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SUSTAINABLE HOUSEHOLD ENERGY SUPPLY: METHODOLOGICAL APPROACHES TO MAKING OPTIMAL ECONOMIC DECISIONS[1]

The destruction of Ukraine's power infrastructure due to military actions exacerbates the problem of sustainable household energy supply. Frequent power, gas, and water outages lead to network overloads, rising tariffs, and decreased energy security. The vulnerability of traditional centralized systems highlights the need to explore alternative power supply approaches for the residential sector, particularly through the development of prosumerism, which involves active household participation in energy generation. This paper examines possible energy strategies for seven groups of typical private households utilizing different energy sources, including renewables. Methodological approaches are proposed for selecting economically optimal energy solutions, considering natural and climatic conditions, energy resource prices, the feasibility of using green technologies and energy efficiency measures, as well as state energy policy. Specifically, the potential of solar and wind power plants, battery storage systems, and diesel generators as means of autonomous energy supply for the residential sector is analyzed. The advantages and drawbacks of these technologies are assessed in the context of possible short- and long-term disconnections from the main power grid. The study results indicate that an effective household energy strategy should be based not only on minimizing economic costs but also on increasing energy independence and resilience to crises. Optimal economic decisions must take into account all energy-related home expenditures (including costs for heating, cooking, water heating, lighting, and economic losses caused by power outages) as well as potential revenues (such as savings achieved through self-produced energy consumption and income from selling energy surpluses). Key factors influencing household decision-making include government support, the availability of investment resources, and the implementation of economic mechanisms to stimulate the use of renewable energy sources. The proposed methodological approaches

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contribute to strengthening the country's overall energy security and to developing effective models of sustainable energy supply for households.

Keywords: **energy strategy, household, renewable energy sources, autonomous power supply, sustainable development, optimal solution, UN SDG7**.

JEL Classification: Q42, Q48, D61.

Introduction. The destruction of Ukraine's energy infrastructure as a result of the ongoing war has intensified the issue of sustainable energy supply for domestic households. Near-constant power, gas, and water outages – both scheduled and emergency – have led to energy grid overloads, premature wear of infrastructure, and rising costs of utility services. In addition, amid military conflict and the global energy crisis, new threats to energy security are emerging, requiring the state and society to seek new approaches to power provision. Traditional centralized power supply systems have proven vulnerable to Russian attacks, prompting a shift toward the idea of decentralized energy supply. This includes the development of the prosumerism concept, in which households not only consume energy but also generate it independently for their own needs. Such an approach increases household autonomy and resilience to external energy shocks.

However, transforming households into prosumers requires significant investment, particularly in the context of an economic crisis caused by war. With growing energy poverty, where a large portion of the population cannot afford high utility tariffs, issues of financial accessibility to energy technologies become increasingly urgent. Therefore, it is vital to develop approaches for forming optimal household energy strategies that enable the most effective combination of energy sources for sustainable power supply and daily functioning of homes.

Literature review. The issue of optimizing energy supply for the residential sector is highly relevant, especially amid global challenges such as energy security, climate change, and rising energy prices. Recent scientific literature explores diverse approaches to sustainable household energy supply, combining conventional and renewable sources, energy-efficient technologies, and innovative solutions.

Many researchers highlight the need to integrate renewable energy and digital technologies into cost-optimal household energy practices. A bibliometric analysis provided by Wang et al. (2024) focuses on household energy consumption patterns, environmental impacts, and energy-saving strategies. They recommend advancing smart home technologies, ensuring stable energy access, and addressing the needs of low-income and aging households.

Tran et al. (2023) examine energy consumption drivers using hybrid modelling and emphasize behavioural factors while developing energy conservation approaches for Asia-Pacific regions. Sangeeth et al. (2023) analyze demand response strategies, stressing the role of informational interventions and behavioural science in shaping consumption patterns for homes. Han et al. (2023) explore household energy management systems, assessing scheduling optimization and communication technologies, while outlining the shift toward complex, integrated architectures.

Chowdhury et al. (2024) apply predictive modelling to identify key socioeconomic and climatic factors influencing residential consumption to develop optimal energy strategies. Zhang et al. (2023) investigate household carbon emissions in China, showing how socioeconomic traits shape sustainable policies for homes. Kruekaew et al. (2023) study residential energy management integrating electric vehicles, solar panels, and storage systems, finding potential for over 20% cost reduction.

Arens et al. (2020) focus on sustainable home energy supply strategies through cross-sector integration, insulation, and localized power generation. Nacht et al. (2023) review residential energy modelling methods to assess energy-efficient and renewable energy technology upgrades and innovations. I. Krómer (2009) proposes a systems engineering approach to evaluate household energy supply using decentralized resources and cogeneration, emphasizing reduced primary energy use and emissions.

