Chapter 13

ECOLOGICAL ASPECTS OF SUSTAINABLE DEVELOPMENT OF UKRAINE'S REGIONS: INTEGRATION OF HEAT PUMPS AND RENEWABLE SOURCES OF ENERGY

Ostapenko Olha
DOI https://doi.org/10.30525/978-9934-26-539-6-13

INTRODUCTION

Sustainable development of the regions of Ukraine requires a comprehensive approach to the socio-economic and environmental development of territories[1]. In this case, it is necessary to consider balanced economic development, taking into account local characteristics and resources, innovative development through the introduction of new technologies, environmental sustainability with an emphasis on the rational use of natural resources, the introduction of "green" technologies, and minimizing the negative impact on the environment. The key goal of ensuring sustainable development is to achieve harmonious and self-sufficient development of regions, taking into account the long-term perspective[2].

1. Ecological aspects of sustainable development of Ukraine's regions

The environmental aspects of sustainable development include the rational use of natural resources, ensuring climate security by reducing greenhouse gas emissions and developing renewable energy, applying circular economy approaches by minimizing waste, developing closed production cycles and introducing reuse technologies, applying innovative environmental solutions – in particular, introducing "green" technologies, developing environmentally friendly transport and supporting environmentally friendly businesses. The aim of this approach is to ensure the harmonious interaction of economic activity with natural ecosystems.

[1] Support Sustainable Development and Climate Action. URL: https://www.un.org/en/our-work/support-sustainable-development-and-climate-action/

[2] A European Green Deal. Striving to be the first climate-neutral continent. URL: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/ european-green-deal_en

The environmental goals of sustainable development are to preserve biodiversity, mitigate climate change, reduce environmental pollution, protect ecosystem integrity and ensure the conservation of natural resources.

Key strategic dimensions are ecosystem protection, climate action (reduction of greenhouse gas emissions, transition to renewable energy sources, carbon neutrality), resource management (rational use of water, application of circular economy principles, effective land management), pollution control (reduction of waste, implementation of clean technologies, improvement of environmental quality), preservation of biodiversity. The mechanisms for implementing the Green Deal and the green economy are international environmental agreements, policy frameworks, investments in green technologies, community engagement and scientific monitoring systems.

The main principles of the green course and the green economy are environmental justice between generations, ecosystem sustainability, balance between man and nature, and a holistic approach to development.

Climate security in the context of sustainable development encompasses combating climate change (including reducing greenhouse gas emissions, transitioning to low-carbon technologies, and increasing energy efficiency), adaptation measures (including strengthening the resilience of infrastructure), international cooperation (including implementing climate agreements, exchanging technologies and experience, and implementing joint environmental projects), and investments in the "green" economy (which involves the introduction of renewable energy technologies, clean transport systems, and innovative climate solutions). The goal of this approach is to minimize climate risks and ensure environmental sustainability[3].

Renewable energy in the context of sustainable development includes the development of solar energy, wind power, hydropower, and geothermal and bioenergy. The advantages of implementing renewable energy technologies in the regions of Ukraine are the reduction of greenhouse gas emissions, diversification of energy sources, reduction of the energy sector's dependence on fossil resources, strengthening energy security and energy independence, and creation of new jobs in the regions. Among the technological innovations, it should be noted the increase in energy conversion efficiency (in particular, using heat pump technologies), the development of electricity storage, smart grids, and microgeneration. Economic mechanisms for the implementation of renewable energy are state

---

[3] Ostapenko Olga. Estimation of tendencies of transforming the energy sectors of World, European Union and Ukraine in the perspective to 2050 with using the renewable energy sources in the concept of Sustainable Development. In: *Social capital: Vectors of development of behavioral economics*: Collective monograph, pp. 99–139. ACCESS Press Publishing house. Veliko Tarnovo, Bulgaria (2021)

support for “green” energy, preferential lending, tax incentives, and international investments. The goal of implementing renewable energy technologies in the regions of Ukraine is the establishment of an environmentally friendly and sustainable energy supply[4].

The Green Deal and the Green Economy are key concepts of sustainable development. The Green Deal aims to support a strategy for decarbonizing the economy, transforming production systems and achieving climate neutrality by 2050. The main goals are to reduce greenhouse gas emissions by 55% by 2030, transition to renewable energy sources, develop a circular economy, protect biodiversity and eliminate pollution. The main areas of activity are clean energy, sustainable transport, green industrial transformation, ecosystem restoration and climate adaptation. The economic impact consists of creating green jobs, introducing technological innovations, restructuring the regional economy. The global significance of the Green Deal lies in providing a model of potential sustainability and implementing international policies. The challenges associated with the Green Deal are economic restructuring, high initial costs and complex implementation.

Environmental aspects of sustainable regional development in Ukraine include the main environmental challenges (in particular, high levels of industrial pollution, significant environmental degradation, post-war ecosystem restoration needs and vulnerability to climate change), regional development strategies (renewable energy infrastructure, ecosystem rehabilitation, green agricultural practices, biodiversity conservation and improved waste management). The priority regions for implementing the sustainable development strategy are industrial areas, the Chernobyl Exclusion Zone, mountain ecosystems of the Carpathians and coastal zones of the Black Sea[5].

Approaches to ensuring sustainable development include the implementation of a circular economy, the development of an eco-network, environmental monitoring systems, investments in green technologies, and climate adaptation planning[6].

---

[4] Ostapenko O, Alina G, Serikova M, Popp L, Kurbatova T and Bashu Z. (2023) Towards Overcoming Energy Crisis and Energy Transition Acceleration: Evaluation of Economic and Environmental Perspectives of Renewable Energy Development. In: Koval V, Olczak P (eds) *Circular Economy for Renewable Energy. Green Energy and Technology*. Cham: Springer,. https://doi.org/10.1007/978-3-031-30800-07

[5] Ostapenko, O., Olczak, P., Koval, V., Hren, L., Matuszewska, D., Postupna, O. Application of Geoinformation Systems for Assessment of Effective Integration of Renewable Energy Technologies in the Energy Sector of Ukraine. Appl. Sci., 12, 592 (2022). https://doi.org/10.3390/app12020592

[6] Transforming our world: the 2030 Agenda for Sustainable Development. URL: https://www.undp.org/ukraine/publications/transforming-our-world-2030-agenda-sustainable-development .

Key mechanisms for implementing the concept of sustainable development include the development of local environmental policies, international cooperation, the attraction of green investments, community involvement, and technology transfer programs.

The specific focus of ecological restoration is on the reclamation of industrial sites, the protection of water resources, the restoration of forests and agricultural lands, and the development of urban green infrastructure.

Challenges in implementing the concept of sustainable development and the green course include limited financial resources, prolonged military confrontation, limited institutional capacity, and the need for technological modernization.

The green economy ensures the development of low-carbon technologies, introduces circular production, renewable energy technologies and environmentally friendly innovations.

The main principles of the “green deal” and the “green economy” are to minimize the impact of production on the climate, ensure resource efficiency, social justice and economic competitiveness.

The mechanisms for implementing the “green deal” and the “green economy” are state regulation, investments in “green” technologies, international cooperation and support for innovations. The goal of the “green deal” and the “green economy” is to ensure sustainable development through the ecological transformation of the economy.

Climate neutrality by 2050 involves: ensuring the implementation of key goals (ensuring zero net greenhouse gas emissions, limiting global warming to 1,5 ºC, ensuring full decarbonization of the economy), supporting strategic directions (transition to renewable energy, electrification of transport, modernization of industry and implementation of “green” technologies), developing mechanisms for achieving them (through international climate agreements, state regulation, implementation of technological innovations and carbon pricing). The expected results of ensuring climate neutrality by 2050 should be considered as stopping climate change, preserving ecosystems, economic transformation and social adaptation. The goal of maintaining climate neutrality by 2050 is to ensure the ecological sustainability of the planet[7].

Increasing the efficiency of energy conversion as a technological innovation includes such technological solutions as improving energy converters, using nanotechnology, and developing semiconductor materials. The key areas for increasing the efficiency of energy conversion are the introduction of new generation solar panels, highly efficient heat pumps, innovative fuel cells, and cogeneration systems. Methods for increasing the

---

[7] Net Zero by 2050. IEA, Paris. URL: https://www.iea.org/reports/net-zero-by-2050.

efficiency of energy conversion include optimizing structures, reducing heat losses, using intelligent control systems, and implementing artificial intelligence. As a result of increasing the efficiency of energy conversion, one should consider reducing energy costs, increasing the efficiency, and reducing greenhouse gas emissions. The goal of increasing the efficiency of energy conversion is to maximize the efficiency of energy resource conversion.

The environmental aspects of sustainable development of the regions of Ukraine include environmental protection priorities, climate adaptation, environmental modernization (the introduction of "green" technologies, the development of renewable energy, support for environmentally friendly production), the influence of regional characteristics (Carpathian region: forest conservation, Black Sea region: protection of marine ecosystems, industrial regions: deindustrialization)[8].

The purpose of taking into account the environmental aspects of sustainable development is to ensure environmental safety and sustainable development of the regions of Ukraine.

The introduction of "green" technologies in the regions of Ukraine can be ensured by introducing renewable energy technologies, rational use of resources and the introduction of technologies with a low carbon footprint[9].

Innovative solutions in the implementation of "green" technologies in the regions include solar and wind power plants, biotechnology, smart grids and environmental cleaning technologies.

Economic mechanisms for implementing "green" technologies in the regions of Ukraine involve the use of state subsidies, tax breaks, investment programs, and international financing.

