Ensuring the Economic Competitiveness of Small Green Energy Projects*

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Small green energy projects are considered an important tool to help poor people achieve sustainable development goals. However, green projects' economic results do not always compete with the traditional energy business. The main reason is the imperfection of the existing renewable energy technologies and the comparatively high energy generation cost with their help. The example of Ukraine, which significantly depends on fossil fuel import and develops renewable energy with state support, shows that green energy competitiveness problems exist within the overall energy market, i.e., convenient energy technologies. The key barriers to increasing the competitiveness of small green energy projects are the lack of available financial resources, the inconsistency of state energy policy, energy pricing gaps, etc. These factors significantly inhibit the spread of green energy technologies in the domestic economy.

The competitiveness assessment of the renewable energy business model on the example of a private rooftop solar photovoltaic power plant has proved that green energy generation is available to every household and small business owner and is economically profitable due to existing government support mechanisms. Today, there is no competition in the Ukrainian renewable energy market, so creating a business in this field is relevant. In the long run, competitive green energy projects will provide reasonable electricity prices for consumers and profits for energy producers and stimulate the energy sector's decarbonization. Further directions for improving public policy in the green energy industry are continuing energy pricing reforms, expanding energy efficiency programs focusing on demand management, creating new jobs, and increasing investment in renewable energy sources to ensure energy security and greenhouse gas emission reduction.

Keywords: economic competitiveness, energy generation, profitability, project, renewable energy, solar energy, solar photovoltaic power plant, sustainable development.

Abbreviations:
FIT – feed-in tariff;
PV – photovoltaic;
SPP – solar power plant;
RE – renewable energy.

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Introduction. In the contemporary world, access to quality and affordable energy services is crucial in reducing poverty in developing countries. Governments of both developed and developing states recognize small renewable energy (RE) projects as an important tool to help poor people achieve sustainable development goals. For deployment of national RE sectors, the considerable aspects are 1) long-term planning and development of small energy projects; 2) formation of strategies for green energy business implementation and determination of the optimal capacity for RE facilities; 3) ensuring green energy competitiveness compared to convenient energy generation technologies [34].

It is also essential to boost small RE businesses in countries with a strong RE potential and high energy dependence on importing fossil fuels. Ukraine is a striking example of such a state. The domestic green energy sector's deployment may contribute to the reduction of energy import due to its replacement by RE sources, increase energy independence, decarbonize the economy, create new jobs, and improve environmental quality and social welfare. However, the RE advancement still faces many obstacles, the main of which are organizational and economic barriers, including ensuring the economic competitiveness of RE projects, in particular small and medium-sized ones.

Analysis of the recent literature. The problems of green energy development and economic competitiveness of RE technologies are widely studied by many foreign and Ukrainian scientists, such as A. Behrens, A. S. Giljum, J. Kovanda, S. Niza [4], S. Cohen [7], M. Hitzeroth, A. Megerle [11], O. Kuik, F. Branger, P. Quirion [13], T. Kurbatova [31], M. Ligus [15], K. Moorthy, N. Patwa, Y. Gupta, [26], S. Žiković, I. Gržeta [38], Yu. Bashinska [3], S. Denisyuk, G. Strelkova, K. Pfeiffer [8], G. Kuznetsova [14], G. Trypolska [35] and others. However, few research papers analyze and compare the impact of RE projects on living conditions and sustainable development of local communities, individual households, and small entrepreneurs in green energy facilities implementation. Given the available scientific achievements and recent practical challenges, it is necessary to cover the existing gap in the justification of the RE micro-projects' deployment in the Ukrainian cities based on evaluating their economic competitiveness.

The purpose of the research is to assess the economic competitiveness of small business projects in the green energy sector on the example of Ukraine and find ways to ensure their competitiveness at the national and local levels.

Research results. Recently, fossil fuel consumption has become more global and intense, especially given the political instability in the world. Consequently, there is a growing need not only to save convenient energy resources intensively but also to find new ways of using them more efficiently in fewer quantities [9, 22, 27, 37]. The existing methods of energy saving are quite diverse. Unfortunately, their application does not often bring the expected results and fails to significantly reduce many nations' dependence on gas and oil products imports, including Ukraine (Table 1). In this context, it is expedient to expand RE technologies, which can replace fossil fuels and ensure states' sustainable energy development.