Tadesse et al. (2024) model an optimized mix of residential photovoltaics, hybrid heat pumps, and battery storage, showing cost savings through dynamic tariffs. Kgopana & Popoola (2022) assess hybrid systems combining solar and wind, enhancing the reliability and efficiency of energy strategies in households. Li et al. (2020) explore micro-cogeneration for affordable, efficient energy use to optimize home energy costs.

Prokopenko et al. (2024) identify key factors for optimal energy strategies in Ukrainian households, such as income, subsidies, and technology adoption, highlighting successful cases like solar panels and energy-efficient appliances. Veremiichuk et al. (2017) address energy planning issues in Ukraine's residential complexes, promoting the integration of decentralized and diverse energy sources.

To sum up, household energy strategy development and decision-making are multidimensional, involving economic, environmental, technological, policy, and behavioural aspects. The integration of renewables, energy-saving measures, smart technologies, and government support is essential for success. Therefore, future research should focus on detailed analysis of these factors to tailor optimal solutions for various household types and conditions.

Given the mentioned above, **the aim of this study** is to develop methodological approaches to making optimal economic decisions on energy strategies for typical groups of private households. These strategies should provide an optimal combination of energy sources to ensure sustainable household power supply, taking into account natural and climatic conditions, energy resource prices, energy-efficiency measures, the use of renewable power technologies, as well as national energy and environmental policies, among other factors.

Main research results. In general, the decision-making on an energy strategy of a private household (as an entity that does not aim to maximize economic profit) should focus on creating the most comfortable living conditions for household members with the lowest possible economic costs. Thus, private homes aim to minimize their energy expenditures while meeting their basic needs for heating, water heating, cooking, lighting, and so on. Modern decentralized power supply technologies offer various options for installing autonomous energy generation sources in the residential sector, especially in private homes. For instance, within the legal framework in Ukraine, private households are allowed to install small solar (SPPs) and wind power plants (WPPs) with a capacity of up to 30 kW and take advantage of the preferential feed-in tariff for selling surplus electricity not used for their own needs. This tariff is valid until December 31, 2029 (Verkhovna Rada of Ukraine, 2024).

Another option is the installation of diesel generators and battery storage systems to meet electricity needs during outages in centralized power grids. However, relying solely on diesel generators and/or batteries does not solve the issue of long-term sustainable energy supply, especially during prolonged outages. The cost of diesel fuel, its safe storage at home, and the negative environmental impact of its combustion make diesel generators a less attractive option, although they are effective in emergency situations for relatively short periods. Battery storage systems can also supply electricity during short-term outages but require regular and often lengthy recharging, adding further strain to power grids that are already operating at maximum capacity due to the war. Therefore, from the perspective of energy security and sustainable supply, building household-level autonomous power generation using renewable sources is the most viable option. However, the installation of small SPPs and WPPs requires substantial investment, which must be assessed when forming and selecting an optimal household energy strategy.

To create a pool of possible power supply strategies within our research, it is appropriate to consider typical groups of households based on the technologies they can implement (Sotnyk et al., 2024). Table 1 presents the characteristics of such household groups, as well as the non-economic advantages and disadvantages of the energy supply technologies they use.

The advantages and drawbacks of the energy technologies used by households can be either amplified or offset by economic factors, which also play a significant role in determining the choice of energy supply strategy. Therefore, it is expedient to analyze the components of household energy expenditures for each typical group.

Table 1 – **Characteristics of typical household groups based on their use of self-sufficient energy supply technologies in the short- and long-term**

Typical group of private households	Advantages of the used energy technology	Drawbacks of the used energy technology
1 Do not have their own independent energy sources	–	Lack of energy supply during outages
2 Have battery storage systems to cover own electricity needs	Ability to cover own energy needs during short-term outages	Batteries require charging, often for extended periods; they create additional load on the grid during charging; no power supply during prolonged outages
3 Have diesel generators to cover own electricity needs	Ability to cover own energy needs during short-term outages	Diesel generators require a specially equipped area for safe fuel storage; have a negative environmental impact from fuel combustion; do not solve the issue of sustainable energy supply during long-term outages
4 Have both diesel generators and battery storage systems to cover electricity needs	Ability to cover own energy needs during short-term outages	Diesel generators require a specially equipped area for safe fuel storage and have a negative environmental impact from fuel combustion; batteries require charging, often for extended periods, and create extra load on the grid; the combination of technologies still does not ensure sustainable energy supply during long-term outages
5 Installed and operate a grid-connected small SPP, WPP, or a hybrid wind-solar power plant to cover own electricity needs while selling excess energy under the feed-in tariff	Ability to cover own energy needs and generate ad-additional electricity for the grid	No electricity supply during outages, as the power plant depends on grid electricity for operation
6 Installed and operate a grid-connected small SPP, WPP or hybrid wind-solar system with battery storage for covering own electricity needs and selling excess energy under the feed-in tariff	Ability to cover own energy needs, including during short-term outages, and generate ad-additional electricity for the grid	No energy supply during long-term outages when the battery is discharged and cannot power the station; unstable generation due to the use of weather-dependent renewable energy sources
7 Installed and operate an autonomous small SPP, WPP or hybrid wind-solar system with battery storage for covering own electricity needs	Ability to fully meet own energy needs in both the short- and long-term	Possible instability of electricity generation due to weather dependence and insufficient battery capacity or inability to recharge in time; limited generation capacity due to inability to supply surplus electricity to other consumers

