

# The price for sustainable development of renewable energy sector: the case of Ukraine

*Iryna Sotnyk<sup>1,\*</sup>, Tetiana Kurbatova<sup>2</sup>, Oleksandr Kubatko<sup>1</sup>, Yevhen Baranchenko<sup>3</sup>, and Rui Li<sup>4</sup>*

<sup>1</sup>Sumy State University, Department of Economics, Entrepreneurship and Business Administration, 2 Rymskogo-Korsakova Str., Sumy, 40007, Ukraine

<sup>2</sup>Sumy State University, Department of International Economic Relations, 2 Rymskogo-Korsakova Str., Sumy, 40007, Ukraine

<sup>3</sup>Northumbria University, Department of Entrepreneurship, Innovation and Strategy, Faculty of Business and Law, Sutherland Building, Newcastle-upon-Tyne, NE1 8ST, UK

<sup>4</sup>Xi'an University of Finance and Economics, Research Center of Western Energy Economy and Regional Development, Economics Institute, 81 Xiaozhai East Road Xi'an, Shaanxi Province, China

**Abstract.** While implementing state support mechanisms for renewable energy deployment, each country faces the problem of assessing and forecasting their consequences and must timely adjust their set to ensure sustainable energy development. The article estimates the price for sustainable development of the renewable energy sector on the example of Ukraine based on evaluating the effectiveness of the key mechanism of state support for the industry advancement - the feed-in tariff. The comparison of feed-in tariff rates with the LCOE indicators for the electricity generated from solar and wind power plants has shown that the current feed-in tariffs for two of the most popular renewable energy technologies are inflated several times and do not meet global trends in reducing the cost price of electricity generated by these technologies. The consequence of applying economically unreasonable tariffs is the annual over-expenditures of the state budget of Ukraine, which recently count hundreds of millions of euros. In the context of the country's growing green energy generation, the conditions for further use of the feed-in tariff and the transition to other state support mechanisms are substantiated.

## 1 Introduction

Renewable energy (RE) deployment is a progressive trend in modern world development that contributes to the achievement of the Global Sustainable Development Goals #7 "Affordable and clean energy" and #13 "Climate action" [1]. However, RE technologies' technical imperfection still causes the high generation cost of green energy compared to its analog generated from fossil fuels. The higher price significantly reduces the RE competitiveness in the global market and hinders the implementation of green energy technologies in business entities and households' everyday activities. Therefore, while developing the RE sector, countries apply state support mechanisms for the RE generation and consumption. The most popular schemes include feed-in tariffs, renewable portfolio standards, net metering, green auctions, tax, financial privileges, etc. [2-8].

When choosing and implementing support instruments, it is advisable to consider the stage of the RE development in a country and the energy policy goals as well as estimate possible social, economic, environmental and political consequences of the introduced levers. Unreasonable and inconsistent application of economic mechanisms for the RE development can not only fail to achieve the state green energy policy goals but also negatively affect the

national economy through state budget overspending, deteriorating the investment climate, discouraging business entities and households from introducing RE technologies, etc. In particular, Spain is an example of such a negative experience. In the early 2000s, the country faced a heavy financial burden on the state budget due to high feed-in tariffs introduced for developing the RE sector. To solve the problem, the national legislation was changed, and feed-in tariffs were cut. However, the country was forced to pay compensations to the RE projects' investors close to 1 billion euro on lawsuits won for violations of their rights due to changes in the RE legislation [9]. Thus, each state that implements state support mechanisms for green energy faces assessing and forecasting their consequences and must timely adjust the toolset for the RE sector's sustainable development.

