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Municipal Heat Energy of Ukraine – Adaptation to Global Warming

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Abstract: Rising global temperatures have exacerbated the problems of adaptation to climate change in various sectors of the economy, including municipal energy. Therefore, the task is to develop measures and mechanisms, the implementation of which will guarantee cost-effective comfortable and reliable heat and cold supply of buildings and structures in climate change. Experimental studies of heat transfer and monitoring of thermal regimes in enclosing structures and building elements were conducted with the development of innovative engineering systems for energy supply of a passive house of the "zero-energy" type. Experimental developments of innovative energy-efficient greenhouse gas-reducing technologies and equipment for energy supply systems of buildings have been performed and their architectural and construction solutions for adaptation to climate change have been optimized. In order to expand and deepen the theory and practice of improving the energy efficiency of buildings in the near future, the scientific priority and subject of basic and applied research have been identified. Developed adaptive to climate change innovative, energy efficient technologies and equipment of engineering systems of energy supply of buildings with the use of renewable energy sources can be used in the practice of energy supply of housing and communal services.

Keywords: global warming, municipal energy, innovations, adaptation, energy efficiency of buildings

1. Introduction

From the second half of the twentieth century, meteorologists began to instrumentally record significant climate change on our planet, including rising global temperatures. At the end of 2020, experts from the UN World Meteorological Organization (WMO) noted that the average temperature increased by 1.2°C compared to the period 1850-1900. Currently, the geophysical phenomenon of global warming is explained by the intensification of the greenhouse effect due to the increase in the concentration of so-called greenhouse gases (GHG) in the Earth's atmosphere. This problem has caused concern and debate in the expert community and among politicians, as global climate change directly affects the living conditions of the world's population. Numerous publications make various predictions and discuss the dramatic consequences of global warming. Different regions of the planet have their own capabilities both to counter the effects of abrupt climate change and to adapt to new conditions.

Today, no one denies the rise in global temperature, but there is no consensus on the nature of such climate change. From time to time, new objects of environmental research appear that affect the climate due to natural GHG emissions.

It is known that GHG emissions due to natural factors significantly exceed greenhouse gas emissions due to anthropogenic activities. As humanity is not yet able to significantly influence GHG emissions of natural origin, the international community is widely discussing and trying to take measures to reduce anthropogenic emissions.

Supporters have both anthropogenic and natural concepts of increasing global temperature. The anthropogenic concept is advocated by the Intergovernmental Panel on Climate Change (IPCC). However, there are reputable experts and leading research teams who believe that the key cause of global warming is natural factors. Yet today, the IPCC approach remains the main scientific basis for studying climate change. According to the IPCC, the determining factor of global warming is the anthropogenic impact, namely: the increase in the GHG concentration in the Earth's atmosphere, primarily the main one – CO_2, due to the combustion of fossil fuels. Indeed, the concentration of carbon dioxide in the atmosphere increased from 278 ppm in 1750 (pre-industrial period) to 414 ppm in 2020, methane, respectively, – from 722 to 1869 bpm, and nitric oxide – from 270 to 331 bpm. In the period from 1990 to 2018, the concentration of long-lived GHGs in the atmosphere increased by 43%, with CO_2 accounting for 81% of this increase (WMO Greenhouse Gas Bulletin, 2019).

In total, in 2019, the total emissions of all GHGs were 59.1 gigatonnes (Gt) in CO_2 equivalent. CO_2 accounted for 65% of the world's GHG emissions, mainly due to energy production and use, and CH_4 and N_2O emissions were generally due to agriculture and nature. All energy is responsible for 41% of

GHG emissions, industry accounted for 20%, transport – 14%, and agriculture and waste generated 15% of GHG (Emissions Gap Report 2020).

In 2019, CO_2 emissions from the use of fossil fuels reached a record level, amounting to 38.0 Gt CO_2 (range: ± 1.9 Gt CO_2). Due to the COVID-19 pandemic, total CO_2 emissions in 2020 could be reduced by approximately 7 percent (range: 2-12%) compared to emission levels in 2019, but the expected reduction in GHG emissions will be not so significant, as GHG emissions (other than CO_2) are likely to be altered to a lesser extent.