Source: developed by the authors based on (Sotnyk et al., 2024).

Annual (running) energy costs of the household from group 1 (HEC_1, UAH) generally consist of the following elements:

$$HEC1 = THC + WHC + ECC + LC + OL – NES, \quad (1)$$

where THC – refers to the total annual expenses (UAH) associated with heating the house where the household members reside. In this study, the household is assumed to own a private house equipped by autonomous heating system and connected to centralized gas and electricity networks, as well as cold water supply. THC includes household running costs of energy carriers used for heating during the heating season, and fixed costs for the operation of heating equipment under various heating options. The fixed costs cover annual depreciation costs and additional fixed electricity costs required to operate the equipment. The methodology for optimizing these costs is described in detail in (Sotnyk et al., 2024a);

WHC – is the annual cost of water heating for domestic needs (UAH):

$$WHC = Q_{hwcons} \cdot WHC_{sp}, \quad (2)$$

where Q_{hwcons} – is the annual volume of hot water (of a defined temperature) consumed by the household (m³);

WHC_{sp} – is the specific cost of heating water with a chosen technology (UAH/m³). Since the share of water heating in the overall energy expenses of a private household is significantly smaller than that of space heating, the water heating technology will typically depend on the chosen heating strategy. This is because the equipment used for heating may also serve to heat water. Optimization of these costs is possible through the implementation of energy-efficient and water-saving measures.

ECC – is the annual household energy cost for cooking (UAH):

$$ECC = \sum_{i=1}^{N} P_i \cdot Q_i + MC_{cook}, \quad (3)$$

where P_i – is the purchase price of the i-th type of energy carrier used for cooking (UAH/unit of energy carrier);

Q_i – is the annual household consumption volume of the i-th type of energy carrier used for cooking (units);

N – is the number of energy types used for cooking (e.g., gas, electricity, firewood);

MC_{cook} – is the annual fixed (depreciation) cost for the maintenance of household cooking appliances (e.g., gas stove, microwave, electric stoveThe chosen cooking technology may also be influenced by the selected heating strategy, as dominant heating costs will dictate the primary energy sources (e.g., using an electric stove if electric heating is selected, instead of a gas stove);

LC – is the annual household cost for lighting and air conditioning (UAH):

$$LC = T_{el1} \cdot Q_{el1} + T_{el2} \cdot Q_{el2} + MC_{light}, \quad (4)$$

where T_{el1}, T_{el2} – are daytime (7:00–23:00) and nighttime (23:00–7:00) electricity tariffs respectively for a private household (UAH/kWh);

Q_{el1}, Q_{el2} – are annual volumes of electricity consumption for lighting and air conditioning during daytime and nighttime respectively (kWh);

MC_{light} – is the annual maintenance cost associated with lighting and air conditioning (e.g., replacement of lighting lamps, depreciation and operating costs for air conditioners) (UAH);

OL – is the economic losses of the private household (UAH) due to disconnections from energy supply interruptions (electricity, gas, etc.). These are determined based on the nature and actual consequences of outages, such as damage to internal electrical wiring, household appliances, and equipment caused by voltage fluctuations in the power grid or pressure fluctuations in the gas or water supply systems; or losses due to inoperable appliances (e.g., defrosted refrigerators) or electronic devices (e.g., interruption of work for household members working remotely with computer technologies);

NES – is the net energy savings, i.e., the annual economic effect (UAH) from energy-saving measures implemented by the household (excluding the installation of batteries, diesel generators, or small renewable power stations), calculated as follows:

$$NES = \sum_{j=1}^{M} P_j \cdot Q_j - ESC, \quad (5)$$

where P_j – is the purchase price of the j-th energy resource saved due to energy-saving measures in the household (UAH/unit of resource);

Q_j – is the annual volume of the j-th type of energy resource saved (units of resource);

M – is the number of types of energy resources saved;

ESC – is the annual operating cost, including depreciation, for implementing energy-saving measures in the household (UAH).