The expected results of the implementation of "green" technologies in the regions of Ukraine may be: reduction of CO_2 emissions, resource conservation, creation of new jobs and improvement of environmental safety.

The goal of the implementation of "green" technologies in the regions of Ukraine is to accelerate the ecological transformation of the economy.

Let's analyze the situation with the volume and structure of greenhouse gas emissions in Ukraine.

Emission sources can be distributed as follows:

– energy sector: 64–68%;

– industrial processes: 15–20%;

---

[8] Zero waste. URL: https://zerowaste.org.ua.

[9] Ostapenko, O., Savina, N., Mamatova, L., Zienina-Bilichenko, A. & Selezneva, O. Perspectives of application of innovative resource-saving technologies in the concepts of green logistics and sustainable development. Turismo: Estudos &Práticas (UERN), Mossoró/RN, Caderno Suplementar, 02. (2020) URL: http://geplat.com/rtep/index.php/tourism/article/view/488.

– agriculture: 10–12%;

– waste management: 3–5%.

Key characteristics of these emissions are: significant annual CO_2 emissions, high carbon intensity and significant dependence on fossil fuels.

Challenges in Ukraine to reduce greenhouse gas emissions include: war-related infrastructure damage; limited technological modernization, economic constraints and slow transition to renewable energy sources.

Strategies that contribute to emission reduction include investments in renewable energy sources, energy efficiency improvements, emission reduction technologies and international transfer of green technologies

Compared to EU countries, Ukraine has higher emissions than the EU average, significant reduction potential and strategic opportunities for decarbonisation. Emissions of harmful substances have a negative impact on the environment, namely leading to ecosystem disruption, accelerating climate change, carrying risks to human health and having long-term environmental consequences.

Let's analyze harmful emissions from energy production.

Primary and secondary emissions from energy production include various types of pollutants emitted during electricity production:

Primary emissions are understood as:

– direct pollutants emitted at the site of energy production, including carbon dioxide (CO_2 – a primary greenhouse gas, the main factor of climate change, has the largest volume of emissions), sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter.

The main sources of emissions are fossil fuel power plants, coal-fired thermal generators, natural gas-fired power plants and oil-based energy production.

Primary emissions vary significantly depending on the energy source, with coal having the highest CO_2 and particulate emissions; natural gas having lower CO_2 emissions compared to coal; renewable sources (solar, wind) having minimal primary emissions during operation.

Secondary emissions are indirect pollutants generated throughout the life cycle of energy production and are generated during the production of equipment, construction of infrastructure, extraction and transportation of fuel, and waste disposal. Examples of such emissions include emissions from the production of solar panels, emissions from the extraction and processing of nuclear fuel, and emissions associated with construction for power plants and infrastructure.

The comparative emission intensity for different fuels and energy sources is as follows (CO_2 g/kWh):

– coal: 820–1040;

– natural gas: 410–650;
– nuclear: 12–20;
– solar PV: 40–50;
– wind: 11–12.

Sulfur dioxide (SO_2) causes acid rain, respiratory health risks, and is a by-product of industrial combustion. Nitrogen oxides (NO_x) cause smog; respiratory damage, and ozone depletion. Particulate matter causes respiratory health risks and environmental pollution.

Energy sources can be classified by emission intensity as follows: coal has the highest emission rates, natural gas has moderate emission rates, and renewable energy sources have the lowest emission rates.

Understanding both primary and secondary emissions provides a complete picture of the overall impact of an energy source on the environment.

Primary emission sectors include electricity generation (including coal-fired thermal power plants, aging infrastructure), industrial production (metallurgy, chemical production, cement production); and agricultural emissions (livestock, soil management, agricultural machinery).

The main sources and drivers of harmful emissions in Ukraine's energy sector are coal-fired power plants, nuclear power plants, natural gas generators, and aging industrial infrastructure.

To mitigate the effects of harmful emissions in accordance with the concept of sustainable development, the following measures are used: transition to renewable energy sources, carbon capture technologies, increasing energy efficiency, investments in clean technologies and emission reduction. The main challenges associated with reducing harmful emissions in Ukraine are: damage to infrastructure related to the war; limited financial resources; technological obsolescence of generation technologies and dependence on fossil fuels. Technological solutions to reduce harmful emissions are the use of solar and wind energy, the spread of nuclear energy, hydrogen technologies, filtration systems. Potential solutions to reduce harmful emissions in Ukraine may be the following: investments in wind and solar energy, international transfer of green technologies, approved emission reduction rules and modernization of energy production systems.

2. Ecological aspects of integration of heat pumps and renewable sources of energy

One of the technologies for increasing the efficiency of energy conversion is the use of heat pumps. Let's analyze the environmental aspects of their implementation. The mechanism of influence of heat pumps on environmental friendliness is the use of renewable sources of heat energy in heat pumps, low greenhouse gas emissions and high energy efficiency. The climatic advantages of using heat pumps are the reduction of CO_2 emissions, reduced dependence on fossil fuels and support for climate neutrality.

Important technological characteristics of heat pumps are: high energy conversion coefficient up to 400%, low electricity consumption and minimal environmental footprint.

Promising areas for the implementation of heat pumps are housing construction, industrial facilities and municipal infrastructure

The purpose of the implementation of heat pumps in the environmental aspect of sustainable development of the regions of Ukraine is to ensure environmentally friendly and energy-efficient heat supply.

There are various programs for assessing the environmental impact of heat pumps. Different methodological approaches are used, in particular, the life cycle of the equipment is assessed, the carbon footprint is assessed, and greenhouse gas emissions are analyzed.

Energy efficiency, CO_2 emission level and interaction with ecosystems can be considered as criteria for assessing the environmental impact of heat pumps.

The following can be used as tools for analyzing the environmental impact of heat pumps: LCA (Life Cycle Assessment), carbon calculators and environmental scenario modeling.

Key parameters for modeling the environmental impact of heat pumps can be: global warming potential, resource consumption and environmental compatibility.

The purpose of using programs for the environmental assessment of heat pumps is a comprehensive assessment of the environmental impact of heat pump technologies.

Modeling environmental scenarios for heat pumps and carbon footprint. The following modeling methods are used: mathematical forecasting, climate simulations and scenario planning.

The carbon footprint assessment is performed based on the analysis of direct and indirect emissions, a full product life cycle assessment, and a sectoral decomposition of emissions. Carbon calculators, computer modeling, and statistical analysis should be considered as analysis tools. Key indicators in modeling are: global warming potential, CO_2 emission level, and greenhouse gas emission dynamics.

The goal of environmental scenario modeling is to accurately predict environmental impacts.

The carbon footprint assessment assesses direct emissions (direct emissions from own sources, resulting from the company’s production processes and use of vehicles), indirect emissions (associated with electricity consumption, taking into account the supply chain and use of the product by the consumer), the product life cycle (taking into account raw material extraction, production, transportation, operation, and disposal), and sectoral decomposition (industry, energy, transport, and agriculture).

The goal of carbon footprint assessment is to fully account for carbon emissions.

When assessing indirect emissions of heat pumps, the sources of emissions are assessed (electricity for operation, equipment production, transportation and disposal), electricity generation (CO_2 emissions from power plants, taking into account the mix of energy sources and the carbon intensity of the network), the production cycle is assessed (emissions during the manufacture of components, material intensity of equipment, production technologies), and a comparison is made with alternatives (lower emissions compared to gas boilers, dependence on the source of electricity, decarbonization potential). The purpose of assessing indirect emissions of heat pumps is to minimize indirect emissions.

The information can be summarized as follows:

– heat pumps have 60–75% lower indirect emissions;

– the critical factor is the source of electricity, the generation structure;

– the potential for further emission reduction is associated with the decarbonization of electricity networks.

Fig. 1 shows a comparison of indirect emissions from a heat pump and a gas boiler.

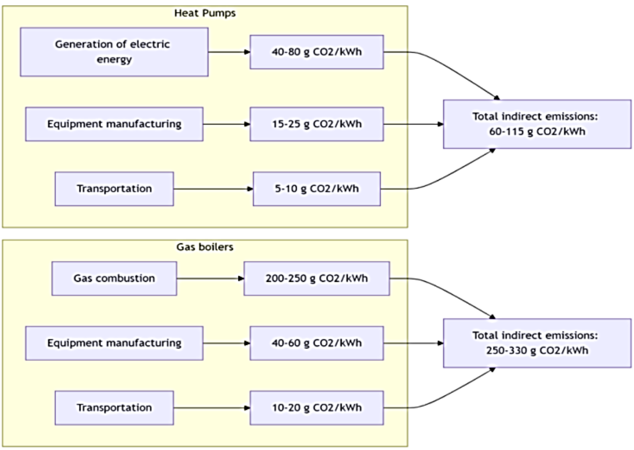


Fig. 1. Comparison of indirect emissions from a heat pump and a gas boiler

Fig. 2 shows a comparison of emission pathways from a heat pump with different refrigerants and boilers with different fuels.

