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Promising Directions of Increasing Energy Efficiency and Development of Green Energy in the Household Sector of Ukraine

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Abstract: The aim of the article is to identify promising directions for increasing energy efficiency in the household sector of Ukraine, focusing on green energy. The study involved a graphical, analytical and prognostic methods, in particular the trend analysis of polynomial regression. The study was based on data on the volumes of generation, RES (renewable energy sources) consumption, and the tariff for renewable energy for 2014-2022. The forecast covered a period of 8 quarters. Solar power plants are the most popular renewable energy source among households. The high tariff for the sale of such energy and the ease of installation of solar power plants are key factors in choosing this method of generating electricity from renewable sources. Household solar power plants account for 11% of the total solar power plant capacity in the country. The number and capacity of these plants are predicted to double every 2 years, which will ensure a proportional increase in household income from the sale of electricity generated by solar power plants. The results of the study open up prospects for studying the payback terms and economic efficiency of using different sources of renewable energy in different regions of Ukraine, which is especially important for households and utilities.

Keywords: renewable energy sources; solar power plants; alternative energy; green energy; household energy efficiency.

JEL Classification: Q42; Q48; O13.

Introduction

The concept of green energy has become extremely widespread over the last 30 years. This is explained primarily by the low negative impact of some energy sources on the environment, climate and ecology. Green energy includes alternative energy sources that do not produce harmful emissions into the environment, and such energy can be obtained almost anywhere on the planet. The energy of the sun, wind, water, electromagnetic waves, etc. is an alternative to fossil fuels, which are used to obtain energy. There are many energy programmes aimed at the development of renewable energy sources (Australian Government 2023; Oguntona *et al.* 2021). Many strategies for the implementation of renewable energy are also being developed at the state, industry, and household levels (Maka and Alabid 2022; Elavarasan *et al.* 2020; Sala *et al.* 2023). Approaches to optimizing the services of utility companies for the reconstruction of residential buildings to increase energy efficiency are being studied (Amirbekova *et al.* 2023).

Alternative energy sources occupy an important place in the context of the economic and energy development of the economy of Ukraine. This is evidenced by the large number of strategies and programmes for the development of renewable energy adopted and implemented in Ukraine:

1) Energy Strategy of Ukraine by 2030 (Cabinet of Ministers of Ukraine 2013), which establishes the main directions of development of renewable energy in Ukraine until 2030. These include increasing the share of renewable energy sources in the total energy balance of Ukraine to 25%; expanding the use of renewable energy sources in different sectors of the economy, in particular in transport, agriculture and the housing sector; creation of favourable conditions for investment in renewable energy; raising awareness of the benefits of renewable energy sources;

2) The National Action Plan for the Implementation of the National Strategy for the Development of Renewable Energy in Ukraine by 2030 (Cabinet of Ministers of Ukraine 2020), which defines specific measures that must be implemented to achieve the goals of the National Strategy for the Development of Renewable Energy in Ukraine by 2030;

3) The Programme of State Support for the Development of Renewable Energy in Ukraine (Verkhovna Rada of Ukraine, 2020). This Programme defines state support measures for the development of renewable energy in Ukraine. In particular, these are the introduction of the green tariff, the provision of tax benefits to investors in renewable energy, the creation of the Fund for the Development of Renewable Energy, the development of a scheme for guaranteed reimbursement of costs for the construction of power plants;

4) The Energy Strategy of Ukraine by 2050 (Cabinet of Ministers of Ukraine 2023);

5) The Law of Ukraine “On Alternative Energy Sources”(Verkhovna Rada of Ukraine 2023).

The alternative energy sources are generally available and the threshold for entering this market is relatively low. Moreover, green energy is also environmentally friendly. Green energy occupies one of the central places in terms of finding ways to independently meet energy needs. A study Diachuk *et al*. (2017) by the Heinrich Boell Foundation examines three scenarios for the development of green energy. A conservative scenario assumes that the level of technology and efficiency of renewable energy will not change by 2050 compared to 2012. Under such conditions, only a small part of the advantages of renewable energy can be used in practice. This scenario is used as a baseline for comparison. The liberal scenario assumes that the share of renewable energy in the final aggregate consumer balance will exceed 30%. The revolutionary scenario assumes that the development of alternative energy will advance at the state and interstate levels. The increased development of this industry will ensure the share of renewable energy up to 91% of the total consumer needs. At the same time, the need for energy will decrease by 42% due to the increased productivity of the economy.

Ukraine actively implements international agreements to promote the development of green energy. Since 2011, Ukraine has been an official member of the European Energy Community, and in 2016 it ratified the Paris Agreement (Verkhovna Rada of Ukraine 2016), taking on commitments to develop renewable energy sources. The Government of Ukraine approved the Energy Strategy of Ukraine (Cabinet of Ministers of Ukraine 2017), which assumes that renewable energy will cover 25% of the energy needs of end consumers by 2035.

As we can see, Ukraine has created all the necessary prerequisites for the development of renewable energy, but the question about the renewable energy sources which are the most promising and cost-effective for the development in Ukraine remains open. The legislation does not distinguish individual priority directions for the development of particular sources. However, not all regions of our country can develop different sources of alternative energy with equal success. This affects the budgetary support for the development of alternative energy and its efficiency (Sotnyk *et al.* 2021).

The novelty of the study consists in the application of a comprehensive analysis of energy production from renewable sources in Ukraine, considering the participation of households in this process, as well as in the formation of an approach to forecasting the further development of this area. The proposed study is important in the context of the development of renewable energy in Ukraine, as it allows determining the potential of solar energy production by households and predicting their impact on the overall energy supply system. Analyzing the volumes of generation and consumption of energy from renewable sources also contributes to balanced planning and management in the country's energy sector. So, the aim of the study is to determine promising directions for increasing the energy efficiency of green energy in the household sector of Ukraine. The aim involves the fulfilment of the following research objectives:

- Study the structure and dynamics of the development of renewable energy sources in Ukraine;
- Explore the state and dynamics of the development of electricity generation from renewable sources by households;
- Determine the forecast indicators of the development of electricity generation by households from renewable sources.

1. Literature Review

Green energy cannot develop separately from other sectors of the economy and is an element of sustainable development of the country. A positive relationship between the development of green energy and the achievement of sustainable development goals is reported (Aktar *et al.* 2020). The authors note that the development of green energy makes energy more accessible, thereby contributing to economic development. But the economic effect can be significant only if there is state support in the form of implementing a national strategy. Otherwise, the development of green energy is partial, which does not have a significant impact on the national scale. In their study, the authors do not consider renewable energy in terms of types of energy production, but this is absolutely necessary when determining the impact of its development on the sustainable development of the country. Such a distribution is even more important in the context of assessing the impact of renewable energy on the economic development of the state as a whole and households in particular. This aspect of the issue under research remains unresolved.

The study of Majeed and Luni (2019) is more informative in this regard, where each type of renewable energy is considered separately in the context of its development potential. The authors focus on the impact of various renewable energy sectors on the environment. In addition, the authors' findings confirm the theory of social choice and welfare economics by substantiating the utility of environmental improvement for consumers. However, the prospects of each type of renewable energy for meeting the needs of households is insufficiently disclosed in the work. It is worth noting that the technological level of development of green energy allows it to be used to meet the needs of various groups of consumers, including households, which is especially relevant for Ukraine.