According to (IEA, Global Energy Outlook 2021) in 2020 the demand for primary energy decreased by almost 4%, global CO_2 emissions related to energy decreased by 5.8% according to the latest statistics from 33.4 Gt CO_2 (in 2019.) to 31.5 Gt CO_2 (in 2020), which is the largest annual decrease since World War II. In absolute terms, emission reductions of almost 2.0 Gt CO_2 are unprecedented in human history – in general, this is equivalent to avoiding all emissions from the European Union. However, the concentration of GHG in the atmosphere continues to rise. For example, the average monthly CO_2 concentrations in Mauna Loa, Hawaii – at the atmospheric monitoring station – in February 2021 were 416.75 ppm, and in February 2020 it was 414.34 ppm, an increase of 0.6%, and the concentration of methane, respectively: 1892.3 bpm (December 2020) compared to 1874.6 bpm in the previous December, an increase of 0.9% (NOAA). In terms of N_2O concentration, the situation is similar: an increase of 0.4% from 332.3 bpm in November 2019 to 333.6 bpm in November 2020. Also at Cape Grimm in Tasmania, another key air pollution measurement station, in September 2020 the CO_2 concentration reached 410.8 ppm compared to 408.58 ppm in September 2019, an increase of 0.55% (Climate change…).

2. Results

2.1. Climate change in Ukraine

The trend of climate change fully applies to Ukraine. Over the last century, the average annual air temperature in Ukraine has risen by more than 1.9°C. In the cold period, the increase in air temperature averages 1.35°C, in the warm – 1.0°C. Since 1989, the average annual temperature in Ukraine has increased by almost 1.0°C. There is an almost continuous period of warming, during which the average air temperature in 70% of cases was higher than normal. The positive fluctuation of air temperature in the period 1989-2013 is the most powerful in the history of instrumental observations of the weather (Lyalko et al. 2016).

The rate of air temperature rise in Ukraine is ahead of global trends. If the world does not abandon the use of fossil fuels in the second half of the century, then in 30 years the average annual temperature in Ukraine may rise by another 1-1.5°C, and by the end of the century by 3.4-4.0°C. There is a steady rise in air temperature in all seasons:

- The world's average annual temperature has risen by 1.2°C over the past one hundred and fifty years.
- In Ukraine the average monthly air temperature in February, March, June, October, November and December 2019 was the highest or one of the highest for these months for the entire period of instrumental weather observations (since the end of the 19th century).
- In Ukraine, since 1991, each subsequent decade has been warmer than the previous one: 1991-2000 – by 0.5°C, 2001-2010 – by 1.2°C, 2011-2019 – by 1.7°C from the level temperature in 1991 (Fig. 1), which exceeds the global temperature growth rate (Ministry 2020).

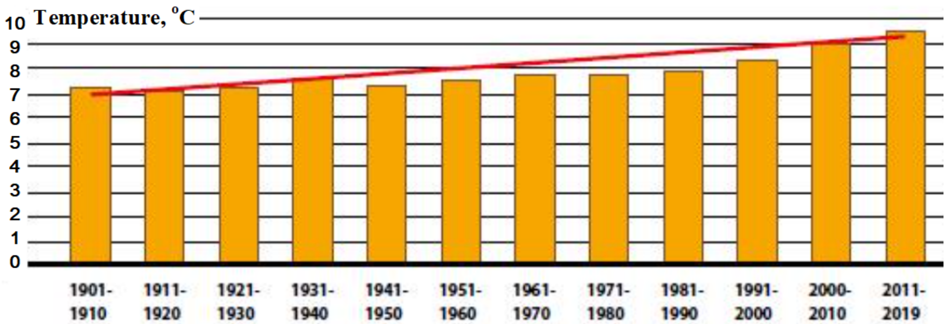

Fig. 1. Average ten-year climate temperatures of all Ukraine in the period 1900-2019