Organizational, legal, economic, and other RE deployment mechanisms in different countries of the world are studied in plenty of research papers, for example [2-6; 10-11; 12]. The authors of [5; 13-15] note the high efficiency of the feed-in tariff application at the initial stages of national RE sectors' development since these tariffs could provide sufficient profits to the owners of green energy generating facilities. Therefore, at the expense of feed-in tariffs, it is possible to ensure the RE supply's formation on the domestic energy market. Many scientists indicate that the application of

\* Corresponding author: [insootnik@gmail.com](mailto:insootnik@gmail.com)

quota obligations or RE portfolio standards is an effective mechanism to provide both supply and demand for green energy [16-19]. However, this scheme must be supported by net metering and financial instruments (in particular, credit lines, partial compensation of loans for the construction of RE facilities by local and state authorities) to encourage active RE development. As the green energy sector expands, it is advisable to use green auctions and tender systems to ensure the creation of a competitive environment in the field [7; 20-22].

Overall, the necessity of evolutionary changes in management mechanisms for sustainable development of the national RE sectors is highly recognized by the researchers. However, few papers examine the feasibility of using specific state support schemes and the criteria for the transition from one tool to another to ensure sustainable RE deployment. As a rule, scientists focus on assessing the benefits and basic parameters of the RE development mechanisms while paying far less attention to the consequences of such incentives for countries' state budgets. For example, E. Dijkgraaf et al. [23] studied the feed-in tariff impact on the green energy advancement by modeling the duration of feed-in tariffs' implementation, their rates, government targets in the RE field, etc. P. del Río [24] evaluated the dynamic efficiency of feed-in tariffs considering technology-specific fixed-tariffs, their degression in the long-run, cap and floor prices, reductions of support over time for existing RE plants, the burden of green energy costs to consumers, maximum RE plant size, and other factors. The author noted the need to cut feed-in tariffs over time to reduce the financial burden on energy consumers while not quantifying such an impact.

S. Matsuda and H. Kubota [25] proposed the concept of "marginal cost of power facility" to analyze the effectiveness of the feed-in tariff mechanism in Japan. They justified the need to take the effect of replacing imported fossil fuels with green energy into consideration. P. Milanés-Montero et al. [26] analyzed the feed-in tariff influence on Spanish companies' profitability, noting its positive impact on business development. M. D. Leiren and I. Reimer [22] substantiated the transition from feed-in tariffs to green auctions in Germany in a historical institutionalist perspective.

Thus, the recent scientific literature has a gap in research concerning quantitative assessments of the price for sustainable RE sector development based on the feed-in tariff and other economic support tools' use. The lack of these studies negatively affects the effectiveness of national energy policies for the RE advancement, causing management errors and reducing the results of the state support instruments' implementation.

Hence, the purpose of this research is to estimate the price for sustainable development of the RE sector on the example of Ukraine based on evaluating the effectiveness of the feed-in tariff as a key state support mechanism for the industry deployment and justifying the feasibility of its further use in the country. To our knowledge, this is the first attempt to substantiate the feed-in tariff implementation regarding the financial loading on the Ukrainian state budget.

## **2 Problems of the feed-in tariff application to ensure sustainable RE development in Ukraine**

Considerably depending on energy import, Ukraine has been actively developing the RE sector over the last decade, using several mechanisms of economic support, including [27]:

- 1) credit/loan programs offered by commercial banks in Ukraine and the European Bank for Reconstruction and Development (EBRD);
- 2) tax and customs incentives (value-added tax exemption for equipment and components used for green electricity generation; custom duty exemption for the imported materials, equipment and components used for the production of alternative fuels or green energy);
- 3) long-term fixed feed-in tariffs;
- 4) an allowance to feed-in tariffs for using domestic equipment during the RE plants construction;
- 5) the guaranteed purchasing of 100% of electricity generated from RE sources;
- 6) free license obligation for connecting household RE plants to the grid;
- 7) the simplification of the procedure for connecting new RE plants to the electrical grid.

Today the feed-in tariff, which rates are the highest in Europe [28], is the main support scheme used in Ukraine. Legislatively introduced for enterprises in 2008 and households in 2014, the feed-in tariff ensured the active RE development in the domestic business and residential segments in 2009–2020. In particular, the most significant growth in RE capacities and the amount of green electricity generated was in the last 5-6 years (2014–2020) and was caused by several reasons. The first one is high feed-in tariff rates, which are fixed until the end of 2029 and make RE projects economically profitable. The second reason is the 100% guarantee of green electricity purchase by the state. The third one is the governmental plan to reduce feed-in tariffs gradually in the next decade, which encourages investors to construct RE facilities today and obtain higher feed-in tariffs.

