility of investment of household funds in RE projects using the case study of solar power industry based on changes in Ukrainian FIT rates in 2020-2025 and 2) an assessment of the sector development prospects on this ground.

Basic material and results. Ukraine has favorable environmental conditions and enormous untapped technically achievable potential of RE at the rate of 98 million tons of conditional fuel annually [3] (Table 1), as well as international commitments to develop the RE sector in the national economy (11% of RES in national energy balance up to 2020) [4]. Based on the existing potential, if there exist adequate mechanisms of government support for the RE development, Ukraine may increase the share of RE in the energy balance up to 25% by 2035, reducing to import a significant share of energy resources [20].

Table 1

Technically achievable potential of RE in Ukraine [3]

Directions of RES development	Annual technically achievable energy potential, mln tons of conditional fuel
Wind power	28,0
Solar power, including:	6,0
- electric power	2,0
- thermal power	4,0
Small hydropower	3,0
Bioenergy, including:	31,0
- electric power	10,3
- thermal power	20,7
Geothermal power	12,0
Environmental power (heat pumps)	18,0
Total amount of replacement of traditional energy resources	98,0

Since 2009, FIT has been implemented as a main incentive instrument for RE development for legal entities in the country and it was extended to include households in 2015. Other benefits and incentive instruments are also used such as: land tax reduction for RE facilities, exemption from income taxation in the RE field, exemption from value added tax and import duties on imported equipment for RE facilities that are not produced in Ukraine, etc. [4, 21]. It should be noted that implementation of FIT, which is the highest in Europe [22], actively promoted the development of RE facilities (Table 2).

Table 2

Installed capacity and volumes of generated energy of RE facilities in Ukraine, operating under feed-in tariff, for the period 2014-2018* [23, 24, 25, 26]

Indicator	Year				
	2014	2015	2016	2017	2018
Installed capacity of RE facilities, MW					
Solar power plants	411	432	531	742	1388
Solar power plants of households	0,1	2	17	51	157
Wind power plants	426	426	438	465	533
Small hydropower plants	80	87	90	95	99
Biomass power plants	35	35	39	39	51
Biogas power plants	15	17	20	34	46
Total	**967**	**999**	**1135**	**1426**	**2274**
The volume of energy generated from RES in Ukraine, mln kWh					
Solar power plants	485	475	492	715	1101
Solar power plants of households	0	0	4	23	92
Wind power plants	1172	974	925	974	1181
Small hydropower plants	251	172	189	212	231
Biomass power plants	60	77	80	101	103
Biogas power plants	40	64	89	94	176
Total	**2008**	**1762**	**1779**	**2119**	**2884**

* data are given without taking into account the temporarily occupied territory of the Autonomous Republic of Crimea

For instance, only during 2014-2018 the installed capacity of facilities, that use green energy, and operate under FIT increased by 2.35 times in Ukraine, but the generation of electricity from RES increased only by 13.7%. Since 2016, the solar power plants (SPP) sector of households has been actively developing: the installed power capacity of such facilities increased by 78.5 times with the growth in the generation of green electricity from 0.4 to 92 mln kWh (by 230 times) for the period 2015-2018. The largest, in terms of installed capacity, today is the solar power sector (61% of the total RE capacity in 2018), but in terms of energy generation, it is inferior to the wind power plants, which consistently rank first in this indicator (41% of generation volumes in the RE sector in 2018). The smallest volumes of installed capacity and electricity generation are characteristic for biomass and biogas power plants, except for the sector of households' SPPs, which is rapidly increasing its indicators. However, even if the installed capacity of small private SPPs exceeded the industrial bioenergy capacities by 62% in 2018, the share of electricity generated by households remains the smallest - 3.2% that indicates the need for further state support and stimulation of the household sector development.

In general, the pace of the RE industry development both in terms of enterprises and households is unsatisfactory from the point of view of fulfilling state plans and international commitments. In particular, as of the end of 2018, the RE share in the country's electric balance did not exceed 1.9% [26]. In addition, the legislation provides the validity of FIT until 31.12.2029 and a gradual decrease in its coefficients [21] as approaching to this date, which over time will reduce the profitability of projects for the construction of RE facilities and will increase their payback periods. Thus, if the state does not implement alternative economic incentives for owners and potential investors of such facilities, we can expect a decrease in the volume of investment in the domestic industry of RE due to the fall of FIT rates in the coming years. From this perspective, the household RE sector is especially vulnerable, since its specifics is the creation of a large number of low-capacity power facilities, which naturally leads to larger capital expenditures per 1 MW of

generated electricity. In this regard, the payback period of such projects increases and their profitability decreases.