Alternative energy is becoming cheaper every year, as evidenced by a study by the United States Environmental Protection Agency (2023). Besides, the development of the alternative energy sector is also evidenced by the increasing number of jobs in the field of installation and maintenance of plants for alternative energy sources. Reducing cost of entering the alternative energy market makes green energy more affordable. As researchers note, the number of installed renewable energy capacities doubled between 2012 and 2018, and renewable energy accounts for 65% of the world’s gross investment in the energy sector (Kurbatova and Perederii 2020). This is one of the main factors in the spread of alternative energy among households. The high cost of initial investment was a traditional obstacle to the mass distribution of alternative energy among Ukrainian households (Sotnyk *et al.* 2022). In combination with an unstable economic situation, accompanied by inflationary and devaluation surges, this made alternative energy practically unaffordable to ordinary Ukrainians. But technology improvements and cost reductions make alternative energy more affordable, which is an important factor in its spread among Ukrainian households and utilities.

In its study, author states that the development of alternative energy can improve the economic situation of such vulnerable population groups as low-income households. In addition to getting cheap energy, they can sell it to the national market as suppliers (Deloitte 2023). Sales of the excess of generated energy into the power grid will provide additional income for this category of population. But this study does not indicate the most cost-effective types of renewable energy for households. This is why determining the most promising types of renewable energy is a key task, if the development of this sector of the economy is focused on households.

In a study of the prospects for investing in renewable energy in Ukraine (Sotnyk *et al.* 2019; Ostapenko *et al.* 2020), the authors conclude that the share of renewable energy in Ukraine can reach 25% by 2030 with proper

institutional support from the state. This issue is especially important in the context of reducing the import of energy carriers, on which Ukraine largely depends. The authors of the study demonstrate the economic efficiency of investments in renewable energy using Net Present Value. However, the authors omit the payback for different types of renewable energy. In our opinion, it is necessary to compare different types of renewable energy and choose the type that is most appropriate for its use by households.

The researchers assess the suitability of the investment climate for installing renewable energy generation capacities (Kuzior *et al.* 2021; Latysheva *et al.* 2020). The authors found that more than 60% of the surveyed respondents support increased tariffs for Ukraine's transition to renewable energy. This support for the transition to green energy indicates significant prospects for the introduction of renewable energy in Ukrainian households.

The analysis of literature showed that renewable energy is popular both in Ukraine and in the whole world. However, the analysed studies do not provide a comprehensive answer to the question about the most promising types of renewable energy in terms of different countries and different categories of consumers.

2. Methodology

The research will be conducted in three stages. The first stage involves the analysis of the structure and dynamics of energy generation from renewable sources in Ukraine. The study covers the following areas in which energy is generated from renewable sources: Heating and cooling systems; Electricity; Transport sector.

At the first stage, the volumes of generation from renewable sources and energy consumption in each sector were analysed. The structure of energy generation from renewable sources includes: Hydroelectric power plants; Solar power plants; Wind power plants; Use of biomass.

The second stage provided for the analysis of electricity generation by households in Ukraine. As households mainly use solar power plants to generate electricity, the generated power, the share in the structure of the generation of all electricity in Ukraine from solar power plants, and the income of households from the sale of electricity obtained from solar power plants were analysed.

To perform the procedures of the first and second stages, graphs will be used to visually demonstrate the dynamics of indicators. Analytical calculations of these indicators will be used to determine the specific weight of indicators.

The third stage of the study involves forecasting the indicators of the development of electricity generation from household solar power plants. Based on the available data, a forecast of growth in the number and capacity of household solar power plants and revenue growth was made. Forecasting was carried out using the trend method and the selection of dependence, which demonstrated the highest degree of model adequacy. Polynomial regression with degree 2 was used in all predictive models.

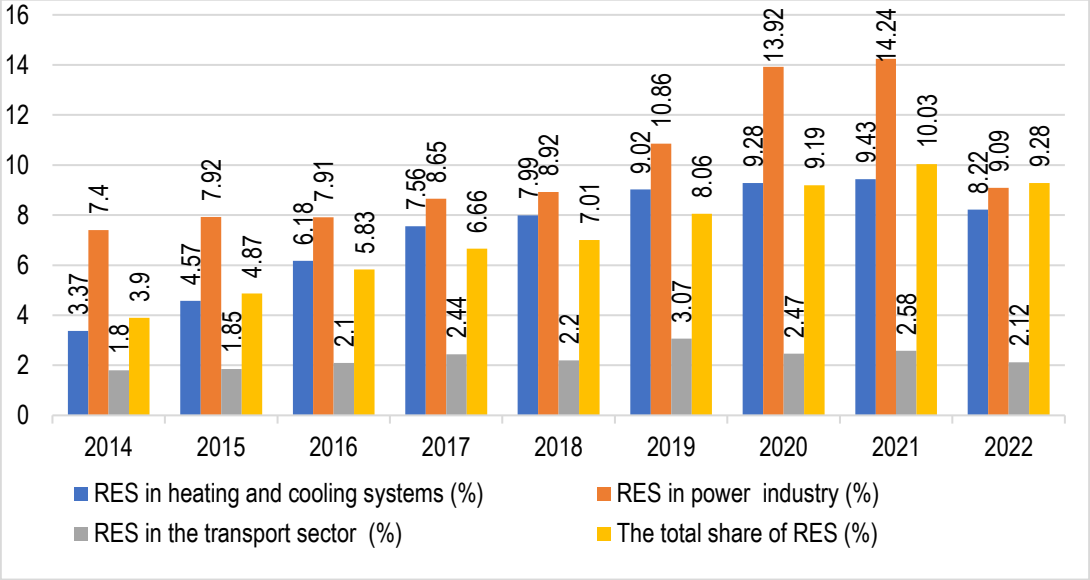
The study used data on generation volumes, RES consumption, and the tariff for RES for 2014-2022. The study used data on generation volumes, energy consumption from renewable sources and the size of the tariff for energy from renewable sources for the period 2014-2022. The study considers the size of tariffs for renewable electricity in 2021. It is during this period that statistical observation is conducted and information is accumulated about the renewable energy industry in Ukraine. The forecast of the above indicators will be carried out for 2023-2024 after the date of the last available observation. This decision is determined by several factors. The first factor is the lack of publicly available information on the state of development of renewable energy in Ukraine for 2022-2023. The second factor is that Russia's full-scale invasion of the territory of Ukraine significantly reduced the number of solar power plants and power generation because of the damage to facilities and infrastructure. Such circumstances are unforeseeable and constitute a force majeure.

Statistics on renewable energy are taken from the official website of the State Agency on Energy Efficiency and Energy Saving of Ukraine (2023), which conducts statistical monitoring and publishes relevant information. Calculations and visualizations were made in Microsoft Excel.

3. Results

Green energy in Ukraine is developing not in all, but only in some industries. As a rule, power generation is aimed at meeting the needs of the generating entities. At the time of the study in Ukraine, renewable energy sources are used for energy generation in the transport sector, heating and cooling systems, and power industry. The share of renewable energy sources in the overall structure of energy production is analysed below (Figure 1).