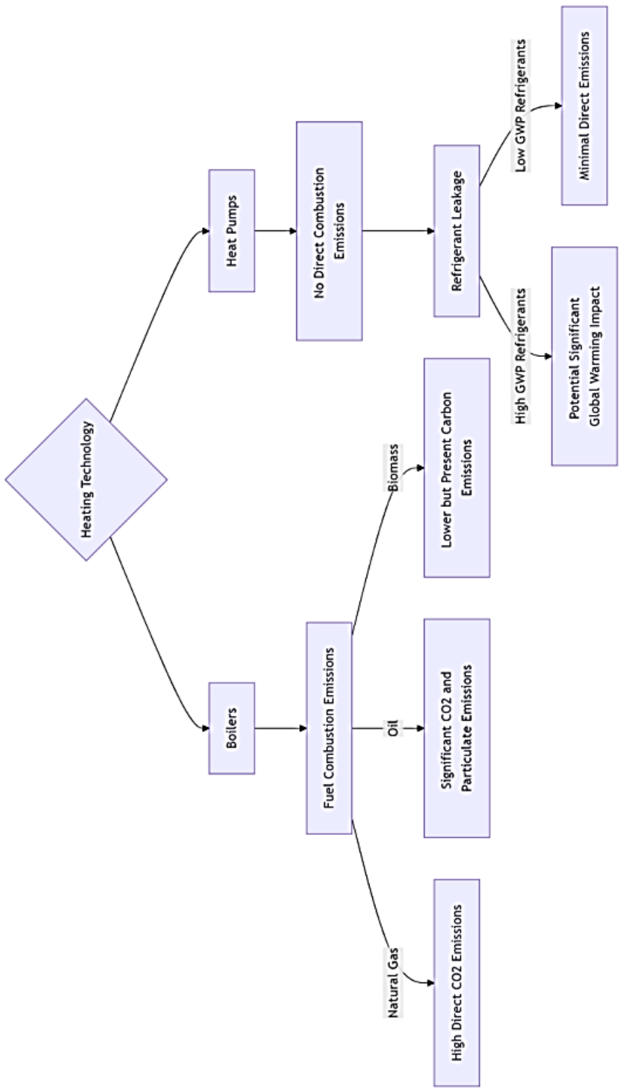


Fig. 2. Comparison of emission pathways from a heat pump with different refrigerants and boilers with different fuels

Fig. 3 shows a comparison of emissions from a heat pump with a COP conversion factor of 3…4 and an electric boiler.

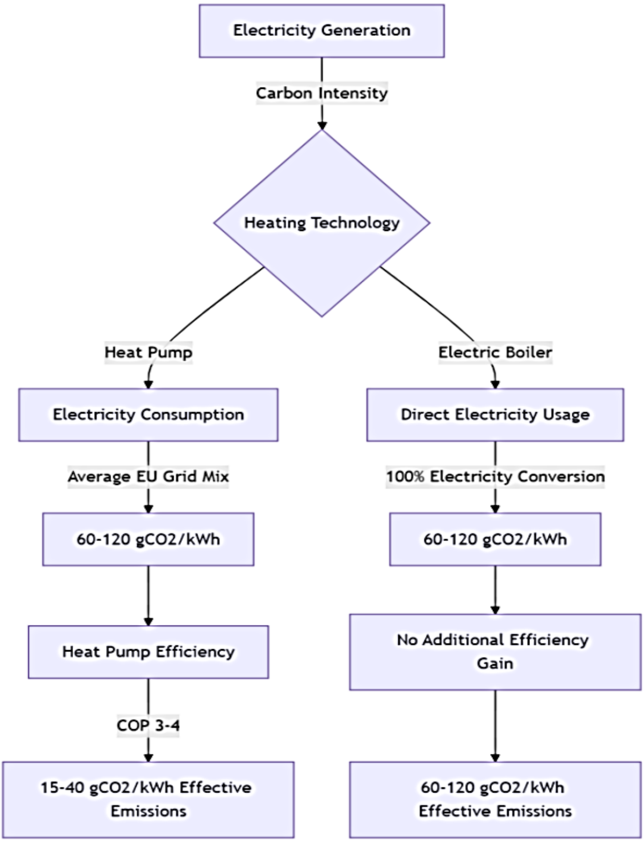


Fig. 3. Comparison of emissions from a heat pump with a COP conversion factor of 3…4 and an electric boiler

Fig. 4 shows a comparison of emissions from a heat pump with a conversion coefficient of COP = 3…4 and a gas boiler.

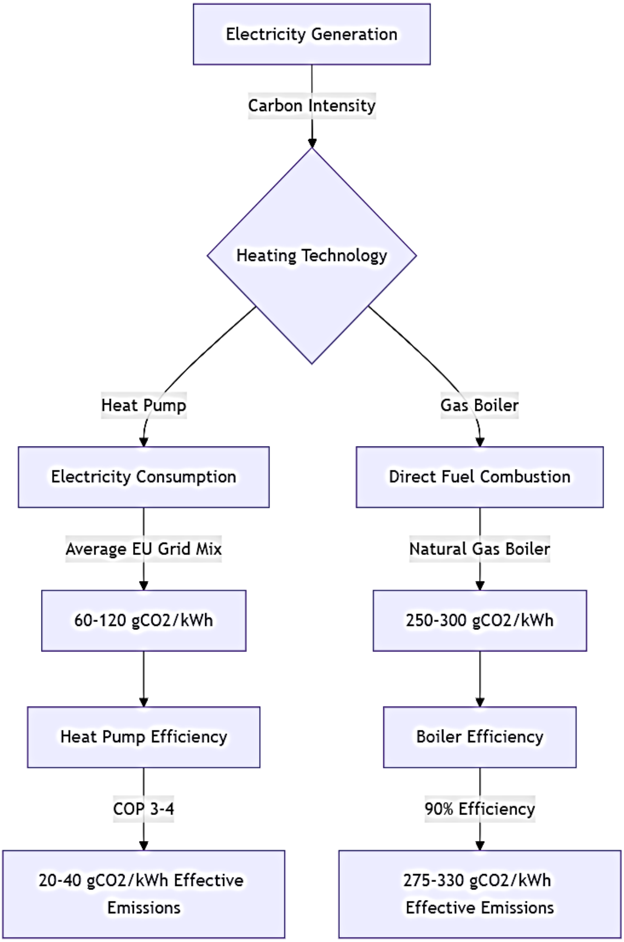


Fig. 4. Comparison of emissions from a heat pump with a COP conversion factor of 3…4 and a gas boiler

Fig. 5 shows a flowchart for selecting a heat pump and a boiler with a specific type of fuel to minimize indirect harmful emissions.

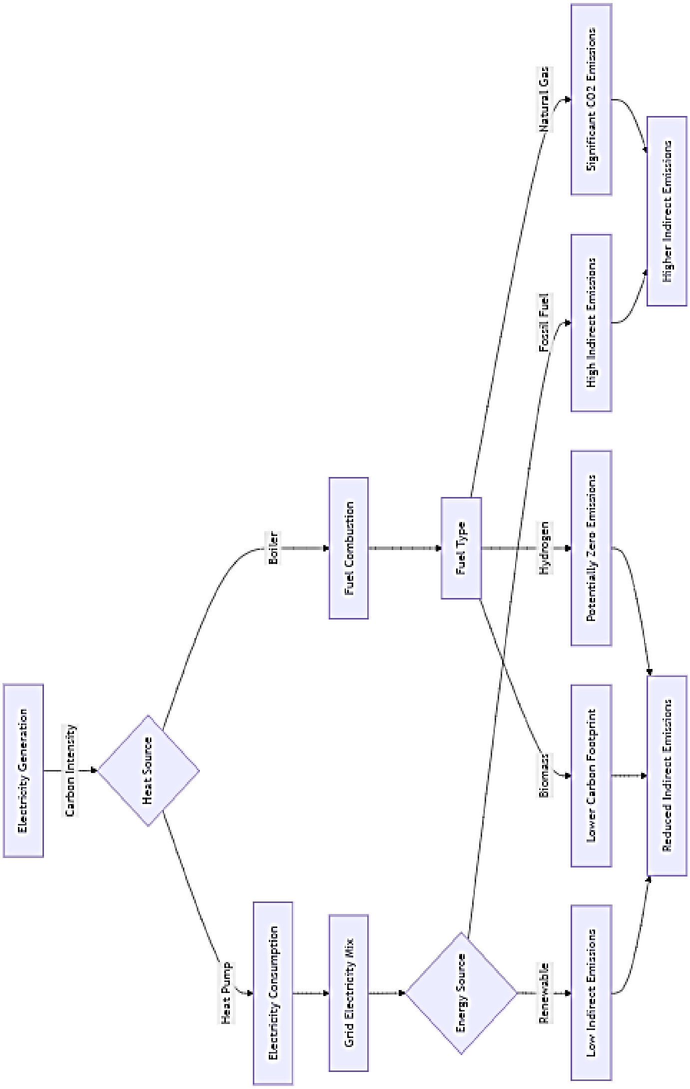


Fig. 5. Flowchart for selecting a heat pump and a boiler with a specific type of fuel to minimize indirect harmful emissions

Fig. 6 shows the structure of CO_2 emissions for a heat pump with different refrigerants and electrical energy sources.

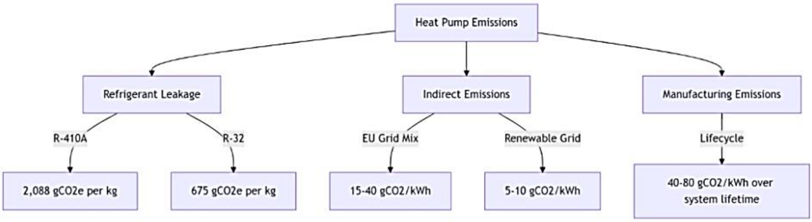


Fig. 6. Structure of CO_2 emissions for a heat pump with different refrigerants and electrical energy sources

Fig. 7 shows the structure of CO_2 emissions at different stages of the heat pump life cycle.