It should be noted that, based on the structure of household expenditures according to formula (1), the minimization of HEC will largely depend on the chosen heating strategy, since the energy carriers defined within it will influence the choice of technologies for water heating, cooking, lighting, and air conditioning (e.g., in the context of the selected electricity tariff). The implementation of energy-efficient measures, for example, using water-saving equipment for water heating, energy-efficient stoves and other kitchen devices, as well as energy-efficient lighting and air conditioning, will reduce overall energy consumption. However, compared to heating costs in the climatic conditions of Ukraine, these measures will have a smaller economic effect. Moreover, energy-saving measures and the reduction of OL will positively affect environmental quality.

Annual (running) energy costs of the household from group 2 (HEC_{bat2}, UAH) include the following elements:

$$HEC_{bat2} = HEC_1 + MC_{bat2} – Sav_{bat2}, \quad (6)$$

where MC_2 – is the annual running cost for battery maintenance (including depreciation cost associated with the purchase, installation, setup, and eventual replacement after the service life, as well as routine maintenance) (UAH);

Sav_{bat2} – is the household savings (UAH) from shifting peak loads and purchasing electricity during off-peak hours for storage and later use (e.g., at the night tariff), as well as from potential sale of stored electricity during peak hours. Additionally, due to improved energy supply stability and reduced load on the internal household power grid, the value of OL (part of formula (1)) will decrease.

Annual (running) energy costs of the household from group 3 (HEC_{dg3}, UAH) consist of the following elements:

$$HEC_{dg3} = HEC_1 + MC_{dg3} + FC_{dg3}, \quad (7)$$

where MC_{dg3} – is the annual running cost for maintaining a diesel generator (including depreciation costs for its purchase, installation, setup, and routine maintenance) (UAH);

FC_{dg3} – is the annual running cost of diesel fuel (UAH), calculated based on the price and consumption of diesel fuel for household energy needs, including costs for fuel storage tanks and logistics for fuel delivery.

In addition to these expenses, the use of diesel generation during outages improves household energy supply stability, thus reducing OL, which is part of HEC1.

Annual (running) energy costs of the household from group 4 ($HEC_{bat+dg4}$, UAH) include the following elements:

$$HEC_{bat+dg4} = HEC_{bat2} + MC_{dg3} + FC_{dg3}. \quad (8)$$

As in the two previous cases, improved energy supply stability and reduced load on the internal household electrical grid will reduce OL, which is a component of HEC_1.

Annual (running) energy costs of the household from group 5 (HEC_{RES5}, UAH) consist of the following elements:

$$HEC_{RES5} = HEC_1 + MC_{RES5} – Sav_{RES5} – I_{FIT5}, \quad (9)$$

where MC_{RES5} – is the annual running cost for maintaining a household grid-connected SPP, WPP or hybrid wind-solar power station (including annual maintenance and depreciation cost for purchase, installation, grid connection, setup, and decommissioning (Kurbatova et al., 2024)) (UAH);

Sav_{RES5} – is the household savings (UAH) from consuming self-generated green electricity instead of purchasing it from the electricity supplier, calculated as:

$$Sav_{RES5} = T_{el1} \cdot Q_{cons1} + T_{el2} \cdot Q_{cons2}, \quad (10)$$

where Q_{cons1}, Q_{cons2} – are the annual volumes of self-generated green electricity consumed by the household during the day and night respectively (kWh);

$Income_{FIT5}$ – is the additional annual income (UAH) from selling the surplus electricity generated by the household at the feed-in tariff, calculated as:

$$I_{RES5} = FIT \cdot (Q_{gen} – Q_{cons1} – Q_{cons2}) \cdot (1 – k_{tax}/100\%), \quad (11)$$

where FIT – is the feed-in tariff (UAH/kWh);

Q_{gen} – is the total annual volume of green electricity generated by the household (kWh);

k_{tax} – is the tax rate on income from the sale of surplus electricity under the feed-in tariff (%) (Sotnyk et al., 2023). In addition to extra income and household savings, the generation of green electricity positively impacts environmental quality.

Annual (running) energy costs of the household from group 6 ($HEC_{RES+bat6}$, UAH) include the following elements:

$$HEC_{RES+bat6} = HEC_{RES5} + MC_{RESbat6} – Sav_{RESbat6}, \quad (12)$$

where $MC_{RESbat6}$ – is the annual running costs for maintaining a battery storage system connected to a grid-connected home power plant (including depreciation cost related to the purchase, installation, and setup of the battery, its replacement at the end of its service life, and routine maintenance cost) (UAH);

$Sav_{RESbat2}$ – is the household savings (UAH) resulting from peak load shifting and purchasing electricity during off-peak periods for storage and subsequent consumption (e.g., at night tariff rates), in cases where the self-generation of green electricity is insufficient or unavailable for meeting household needs. Furthermore, as the power supply becomes more stable and internal household grid loads are reduced, the value of OL (a component in formula (1)) will decrease. In addition, I_{RES5}, a component of HEC_{RES5}, may increase, since the presence of a backup power source (battery) ensures that the home grid-connected power plant can continue to operate during short-term outages, storing generated electricity until the grid connection is restored instead of stopping generation altogether.