The RE deployment's intensification based on the feed-in tariff application has exacerbated financial problems related to the payments for green electricity generated in the country. The growth of RE generation significantly increases the burden on the state budget. As the legislation of Ukraine does not indicate special sources for the feed-in tariff financing, the rise in the green electricity generation causes an increase in payments for it, which are made at the expense of all taxpayers. This affects the escalation of the weighted average price of electricity in the country, necessitating an increase in electricity tariffs for all consumers. Given the energy poverty of a large part of the Ukrainian population, it threatens to worsen the national socio-economic situation and provoke social protests.

The issue with the payment for the generated green energy was especially aggravated in spring 2020 during the first lockdown. On the one hand, RE generating capacities continued to operate as usual while the overall

energy demand decreased due to enterprises' partial shutdown. At that time, it would be expedient to partially turn off the RE facilities and replace expensive green energy with the cheapest one generated by nuclear power plants. However, due to the 100% guarantee of green electricity purchase by the state, the lack of sufficient maneuverability in the Unified Energy System's capacities, and the reluctance of RE plants owners to lose their profits during the lockdown, the share of expensive RE in the overall energy mix increased significantly. The latter caused the deficit growth of SE "Guaranteed Buyer," which paid for the green energy to its suppliers on behalf of the state. At the end of 2020, this enterprise's deficit reached 24.6 billion hryvnias, threatening the national energy billing system collapse [29]. Hence, the current situation requires reforming the economic mechanisms used to support the RE industry in Ukraine. In particular, it is advisable to move to a green auctions system, which the Ukrainian government has not yet launched due to many obstacles [30].

Another alternative is urgently revising the feed-in tariffs and cutting them to a greater extent than planned by law. However, the reduction of feed-in tariff rates is possible only for new RE projects to keep green energy facilities owners and potential investors' trust. In addition, the feed-in tariffs can be cut only based on an objective assessment of the real cost price of green electricity generation, distribution, and supply regarding the stage of RE technologies development. Suppose such a reduction in feed-in tariff rates does not balance the state budget payments for the generated green electricity. In that case, it is expedient to involve other economic incentives for the RE deployment in Ukraine.

Given the above, the research questions are: (1) whether the current feed-in tariff rates in Ukraine are economically justified in terms of ensuring sustainable RE development; (2) how the changes in feed-in tariff rates and green energy generation volumes affect the financial loading of RE on the state budget and (3) whether it is advisable to involve new economic levers to regulate the national RE sector advancement.

### **3 Approaches to assessing the feed-in tariff economic feasibility**

The justification of the feed-in tariff financial burden on the country's state budget can be conducted based on the compliance of the feed-in tariff rates set by the government for a certain RE technology with the average cost price of electricity generated with this technology. In the study, the green energy cost price estimation is based on the Levelized Cost of Electricity (LCOE) method [31]. Carrying out the comparisons for all RE technologies used in the country and determining the weighted average values on their basis make it possible to identify both the degree of feed-in tariffs' justification and their financial burden on the state budget. However, the feed-in tariff rates should be higher than the average cost price of electricity generation for a particular RE technology, as they must at least consider the normal profitability of green energy facilities.

To justify the feed-in tariff rates, the factor of feed-in tariffs' proportionality to the real cost price of green electricity generation ( $k_{REit}$ ) is proposed. It can be calculated as the ratio of the feed-in tariff for the  $i$ -th RE technology in the  $t$ -th year to the cost price of green electricity generated with the  $i$ -th RE technology in the  $t$ -th year:

$$k_{REit} = \frac{FIT_{REit}}{LCOE_{REit}}, \quad (1)$$

where  $FIT_{REit}$  is the feed-in tariff for the  $i$ -th RE technology (or the weighted average feed-in tariff for all RE technologies used in the country) in the  $t$ -th year, euro/MWh;  $LCOE_{REit}$  is the cost price (calculated with the LCOE method) of green electricity generated with the  $i$ -th RE technology (or the weighted average cost price of electricity generated with the set of RE technologies used in the country) in the  $t$ -th year, euro/MWh.