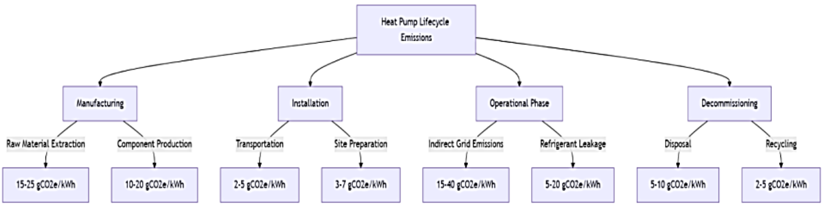


Fig. 7. Structure of CO_2 emissions at different stages of the heat pump life cycle

UBP (Umweltbelastungspunkte or Environmental Impact Points) is a Swiss environmental accounting method that quantifies the environmental impact of a product throughout its life cycle. It aggregates various environmental stressors into a single numerical score, allowing for a comprehensive environmental assessment by converting different types of environmental pressures into comparative scores[10].

UBP (Umweltbelastungspunkte) is an environmental impact assessment method that:

– identifies environmental pressures across life cycle stages;

[10] Umweltbelastungspunkte (UBP). URL: https://www.wecobis.de/service/lexikon/ubplex.html#:~:text=Die%20Ermittlung%20der%20Umweltbelastung%20erfolgt,Einwirkungen%20entsprechend%20ihrer%20Sch%C3%A4dlichkeit%20bestimmt

– converts multiple environmental impacts into a single numerical assessment;

– allows for comparison of the environmental performance of different systems;

– was developed by ESU-services, researchers at the Swiss Federal Institute of Technology;

– measures environmental impacts across multiple categories;

– provides a holistic environmental comparison of products/systems;

– covers greenhouse gas emissions, resource use, pollution and ecosystem impacts.

The main measurement categories for the UBP method include the assessment of greenhouse gas emissions, resource consumption, pollution levels, and ecosystem disruption.

Typical values of the UBP assessment component indicators are as follows[11]:

– production: 70-110 UBP/unit;

– energy production: 20-40 UBP/unit;

– transport: 5–15 UBP/unit;

– disposal/recycling: 10-30 UBP/unit.

Calculation scheme according to the UBP methodology:

– the environmental impact is assessed, converted into standardized points;

– a weighted assessment is performed across several impact categories;

– 1 UBP ≈ environmental load of 1 gram of CO_2 equivalent.

Impact categories assessed using the UBP method: greenhouse gases, resource depletion, ecosystem damage, water pollution, air pollution, waste generation.

The UBP calculation process involves the following steps:

– life cycle analysis (LCA) framework;

– normalization of various environmental stressors;

– aggregation of data into a single numerical score;

– uses scientific impact assessment models;

– allows for intersystem comparison of the environment.

UBP score range:

– 0-1000 UBP, typical for the product life cycle;

– lower value of the indicator means lower environmental impact;

– allows for quantitative assessment of environmental efficiency.

[11] Ökofaktoren Schweiz 2021 gemäss der Methode der ökologischen Knappheit. URL: https://www.bafu.admin.ch/bafu/de/home/themen/wirtschaft-konsum/publikationen-studien/publikationen/oekofaktoren-schweiz.html

Careful mathematical development requires advanced methods of modeling ecological systems and complex multivariate statistical analysis.

Fig. 8 shows the structure of CO_2 emissions of a heat pump using the UBP method.

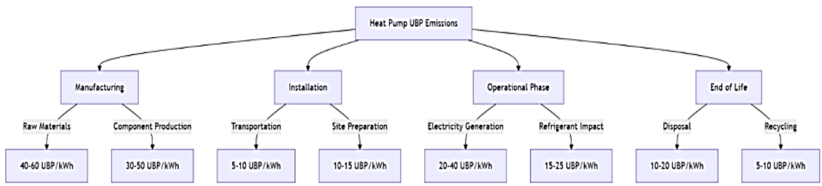


Fig. 8. Structure of CO_2 emissions of a heat pump using the UBP method

We assessed the environmental impact of different heat pump application options using the "UBP (Umweltbelastungspunkte) 2021" method (updated version). The environmental impact of heat pump application options was assessed in the Treeze Ltd program for life cycle assessment for heat pumps[12]. An environmental heat pump calculator program[13] was used, which allows us to study the impact of the low-temperature heat source for the heat pump (renewable energy sources or secondary energy resources), the heat pump COP conversion factor (general and local), the type of building and the structure of the electricity consumed by the heat pump (network or from renewable sources). The results obtained allow us to assess the environmental impact of a specific option and operating mode of the heat pump, as well as the type of electricity consumed by it.

Fig. 9–24 shows the environmental impact indicators of heat pumps using different options of natural renewable low-temperature heat sources in the case of a local and overall efficiency factor of 3, electricity from the ENTSO E mix network and from renewable sources. Based on the analysis of the environmental impact indicators of heat pumps (based on the results of the analysis of the indicators in Fig. 9–24), the improvement of the environmental impact indicators in the case of using natural renewable low-temperature heat sources and electricity from renewable sources in heat pumps is confirmed.

---

[12] Treeze Ltd's life cycle assessment software product. URL: https://treeze.ch.

[13] Heat pump calculator. URL: https://rechner.pawis.ch/HTMLWaermepumpen24_de_v1/Oekobilanzrechner_Waermepumpen_2024_deutsch_v1_UVEK2022.html

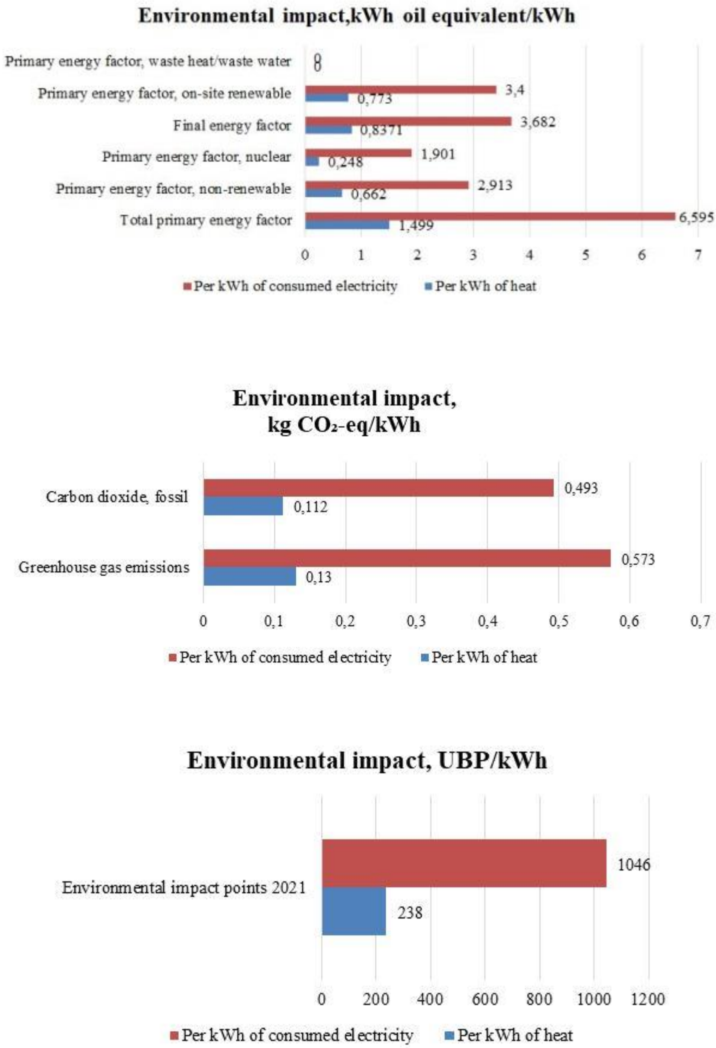


Fig. 9. Environmental impact indicators for an air-to-water heat pump, new building, overall efficiency factor 3, electricity from the ENTSO E mix network