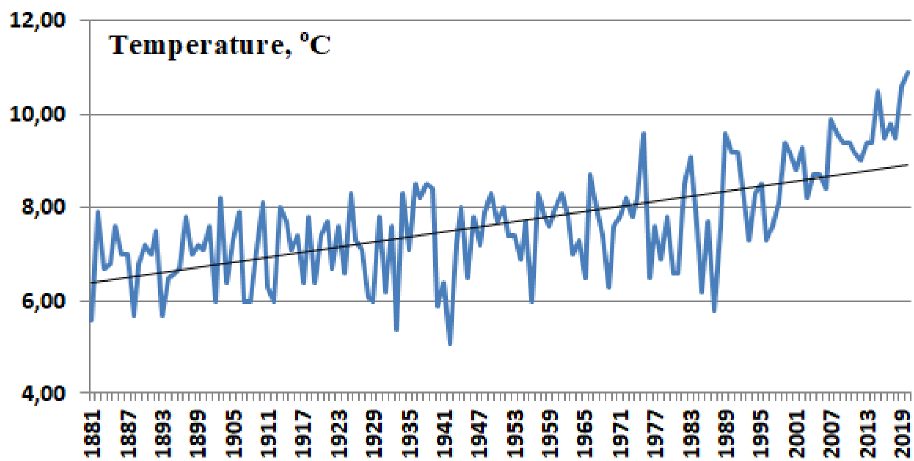

Fig. 2. Average annual air temperatures in Kyiv in the period from 1881 to 2020

The growth rate of temperature in large cities of the country exceeds the all-Ukrainian indicators. For example, the average monthly and annual temperatures in Kyiv (3750 degrees-days of the heated period) in the period from 1881 to 2020 are shown in Fig. 2, (Climatic data…).

The graph shows that for almost 140 years the average annual temperature in Kyiv has increased from about 6.3°C to 8.5°C, ie by 2.2°C. Moreover, temperature fluctuations in the period from 1881 to 1965 remained in the range of 5.4-8.3°C, the temperature began to rise rapidly from the 1990s and no longer became lower than 7ºC. 1942 is the coldest year in the last 140 years (5.1°C), and 2020 is the warmest year (10.9°C).

Scenarios of anthropogenic strengthening of the global greenhouse effect, thermal, hydrological regimes and the main conclusions for possible temperature changes of climate in Ukraine were considered in the early 90s of the twentieth century and presented in (WMO 2019):

1. with global anthropogenic warming of about 1°C (in the first quarter of the XXI century) in the southern regions of Ukraine the level of warming will almost coincide with the global, and in the north may increase to 40%;
2. the latitudinal temperature gradient on the territory of Ukraine will decrease in absolute value to 10% (in the modern era the latitudinal gradient of surface annual temperature is about 0.8°C per 1° latitude);
3. if the annual global temperature rises by 3°C (around the middle of the XXI century), the temperature regime of the northern regions of Ukraine may become similar to the temperature regime of its southern regions.

It is noted that the results obtained by a number of researchers of mathematical modeling of the dynamics of the terrestrial climate system to create RCP scenarios of regional climate change with anthropogenic strengthening of the greenhouse effect are still unreliable. The difficulties here are in the insufficiently deep study of the whole set of physical processes that form the latitudinal-longitudinal distribution of temperature fields and other climatic parameters (precipitation amounts, weather variability, etc.).

The publication of forecasts ten years later showed that in Ukraine the increase in the average surface temperature in the period 1900-2000 was 0.4-0.6°C, and in the regions: northeast about – 1°C, woodland and forest-steppe – 0.7-0.9°C, steppe – 0.2-0.3°C. By seasons: 1.2°C in winter, 0.8°C in spring, 0.2-0.3°C in summer. A negative trend in the number of frosty days and decontinentalization of the climate. Forecast estimates of changes in the average surface temperature in Ukraine by 2050 are reduced to the fact that the increase will be 1.5-2.0°C, and in January for the south – 2.0°C, for the north – 2.8°C and in July for Ukraine – 0.5-1.0°C (Lyalko et al. 2016).

The recent forecast for warming in Ukraine for a number of periods up to 2100 is shown in Fig. 3. It is clear that the results of instrumental measurements of temperature rise and warming forecasts in Ukraine generally correspond to trends in global temperature, and Ukraine faces the same challenges and risks that the world is concerned about (Increasing… 2015). In the near future (by 2030), the average monthly temperatures are projected to increase by 0.44°C; for the medium term (until 2050) – by 1.57°C, for the long term (until 2100) – by 3,15°C. The expected temperature changes will be heterogeneous for different regions of Ukraine.