The euro was used to calculate the indicators included in the proportionality factor formula. It is due to the fact that feed-in tariffs are fixed in euros in Ukraine to avoid hryvnia devaluation risks. This precaution guarantees a stable income from the operation of RE generating capacities to their owners.

The proposed proportionality factor reflects the degree of the state pricing policy efficiency in the RE sector in the current period. It can be calculated for both the RE technologies mix used in the country and a certain RE technology. If the proportionality factor values are far from 1, there is a divergence between the feed-in tariff rates and the real cost prices of green electricity generation. It indicates the ineffectiveness of the state pricing policy in the RE field. On the contrary, the convergence of the proportionality factor components and its values close to 1 indicates growing compliance of feed-in tariffs with the real green energy cost price and, accordingly, optimizing the feed-in tariff financial burden on the state budget.

It is important to monitor and analyze the value of the proportionality factor in dynamics as the development of the RE sector technological base can significantly reduce the cost price of green electricity generation over time. It should be reflected in the periodic review and adjustment of feed-in tariff rates in order to reduce state budget expenditures.

The amount of the country's state budget over-expenditures ( $OE_{sbREit}$ ) associated with excessive payments at inflated feed-in tariffs for the  $i$ -th RE technology in the  $t$ -th year can be calculated as:

$$OE_{sbREit} = (FIT_{REit} - LCOE_{REit} \times (1 + k_{adREit})) \times Q_{REit}, \quad (2)$$

where  $k_{adREit}$  is a coefficient that considers additional economically justified factors influencing the increase in the unit price of electricity generated in the  $t$ -th year with the  $i$ -th RE technology (for example, the normal profit of the RE facility owner, the risk of doing business in the country, credit risks, etc.);  $Q_{REit}$  is the amount of green electricity generated in the  $t$ -th year with the  $i$ -th RE technology.

The amount of the state budget over-expenditures can be calculated both for an individual RE technology and their set used in the country. Over time, the growth of this indicator shows an increase in unreasonable state budget expenditures due to unbalanced feed-in tariffs.

#### 4 Evaluation of the feed-in tariffs' economic feasibility in Ukraine

Based on the above indicators, let us assess how reasonable the Ukrainian feed-in tariffs and the corresponding state budget expenditures are on the example of large solar power plants (with a capacity of more than 10 MW) and wind power plants (with a capacity of more than 2000 MW per turbine). Solar and wind power plants have been chosen for calculations due to the following considerations. First, feed-in tariffs for solar and wind power plants in Ukraine are the highest compared to other RE technologies. Attractive tariffs have led to the predominant development of solar and wind power facilities, which today provide most of the green electricity generation. Accordingly, state payments for them are the largest. Second, the cost price of generating electricity for large solar and wind power plants is lower than for small and medium-sized RE facilities that should be reflected in feed-in tariffs. Third, the last decade has been marked by significant progress in reducing the cost price of solar and wind energy technologies on the world market. Therefore, it is important to ensure that the change in feed-in tariffs is consistent with the downward trend in these technologies' cost prices (other things being equal) since the growing volume of green electricity generation significantly affects the state budget expenditures.