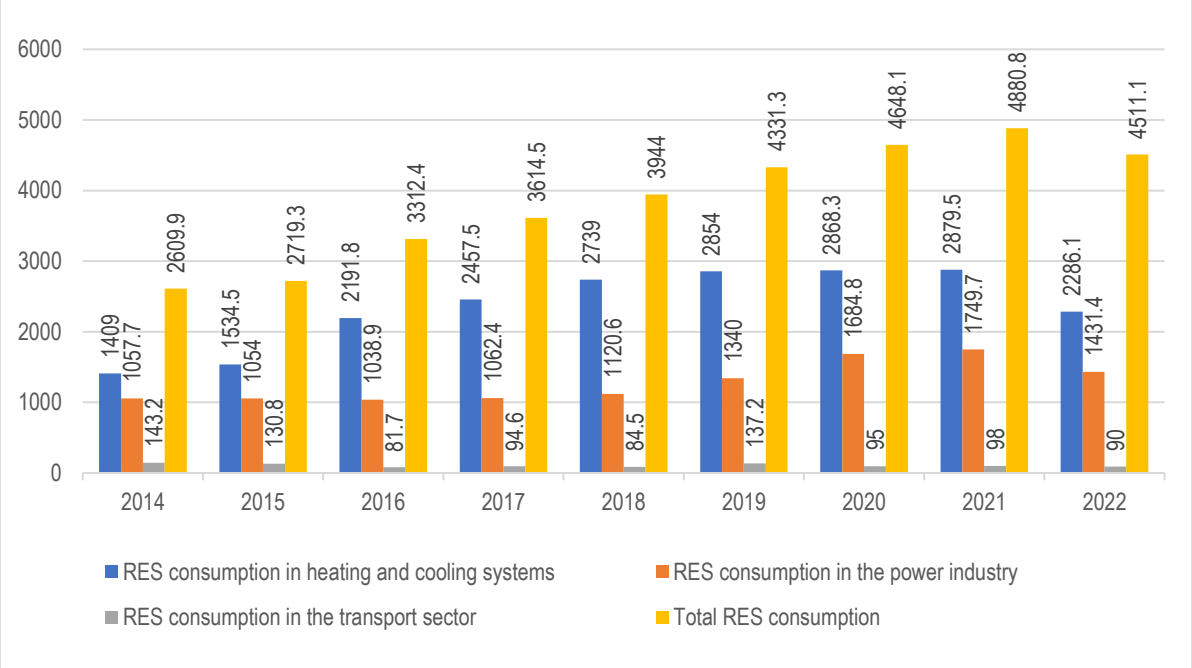
Figure 1. The share of renewable energy sources in the structure of energy production in Ukraine



Since 2014, there has been a gradual increase in the share of renewable energy in the structure of energy production in Ukraine. In 2020, compared to 2014, the share of energy production from renewable sources in heating and cooling systems increased by 175%, in electricity production by 88%, and in the transport sector by 37%. The cumulative increase in energy production from renewable sources was 136%. Such a significant increase in the volume of energy production from renewable sources indicates a steady trend towards the transition to green energy in different industries.

In addition to the analysis of energy production from renewable sources, it is necessary to analyse the structure and volumes of consumption in each of the production sectors (Figure 2).

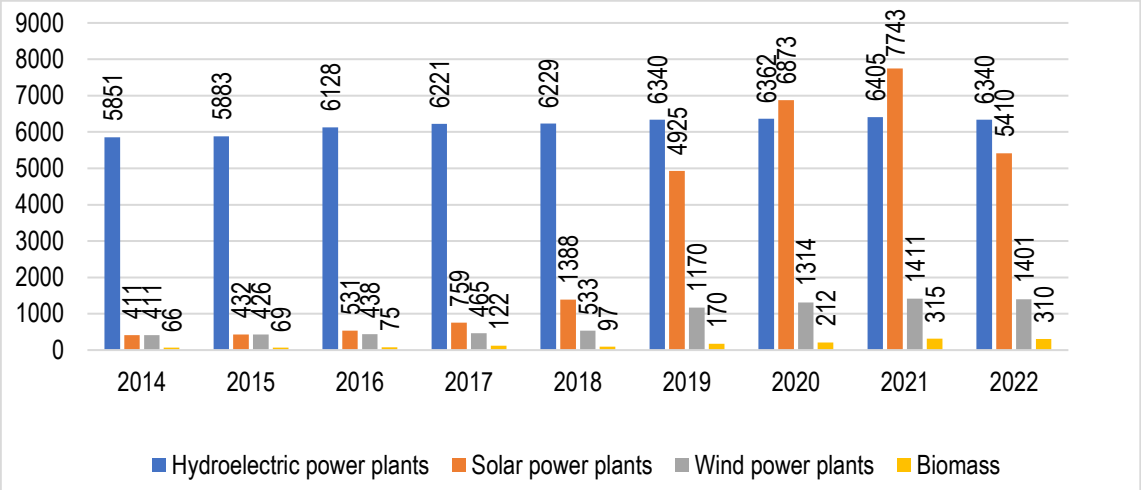
Figure 2. Gross final volume of RES consumption (thousand ktoe)



Statistics indicate a steady trend towards growth in the gross volume of RES consumption in all analysed industries except for transport. The increase in RES consumption in 2020 compared to 2014 is 104% in heating and cooling systems, 59% in electricity generation. The transport sector experienced a 34% drop in consumption. In general, the gross RES consumption increased by 78% during the analysed period.

The structure of energy production in terms of different sources of renewable energy is analysed in more detail below (Figure 3).

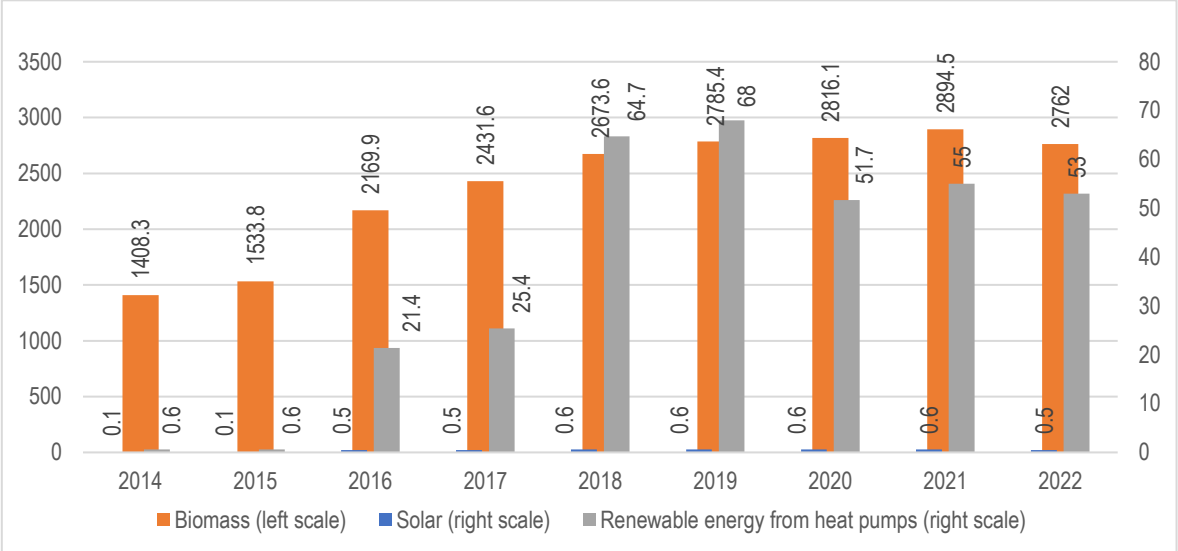
Figure 3. The structure of energy generation from renewable sources in the power industry (MW)



Hydroelectric power plants take the largest share in the structure of electricity generation, but the dynamics of their energy generation growth is only 9% in 2020 compared to 2014. On the other hand, obtaining electrical energy from solar power plants, wind power plants, and from the use of biomass has significantly higher growth rates. The volume of electricity generation from the biomass increased by 221%, from wind power plants increased by 220%, and from solar power plants increased by 1572%. Such a rapid growth of the electrical energy obtained from the use of solar power plants has been observed since 2016, and has a steady tendency to increase.

The dynamics of energy generation in heating and cooling systems is analysed (Figure 4).