Annual (running) energy costs of the household from group 7 ($HEC_{RES+bat\_aut7}$, UAH) consist of the following elements:

$$HEC_{RES+bat\_aut7} = HEC_1 + MC_{RES\_aut7} – Sav_{RES5} + MC_{RESbat\_aut7}, \quad (13)$$

where MC_{RES_aut7} – is the annual running cost for maintaining an autonomous home SPP, WPP or hybrid wind-solar power plant (including annual maintenance cost and depreciation cost related to the purchase, installation, connection, commissioning, and decommissioning of the home power plant (Kurbatova et al., 2024)) (UAH);

MC_{RESbat_aut7} – annual running cost for maintaining a battery storage system connected to an autonomous home power plant (including depreciation cost related to the purchase, installation, and setup of the battery, its replacement after the end of its service life, and routine maintenance cost) (UAH).

The operation of an autonomous home power plant guarantees a stable power supply for the household, which minimizes the OL value included in HEC_1, and provides a positive environmental effect from green energy generation. On the other hand, the autonomous nature of the power plant means that the household will not be able to generate additional income from selling surplus electricity under the feed-in or regular tariffs, but it will achieve full energy independence.

Based on the analysis of household expenditure structures by each typical group (formulas (1) – (13)), choosing the optimal energy strategy should be guided by the minimum cost criterion. However, this approach should not be limited only to economic considerations. It is also important to take into account additional benefits that may significantly influence decision-making in the long run. This refers to non-economic benefits, such as increased stability and independence of the energy supply, which is especially relevant under the current conditions of persistent instability in power grids caused by the war. Moreover, the implementation of renewable energy sources helps to reduce the negative environmental impact, which is also a significant factor in residential energy strategy selection. Overall, the presented methodology takes into account climatic and environmental conditions, energy carriers' prices, household energy efficiency measures, home use of green energy generation technologies, as well as national energy and environmental policies. It serves as a valuable tool for decision-making both at the residential level and for adjusting national sectoral policies. The proposed approaches are key to ensuring a sustainable energy supply for households, reducing their dependence on centralized power systems, and mitigating risks associated with both planned and emergency outages.

Conclusions. The conducted theoretical and methodological study allows for several conclusions. First, the decision-making on an optimal energy strategy for a household should be based on a thorough analysis of the cost structure for technologies that are financially accessible and technically feasible (either individually or in combination) for use by the home to ensure its own energy supply. For this purpose, we have identified seven typical groups of households, each with different options for implementing power supply technologies. From a purely economic perspective, it is important to minimize the running energy supply costs, taking into account equipment maintenance costs, both in the short- and long-term.

Second, despite the significance of financial aspects, the decision regarding the household's energy strategy should also consider other factors, particularly the increase in autonomy and power supply stability, as well as environmental benefits. The use of renewable energy sources, such as home SPP, WPP or hybrid wind-solar power plant, not only reduces dependency on centralized systems but also contributes positively to environmental quality.

Third, the implementation of decentralized energy supply, particularly through the use of small renewable power plants, battery storage systems, and diesel generators, is a critical step toward achieving greater energy independence, reliability and sustainability of residential energy supply, as well as transforming consumers into prosumers. However, such investments require significant financial input, which necessitates thorough economic justification.

Fourth, the effective implementation of decentralized energy solutions requires active state support in the form of incentives, subsidies, or stimulation programs, considering the higher cost of innovative power technologies compared to traditional ones. National energy and environmental policies should promote the adoption of renewable energy sources and support energy-efficient measures at the residential level.

Fifth, the use of decentralized energy sources and the development of prosumer-based approaches to power supply can significantly reduce the load on the national energy system, improve its balancing capabilities, and enhance the country's energy security. This will improve resilience to external threats such as military actions or energy crises.

Therefore, optimizing household energy strategies, considering various economic and environmental factors, is a crucial step towards ensuring sustainable power supply under current challenges. Such an approach will not only improve quality of life but also enhance the country's energy independence. At the same time, further research prospects include assessing the economic affordability of innovative energy technologies for households with varying income levels; developing optimal investment mechanisms at the state and regional levels to help households choose effective energy strategies both on a micro and macro level; studying the impact of residential consumer behaviour on the effectiveness of decentralized energy system implementation and on improving household energy efficiency, among others.