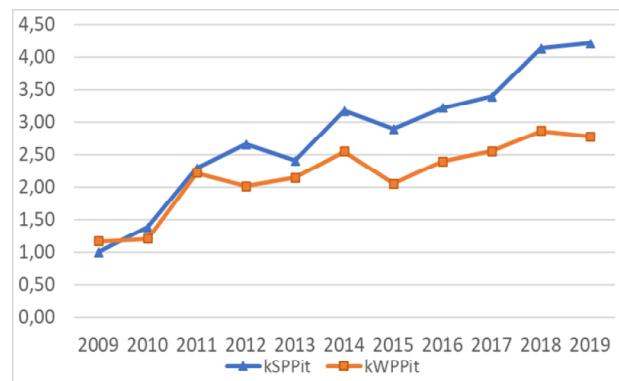
The initial data for assessing the economic feasibility of feed-in tariffs for large solar and wind power plants are given in Table 1. Data on LCOE [32-33] are provided in euros, taking into account the euro / US dollar exchange rate of the European Central Bank [34] in the relevant period.

**Table 1.** Initial data for feed-in tariffs' economic justification (developed by the authors based on [27; 32-33]).

Year	Feed-in tariff on electricity, euro cent/kWh		LCOE, euro cent/kWh	
	SPP*	WPP**	SPP	WPP
2009	25.85	11.31	25.74	9.68
2010	25.85	11.31	18.71	9.35
2011	25.85	11.31	11.28	5.10
2012	25.85	11.31	9.73	5.60
2013	18.85	11.31	7.83	5.27
2014	18.85	11.31	5.95	4.44
2015	16.96	10.18	5.86	4.96
2016	15.99	10.18	4.97	4.25
2017	15.03	10.18	4.43	3.98
2018	15.03	10.18	3.64	3.56
2019	15.03	10.18	3.57	3.66

*Table notes:* \*SPP – solar power plants with a capacity of more than 10 MW; \*\*WPP – wind power plants with a capacity of more than 2000 MW per turbine.

Fig. 1 presents the results of calculating the proportionality factors of feed-in tariffs to the real cost price of green electricity generation obtained on the LCOE basis for two RE technologies, according to formula (1).



**Fig. 1.** Proportionality factors of feed-in tariffs to the real cost price of green electricity generation (by the LCOE method) for solar power plants (capacity of more than 10 MW,  $k_{SPPit}$ ) and wind power plants (capacity of more than 2000 MW per turbine,  $k_{WPPit}$ ) in Ukraine in 2009–2019 (calculated by the authors).

The calculations show that the feed-in tariff for solar power plants with more than 10 MW capacity was almost equal to LCOE in 2009 while slightly exceeding its value. In that year, the feed-in tariff for wind power plants with a capacity of more than 2000 MW per turbine exceeded LCOE by 17%, which is acceptable in ensuring a normal return on the investment and considering the risks of doing business in the country. Thus, the starting feed-in tariff rates were economically justified. During the study period, there was an increase in the divergence between feed-in tariffs and LCOE for the corresponding RE technologies. This is evidenced by the growing values of the proportionality factors. In 11 years, the gap between feed-in tariff and LCOE for solar energy increased to 4.21 times, whereas for wind power plants up to 2.78 times in 2019. Thus, in 2009–2019, there were formed essential reserves to reduce feed-in tariff rates. They indicate the state RE pricing policy's inefficiency and the economic unreasonableness of current feed-in tariffs, which are significantly inflated and need to be corrected. The obtained results are consistent with the trends of cutting feed-in tariffs in the 2000s by developed countries' governments, which actively deploy the RE sector, due to the cost price reduction of RE technologies [22; 35].

#### 5 Estimation of financial over-expenditures of the state budget of Ukraine due to inflated feed-in tariffs

To calculate the state budget over-expenditures for each of the two considered RE technologies in 2009–2019 due to inflated feed-in tariffs, it is necessary to make several assumptions. First, taking into account the Ukrainian realities (credit risks, the profitability of the green energy business, and other factors), economically justified feed-