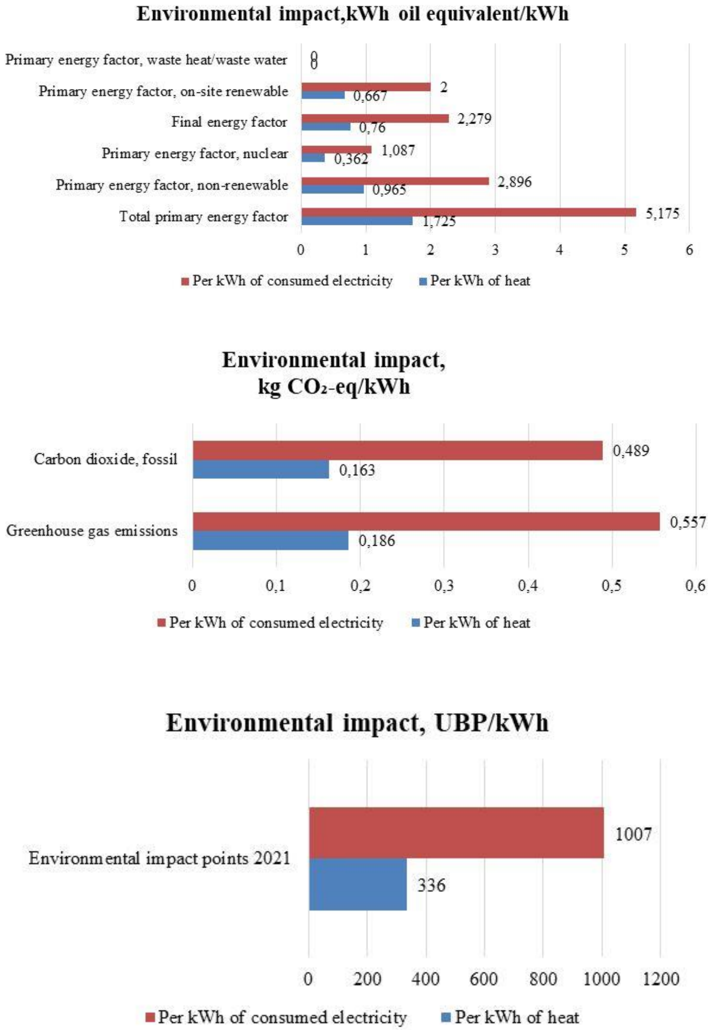
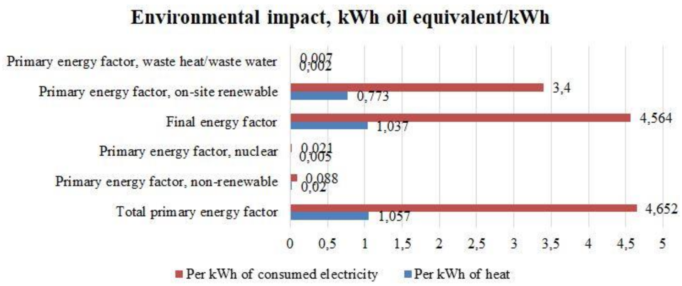
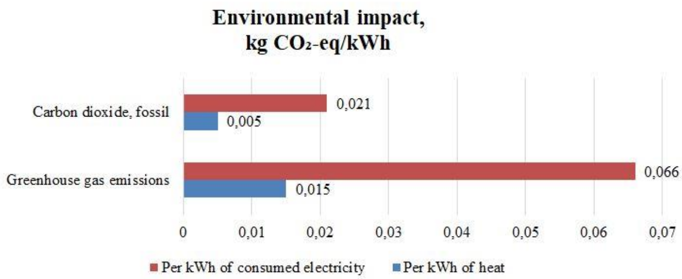


Fig. 10. Environmental impact indicators for an air-to-water heat pump, new building, local efficiency factor 3, electricity from the ENTSO E mix network





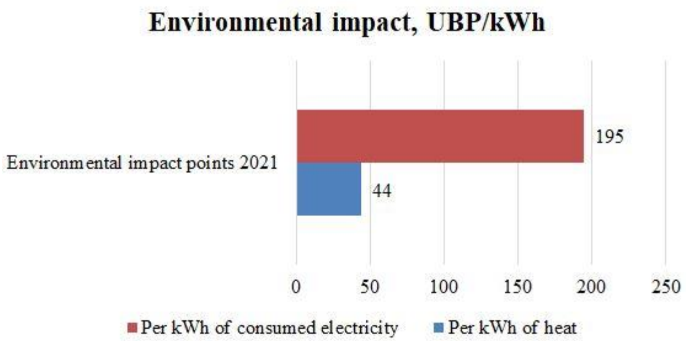


Fig. 11. Environmental impact indicators for an air-to-water heat pump, new building, overall efficiency factor 3, electricity from renewable sources

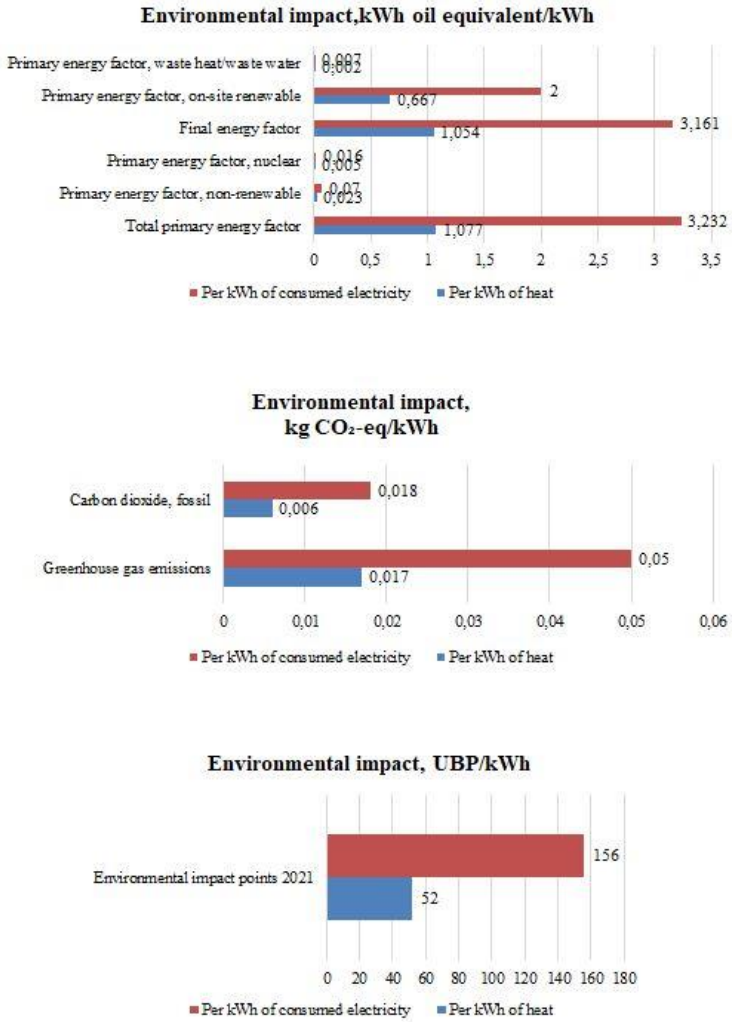
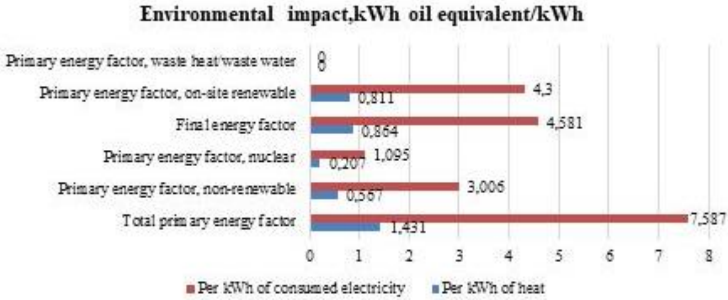
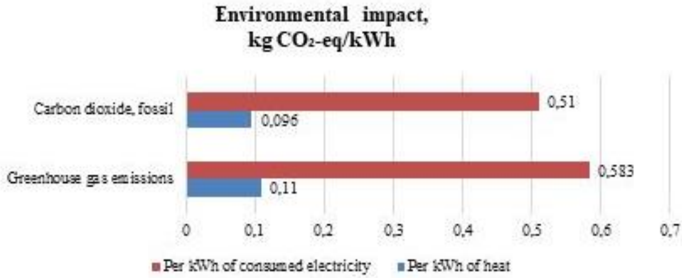


Fig. 12. Environmental impact indicators for an air-to-water heat pump, new building, local efficiency factor 3, electricity from renewable sources





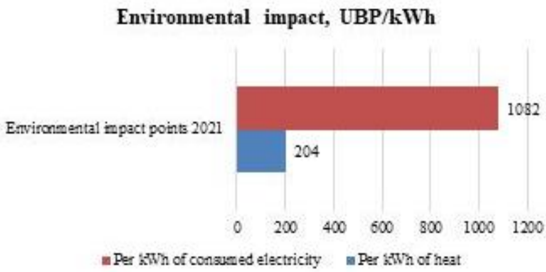
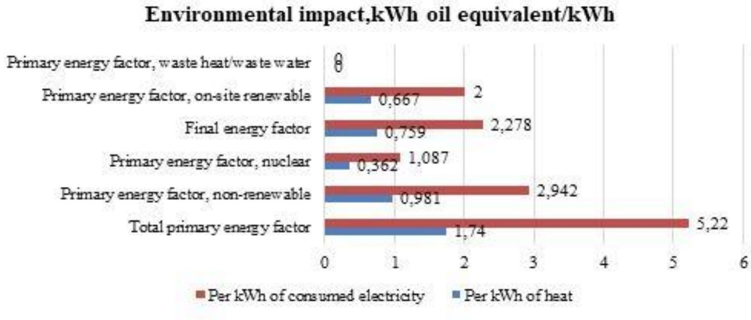
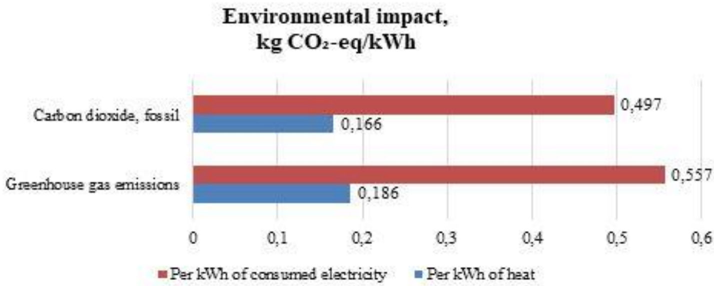


Fig. 13. Environmental impact indicators for brine (geothermal energy)-to-water heat pump, new building, overall efficiency factor 3, electricity from the ENTSO E mix network