REFERENCES

1. Wang, T., Zhao, Q., Gao, W., & He, X. (2024). Research on energy consumption in the household sector: A comprehensive review based on bibliometric analysis. Frontiers in Energy Research, 11. https://doi.org/10.3389/fenrg.2023.1209290

2. Tran, L. N., Cai, G., & Gao, W. (2023). Determinants and approaches of household energy consumption: A review. Energy Reports, 10, 1833-1850. https://doi.org/10.1016/j.egyr.2023.08.026

3. Sangeeth, S. S., Mathew, S. K., & Watson, R. T. (2023). Comfort vs money: Influencing the energy user for sustainable consumption. Edward Elgar Publishing, 207–230. https://doi.org/10.4337/9781802201864.00016

4. Han, B., Zahraoui, Y., Mubin, M., Mekhilef, S., Seyedmahmoudian, M., & Stojcevski, A. (2023). Home energy management systems: A review of the concept, architecture, and scheduling strategies. IEEE Access, 11, 19999–20025. https://doi.org/10.1109/access.2023.3248502

5. Chowdhury, M., Islam, M. S., Montaser, M. A. A., Rasel, Md., Barua, A., Chouksey, A., & Chowdhury, B. (2024). Predictive modelling of household energy consumption in the USA: The role of machine learning and socioeconomic factors. The American Journal of Engineering and Technology, 6(12), 99–118. https://doi.org/10.37547/tajet/volume06issue12-11

6. Zhang, X., Wang, J., Pan, H., Yuan, Z., & Feng, K. (2023). Changes in the socio-economic characteristics of households can decouple carbon emissions and consumption growth in China. Sustainable Production and Consumption, 43, 168–180. https://doi.org/10.1016/j.spc.2023.10.019

7. Kruekaew, A., Khemchan, P., Waengdeesorn, S., Sirisawat, A., Norasarn, A., & Khunchai, S. (2023). Residential energy management system to reduce electricity costs considering the lifespan of energy storage and electric vehicle batteries. IEEE International Conference on Information Technology and Electrical Engineering. https://doi.org/10.1109/incit60207.2023.10412899

8. Arens, S., Schlüters, S., Hanke, B., von Maydell, K., & Agert, C. (2020). Sustainable residential energy supply: A literature review-based morphological analysis. Energies, 13(2), 432. https://doi.org/10.3390/EN13020432

9. Nacht, T., Pratter, R., Ganglbauer, J., Schibline, A., Aguayo, A., Fragkos, P., & Zisarou, E. (2023). Modelling approaches for residential energy consumption: A literature review. Climate, 11(9), 184. https://doi.org/10.3390/cli11090184

10. Krómer, I. (2009). An energy systems engineering approach to household energy supply. Proceedings of the International Conference on Energy 2009, 19–24.

11. Tadesse, Y. Y., Erenoğlu, A. K., Sancar, S., & Erdinç, O. (2024). Optimizing residential energy systems in households: A model integrating energy assets with economic evaluation through LCOCE. IEEE International Conference on Green and Power Electronics (GPECOM). https://doi.org/10.1109/gpecom61896.2024.10582634

12. Kgopana, K., & Popoola, O. (2022). Review on the application and utilization of hybrid renewable energy systems in domestic households. 2022 30th Southern African Universities Power Engineering Conference (SAUPEC), Durban, South Africa, 1–6. https://doi.org/10.1109/SAUPEC55179.2022.9730669

13. Li, Q., Zhang, Y., Li, S., Zhang, J., & Liu, P. (2020). Research on home energy optimization strategy based on micro-sized combined heat and power. Springer, Singapore, 76–86. https://doi.org/10.1007/978-981-33-6378-6_6

14. Prokopenko, O., Kovalenko, Y., Fedyna, S., & Fedyna, S. (2024). Development and analysis of investment strategies in energy efficiency for Ukrainian household prosumers. Journal of Vasyl Stefanyk Precarpathian National University, 11(2), 62–78. https://doi.org/10.15330/jpnu.11.2.62-78

15. Veremiichuk, Y., Yarmoliuk, O., Prytyskach, I., Mahnitko, A., & Varfolomejeva, R. (2017). Analysis of the results of optimal energy consumption planning for residential complex energy hub. International Scientific Conference on Power and Electrical Engineering of Riga Technical University, 1–6. https://doi.org/10.1109/RTUCON.2017.8124817

16. Verkhovna Rada of Ukraine. (2024). The Law of Ukraine "On the Electricity Market." No. 2019-VIII Dated 18 September 2024 (Last Edition). Retrieved from https://zakon.rada.gov.ua/laws/show/2019-19#Text (in Ukrainian)

17. Sotnyk, I., Kurbatova, T., & Yang, Yu. (2024). Methodological framework for choosing optimal strategies for sustainable household power in Ukraine. Sustainable Development: Modern Theories and Best Practices : Materials of the Monthly International Scientific and Practical Conference, October 31 – November 1, 2024, 18–21. Retrieved from https://essuir.sumdu.edu.ua/handle/123456789/97321