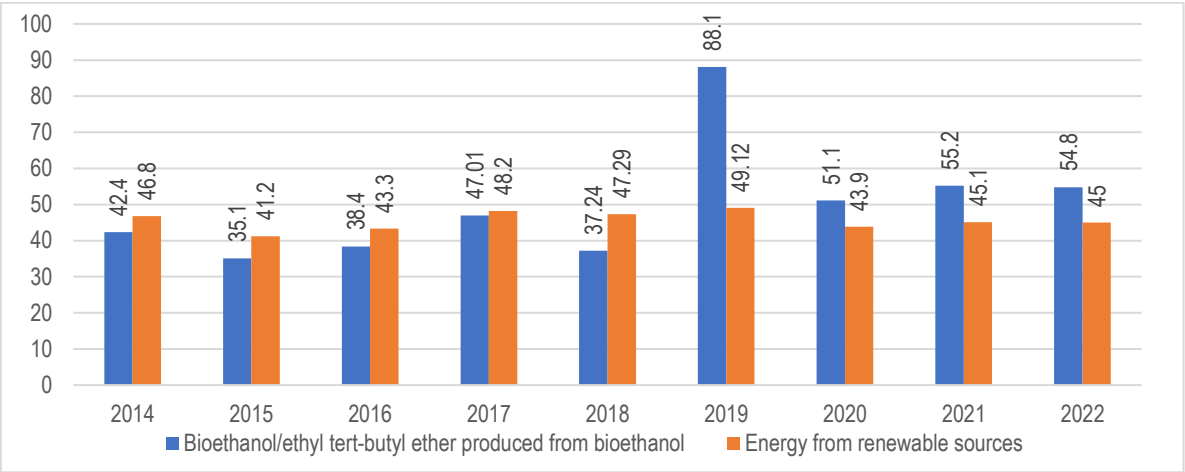
Figure 4. Structure of energy generation from renewable sources in heating and cooling systems (MW)



In heating and cooling systems, the largest share of generated energy is energy obtained from biomass. Moreover, there is a steady trend towards an increase in the share of energy received from this source. The increase in generated energy in 2020 compared to 2014 is 100%. The energy received from solar power plants takes the smallest share of 0.1 MW in 2014, and 0.6 MW in 2020. Renewable energy from heat pumps also demonstrates the positive dynamics of the increase in the volume of generated energy. This is also a promising source of obtaining energy as a result of the accumulation and use of thermal energy from the operation of heat pumps.

Next, the dynamics of changes in the volume of RES in the transport sector is analysed (Figure 5).

Figure 5. Structure of energy generation from renewable sources in the transport sector (MW)

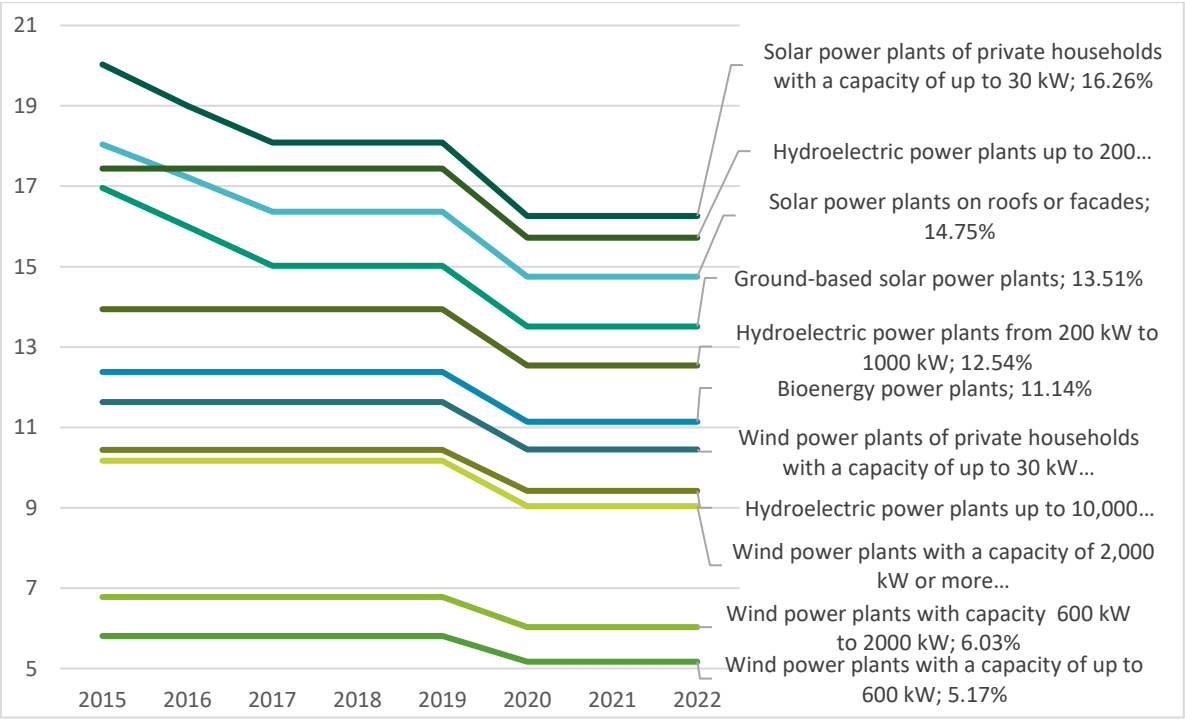


Data analysis shows an increase in the amount of energy generation from the use of bioethanol (a 21% increase in generation in 2020 compared to 2014) and a decrease in energy generation from renewable sources in 2020 by 6% compared to 2014. In general, with the exception of 2019, a steady pace of energy generation in the transport sector is observed.

Analysing the obtained results, we can say that the sphere of energy generation is developing most dynamically in those sectors where consumers are households or small and medium-sized businesses. The largest increase is shown by solar power plants, wind power plants and the use of biomass.

The next stage of the research is the analysis of the dynamics of the green tariff in Ukraine, which is set for RES (Figure 6). In this context, it is worth noting that the green tariff in Ukraine is not a market one. It is set by the state and is higher than the market rate, as the tariff performs a stimulating function for the development of green energy. It is expected to be gradually reduced and transferred to market pricing, which will ensure the development of competition in this market niche of renewable energy.

Figure 6. Dynamics of changes in the green tariff in Ukraine (€ct/kWh)



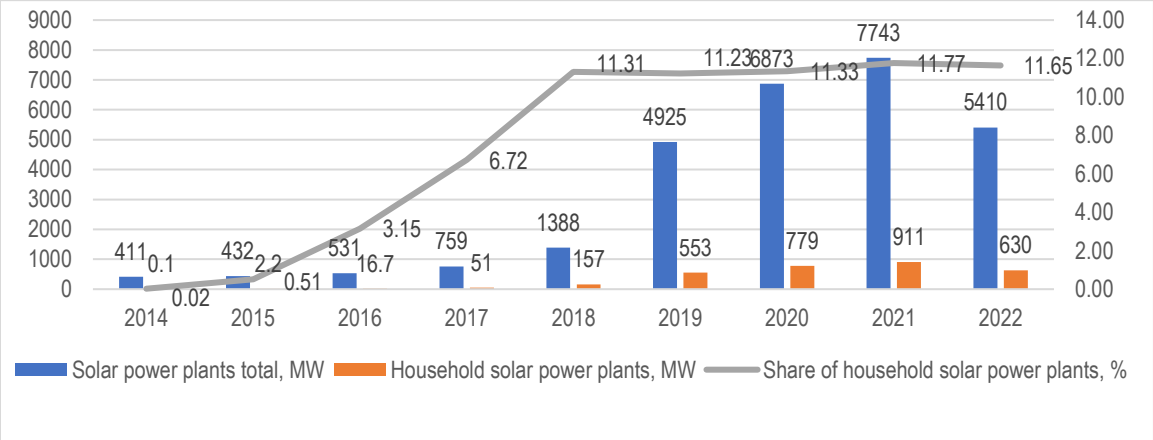
The data of Figure 6 show that in Ukraine the highest tariffs are set for solar power plants, and the lowest — for wind power plants. Most tariffs remained unchanged, but relatively high during 2015-2019. This tariff was the main tool for stimulating the development of renewable energy in Ukraine, but since 2020 it has been reduced for all types of energy sources. At the same time, there is no change in the structure of tariffs for different RES.