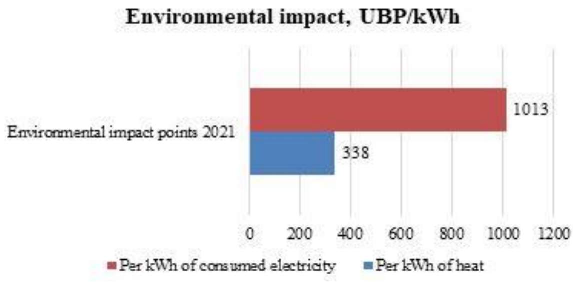


Fig. 14. Environmental impact indicators for brine (geothermal energy)-water heat pump, new building, local efficiency factor 3, electricity from the ENTSO E mix network

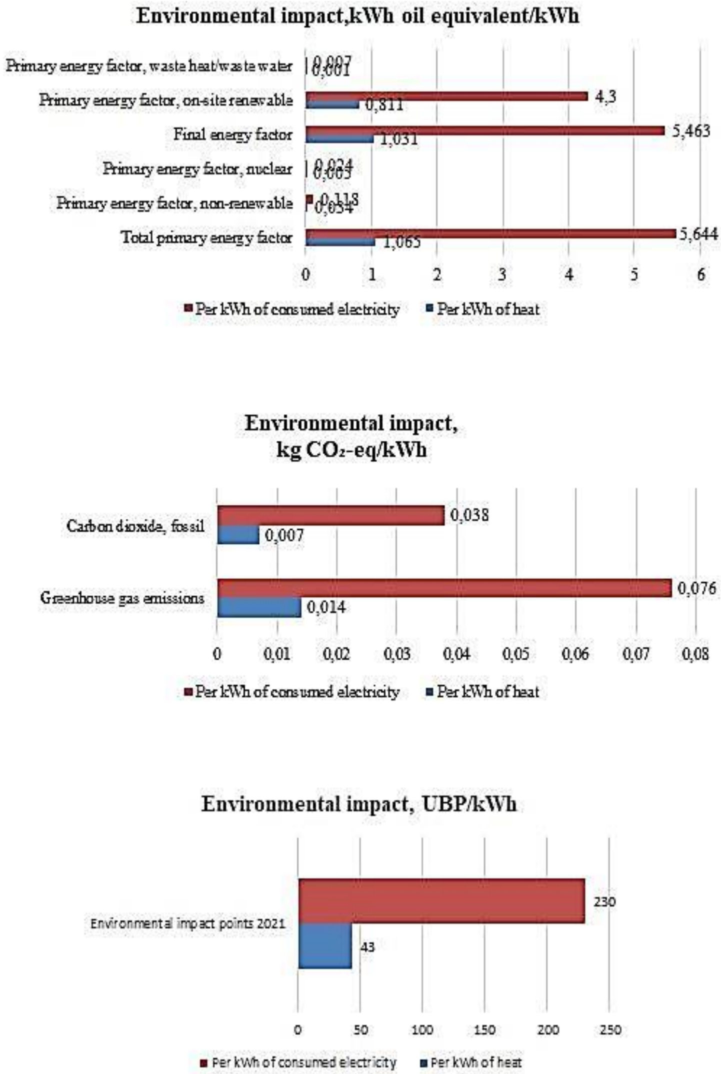


Fig. 15. Environmental impact indicators for brine (geothermal energy)-to-water heat pump, new building, overall efficiency factor 3, electricity from renewable sources

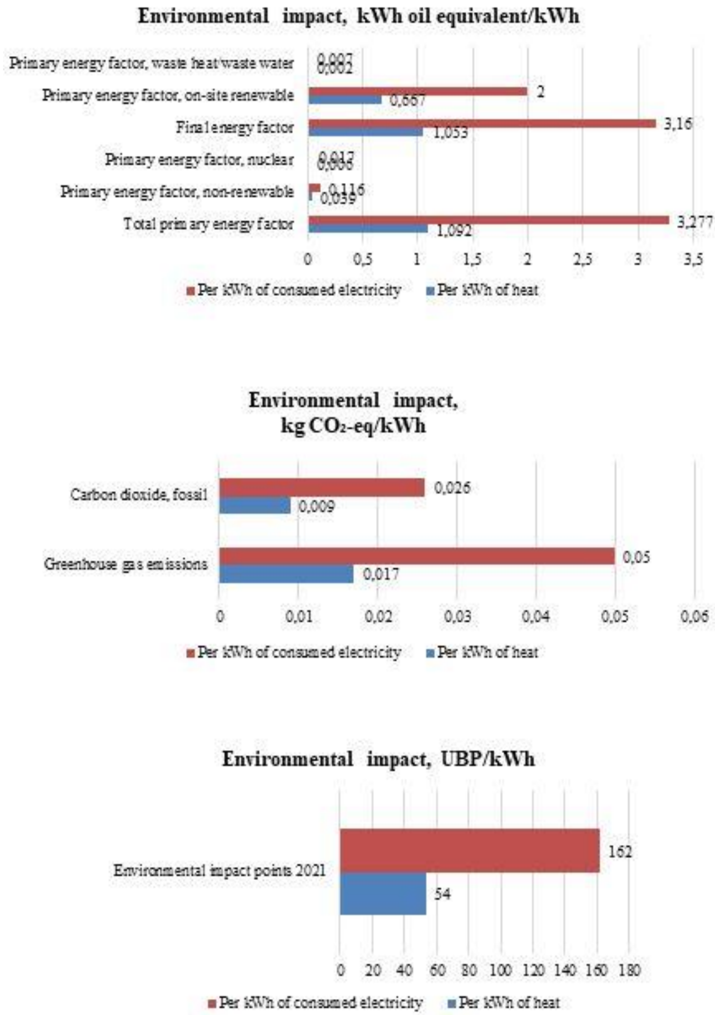


Fig. 16. Environmental impact indicators for brine (geothermal energy)-water heat pump, new building, local efficiency factor 3, electricity from renewable sources

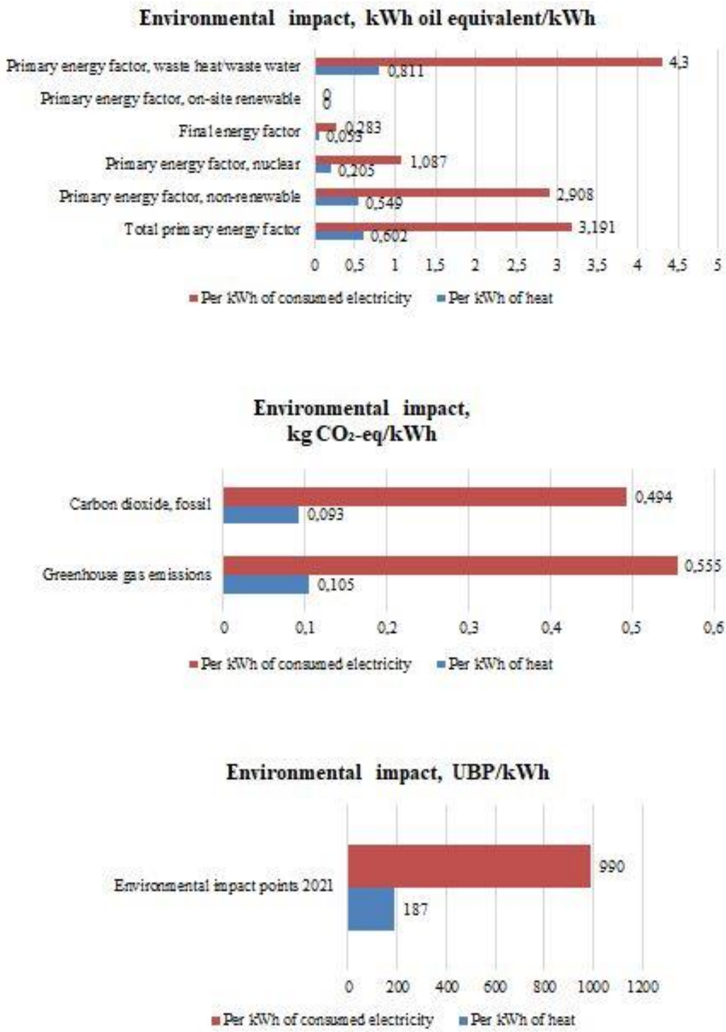
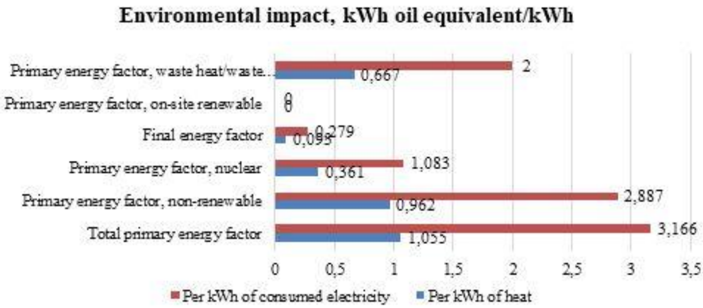
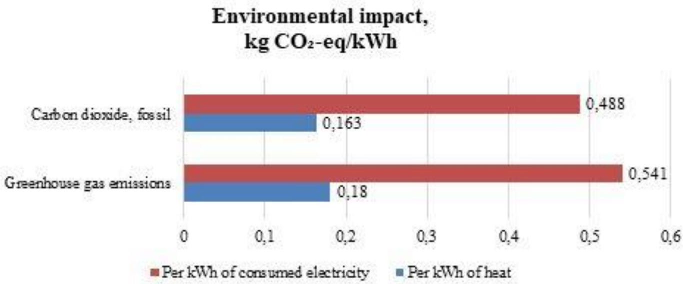