In order to justify the economic feasibility of investing in households' RE projects until 2029 and to identify the promising trends in this sector development in Ukraine, it is expedient to assess the economic efficiency of a project of 10 kW SPP construction in a typical Ukrainian household under condition of its putting into operation each year during the period 2019-2029 starting from January 1. With this purpose, we calculate the net present value, the discounted payback periods of the projects and their profitability indices. Calculations are carried out in a relatively stable currency – the euro, if 100 euro = 3171.4138 UAH as of January 1, 2019 on the National Bank of Ukraine rate [27].

The choice of the object of the study, i.e. household's SPP with energy capacity of 10 kW, is caused by the following facts. Firstly, such objects are more acceptable for investment by the Ukrainian population due to smaller capital investments. Secondly, the projects for the construction of these objects have longer payback period due to small power generation capacity, therefore they will experience the greatest negative impact of the decrease in FIT rates and will be the first ones to be closed throughout the country. Consequently, mentioned projects can act as indicators of changes in the RE market during 2019-2029 due to their vulnerability.

Below there are input conditions for calculating the economic efficiency indicators of the project for the 10 kW SPP construction in a household, provided that it will be put into operation in different years (2019-2029). The household is located in the northeast of Ukraine, in Sumy city. It is a private house with area of 200 m^2, and SPP is located on its roof. The house is connected to the grid of three-phase electric power, gas and central water supply. The contractual limit of the use of the installed capacity for this object is 3 kW. The annual electricity consumption for own needs is 1381 kWh. The household uses dual-zone tariff for the population to pay for consumed electricity. The electricity tariff coefficients are as follows: 1.0 for day time and 0.5 for night time with the base rate (as of 01.01.2019) of 2.84 eurocents/kWh with monthly consumption of up to 100 kWh and 5.3 eurocents/kWh with monthly consumption over 100 kWh [28]. Annual generation volumes of green electricity are 10325 kWh. Taking into account the monthly electricity flows during the year (generation and consumption by the household for own needs) the annual sales amount of green electricity supplied to the electrical grid is 9234 kWh.

Putting SPP into operation each year during the period of 2019-2029 provides the establishment of various FIT rates for a household by applying its various coefficients (Table 3). At the same time, the value of FIT received in a certain year is fixed and is not changed until the end of its validity period (until 31.12. 2029). In addition, depending on the year of putting SPP into operation, the number of years during which the household will receive increased revenues from the sale of green electricity through FIT will change. The standard service life of solar panels is 25 years. That is, for example, if the SPP is put into operation on January 1, 2019, then for 11 years (2019-2029) the household will receive payment for sold electricity under FIT, which is higher than the traditional price for electricity by 3.36 times and is equal to 0.18 euro/kWh [21, 29]. During next 14 years, starting from 01.01.2030, this payment will be made at market prices. These prices in the research are such that do not take into account the increased FIT coefficients and are equal to an average of 5.33 eurocents/kWh (Table 3).

Table 3

Rates and coefficients of FIT for SPPs of Ukrainian households during the period 2019-2029 (calculated by the authors based on [21])

Period	FIT coefficient	FIT rate, euro/kWh	The number of years of receiving FIT, starting from January, 1 each year
01.01.2019 - 31.12.2019	3.36	0.18	11
01.01.2020 –31.12.2020	3.02	0.163	10
01.01.2021 – 31.12.2021	3.02	0.163	9
01.01.2022 – 31.12.2022	3.02	0.163	8
01.01.2023 – 31.12.2023	3.02	0.163	7
01.01.2024 – 31.12.2024	3.02	0.163	6
01.01.2025 – 31.12.2025	2.69	0.145	5
01.01.2026 – 31.12.2026	2.69	0.145	4
01.01.2027 – 31.12.2027	2.69	0.145	3
01.01.2028 – 31.12.2028	2.69	0.145	2
01.01.2029 – 31.12.2029	2.69	0.145	1

The capital costs for the construction and putting SPP into operation consist of the costs of purchase and installation of the relevant equipment as well as a one-time fee to the local electricity supply company for increasing the connected capacity at the rate of 40.99 euro for each additional kW of connected capacity [30]. We take for the conditions of this study, that the cost of SPP equipment is at the level of 10,500 euro and a fee for an additional 7 kW of connected capacity is at the level of 286.94 euro. There are no current costs. Thus, the project initial investment (total capital costs) will amount to 10,786.94 euro and, presumably, will not change depending on the year in which SPP is put into operation.