So, the state continues to prioritize the development of solar power plants. Such a decision by the regulators is logical, as solar power plants are the most simple and affordable source of energy generation that does not require technologically complex equipment and expensive maintenance. This is the reason why solar power plants have become so popular among households in Ukraine.

If the household sector of energy consumers in Ukraine is analysed, the vast majority use solar power plants to generate power from renewable sources.

The share of solar power plants belonging to households is constantly increasing in the entire gross power generation from solar power plants (Figure 7).

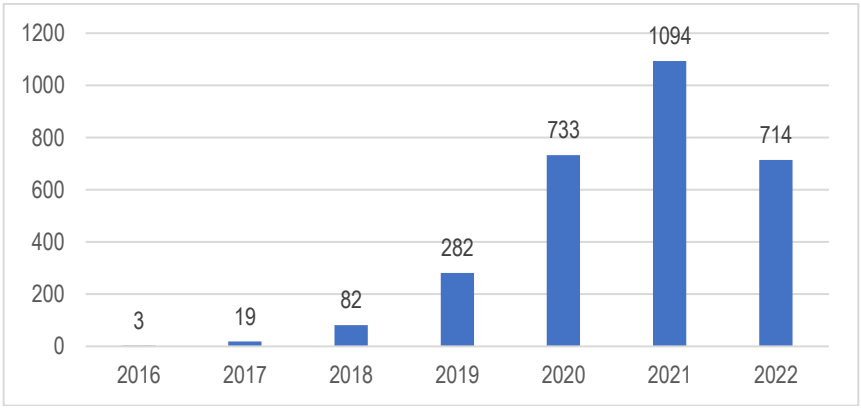
Figure 7. The ratio of the capacity of household solar power plants to the total generation of solar power plants in Ukraine



Since 2014, the share of household power plants has increased from 0.02% to 11.31% in 2018. The share remains the same thereafter, although capacity continued to grow from 157 MW in 2018 to 779 MW in 2020. The unchanged share of household solar power plants is explained by the parallel growth of the share of power plants owned by companies.

In connection with the rapid growth of power generation by household solar power plants, there was also an increase in the volume of sold power generated by the latter (Figure 8).

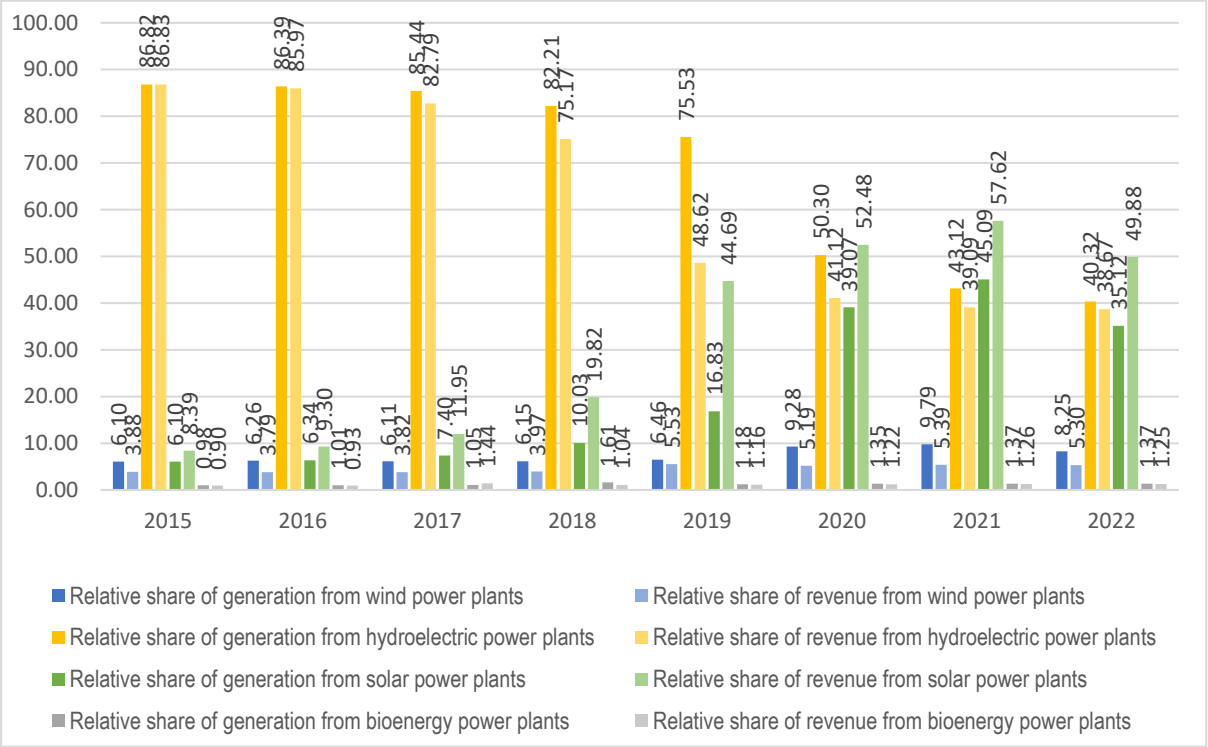
Figure 8. Volume of sold power generated by household solar power plants, million kWh



As the highest tariff for the purchase of electricity was established for solar power plants of private households, this entailed an increase in the volume of electricity sales from 3 million kWh in 2016 to 1,094 million kWh in 2021. The dynamics of increasing amount of sold electricity generated by household solar power plants is explained by the possibility of obtaining high income from the sale of electricity. Even after the downward revision of the green tariff after 2020, household solar power plants are expected to have the highest tariff.

The amount of revenue that owners of green energy facilities can receive was analysed to assess the profitability of power generation from different renewable sources (Figure 9). For a better understanding of the situation, the relative share of revenue from each source of renewable energy was calculated, not the absolute amount of revenue in euros.

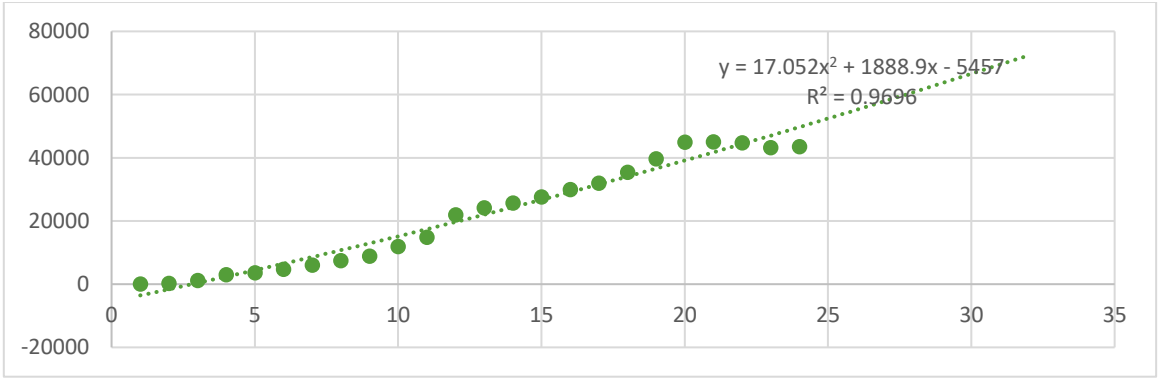
Figure 9. Shares of types of renewable energy in power generation in gross revenue from sold electricity



The data of Figure 9 indicate that the share of revenue from the sale of electricity generated by solar power plants exceeds the share of the generation of such electricity. This indicates that electricity from solar power plants brings significantly higher profitability compared to other RES, for which the specific weight of generation and revenue maintains its proportionality.