18. Sotnyk, I., Sotnyk, M., Kurbatova, T., Prokopenko, O., & Telizhenko, O. (2024a). Shaping cost-optimal and environmentally friendly strategies for household heating systems: Case of Ukraine. Polityka Energetyczna – Energy Policy Journal, 27(3), 161–192. https://doi.org/10.33223/epj/127921

19. Kurbatova, T., Sotnyk, I., Perederii, T., Prokopenko, O., Wit, B., Pysmenna, U., & Kubatko, O. (2024). On-grid hybrid wind-solar power plants in Ukraine's residential sector: Economic justification of installation under different support schemes. Energies, 17, 5214. https://doi.org/10.3390/en17205214

20. Sotnyk, I., Kurbatova, T., Blumberga, A., Kubatko, O., & Prokopenko, O. (2023). Solar business prosumers in Ukraine: Should we wait for them to appear? Energy Policy, 178, 113585. https://doi.org/10.1016/j.enpol.2023.113585

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СПИСОК ВИКОРИСТАНИХ ДЖЕРЕЛ

1. Wang T., Zhao Q., Gao W., He X. Research on energy consumption in the household sector: A comprehensive review based on bibliometric analysis. Frontiers in Energy Research. 2024. No. 11. https://doi.org/10.3389/fenrg.2023.1209290

2. Tran L. N., Cai G., Gao W. Determinants and approaches of household energy consumption: A review. Energy Reports. 2023. No. 10. P. 1833–1850. https://doi.org/10.1016/j.egyr.2023.08.026

3. Sangeeth S.S., Mathew S.K., Watson R.T. Comfort vs money: Influencing the energy user for sustainable consumption. Edward Elgar Publishing, 2023. P. 207–230. https://doi.org/10.4337/9781802201864.00016

4. Han B., Zahraoui Y., Mubin M., Mekhilef S., Seyedmahmoudian M., Stojcevski A. Home energy management systems: A review of the concept, architecture, and scheduling strategies. IEEE Access. 2023. Vol. 11. P. 19999–20025. https://doi.org/10.1109/access.2023.3248502

5. Chowdhury M., Islam M.S., Montaser M.A.A., Rasel Md., Barua A., Chouksey A., Chowdhury B. Predictive modelling of household energy consumption in the USA: The role of machine learning and socioeconomic factors. The American Journal of Engineering and Technology. 2024. Vol. 6, No. 12. P. 99–118. https://doi.org/10.37547/tajet/volume06issue12-11

6. Zhang X., Wang J., Pan H., Yuan Z., Feng K. Changes in the socio-economic characteristics of households can decouple carbon emissions and consumption growth in China. Sustainable Production and Consumption. 2023. Vol. 43. P. 168–180. https://doi.org/10.1016/j.spc.2023.10.019

7. Kruekaew A., Khemchan P., Waengdeesorn S., Sirisawat A., Norasarn A., Khunchai S. Residential energy management system to reduce electricity costs considering the lifespan of energy storage and electric vehicle batteries. IEEE International Conference on Information Technology and Electrical Engineering. 2023. https://doi.org/10.1109/incit60207.2023.10412899

8. Arens S., Schlüters S., Hanke B., von Maydell K., Agert C. Sustainable residential energy supply: A literature review-based morphological analysis. Energies. 2020. Vol. 13, No. 2. Article 432. https://doi.org/10.3390/EN13020432

9. Nacht T., Pratter R., Ganglbauer J., Schibline A., Aguayo A., Fragkos P., Zisarou E. Modelling approaches for residential energy consumption: A literature review. Climate. 2023. Vol. 11, No. 9. Article 184. https://doi.org/10.3390/cli11090184

10. Krómer I. An energy systems engineering approach to household energy supply. Proceedings of the International Conference on Energy 2009. 2009. P. 19–24.

11. Tadesse Y.Y., Erenoğlu A.K., Sancar S., Erdinç O. Optimizing residential energy systems in households: A model integrating energy assets with economic evaluation through LCOCE. IEEE International Conference on Green and Power Electronics (GPECOM). 2024. https://doi.org/10.1109/gpecom61896.2024.10582634

12. Kgopana K., Popoola O. Review on the application and utilization of hybrid renewable energy systems in domestic households. 30th Southern African Universities Power Engineering Conference (SAUPEC). Durban, South Africa. 2022. P. 1–6. https://doi.org/10.1109/SAUPEC55179.2022.9730669

13. Li Q., Zhang Y., Li S., Zhang J., Liu P. Research on home energy optimization strategy based on micro-sized combined heat and power. Springer, Singapore, 2020. P. 76–86. https://doi.org/10.1007/978-981-33-6378-6_6