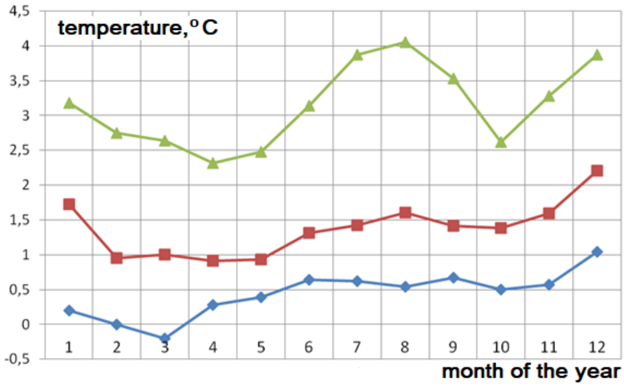

Fig. 3. Projections of changes in average monthly air temperatures in Ukraine with confidence intervals for an ensemble of 10 RCM (regional numerical climate models) compared to 1991-2010. Designations: ◆ – 2011-2030 (average value – 0.44°C), ■ – 2031-2050 (average – 1.57°C), ▲ – 2051-2100 (average – 3.15°C)

2.2. Adaptation to global warming

Measures and mechanisms to mitigate the possible negative effects of climate change and implement the inevitable adaptation to such changes in the lives and economies of countries and regions are actively discussed at international summits. Ukraine has also taken a number of initiatives on climate change. At the disposal of the Cabinet of Ministers of Ukraine dated December 7, 2016, #932-r. "On approval of the Concept for the implementation of state policy in the field of climate change until 2030" (On… 2016) it was emphasized that one of the main directions of "implementation of the Concept is adaptation to climate change, increasing resilience and reducing risks associated with climate change." Such adaptation is carried out through the development and implementation of a medium-term strategy for adaptation to climate change in Ukraine for the period up to 2030, coordinated with strategies and plans for the development of economic sectors and regional development strategies. Currently (in 2021) the draft "Strategies for Environmental Safety and Adaptation to Climate Change until 2030", which is sponsored by the Ministry of Environment of Ukraine, is being actively discussed in society. The importance of adaptation to climate change in Ukraine is of particular importance in the context of the Association Agreement between Ukraine and the European Union, as in Art. 365 states that the cooperation of the parties covers the development and implementation of climate change policy.

Adaptation is the process of adapting to an existing or expected climate and its impacts. In anthropogenic systems, the purpose of adaptation is to reduce harm, prevent it, or take advantage of opportunities. Adaptation to global climate change and global warming is the adaptability of natural or man-made systems in response to actual or expected climate change, which allows you to reduce your own vulnerability and take advantage of favorable conditions. Another definition can be proposed: the strategy of adaptation to climate change is the development of such measures and mechanisms for their implementation, which allow in a technically and economically sound way, taking into account the current and projected state of the economy to eliminate or mitigate the negative effects of climate change of Ukraine. The policy of adaptation to climate change involves conducting comprehensive interdisciplinary research with the development of the necessary technological (at the level of the 5th and 6th technological modes of development) innovations: from identifying and clarifying the causes of climate change, possible threats and consequences of these changes to develop measures, aimed at preventing or reducing the negative impact of changes or adaptation to them sectors of the economy and life of the population.

The purpose of the strategy of adaptation to climate change for municipal energy is to ensure a state of municipal energy supply (heating and air conditioning), which guarantees a comfortable and reliable current and future heat and cold supply in a technically and economically sound way while complying with environmental requirements.

It is important for housing and communal services and heat utilities to know how the demand for heat supply may change in the coming years due to global warming. According to observations, the parameters of low-frequency variability of the average heating temperature in the south of Ukraine and the corresponding change in energy consumption for heat supply for the population were analyzed, changes in average monthly temperatures in the regions of Ukraine from 1961 to 1991 were analyzed, their trends from October to April energy consumption for heating buildings (Anisimov 1999, Degterev et al. 2002, Degterev et al. 2008).

Further work on the assessment, determination of the effects of global warming and its impact on the characteristics of the heating season was expanded and deepened. Studies (Lyalko et al. 2015, Lyalko et al. 2016, Khodakov et al. 2016, Stepanenko et al. 2015, Degterev 2020) determine the temperature characteristics and dynamics of changes in the heating period for 1900-2013 and in some periods of this range and show a significant reduction in the duration of the heating period. There is also a brief analysis of previous publications on changes in climatic characteristics of the heating period using data that are important for a methodological approach to the study of patterns of changes in the parameters of the heating period (Lyalko et al. 2016). The impact of climate on humans and socio-economic systems is traced, in particular, climate change in connection with global warming and their impact on the efficiency of activities in various sectors of the economy of Ukraine until 2050 (Boychenko 2008). An assessment of the change in the duration of the heating period, the possibilities of development of solar and wind energy. The results of these studies can serve as a basis for further development of work on the adaptation of municipal energy supply to climate change.