It is worth noting that the full-scale war in Ukraine significantly complicated the process of development of alternative renewable energy. The energy sector has faced significant challenges both in terms of installing new capacity and in realizing energy due to damage to the energy infrastructure. This is followed by the analysis of how the sector of electricity generation by households using solar power plants would develop. Figure 10 shows the forecast dynamics of growth in the number of household solar power plants during 2023-2024.

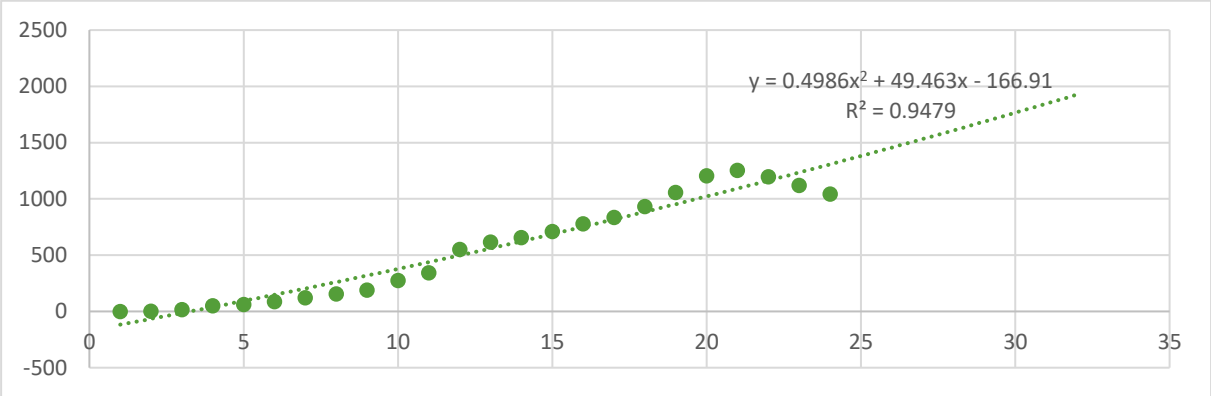
Figure 10. Estimated number of household solar power plants in Ukraine for 2023-2024 (forecast base 2015-2022)



There were 43,540 solar power plants at the end of 2022, and their number is expected to reach about 70,000 by the end of 2023. That is, every 2 years the number of household solar power plants in Ukraine would double.

Similarly, the capacity of such power plants would grow (Figure 11).

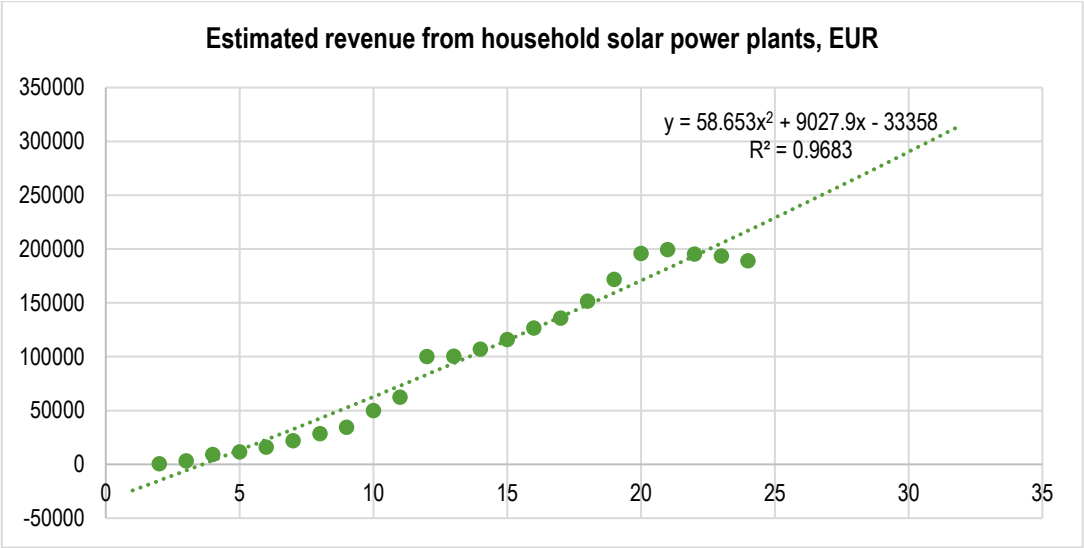
Figure 11. Forecast capacity of household solar power plants in Ukraine for 2023-2024 (forecast base 2015-2022)



If at the end of 2022 the capacity of household solar power plants was 1,043 MW, it would reach 2,000 MW by the end of 2024. But these forecast calculations do not take into account the development of technologies. With the improvement and use of more efficient solar panels, the generated power can more than double every 2 years.

Given that the size of the green tariff is established and fixed for the entire period of 2020-2024, we can make a forecast of the annual increase in revenue from the sale of electricity from household solar power plants in Ukraine (Figure 12).

Figure 12. Forecast growth of revenue from the sale of electricity from household solar power plants in Ukraine for 2023-2024 (forecast base 2015-2022)



The obtained results indicate that the most promising direction of increasing energy efficiency in the household sector is the transition to RES. The practical experience of implementing programmes for the development of green energy has shown that Ukrainian household consumers are interested in investing in the installation of solar power plants to obtain electrical energy, and in case of its excess in selling it to the grid. A forecast of the growth dynamics of the number and capacity of household solar power plants showed that these figures would double every 2 years. A similar situation is observed with the revenue from the sale of electricity at the green tariff fixed for the studied period.

4. Discussions

Comparing the obtained results with other studies on this issue, it is worth paying attention to studies on human rights in the context of sustainable development (United Nations Human Rights Office of the High Commissioner 2022) and on the acceleration of innovations in the field of renewable energy (World Economic Forum 2018). The authors of the study claim that free access to energy is one of the main human rights, which contributes to the sustainable development of mankind. Our research confirms this position, because households in Ukraine, realizing their right to access to energy, not only fully provide themselves with electricity, but also act as

participants in the energy market of Ukraine. Selling the excess of generated electricity into the country's unified grid, households provide other subjects with electricity and receive income for it, which stimulates consumption and forms solvent demand. This proves that the development of renewable energy is a positive driver of economic development and ensures the achievement of the sustainable development goals.

The behaviour of households in Ukraine regarding the growing demand for RES is consistent with the household behaviour pattern in the EU. According to the results of the study (European Court of Auditors 2018), the target indicator of the share of renewable energy in the EU is 20% in 2020 and will be 27% by 2030. In Ukraine, the target indicators retain approximately the same level, but the results of our research show that if the share of energy from household solar power plants doubles every 2 years, by 2030 this indicator may exceed the one in the EU. Moreover, as a number of studies (Diatlova and Petryk 2019; Prokopenko *et al.* 2021; Brych *et al.* 2021) noted, Ukraine has chosen one of the most effective methods of stimulating the development of alternative energy – the formation of RES market. This ensures the interest of investors and the development of new RES projects, including among households.