Table 1

Total primary energy supply in Ukraine in 2007–2019, thousand tons of oil equivalent [32]

Indicator	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coal and peat	42657	41798	35870	41490	42490	42718	41427	35576	27344	32450	25757	28055	25718
Crude oil	14926	11166	11384	11497	9100	5050	3978	3043	2851	2806	3351	3635	3786

Table 1(continued)

Oil products	291	3202	2518	1682	3360	6559	5928	7645	7700	8387	9345	9690	9747
Natural gas	55586	52805	40789	55229	46841	43018	39444	33412	26055	25603	24554	25653	23383
Nuclear energy	24273	23566	21764	23387	32672	23653	21848	23191	22985	21244	22449	22145	21771
Hydropower	872	990	1026	1131	941	901	1187	729	464	660	769	897	560
Wind, solar energy and other RE sources	4	4	4	4	10	53	104	134	134	121	149	197	426
Biofuels and waste	1508	1610	1433	1476	1563	1522	1875	1934	2102	2832	2989	3208	3362
Electricity	-789	-579	-367	-349	-541	-987	-851	-725	-116	-323	-445	-522	-348
Heat	…	…	…	…	…	…	1000	745	571	599	546	534	667

In Ukraine, the Energy Strategy of Ukraine for the period up to 2035 "Security, energy efficiency, competitiveness" is the basic document that defines the strategic guidelines for developing the national energy complex and RE industry in particular. The country seeks to remain one of the largest hydrocarbons producers in continental Europe and a reliable partner for energy transit (primarily natural gas and oil). Another aim is to ensure a secure and reliable energy supply to the domestic consumers and related markets while providing energy resources extraction and delivery with a high level of environmental and social responsibility as well as complying with commitments to reduce greenhouse gas emissions [6].

The purpose of Ukraine's Energy Strategy is to meet the needs of society and the national economy in fuel and energy resources in a technically reliable, safe, cost-effective, and environmentally friendly way to ensure the improvement of living conditions in the country. The strategic vision for the domestic energy complex development includes: 1) the formation of a conscious and energy-efficient society; 2) achievement of energy independence, reliability, and stability of the energy sector; 3) energy markets' development; 4) increase in the energy complex's investment attractiveness; 5) grid integration; 6) the formation of the modern energy sector management system [6]. The RE industry is considered a vital lever to reach these goals specified in the National Renewable Energy Action Plan until 2020 [5].

During 2015–2020, Ukraine demonstrated exponential growth in the RE installed capacity. However, the country's difficult economic situation did not contribute to achieving the benchmarks set by the National Renewable Energy Action Plan in full. As of January 1, 2020, domestic green energy facilities counted 1.142 industrial and 21.968 household solar power plants (SPPs) with a feed-in tariff (FIT) and a total capacity of 6.932 MW (including 852 SPPs with a capacity of 4.925 MW); 69 wind power plants with a capacity of 1.170 MW; 157 small hydropower plants with a capacity of 114 MW; 49 biogas power plants with a capacity of 86 MW and 15 biomass power plants with a capacity of 84 MW [25].

In recent years, green energy investments have become a source of pride for the Ukrainian government. Only in few industries have foreign investors invested in the national economy on such a scale. In 2019 alone, according to the State Agency for Energy Efficiency and Energy Saving of Ukraine, a record 3.7 billion euros were invested. As of the end of 2019, 3.3 million households in Ukraine provided themselves with environmentally friendly electricity [25].

The possibility of further domestic energy sector greening has great potential, given the mostly untapped RE reserves to improve energy efficiency, subsidy reformation, and green energy development [6, 23]. Competition and modernization of industrial energy facilities and infrastructure will increase the country's energy and material efficiency to European standards while declining industrial pollution and creating new jobs [16; 19; 20; 29]. Subsidies' reformation should also encourage entrepreneurs to develop private RE business. Rising competition in the national green energy market will reduce dependence on fossil fuel imports while opening domestic financial sources to support RE transition and stimulate energy efficiency through higher energy prices [6, 17, 18, 28, 30].