in tariffs should exceed the cost price (LCOE) at least by 25%. Thus,  $k_{adREit} = 0.25$ . Secondly, the calculations will be performed only for the business sector, excluding households as the technical, economic, and other operating conditions of RE facilities for these two types of energy suppliers differ significantly. Third, open and detailed statistical data concerning green energy generation by solar power plants with a capacity of more than 10 MW and wind power plants with a capacity of more than 2000 MW per turbine are absent for 2009–2019. Therefore, it is assumed that all volumes of green energy generated by solar business facilities were provided by the operation of solar power plants with the capacity of more than 10 MW. The same assumption is applied to the green electricity generated by wind energy facilities. Feed-in tariffs for large power plants are usually lower than for smaller power plants, considering lower specific fixed and investment costs. Therefore, our estimates of budget overruns, calculated for the entire energy generation of the respective solar or wind sector, can be counted as the state budget financial losses' minimum threshold. The results of calculations according to formula (2) are given in Table 2.

**Table 2.** Estimates of the state budget over-expenditures on electricity generated by solar and wind power plants in Ukraine in 2009–2019 due to inflated feed-in tariffs (calculated by the authors based on [36–42]).

Year, <i>t</i>	Solar energy sector		Wind energy sector			
	$k_{adSPPt}$	$Q_{SPPt}$ , mln kWh	$OE_{sbSPPt}$ , thousan d euro	$k_{adWPPt}$	$Q_{WPPt}$ , mln kWh	$OE_{sbWPPt}$ , thousan d euro
2009	0.25	0.0	0*	0.25	41.1	0*
2010	0.25	0.5	12	0.25	49.2	0*
2011	0.25	30.0	3526	0.25	89.0	4392
2012	0.25	334.0	45720	0.25	257.5	11085
2013	0.25	562.8	50999	0.25	636.4	30049
2014	0.25	485.2	55394	0.25	1171.5	67462
2015	0.25	475.2	45795	0.25	973.7	38788
2016	0.25	492.2	48132	0.25	924.5	45045
2017	0.25	714.7	67879	0.25	973.5	50630
2018	0.25	1080.0	113171	0.25	1180.2	67680
2019	0.25	2932.0	309728	0.25	2022.0	113274

*Table notes:*  $k_{adSPPt}$ ,  $k_{adWPPt}$  are coefficients of additional energy price factors for solar and wind power plants respectively;  $Q_{SPPt}$ ,  $Q_{WPPt}$  are amounts of green electricity generated by solar and wind power plants respectively;  $OE_{sbSPPt}$ ,  $OE_{sbWPPt}$  are the state budget over-expenditures for feed-in tariffs for solar and wind power plants respectively; \* means no overspending.

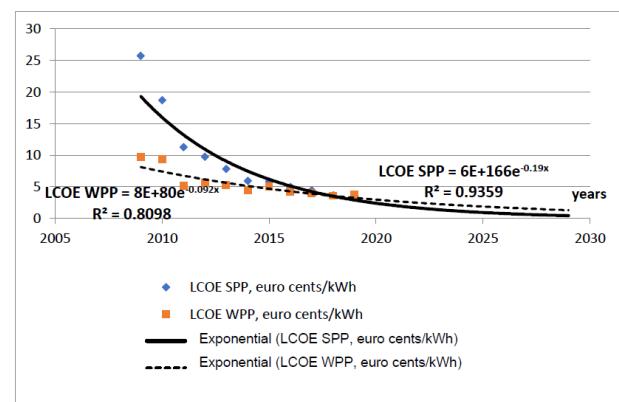
Thus, the obtained data (Table 2) show an exponential increase in state budget overruns for green electricity generated by solar facilities in 2016–2019, while budget over-expenditures for green electricity generated by wind turbines are much lower. In particular, in 2018, with the ratio of electricity generation by solar and wind power plants 0.92:1, the proportion of state budget overruns was 1.67:1. This indicates extremely high feed-in tariffs for solar energy even compared to feed-in tariffs for wind energy, which are also inflated. It confirms that Ukrainian legislators do not monitor the downward trend in the cost price of

electricity generation from renewables and do not adjust feed-in tariffs on time. The result is irrational spending of taxpayers' money, which is recently counted of millions of euros. Today all Ukrainians pay for green energy, and only a few oligarchic clans receive extra profits from it. It threatens the sustainable development of the RE industry in the near future.