It is interesting to compare the obstacles to the development of renewable energy in Ukraine and other countries. The study indicates that most countries are characterized by the following obstacles: excessive dependence on fossil fuels (coal), political and regulatory barriers, technical barriers, market barriers, socio-cultural barriers, financial and economic barriers, as well as geographic and environmental barriers (Kariuki 2018). Our results show that financial obstacles are the most characteristic for Ukraine. Although alternative energy is becoming more affordable and its generation is increasing every year (Federal Ministry for Economic Affairs and Energy 2019; Resilient Energy Platform 2019), initial investments are still quite high for the average Ukrainian household. The novelty of the obtained is the determined trends in the development of green energy in Ukraine among households and forecasted trends in the development of renewable energy under the conditions of a free market and the absence of military actions.

Conclusions and Further Research

The problem of meeting energy needs is acute for almost all economies in the world, and Ukraine is no exception. This problem is even more acute for household consumers, who are largely dependent on energy price fluctuations. In such conditions, the development of green energy is a way to solve this problem. Renewable energy sources ensure the availability of energy for household consumers and utilities, and the government policy in Ukraine enables selling the excess of generated energy in a unified grid.

The conducted research showed that the vast majority of households in Ukraine use solar power plants to generate electricity. The main motivation is self-provision with electricity. Additional motivation is the possibility of selling excess electricity and making a profit. The predominance of solar power plants for energy generation is determined by the high tariff for such energy and the relative ease of installation of solar power plants. Household solar plants account for 11% of the total capacity of solar power plants in Ukraine. Calculation of the forecast values of the number and capacity of solar power plants showed that they will double every 2 years. This will ensure a proportional increase in household income from the sale of electricity generated from solar power plants.

The obtained results can be applied in the development and economic justification of investment projects for the development of household solar power plants and in the implementation of state programmes for the development of green energy.

The conducted research opens up prospects for further studies, in particular regarding payback terms and economic efficiency of using different RES in the regions of Ukraine.

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Credit Authorship Contribution Statement

Olha Prokopenko: Conceptualization, Investigation, Methodology, Project administration, Software, Formal analysis, Writing – original draft, Supervision, Data curation, Validation, Writing – review and editing, Visualization, Funding acquisition.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Aktar, M.A., Harun, M.B., and Alam, M.M. 2020. Green energy and sustainable development. In W. Leal Filho, A. Azul, L. Brandli, A. Lange Salvia, and T. Wall (Eds.), Affordable and Clean Energy. Encyclopedia of the UN Sustainable Development Goals. Springer, Cham. DOI: https://doi.org/10.1007/978-3-319-71057-0_47-1

[2] Amirbekova, A., Abdykarimova, S., Oliynyk, O. 2023. Renovation of residential buildings of the first mass series from a sustainable development point of view. *Civil Engineering and Architecture*, 11(4): 1814–1823. DOI: https://doi.org/10.13189/cea.2023.110412

[3] Brych, V., Zatonatska, T., Dluhopolskyi, O., Borysiak, O., and Vakun, O. 2021. Estimating the efficiency of the green energy services' marketing management based on segmentation. *Marketing and Management of Innovations*, (3): 188-198. DOI: http://doi.org/10.21272/mmi.2021.3-16

[4] Diachuk, O., Chepeliev, M., Podolets, R., and Trypolska, G. 2017. Transition of Ukraine to the renewable energy by 2050. In Y. Oharenko and O. Aliieva (Eds.), Heinrich Boell foundation regional office in Ukriane. Kyiv: Publishing house "Art Book" Ltd. pp. 1-88. https://ua.boell.org/sites/default/files/transition_of_ukraine_to_the_renewable_energy_by_2050_1.pdf

[5] Diatlova, V., and Petryk, I. 2019. Strategic approach to renewable energy development: EU experience. Economic Sciences. DOI: https://doi.org/10.32515/2663-1636.2019.2(35).9-19

[6] Elavarasan, R.M., Shafiullah, G., Padmanaban, S., Kumar, N.M., Annam, A., Vetrichelvan, A.M., Mihet-Popa, L., Holm-Nielsen, J.B. (2020). A comprehensive review on renewable energy development, challenges, and policies of leading Indian States with an international perspective. IEEE Access, 8: 74432-74457. DOI:https://doi.org/10.1109/ACCESS.2020.2988011

[7] Kariuki, D. (2018). Barriers to Renewable Energy Technologies Development. Keele University. DOI:http://dx.doi.org/10.1515/energytoday-2018-2302

[8] Kurbatova, T., and Perederii, T. 2020. Global trends in renewable energy development. In 2020 IEEE KhPI Week on Advanced Technology (KhPIWeek), Kharkiv, Ukraine, pp. 260-263. Available at: https://essuir.sumdu.edu.ua/bitstream-download/123456789/84257/1/Kurbatova_trends.pdf

[9] Kuzior, A., Lobanova, A., and Kalashnikova, L. 2021. Green energy in Ukraine: State, public demands, and trends. Energies, 14(22): 7745. DOI: https://doi.org/10.3390/en14227745

[10] Latysheva, O., Rovenska, V., Smyrnova, I., Nitsenko, V., Balezentis, T., and Streimikiene, D. 2020. Management of the sustainable development of machine-building enterprises: A sustainable development space approach. *Journal of Enterprise Information Management*, 34(1): 328-342. DOI:http://doi.org/10.1108/JEIM-12-2019-0419

[11] Majeed, M. T., and Luni, T. 2019. Renewable energy, water, and environmental degradation: A global panel data approach. *Pakistan Journal of Commerce and Social Sciences*, 13(3): 749-778.

[12] Maka, A.O.M., Alabid, J.M. (2022). Solar energy technology and its roles in sustainable development. *Clean Energy*, 6(3): 476-483. DOI: https://doi.org/10.1093/ce/zkac023

[13] Oguntona, O.A., Aigbavboa, C.O., Monnanyana, T., and Thwala, W.D. 2021. Drivers of Renewable Energy Adoption in the Built Environment: A Case of South Africa. IOP Conference Series: Materials Science and Engineering, 1107: 012217. Available at: https://iopscience.iop.org/article/10.1088/1757-899X/1107/1/012217/pdf

[14] Ostapenko, R., *et al.* 2020. Analysis of production and sales of organic products in Ukrainian agricultural enterprises. *Sustainabilit*, 12(8): 3416. DOI: http://doi.org/10.3390/SU12083416

[15] Prokopenko, O., Chechel, A., Sotnyk, I., Omelyanenko, V., Kurbatova, T., and Nych, T. 2021. Improving state support schemes for the sustainable development of renewable energy in Ukraine. *Energy Policy Journal*, 24(1), 85-100. DOI: https://doi.org/10.33223/epj/134144

[16] Sala, D., *et al.* 2023. Investment and Innovation Activity of Renewable Energy Sources in the Electric Power Industry in the South-Eastern Region of Ukraine. *Energies*, 16(5): 2363. DOI:https://doi.org/10.3390/en16052363

[17] Sotnyk, I., Kovalenko, Y., Chortok, Y., and Kripak, Y. 2019. Prospects of investment in green energy projects in ukrainian households. *Science Journal «Economics and Region»*, 2(73): 12-21. DOI:https://doi.org/https://doi.org/10.26906/EiR.2019.2(73).1621

[18] Sotnyk, I., *et al.* 2022. Solar energy development in households: Ways to improve state policy in Ukraine and Latvia. *International Journal of Sustainable Energy*, 41(11): 1623-1649. DOI:https://doi.org/10.1080/14786451.2022.2092106

[19] Sotnyk, I., *et al.* 2021. The price for sustainable development of renewable energy sector: The case of Ukraine. In E3S Web of Conferences, 280: 02006. DOI: https://doi.org/10.1051/e3sconf/202128002006

[20] Verkhovna Rada of Ukraine. 2016. Document No1469-VIII. Law of Ukraine "On the ratification of the Paris Agreement". Available at: https://zakon.rada.gov.ua/laws/show/1469-19#Text, accessed on May 12, 2023.