14. Prokopenko O., Kovalenko Y., Fedyna S., Fedyna S. Development and analysis of investment strategies in energy efficiency for Ukrainian household prosumers. Journal of Vasyl Stefanyk Precarpathian National University. 2024. Vol. 11, No. 2. P. 62–78. https://doi.org/10.15330/jpnu.11.2.62-78

15. Veremiichuk Y., Yarmoliuk O., Prytyskach I., Mahnitko A., Varfolomejeva R. Analysis of the results of optimal energy consumption planning for residential complex energy hub. International Scientific Conference on Power and Electrical Engineering of Riga Technical University. 2017. P. 1–6. https://doi.org/10.1109/RTUCON.2017.8124817

16. Верховна Рада України. Закон України «Про ринок електричної енергії» № 2019-VIII від 18 вересня 2024 р. (остання редакція). URL: https://zakon.rada.gov.ua/laws/show/2019-19#Text

17. Sotnyk I., Kurbatova T., Yang Yu. Methodological framework for choosing optimal strategies for sustainable household power in Ukraine. Sustainable Development: Modern Theories and Best Practices: Materials of the Monthly International Scientific and Practical Conference, October 31 – November 1, 2024. P. 18–21. URL: https://essuir.sumdu.edu.ua/handle/123456789/97321

18. Sotnyk I., Sotnyk M., Kurbatova T., Prokopenko O., Telizhenko O. Shaping cost-optimal and environmentally friendly strategies for household heating systems: Case of Ukraine. Polityka Energetyczna – Energy Policy Journal. 2024. Vol. 27, No. 3. P. 161–192. https://doi.org/10.33223/epj/127921

19. Kurbatova T., Sotnyk I., Perederii T., Prokopenko O., Wit B., Pysmenna U., Kubatko O. On-grid hybrid wind-solar power plants in Ukraine's residential sector: Economic justification of installation under different support schemes. Energies. 2024. Vol. 17. Article 5214. https://doi.org/10.3390/en17205214

20. Sotnyk I., Kurbatova T., Blumberga A., Kubatko O., Prokopenko O. Solar business prosumers in Ukraine: Should we wait for them to appear? Energy Policy. 2023. Vol. 178. Article 113585. https://doi.org/10.1016/j.enpol.2023.113585

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СТАЛЕ ЕНЕРГОЗАБЕЗПЕЧЕННЯ ДОМОГОСПОДАРСТВ: МЕТОДИЧНІ ПІДХОДИ ДО ВИБОРУ ОПТИМАЛЬНИХ ЕКОНОМІЧНИХ РІШЕНЬ

Руйнування енергетичної інфраструктури України через військові дії загострює проблему сталого енергозабезпечення домогосподарств. Часті відключення електро-, газо- та водопостачання призводять до перевантаження мереж, зростання тарифів та зниження енергетичної безпеки. Вразливість традиційних централізованих систем актуалізує пошук альтернативних підходів до енергозабезпечення побутового сектору, зокрема розвиток просьюмеризму, який передбачає активну участь домогосподарств у генерації енергії. У статті розглядаються можливі енергетичні стратегії для семи груп типових приватних домогосподарств із використанням різних джерел енергії, включаючи відновлювані. Запропоновано методичні підходи до вибору економічно оптимальних енергетичних рішень з урахуванням природно-кліматичних умов, рівня цін на енергоресурси, можливостей використання «зелених» технологій та енергоефективних заходів, а також державної енергетичної політики. Зокрема, проаналізовано потенціал сонячних і вітрових електростанцій, акумуляторних систем та дизельних генераторів як засобів автономного енергозабезпечення споживачів побутового сектору, оцінено переваги і недоліки цих технологій в умовах можливих відключень від енергомереж у коротко- і довгостроковому періодах. Результати дослідження свідчать, що ефективна енергетична стратегія домогосподарства має ґрунтуватися не лише на мінімізації економічних витрат, а й на підвищенні рівня енергонезалежності та стійкості до кризових ситуацій. Оптимальні економічні рішення мають враховувати всі енерговитрати (зокрема, витрати на опалення, приготування їжі, підігрів води, освітлення, економічні збитки внаслідок відключень від енергомереж) і потенційні доходи побутових споживачів (економію витрат домогосподарства, отриману завдяки використанню енергії власного виробництва, та доходи від продажу її надлишків). Важливими чинниками при прийнятті рішень домогосподарствами є державна підтримка, доступність інвестицій та впровадження економічних механізмів стимулювання використання відновлюваних джерел енергії. Запропоновані методичні підходи сприяють підвищенню енергетичної безпеки країни та формуванню ефективних моделей сталого енергозабезпечення в домогосподарствах.

Ключові слова: **енергетична стратегія, домогосподарство, відновлювані джерела енергії, автономне енергозабезпечення, сталий розвиток, оптимальне рішення, ЦСР ООН №7.**
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