Project income for each year of its implementation was calculated based on the amount of annual income from the sale of green electricity (depending on FIT rates in a certain year within its validity period and market prices for electricity beyond validity period of FIT) excluding personal income tax (18%) and military tax (1.5%), as well as annual savings in payment for consumed electricity, achieved through the use of electricity generated by the household for its own needs. At the same time, it was assumed that market prices are constant, as well as volumes of annual electricity consumption for own needs.

Thus, based on the above mentioned initial data and assumptions, the net present value (*NPV*), discounted payback period (*PP*) and investments profitability index (*PI*) for the project on the 10 kW SPP construction have been calculated provided that power facility will be put into operation by the household in different years. We use the following formulas:

$$NPV = \sum_{t=1}^{T} \frac{R_t}{(1+r)^t} - I, \quad PI = \frac{\sum_{t=1}^{T} \frac{R_t}{(1+r)^t}}{I} 100\%, \quad PP =,$$

where T – project implementation period, years; R_t – project income in the t-th year of the project implementation, euro; r – discount rate; I – initial investment (total capital costs), euro; m – year in which the cumulative amount of discounted income is less than the amount of initial investment; $(m+1)$ – year in which the cumulative amount of discounted income covers the amount of initial investment; R_m – cumulative discounted income for full years in which its amount is less than amount of initial investment, euro, R_{m+1} – project income in $(m+1)$-th year, euro [31].

The annual discount rate r has been assumed as equal to 3%, which reflects the opportunity cost of using investment when placing these funds in a deposit bank account (based on the average market rate for deposits in euro in 2019). The results of calculations of the abovementioned indicators of project economic efficiency of the construction of 10 kW SPP are given in Table 4.

It follows from the calculations that the annual project income within FIT validity period decreases stepwise depending on the change in the FIT coefficients over the years: from 1369.37 euro in 2019 to 1243.00 euro in 2020-2024 and up to 1109.20 euro in 2025-2029. Annual income beyond FIT validity period is 429.58 euro. Due to the gradual reduction of FIT validity period with late putting SPP into operation, there is a decrease in the project discounted income within FIT validity period (from 12483.52 euro in 2019 to 1076.89 euro in 2029) and increase in the project discounted income beyond FIT validity period (from 1901.66 euro in 2019 to 5221.317 euro in 2029). Therefore, with putting SPP into operation in 2019, the share of income from FIT in the total amount of project discounted income is 86.8%, and with putting SPP into operation in 2029 – only 17.1%. The calculations of the net present value of options for implementing the SPP construction project over the years show the profitability of projects, which provide putting SPP into operation in 2019-2023. At the same time, *NPV* has the highest level while implementing the project in 2019 (3598.25 euro) and is almost close to zero while implementing the project in 2023 (35.16 euro). Accordingly, the profitability index of the project in 2019 is 133.36% with a discounted payback period of 9.13 years, that is, the implementation of the project this year provides full return on investment and additional 33.36% of net income on invested capital. However, for the project in 2023, the profitability index is 100.33% with a discounted payback period of 24.48 years that is close to the service life of solar panels (25 years). Therefore, the project is paid back, but practically is not profitable. After 2023, the implementation of SPP projects becomes unprofitable. It is evidenced by negative values of their net present value, profitability indices (less than 100%) and dynamic payback periods exceeding the standard service life of SPP equipment.

Table 4.

Indicators of economic efficiency of 10 kW SPP construction project depending on the year when it is put into operation (calculated by authors)

Discounted payback period (*PP*), years	Investment profitability index (*PI*), %	Net present value of a project (*NPV*), euro	Total amount of project discounted income, euro	Project discounted income beyond FIT validity period, euro	Project discounted income within FIT validity period, euro	Annual project income beyond FIT validity period, euro	Annual project income within FIT validity period, euro	Initial investment *I*, euro	Indicator	
9.13	**133.36**	**3598.25**	14385.19	1901.66	12483.52	429.58	1369.37	10786.94	2019	Year of putting into operation SPP with capacity of 10 kW (starting from January 1)
10.94	**117.77**	**1917.07**	12704.01	2159.806	10544.2		1243.00		2020	
13.61	**112.38**	**1334.98**	12121.92	2443.764	9678.152				2021	
17.62	**106.44**	**694.67**	11481.61	2756.117	8725.494				2022	
24.48	**100.33**	**35.16**	10822.1	3077.841	7744.257				2023	
more than 25 years	94.03	-644.14	10142.8	3409.217	6733.582				2024	
	81.86	-1956.59	8830.352	3750.534	5079.818		1109.20		2025	
	76.25	-2561.84	8225.102	4102.091	4123.011				2026	
	70.47	-3185.25	7601.694	4464.195	3137.5				2027	
	64.52	-3827.36	6959.584	4837.161	2122.423				2028	
	58.39	-4488.73	6298.211	5221.317	1076.89				2029	

Conclusions. Based on the conducted analysis and provided the preservation of the planned dynamics of FIT rates reduction and other equal conditions, it is expected to observe a gradual outflow of investments from RE sector of households since 2022-2023 due to the decrease in FIT rates and a corresponding decrease in the profitability of private RE projects with small power capacities. The number of private SPPs with a capacity of 10 kW and less will reduced due to the unsatisfactory economic efficiency of projects.