Fig. 17. Environmental impact indicators for a waste water-to-water heat pump, new building, overall efficiency factor 3, electricity from the ENTSO E mix network





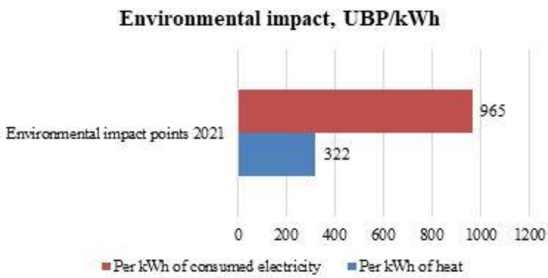
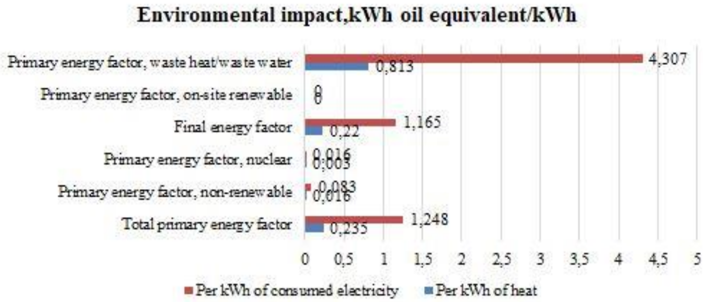
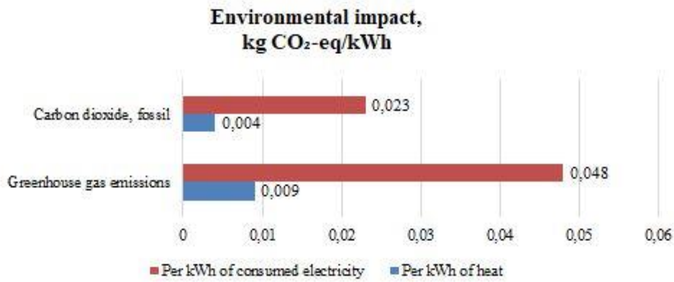


Fig. 18. Environmental impact indicators for a waste water-to-water heat pump, new building, local efficiency factor 3, electricity from the ENTSO E mix network





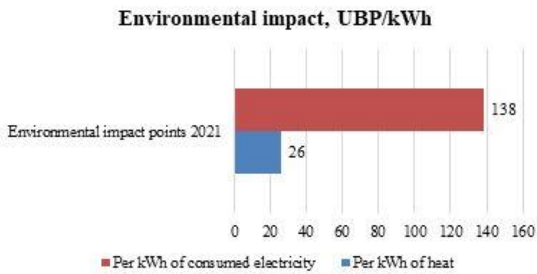


Fig. 19. Environmental impact indicators for a waste water-to-water heat pump, new building, overall efficiency factor 3, electricity from renewable sources

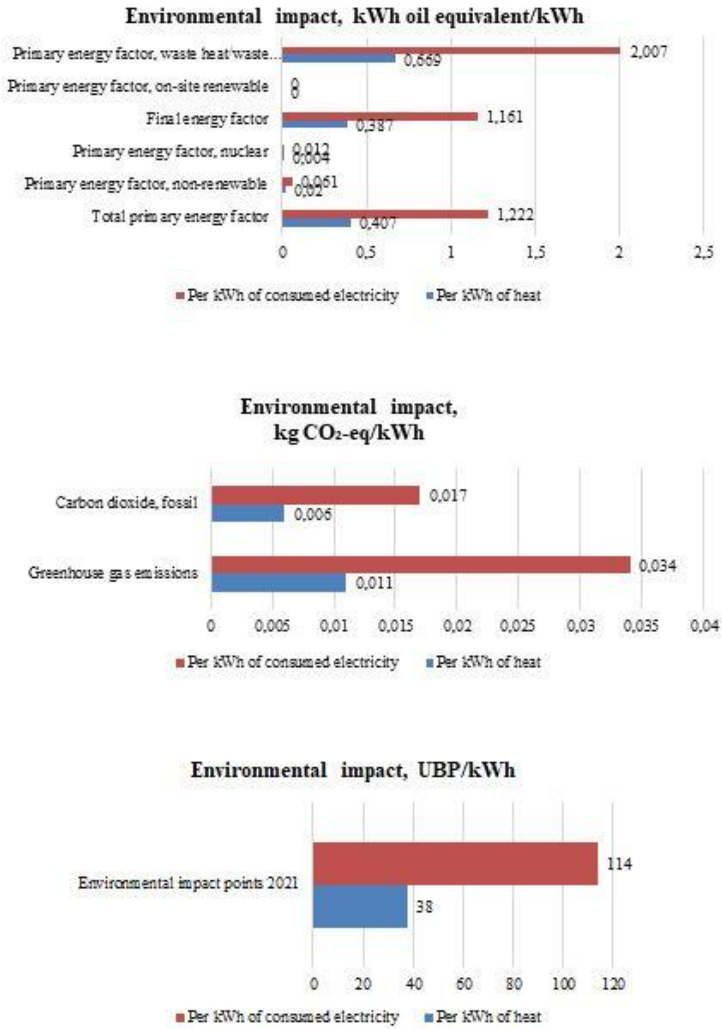
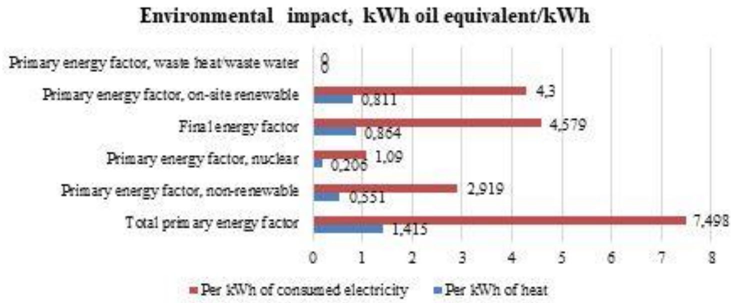
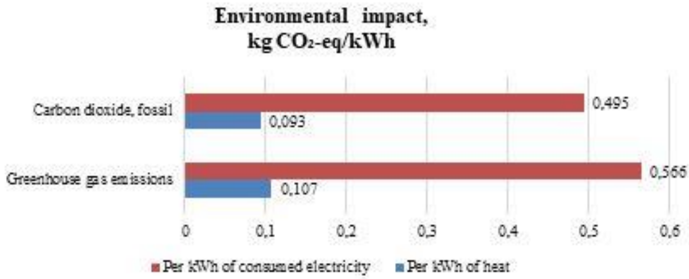


Fig. 20. Environmental impact indicators for a waste-to-water heat pump, new building, local efficiency factor 3, electricity from renewable sources





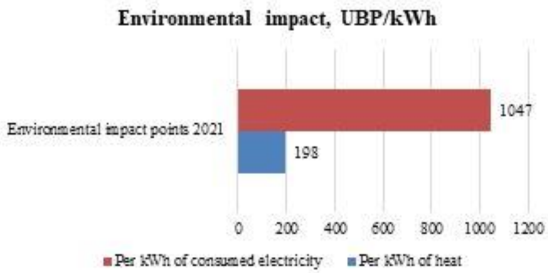
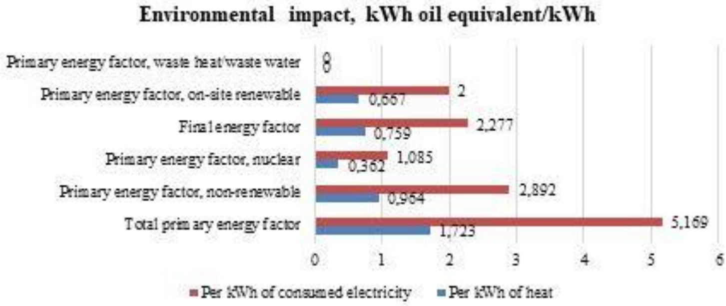
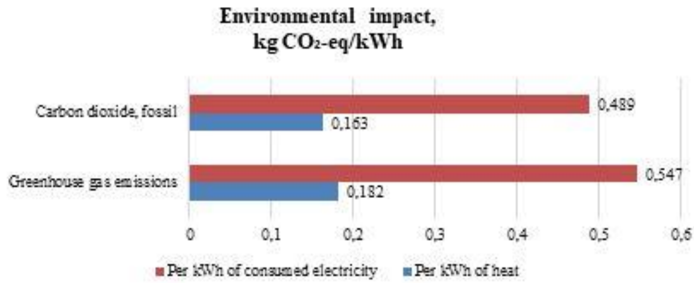


Fig. 21. Environmental impact indicators for a ground-water-to-water heat pump, new building, overall efficiency factor 3, electricity from the ENTSO E mix network