Ukraine has succeeded in working with regional partners to develop competition and financial support for RE, including the Partnership for Energy Efficiency and Environment in Eastern Europe (E5P). In 2013, with the help of E5P, the country launched nine projects with a savings potential of 772 thousand MWh and carbon dioxide emissions reduction by more than 272 thousand tons per year for 15 years. The partnership includes links with well-known international donors such as the European Bank for Reconstruction and Development, the European Investment Bank, the International Finance Corporation, the Nordic Environmental Finance Corporation, the Nordic Investment Bank, and the World Bank [36].

In our opinion, at first, it is expedient to develop a competitive environment in the solar energy field. Since tariffs for non-renewable energy resources are growing every year and FITs are still consistently high, solar energy is becoming increasingly popular. For instance, in 2017–2020, domestic electricity tariffs raised three times [21, 31], so household owners are seriously assessing the feasibility of installing SPPs to save their money. The key economic motivation here is getting a quick payback of initial investment with subsequent earnings.

Due to the geographical location, Ukraine has quite good indicators of annual surface insolation. On average, throughout Ukraine, the solar insolation value is about 1 000 kWh per 1 m^2 of surface per year. However, this does not mean that someone can get 1 000 kWh from 1 m^2 of solar panel per year, as there are significant losses in solar energy conversion, which can reach 30 % [10]. To reduce environmental pollution caused by electricity generation and increase energy independence, Ukraine has introduced FITs to encourage solar electricity generation by legal entities and households. FITs are valid until 2030 and allow not only saving but even earning on RE [31]. The advantages of using SPPs to obtain FIT are minimal maintenance costs and the possibility of their installation on small areas and roofs, which is significant in implementing small and medium green energy projects.

Given the existing state support mechanisms for the RE development in Ukraine, projects' economic competitiveness for the small SPPs' construction, including photovoltaic (PV) SPPs, is growing continuously. However, this energy business's profitability largely depends on the correct choice of the PV SPPs' type. By purpose, PV SPPs are divided into:

1. Large on-grid PV SPPs (with an installed capacity of 16 kW and more) designed to generate and sell green electricity to the grid using FIT.
2. PV SPPs for electricity savings. This PV SPP type is designed to partially replace electricity from the grid by generating electricity from solar radiation. Therefore, the PV SPP's essential characteristics are a share of total energy consumption covered by solar energy generation and possible electricity bill savings.
3. Intelligent PV SPPs for electricity saving and accumulation. This PV SPP type allows not only electricity savings but also storing and using energy in periods when there is no solar radiation. Intelligent or off-grid PV SPPs can provide an uninterruptible power supply and becomes a voltage stabilizer [24, 33].

For PV SPPs operating on FIT, the choice of an installed capacity is limited only by the amount of available funds and space. In addition, the price of equipment depends on a PV SPP size. That is, the unit cost of 1 kW of installed capacity for a PV SPP with a capacity of

100 kW will usually be higher than for a PV SPP with a capacity of 1 MW. For PV SPPs built to save electricity, it is necessary to decide at the start whether all energy generated is going to be consumed or whether electricity surpluses are going to be sold using FIT. The further approach to PV SPP's capacity calculations depends on this decision, which is due to the specific attitude of NEC «Ukrenergo» to unlicensed electricity sellers. In the absence of a FIT contract, if a PV SPPs' installed capacity is selected incorrectly, at a certain point in time, energy generation may exceed its consumption (so-called "reverse flow of power into the grid"). Provided that the energy supply company detects illegal flow into its grid, it may cause a PV SPP's owner's criminal responsibility. That is why it is essential to strictly follow the recommendations for choosing PV SPPs' capacity and verify the final decision with specialists [24].

Let us assess small business project's economic competitiveness indicators on the example of a household PV SPP with a 5-kW capacity installed on the multi-apartment building roof. The PV SPP owner is an individual who lives in the building in a one-bedroom apartment. The main elements of the PV SPP include solar panels, an inverter, an electricity meter, consumers, and a general power grid. The turnkey cost of such PV SPP was 4,200 USD in 2020 (Table 2) [12].

