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POSSIBILITIES OF APPLYING INNOVATIVE HEAT PUMP TECHNOLOGIES IN UKRAINE: ENVIRONMENTAL ASPECTS FOR IMPLEMENTING A SUSTAINABLE DEVELOPMENT PROGRAM

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Introduction. The introduction of heat pump technologies in Ukraine has significant potential in terms of environmental sustainability and energy efficiency. Heat pumps are energy-efficient equipment that allows: to reduce greenhouse gas emissions by 50-80% compared to traditional heating systems, to use renewable energy sources (heat from the ground, water, air) and to significantly reduce fossil fuel consumption.

Ukraine has favorable conditions for the introduction of heat pump technologies. These include, in particular, the significant potential of low-potential heat sources (soil, groundwater, water bodies), the need to modernize the outdated heat supply system, obligations to reduce CO_2 emissions in accordance with international agreements, the course towards energy independence and decarbonization (Ostapenko et al., 2020; Ostapenko, 2021; Ostapenko et al., 2022; Ostapenko et al., 2023).

The implementation of heat pump technologies directly corresponds to several UN Sustainable Development Goals: Goal 7 “Affordable and Clean Energy”, Goal 11 “Sustainable Urban and Community Development”, Goal 12 “Responsible Consumption”, and Goal 13 “Combating Climate Change” (UNDP, “Transforming our world: the 2030 Agenda for Sustainable Development”, 2018; UN, “Support Sustainable Development and Climate Action”, 2018).

Data and Methods. The study used methodological and statistical data from the databases of the International Energy Agency (IEA), of the International Renewable Energy Agency (IRENA), the World Bank, the United Nations Statistical Department (UNSD) and others. Our study used systemic, structural, statistical, factor, and comparative analyses.

Results. Large-scale implementation of heat pump technologies can become an important element of Ukraine's green recovery and its integration into the European energy space, taking into account the requirements of the European Green Deal (EC, "A European Green Deal. Striving to be the first climate-neutral continent", 2019; IEA, "Net Zero by 2050", 2021).

Heat pumps provide significant environmental benefits for Ukraine, especially in the context of modern environmental challenges and energy transition.

The introduction of heat pumps will ensure a reduction in direct CO_2 emissions by 50-80% compared to gas boilers and by 70-90% compared to coal-fired thermal power plants; will contribute to the reduction of methane emissions associated with the extraction and transportation of natural gas; will ensure a reduction in the overall carbon footprint of the heating and hot water supply system.

The introduction of heat pumps will also ensure a reduction in local air pollutants, namely: the absence of direct emissions of nitrogen oxides (NOx), sulfur oxides (SOx), carbon monoxide (CO) and particulate matter characteristic of fossil fuel combustion; improving air quality in cities, especially during the heating season; reducing the risks of respiratory diseases associated with air pollution.

The introduction of heat pumps in Ukraine will contribute to the conservation of natural resources. The consumption of non-renewable fossil resources (gas, coal, oil) will be reduced, energy will be used efficiently in heat pumps and the load on the power grid will be reduced due to high energy efficiency.

The synergy of heat pumps with renewable energy sources will be ensured. The following will be provided: the possibility of working in conjunction with solar power plants, wind generators; increasing the share of "green" energy in the energy balance of Ukraine, promoting the decarbonization of the heat sector through the use of electricity from renewable sources.

The introduction of heat pumps will reduce heat pollution: no direct discharge of hot water into water bodies (unlike some CHPs and industrial facilities), reducing the heat load on urbanized areas. Water resources will also be conserved, namely: reducing the consumption of water required for cooling traditional generating capacities; preventing pollution of water bodies with wastewater associated with the extraction and processing of fossil fuels.

In the foreseeable future, replacing 40% of gas boilers with heat pumps in Ukraine could reduce CO_2 emissions by 10-15 million tons annually, and reduce natural gas consumption by 5-7 billion m^3 per year. These actual figures demonstrate the significant potential of heat pumps as an environmentally friendly alternative to traditional heating systems, especially in the context of the goals of decarbonization and improving the state of the environment in Ukraine.

Conclusions. As a result of the widespread introduction of heat pumps in Ukraine, long-term environmental effects will be ensured – contributing to the achievement of Ukraine's climate goals in accordance with the Paris Agreement, supporting the goals of the European Green Deal in the context of European

integration; preserving ecosystems that suffer from the consequences of fossil fuel extraction (mines, gas extraction).

In the conditions of Ukraine, the introduction of heat pumps is of particular importance for ensuring environmentally sustainable restoration of infrastructure and modernization of the energy sector, which will contribute to the overall improvement of the environment and public health.

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