At the same time, reduction of the cost of SPP equipment, that, in its turn, will reduce the capital costs of their construction and positively influence the financial performance of projects, can stabilize the situation and prevent the outflow of funds from this part of RE sector. This possibility is supported by global trends in price reductions for solar modules. The cost of solar generation is constantly decreasing and, for example, in 2017 was 54 USD per 1MWh versus 49 USD per 1 MWh for electricity generation by using natural gas, 66 USD by using coal and 174 USD for nuclear power plants [1].

In addition, along with the decrease of the investment attractiveness of small solar energy projects, caused by the decline in incomes of SPPs owners, there will be observed growth of share of expensive green electricity in the country's total electricity balance. This, in its turn, will increase average market prices for electricity that will cause an increase in incomes of energy producers with low FIT rates or without FIT at all. In the context of current restructuring the energy market of Ukraine, it is still quite difficult to predict the impact of the dynamics of average market prices for electricity on the development of RE. At the same time, the experience of restructuring the energy markets of the developed countries shows, that average market prices for energy tend to increase at the initial stages of liberalization, and they are gradually decreasing with creating a highly competitive environment in power industry. Therefore, in the coming years, it is advisable to expect the appearance of certain compensatory trends in the form of an increase in the income of small SPPs owners from the sale of generated green electricity at market prices versus to a decrease in income from the sale of it under FIT.

In general, despite the low incomes of the overwhelming majority of the Ukrainian population and the lack of sufficient free funds of households that could be invested in RE, the decrease in FIT rates should be offset by other alternative types of state economic support that would ensure the investment attractiveness of small facilities of green power sector in Ukraine. Taking into account the experience of the developed countries, these could be tax benefits, long-term loans at low rates, the creation of a competitive environment for energy producers, green auctions, green certificates trading, etc. In this context, the significant attention should be paid to long-term loan support for small-scale solar power projects involving a wider range of lenders. The last ones can include both Ukrainian commercial banks, which issue long-term targeted loans within targeted state and regional RE development programs, and international credit institutions, for example, the European Bank for Reconstruction and Development, which has opened credit lines in Ukraine, Ukraine Sustainable Energy Lending Facility [32] and Ukraine Energy Efficiency Program [33], which have not been applied to households yet.

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Ключові слова: електроенергія, відновлювальна енергетика, інвестиції, домогосподарство, зелений тариф, ефективність.

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Sotnyk Iryna, DSc (Economics); **Kovalenko Yevhen**, PhD (Economics); **Chortok Yuliia**, PhD (Economics); **Kripak Yevheniia**, student, Department of Economics, Entrepreneurship and Business-Administration, Sumy State University. **Prospects of Investment in Green Energy Projects in Ukrainian Households.** For Ukraine the issue of renewable energy development is extremely relevant in view of energy (increase in energy independence), economic (reduction of energy resources import costs), environmental (reduction of environmental pollution) and social (improvement of energy supply, increase in income of the population) problems that can be solved at its expense. Based on the existing potential, if there exist adequate mechanisms of government support for the renewable energy development, Ukraine may increase the share of renewable energy sources in the energy balance up to 25% by 2035, reducing to import a significant share of energy resources. In order to justify the economic feasibility of investing in households' renewable energy projects until 2029 and to identify the promising trends in this sector development in Ukraine, the authors have assessed the economic efficiency of a project of 10 kW solar power plant construction in a typical Ukrainian household under some conditions. The results have shown that it is expected to observe a gradual outflow of investments from renewable energy sector of households since 2022-2023 due to the decrease in feed-in tariff rates and a corresponding decrease in the profitability of private renewable energy projects with small power capacities. Therefore an alternative powerful state support will be needed to provide the development of renewable energy sector.

Key words: electricity, renewable energy, investment, household, feed-in tariff, efficiency.

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Ключевые слова: электроэнергия, возобновляемая энергетика, инвестиции, домохозяйство, зеленый тариф, эффективность.