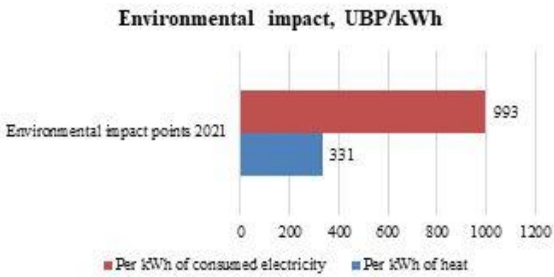
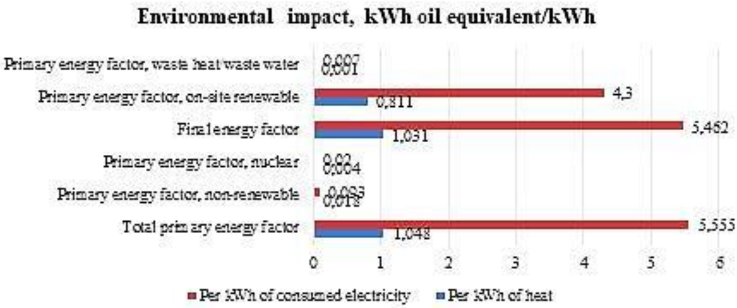
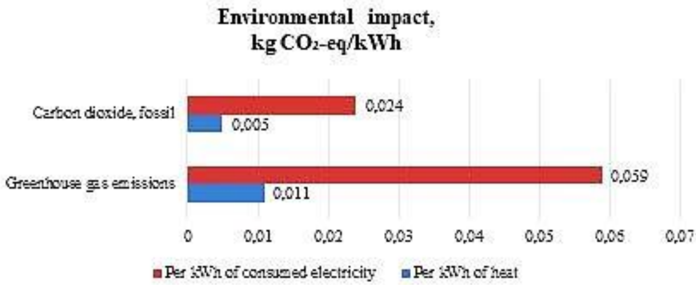


Fig. 22. Environmental impact indicators for a ground-water-to-water heat pump, new building, local efficiency factor 3, electricity from the ENTSO E mix network





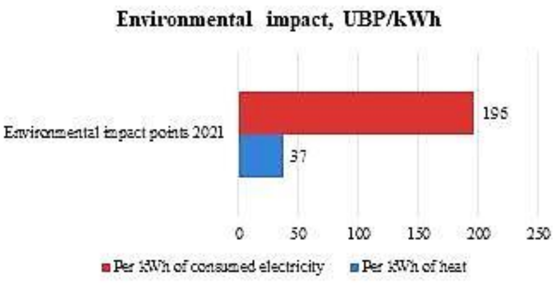
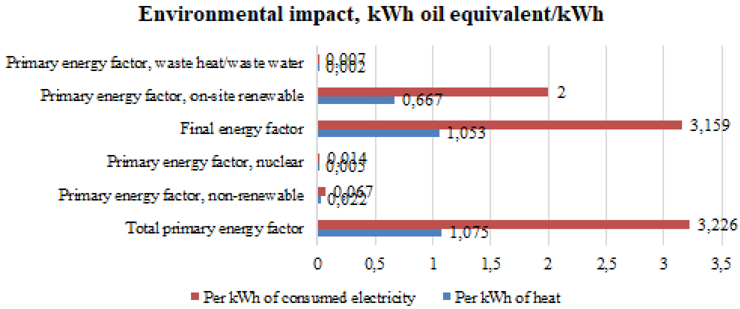
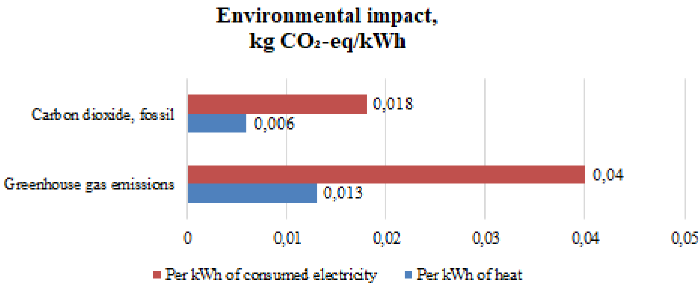


Fig. 23. Environmental impact indicators for a ground-water-to-water heat pump, new building, overall efficiency factor 3, electricity from renewable sources





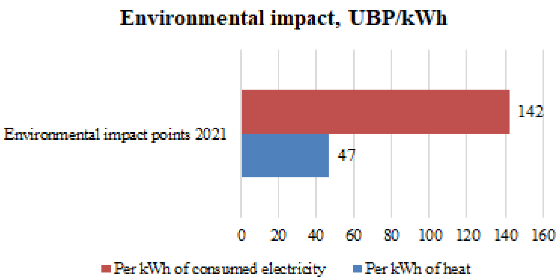


Fig. 24. Environmental impact indicators for a ground-water-to-water heat pump, new building, local efficiency factor 3, electricity from renewable sources

Our study assessed the environmental aspects of sustainable development of regions of Ukraine, assessed the impact of integration of heat pumps and renewable energy sources on environmental impact indicators, assessed the environmental impact indicators of heat pumps, confirmed the improvement of environmental impact indicators in the case of using natural renewable sources of low-temperature heat and electricity from renewable sources in heat pumps. Our study used scientific and methodological foundations and results from previous studies.

CONCLUSIONS

Sustainable development of the regions of Ukraine requires a comprehensive approach to the socio-economic and environmental development of territories. In this case, it is necessary to consider balanced economic development, taking into account local characteristics and resources, innovative development through the introduction of new technologies, environmental sustainability with an emphasis on the rational use of natural resources, the introduction of "green" technologies, and minimizing the negative impact on the environment. The key goal of ensuring sustainable development is to achieve harmonious and self-sufficient development of regions, taking into account the long-term perspective.

Our study assessed the environmental aspects of sustainable development of regions of Ukraine, assessed the impact of integration of heat pumps and renewable energy sources on environmental impact indicators, assessed the environmental impact indicators of heat pumps, confirmed the improvement of environmental impact indicators in the case of using natural renewable sources of low-temperature heat and electricity from renewable sources in heat pumps. Our study used scientific and methodological foundations and results from previous studies.

SUMMARY

Sustainable development of the regions of Ukraine requires a comprehensive approach to the socio-economic and environmental development of territories. The key goal of ensuring sustainable development is to achieve harmonious and self-sufficient development of regions taking into account the long-term perspective. Our study assessed the environmental aspects of sustainable development of the regions of Ukraine, assessed the impact of the integration of heat pumps and renewable energy sources on environmental impact indicators, assessed the environmental impact indicators of heat pumps, and confirmed the improvement of environmental impact indicators in the case of using natural renewable sources of low-temperature heat and electricity from renewable sources in heat pumps. Our study used scientific and methodological foundations and results from previous studies.

Bibliography

1. A European Green Deal. Striving to be the first climate-neutral continent. URL: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/ european-green-deal_en_.

2. Heat pump calculator. URL: https://rechner.pawis.ch/ HTMLWaermepumpen24_de_v1/Oekobilanzrechner_Waermepumpen_ 2024_deutsch_v1_UVEK2022.html

3. Net Zero by 2050. IEA, Paris. URL: https://www.iea.org/reports/ net-zero-by-2050.

4. Ökofaktoren Schweiz 2021 gemäss der Methode der ökologischen Knappheit. URL: https://www.bafu.admin.ch/bafu/de/home/themen/ wirtschaft-konsum/publikationen-studien/publikationen/oekofaktoren-schweiz.html

5. Ostapenko O, Alina G, Serikova M, Popp L, Kurbatova T and Bashu Z. (2023) Towards Overcoming Energy Crisis and Energy Transition Acceleration: Evaluation of Economic and Environmental Perspectives of Renewable Energy Development. In: Koval V, Olczak P (eds) *Circular Economy for Renewable Energy. Green Energy and Technology*. Cham: Springer,. https://doi.org/10.1007/978-3-031-30800-0_7

6. Ostapenko, O., Olczak, P., Koval, V., Hren, L., Matuszewska, D., Postupna, O. Application of Geoinformation Systems for Assessment of Effective Integration of Renewable Energy Technologies in the Energy Sector of Ukraine. Appl. Sci., 12, 592 (2022). https://doi.org/10.3390/ app12020592

7. Ostapenko Olga. Estimation of tendencies of transforming the energy sectors of World, European Union and Ukraine in the perspective to 2050 with using the renewable energy sources in the concept of Sustainable Development. In: *Social capital: Vectors of development of behavioral economics*: Collective monograph, pp. 99 – 139. ACCESS Press Publishing house. Veliko Tarnovo, Bulgaria (2021)

8. Ostapenko, O., Savina, N., Mamatova, L., Zienina-Bilichenko, A. & Selezneva, O. Perspectives of application of innovative resource-saving technologies in the concepts of green logistics and sustainable development. Turismo: Estudos &Práticas (UERN), Mossoró/RN, Caderno Suplementar, 02. (2020) URL: http://geplat.com/rtep/index.php/tourism/article/view/488.

9. Transforming our world: the 2030 Agenda for Sustainable Development. URL: https://www.undp.org/ukraine/publications/transforming-our-world-2030-agenda-sustainable-development .

10. Treeze Ltd's life cycle assessment software product. URL: https://treeze.ch.

11. Support Sustainable Development and Climate Action. URL: https://www.un.org/en/our-work/support-sustainable-development-and-climate-action/

12. Umweltbelastungspunkte (UBP). URL: https://www.wecobis.de/service/lexikon/ubplex.html#:~:text=Die%20Ermittlung%20der%20Umwelt belastung%20erfolgt,Einwirkungen%20entsprechend%20ihrer%20Sch%C3%A4dlichkeit%20bestimmt

13. Zero waste. URL: https://zerowaste.org.ua.

Information about the author:
Ostapenko Olha Pavlivna,
Candidate of Technical Sciences,
Associate Professor at the Department of Heat Power Engineering
Vinnytsia National Technical University
95, Khmelnytskyi Highway, Vinnytsia, 21021, Ukraine