It is advisable to adopt medium- and long-term roadmaps that provide for the development of programs (https://niss.gov.ua/doslidzhennya/nacionalna-bezpeka/prioriteti-politiki-ukraini-schodo-poperedzhennya-globalnogo), the implementation of which in relation to heat should be aimed at:

1) reduction of anthropogenic GHG emissions,
2) preservation and improvement of the quality of natural ecosystems,
3) adaptation of life of the population and sectors of economy.

The main volume (about 70-80%) of anthropogenic GHG emissions in Ukraine (Ukraine and the policy of combating climate change, 2016) falls on the fuel and energy complex. It is generated mainly during the combustion of hydrocarbon fuels in "large" energy (thermal power plants) and in municipal heat (thermal power plants, district and autonomous boilers). Regarding this energy sector of the economy, the directions of reducing greenhouse gas emissions are as follows:

1) increase energy efficiency of energy resources by:
    - improvement of organizational and economic mechanisms of management of objects of fuel and energy complex;
    - introduction of energy-efficient innovation-oriented technologies in the entire technological chain – from production to end use of energy resources;
2) optimization of hydrocarbon fuel combustion processes with improved environmental performance (low-emission environmentally friendly combustion);
3) the use of economically and environmentally justified way of renewable energy sources – the so-called low-carbon energy.

The main measures and mechanisms of adaptation to climate change for communal energy should be developed for the final consumer – energy supply of buildings of the housing and communal sector. Observations of changes in climatic characteristics – duration and average temperature of the heating period, amplitude of outdoor temperature fluctuations, number of the coldest days, etc. determine plans and forecasts of energy consumption, changes in capacity of heat generating plants, the degree of involvement in the fuel cycle of renewable energy sources. At the same time, the role of adaptation measures related to the introduction of architectural and construction innovations of buildings – thermal modernization of enclosing structures; the choice of materials that reflect or, conversely, absorb solar radiation; "Green" shielding of building facades, etc. There is a growing interest in bionics – the development of mechanisms for adaptation to climate change, created by analogy with their action in wildlife. The world now has high hopes for such global technologies to solve the global environmental crisis. These technologies involve the creation of innovations based on duplication in the technosphere of efficient processes observed in wildlife (reproducible technologies); development of technological systems using the transfer to the technosphere of an effective functional structure of the behavior of matter and energy in biological systems (convergent technologies) (Trubetskoi et al. 2020). One of the urgent tasks of architectural bionics (architectural style based on the use of bionics principles in architecture) is to find such architectural and technical solutions that would allow the use of environmentally friendly types of energy – solar, wind, soil, water, etc. (Lebedev et al. 1990, Hugh Aldersey-Willams 2003).

2.3. Experimental house

In this direction, in order to thoroughly study innovative scientific and technical measures to improve the energy efficiency of existing housing and modern buildings, a project was developed and built on the territory of the Institute of Technical Thermophysics of NAS of Ukraine a unique experimental passive house type "zero energy".

The building has three full floors (main building), the fourth floor with an area of 70% of the main building and the fifth – with an area of 30% of the main building, which houses a research climate chamber of the real climate of the environment. The first ground floor at 2/3 of the height (about 2.0 m) is sunk into the ground. The total heated area is 306 m^2, ie it is analogous to a cottage for the middle class. The house is clearly oriented around the world, has a flat pitched roof to the south. Facade walls on all floors are made of various combinations of socially available building materials (mostly environmentally friendly and chemically non-aggressive), they have a thickness of 38-40 cm (analog of the wall thickness of one and a half ordinary bricks).

Additionally, the facade is glued with a multilayer thermal insulation of light thermal insulation materials with a total thickness of 33-34 cm. The roof of the house is insulated with a layer of light basalt wool with a total thickness of 50 cm. The southern and northern facades are deaf, without windows. Windows of the eastern and western facades are double, double-chamber, with the formula 4M1i-8-4M1i-8-4M1 and 4M1i-10-4M1i-10-4M1, respectively. Window profiles of frames – five-chamber.