Table 2

Basic technical and economic indicators of the PV SPP [12, 24, 33]

Indicator	Indicator value
The required capacity of solar panels, W	5.000
Insolation for the study region, W/m^2	3.600
Insolation for standard conditions, W/m^2	3.200
The capacity of solar batteries, W/m^2	250
Price of 1 m^2 of solar panels, UAH	3.900
Transportation costs, UAH	Free in Ukraine
Installation costs, UAH	30.000

The PV SPP's payback period (*PP*, years) can be calculated by the formula:

$$PP = C / Inc, \quad (1)$$

where *C* is the cost of installing the PV SPP, *C* = 4.200 USD or 113.400 UAH (at the average exchange rate of 27 UAH for 1 USD in 2020); *Inc* is annual income from electricity generation (less energy consumption) using FIT and electricity consumption savings, UAH / year;

$$Inc = FIT \times (Gen - Cons) + Cons \times P, \quad (2)$$

where *Gen*, *Cons* are annual green electricity generation and consumption respectively, kWh / year; *FIT* is a feed-in tariff for electricity generated by the PV SPP, UAH / kWh; P is a tariff for electricity from the grid, UAH / kWh.

Assume that the electricity consumption for the average family is *Cons* = 200 kWh / month or 2.400 kWh / year. At *P* = 1.68 UAH / kWh, *Cons* × *P* = 2.400 × 1.68 = 4.032 UAH / year.

If *Gen* = 4.830 kWh / year, then *FIT* = 0.16 EUR × 34.50 UAH / EUR (at the exchange rate of UAH / EUR in 2020) = 5.52 UAH / kWh (this FIT rate is in force until 2024). Accordingly, the income from the green electricity generation at the facility is calculated as

Inc = 5.52 × (4,830 – 2,400) + 4.032 = 17.445.6 UAH / year. The PV SPP's payback period equals *PP* = 113.400 / 17.445.6 = 6.5 years.

Given the calculation above, the PV SPP will pay off in 6.5 years, i.e., within the FIT validity period, and will bring a net income during the following years. The average lifecycle term of solar panels and other PV SPP's equipment is 25-30 years. Therefore, the payback period is within this term.

Let calculate the net present value of the considered business project (*NPV*) based on [10]. For this case, revenues will be different within the FIT period and after its expiration. Assume that the PV SPP was commissioned in early 2020, and the FIT is valid until the end of 2029. Therefore, the PV SPP's owner will receive additional income from the FIT for ten full years. For the rest of the PV SPP's lifecycle term (15 years out of 25 after the FIT expiration), the owner will sell the surplus of generated green electricity at a usual tariff (1.68 UAH / kWh). Therefore, the project's *NPV* is calculated as:

$$NPV = -C + \sum_{t=1}^{10} (FIT \times (Gen - Cons) + Cons \times P)/(1+r)^t +$$
$$+ \sum_{t=11}^{25} (P \times (Gen - Cons) + Cons \times P)/(1+r)^t, \quad (3)$$

where *r* is a discount rate (assume that *r* = 12% for the Ukrainian conditions, considering the risk of doing business, inflation expectations, and the guarantee of FIT fixing in euros).

$$NPV = -113400 + \sum_{t=1}^{10} (17445.6)/(1+0.12)^t +$$
$$+ \sum_{t=11}^{25} (1.68 \times (4830 - 2400) + 4032)/(1+0.12)^t = 2965.73 \text{ UAH}.$$

Profitability index (*PI*) [1] of the project equals:

$$PI = (\sum_{t=1}^{10} (17445.6)/(1+0.12)^t + \sum_{t=11}^{25} (1.68 \times (4830 - 2400) + 4032)/(1+0.12)^t) /$$
$$/13400 = 1.026.$$

Based on the calculated indicators, the project is quite competitive. It has an acceptable payback period of 6.5 years, provides an *NPV* of 2,965.73 UAH (109.84 USD) for the period of its implementation, and a profitability index of 1.026 at a discount rate of 12 %. Although the project generates a small NPV, it ensures the household's energy independence, which is extremely important, and a little additional income.

Along with the assessment of competitiveness, when choosing PV SPPs as a source of electricity, investors should consider their advantages and drawbacks:

• advantages: solar energy is an infinite resource and does not pollute the environment, unlike fossil fuels used for electricity generation (oil, coal, nuclear power, etc.). The maintenance of the solar panels' efficiency does not require large funds; it is sufficient to clean them regularly from dust and check the reliability of electrical connections;

• drawbacks: large initial investments; instability of electricity generation, reduced generation efficiency (at night, on cloudy days); significant losses in energy conversion; inconsistency of solar panels with the Ukrainian climate (for example, instability to precipitation, such as hail) [2].