[21] Verkhovna Rada of Ukraine. 2020. Document 1505-97-п. Law of Ukraine "On the state support program for the development of non-traditional and renewable energy sources and small hydropower and thermal power". Available at: https://zakon.rada.gov.ua/laws/show/1505-97-п#Text, accessed on May 14, 2023.

[22] Verkhovna Rada of Ukraine. 2023. Document 555-IV. Law of Ukraine "On Alternative Energy Sources". Available at: https://zakon.rada.gov.ua/laws/show/555-15#Text.

[23] Australian Government. 2023. Australia's Clean Energy Workforce. Discussion Paper. https://www.jobsandskills.gov.au/sites/default/files/2023-04/Clean%20Energy%20Capacity%20Study%20-%20Discussion%20Paper.pdf.

[24] Cabinet of Ministers of Ukraine. 2013. Document 1071. Energy Strategy of Ukraine until 2030. https://de.com.ua/uploads/0/1703-EnergyStratagy2030.pdf.

[25] Cabinet of Ministers of Ukraine. 2017. Document 605. On the approval of the Energy Strategy of Ukraine until 2035 "Security, Energy Efficiency, Competitiveness". https://zakon.rada.gov.ua/laws/show/605-2017-%D1%80#Text.

[26] Cabinet of Ministers of Ukraine. 2022. On the National Action Plan for the Development of Renewable Energy for the period up to 2030. https://saee.gov.ua/sites/default/files/DraftNPDVE_2030_SAEE_21_09_2022.pdf.

[27] Cabinet of Ministers of Ukraine. 2023. Document 373. On the approval of the Energy Strategy of Ukraine until 2050. Retrieved from https://zakon.rada.gov.ua/laws/show/373-2023-p#Text.

[28] Deloitte. 2023 Renewable Energy Industry Outlook. https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-eri-renewable-energy-outlook-2023.pdf.

[29] European Court of Auditors. 2018. Renewable energy for sustainable rural development: significant potential synergies, but mostly unrealized. Special Report No 05. Luxembourg: Publications Office of the European Union. https://www.eca.europa.eu/Lists/ECADocuments/SR18_05/SR_Renewable_Energy_EN.pdf.

[30] Federal Ministry for Economic Affairs and Energy. 2019. Renewable energy sources in figures. https://www.bmwk.de/Redaktion/EN/Publikationen/renewable-energy-sources-in-figures-2018.pdf?__blob=publicationFileandv=1.

[31] Resilient Energy Platform. 2019. Renewable energy to support energy security. Available at: https://www.nrel.gov/docs/fy20osti/74617.pdf.

[32] State Agency of Energy Efficiency and Energy Saving of Ukraine. 2023. Statistics on the development of renewable energy. Available at: https://saee.gov.ua/uk/content/informatsiyni-materialy.

[33] United Nations Human Rights Office of the High Commissioner. 2022. Renewable energy and the right to development: Realizing human rights for sustainable development. Available at: https://www.ohchr.org/sites/default/files/2022-05/KMEnergy-EN.pdf.

[34] United States Environmental Protection Agency. 2023. Guide to purchasing green power. Available at: https://www.epa.gov/greenpower/guide-purchasing-green-power.

[35] World Economic Forum. 2018. Accelerating sustainable energy innovation. Available at: https://www3.weforum.org/docs/Accelerating_sustainable_energy_innovation_2018.pdf.

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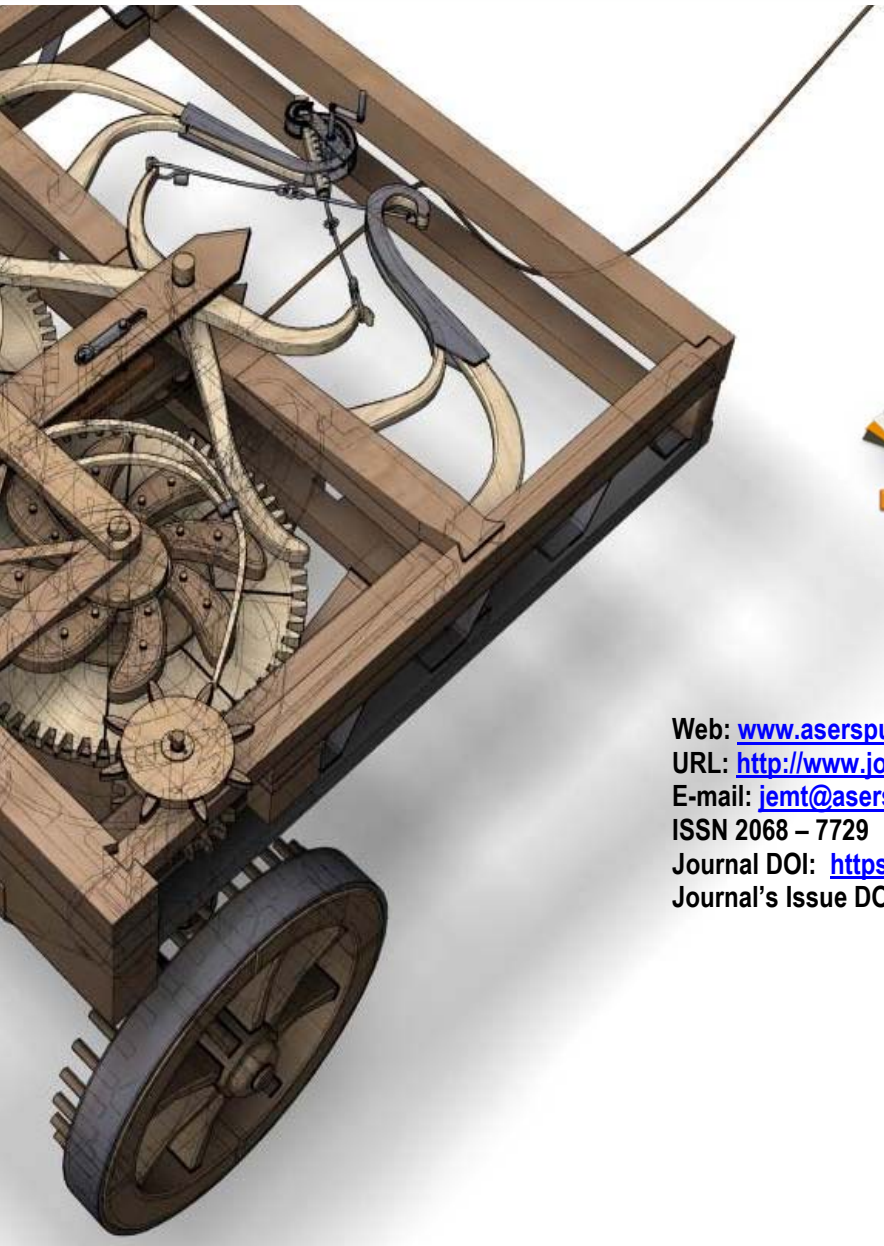

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