This design of wall facades allowed to obtain heat transfer resistance from 10.5 to 11.4 m^2·K/W, which is 3.3 times higher than the requirements of the current standard DBN B.2.6-33:2018. The heat transfer resistance of translucent structures has increased to 2.0 m^2·K/W, which is 2.7 times higher than the standard. The estimated specific annual (monthly) heat consumption of such a passive house is 14.8 kW·hour/(m^2·year) at -1.1°C (standard average temperature of the heated period for the climate of Kyiv) and 21.8 kW·hour/(m^2·year) at -10.0°C (standard average temperature of the coldest month of the heated period (January) for the climate of Kyiv). The average estimated heat consumption of the heating period is 2.6 kW, ie up to 12.0 W per 1 m^2, the actual heat consumption of the house is even less. Note that in the EU, despite a much more favorable climate, a passive house consumes 15.0 kWh(m^2·year). Experimental specific heat losses through the facades of the house at an ambient temperature of -10°C are only 1.2-1.8 W/m^2.

2.4. Innovative engineering systems of power supply of an experimental house

Heat supply. A basic low-temperature storage heat pump system (capacity 6 kW) was used for heating and hot water supply. Natural and/or accumulated heat of soil or water (in a water intake well) is used as a source of low-potential energy. For this purpose, a landfill of soil heat exchangers of different geometries was built on the territory around the house (horizontal shallow, vertical; multi-loop pipes, multi-pass, borehole; soil-water (liquid), soil-water-water, soil-air type). Solar heat collectors (flat, tube-vacuum) were used as an additional heat source. Heating devices are warm water floors of various laying geometries, including capillary floor, warm wall, warm partition, floor and wall fan coils. As a backup or peak heating system, the classic radiator-convector heating system based on the Viadrus solid fuel boiler, equipped with an original automated pellet burner, and/or partially floor and wall electric heating is used. According to the obtained experimental data, the use of energy-active windows for heat supply is promising. For emergencies (in the complete absence of electricity) an upgraded wood-burning furnace with a passive free-convection air heating system of the first two floors is used.

Power supply. The basic power supply is realized by solar BAPV-panels (Building Applied Photovoltaics) with a total area of 80 m^2 and a nominal power of 10 kW (photomodules on polycrystalline silicon and on thin films of cadmium telluride). Photovoltaics are supplemented by a Fortis Montana wind turbine with a nominal power of 5.0 kW and a block of lead-acid batteries. A 2.6 kW Honda portable gasoline power plant is used as a reserve. As an additional power source it is planned to use BIPV-windows (Building Integrated Photovoltaics), organically and structurally built into the structure.

Thus, in the building consistently during construction and operation implemented a chain: basic building – energy efficient building (facade walls of thermal insulation materials) – passive building (originally thermo-modernized facades) – zero-energy building (energy-independent) – "smart" building (diagnostics systems and operational monitoring, extensive use of process automation in engineering systems) – energy-efficient building (this is still in our plans – the excess electricity in the summer will be given to the needs of the Institute).

2.5. Auxiliary engineering systems

Ventilation. The basic ventilation system is recuperative with additional heating of the air leaving the heat exchanger and pre-passage of the supply air through the bulk ground accumulator. In another embodiment, the supply air forcibly passes through a tubular ground heat exchanger and enters the room directly. Experiments have shown that in winter the temperature of such air does not fall below 2°C, and in summer it does not rise above 18°C, the ventilation system partially performs the function of air conditioning. Basic recuperative ventilation in winter contributes to the heating system of a passive house, providing up to 30-35% of heat. For ordinary houses, this share averages about 10-15%.

Air conditioning. The basic cooling system uses a cold circuit of a passive heat pump, a system of heated floors and fan coils, as well as a separate mini-sewer system for condensate drainage. Additionally, a system of ground (geothermal) ventilation is used.

Air and heat protection. A system of passive thermal protection of all facades and the roof of the house has been developed due to the organization of a free layer in the system of facade and roof insulation, in which air flows freely from outside through bulk soil accumulators (northern and southern), heating in winter (maximum 8°C) and cooling in summer (12°C) when interacting with the soil. In the environment, the flow goes to the top of the house. In fact, it is a system of washing almost the entire house with air with more favorable temperature than the environmental parameters, ie the creation of a special external-local microclimate.