In general, investing in PV SPPs is quite profitable and characterized by low risk. It requires significant financial resources that are paid back in 6.5 years. Although roof solar panels are not suitable for everyone, they are the best option for many households and small businesses. Practitioners have already tested the efficiency of solar modules. That is why the last decade's trend has been the abandonment of nuclear and thermal power plants' construction and the active development of solar energy projects in many countries around the world.

Conclusions and prospects of further research. The research results indicate that the RE development scenario can significantly reduce fossil fuel consumption in Ukraine and other countries. The deployment of green energy business reveals the problems of its competitiveness within the general energy market, i.e., compared to traditional energy projects, as RE still cannot develop without state support. There is also an insufficient number of institutions and programs aimed at financing RE projects. Due to inconsistent regulation policy in the Ukrainian green energy sector, financial institutions usually offer high credit rates and require a twice higher share of equity investment as a condition for RE loans. It significantly inhibits the spread of green energy technologies in the domestic economy and reduces their competitiveness.

The competitiveness assessment of the RE business model on the example of a private rooftop PV SPP showed that the green energy generation is available to every household and small business owner and is economically profitable under the existing government support mechanisms. Today, there is no competition in the Ukrainian RE market, so creating a business in this field is relevant. In the long run, competitive green energy business projects will provide reasonable electricity prices for consumers and profits for energy producers and stimulate the energy sector's decarbonization. Further directions for improving public policy in the RE industry are continuing energy pricing reforms, expanding energy efficiency programs focusing on demand management, creating new jobs, and increasing RE sources' investment to ensure energy security and greenhouse gas emission reduction.

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Забезпечення економічної конкурентоспроможності малих проєктів «зеленої» енергетики

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Малі «зелені» енергопроекти визнані важливою формою допомоги малозабезпеченим верствам населення для досягнення цілей сталого розвитку, проте їх економічна віддача не завжди дозволяє конкурувати з традиційними енергопроєктами. Основна причина тому – недосконаліть існуючих технологій відновлюваної енергетики та порівняно висока вартість виробництва енергії за їх допомогою. На прикладі України, що має значну залежність від імпорту викопних палив і розвиває відновлювану енергетику за державної підтримки, показано, що проблеми конкурентоспроможності галузі існують в межах загального енергоринку, тобто порівняно з проєктами традиційними енерговиробництв. Ключовими бар'єрами зростанню конкурентоспроможності малих «зелених» енергопроєктів є брак доступних фінансових ресурсів, непослідовність державної енергополітики, прогалини у ціноутворенні в енергосекторі та інші. Зазначені фактори суттєво стримують поширення технологій зеленої енергетики у вітчизняній економіці.

Поряд з цим, оцінювання конкурентоспроможності моделі «зеленого» енергобізнесу на прикладі приватної дахової сонячної фотоелектричної станції показало, що виробництво «зеленої» енергії доступне кожному домогосподарству та малому підприємцю і є економічно прибутковим за існуючих механізмів державної підтримки. На ринку відновлюваної енергетики України сьогодні поки що немає конкуренції, тому створення бізнесу в цій сфері є доцільним і актуальним. У перспективі конкурентоспроможні «зелені» бізнес-проєкти забезпечать помірні ціни на електроенергію для споживачів та прибутки для енерговиробників, стимулюватимуть декарбонізацію енергосектору. Продовження реформ з ціноутворення на енергію, розширення програм з енергоефективності з акцентом на управління попитом та постійне інвестування у відновлювальні джерела енергії для забезпечення енергетичної безпеки і скорочення викидів парникових газів, створення нових робочих місць є подальшими напрямами вдосконалення державної політики у сфері відновлюваної енергетики.

Ключові слова: економічна конкурентоспроможність, енергогенерація, прибутковість, проєкт, відновлювальна енергетика, геліоенергетика, сонячна фотоелектрична станція, сталий розвиток.

JEL Codes: L51, O13, P28, Q42 Table: *2*; References: *38*

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