It is worth noting that each country, which deploys green energy through the feed-in tariff introduction, faces the problem of budget overspending due to the RE volumes' growth and high feed-in tariffs. In particular, Spain, Germany, the Netherlands, and other developed states had to solve this issue at a certain stage of their RE advancement [9; 22; 35]. A national government's task is to monitor the existing feed-in tariffs' compliance with trends in reducing the green energy cost price. On this basis, the government should timely adjust the set and parameters of state support instruments for RE development while avoiding or minimizing state budget overspending.

## 6 Prospects for change of feed-in tariffs in Ukraine

Based on the data from Table 1, in 2019, the cost prices of generating electricity from solar energy became lower than from wind energy for the first time. While maintaining the current trends of cheapening technologies until 2030 (Fig. 2), the cost price of solar energy generation per unit will be 1 euro cent/kWh, and the cost price of wind energy generation per unit will be 2 euro cents/kWh. In addition, both green energy cost price indicators will be lower than their analogs for energy generated from non-renewable sources.



**Fig. 2.** Cost price reduction forecast of green electricity generation (by the LCOE method) for solar power plants (capacity of more than 10 MW, LCOE SPP) and wind power plants (capacity of more than 2000 MW per turbine, LCOE WPP) in 2020–2029 (calculated by the authors).

According to the planned decline in feed-in tariff rates in Ukraine in 2021–2029, the lowest feed-in tariff will be 12.01 euro cents/kWh for the considered solar power plant type and 7.92 euro cents/kWh for the considered wind power plant type starting 2025 [27]. Compared to the forecast data on LCOE, feed-in tariff

rates will be several times higher than the expected LCOE for the two RE technologies. That is, in the absence of the further legislative revision of the feed-in tariff rates, the divergence between tariffs and the real cost price of green energy generation will increase. The consequence will be continuing excessive growth in the state budget overspending covered by Ukrainian taxpayers.

Given the projected significant reduction in the cost of green electricity, the latter may gradually become a real competitor for traditional electricity. Under such conditions, the feed-in tariff as an economic support instrument for the development of solar power plants with a capacity of more than 10 MW and wind power plants with a capacity of more than 2000 MW per turbine will exhaust itself. It should be abolished for new similar projects in the RE field in Ukraine. However, the feed-in tariff may be preserved for small and medium-sized RE plants, which have a higher cost price of green electricity generation. Relevant practices for small RE facilities are successfully used by many countries worldwide, ensuring the decentralization of energy supply by involving green energy sources [22; 24; 35; 43].

## 7 Conclusions

The study results on the example of large solar and wind power plants show that current feed-in tariffs in Ukraine are inflated several times and do not correspond to the economically justified level. Such an imbalance in pricing policy for the RE sector causes the disproportionate development of large green energy capacities in the country and devastates the state budget, the losses of which are already estimated at hundreds of millions of euros. Today ordinary Ukrainians pay an exorbitant price for green energy. Preservation of existing and planned reduction of feed-in tariff rates threatens sustainable RE sector development and may cause the industry's financial crisis.

On the one hand, to avoid the mentioned negative consequences, it is advisable to revise the current feed-in tariffs and bring them in line with global trends of the cost price reduction for green electricity generation. However, it is important to consider the additional factors that can increase the unit price for green electricity and refer to the conditions of doing RE business in Ukrainian realities.

On the other hand, with the preservation of feed-in tariffs, the amount of electricity generated by RE facilities operating on feed-in tariffs will only increase. Consequently, state budget expenditures will rise further even with fair feed-in tariffs. Therefore, it is necessary to gradually move away from using the feed-in tariff mechanism, which ensured the successful start of RE development in Ukraine, and apply other levers to regulate sustainable RE development. The latter may include introducing green auctions, renewable portfolio standards, net metering, green certificates market, and other instruments, which will ensure the continued

sustainable advancement of the RE sector without creating excessive loading on the Ukrainian state budget.

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