The use of autonomous heat and power supply systems during the year allows us to classify our experimental passive house as a "zero-energy" type of building, ie energy-autonomous (and non-energy-efficient) building that does not attract energy from centralized networks, but produces it in the building or on the adjacent area from renewable energy sources. In general, this house is a typical example of successful implementation of energy-efficient solutions for autonomous energy supply of passive buildings using only environmental energy, which meets current trends in low-carbon energy and helps reduce greenhouse gas emissions.

In the upper part of the house there is a climatic chamber of real climate, which allows year-round monitoring of building structures and building insulation materials up to 20 cm thick.

In general, the building is a full-scale research and diagnostic demonstration stand for the study of thermophysical properties of promising thermal insulation building materials in real conditions of their operation; to create reliable building facade thermal insulation structures from them and innovative energy (resource) -supply systems. In fact, the house is an example of the latest trend in efficient construction – the creation of Triple Zero buildings – the concept of "three zeros" by architect Werner Zobek: 0-energy, 0-CO_2 emissions, 0-waste, because after the end of life all structures are recycled and used and do not harm the environment.

2.6. Areas of research

In a more general aspect (Paton et al. 2014, Basok et al. 2018), conducted detailed studies on energy efficiency of the entire heat supply sector. Proposals for technological, organizational and socio-economic innovations aimed at improving the energy efficiency of buildings, as well as equipment and engineering systems for their energy supply, in particular in the construction of passive buildings such as "zero energy". The results of these studies, important for the development of energy efficiency and innovation strategy for energy supply of buildings and, as a consequence, reducing the use of primary energy resources and energy intensity of the economy of Ukraine, are given in (Basok et al. 2017), in particular:

- substantiated new original approaches, principles and methods of solving strategic management of technological modernization of energy supply and energy efficiency of buildings and structures with the use of technological and organizational and economic innovations, taking into account the trend of renewable energy sources and intelligent systems;
- a system of indicators and guarantees of technological modernization of heat supply of buildings and structures aimed at safety, preservation and improvement of the quality of human life in the implementation of technological solutions has been developed;
- formulated a new scientific direction – methodology of organizational, economic and innovative support for modernization of energy supply systems and energy efficiency of buildings and structures, taking into account their thermal modernization and the trend of low-carbon technologies in the energy-economy-ecology triad.

The social significance of the work was the scientific substantiation of innovative development of energy supply of settlements of Ukraine in the context of climate change (taking into account the trend of renewable energy sources and the relationship of requirements for energy efficiency, economy, environmental friendliness), competitiveness and competitiveness energy supply of buildings and structures of housing and communal and public spheres.

Taking into account the results of research on the energy supply infrastructure of the demonstration passive house and in order to deepen and expand the theory and practice of energy efficiency of buildings, in the near future the main objectives of research, basic and applied research, topics, methods and tools of such research.

Basic research. The subject of research is the development of scientific and technical bases for the development of energy-efficient technologies for energy supply of buildings in the housing and communal sphere. Research topics:

1) deepening and expanding the theory of heat transfer in the construction of buildings, in particular, taking into account the thermal balance of buildings passive contribution of solar energy;
2) deepening and expansion of the theory of heat transfer in soil massifs when using geothermal energy of upper layers of soil for energy supply of buildings;
3) systematic and continuous accounting during the year of all manifestations of climatic factors (solar radiation, wind speed and direction, outdoor air temperature), analysis of their impact on heat transfer through the external elements of buildings.

Applied research. The subject of research is the development of technologies for energy efficient energy supply systems of buildings, taking into account the optimization of architectural and planning solutions of buildings. Research topics:

1) assessment of the potential and state of the market of fuel and resource base of energy supply, including taking into account non-traditional and renewable energy sources;
2) experimental researches on development of scientific and constructive decisions at creation of energy-efficient technologies and the equipment of power supply of buildings with definition of initial data and dependences for engineering calculations of the equipment and constructive elements of buildings;
3) development of methods of in-depth technical and economic analysis of energy efficiency of energy supply of the building;
4) development of organizational, economic and managerial measures and mechanisms to increase the efficiency of energy supply of buildings.

In 2016, the European Parliament adopted the EU Strategy on Heating and Cooling (COM 2016), the main priorities of which are to increase energy efficiency and decarbonization of existing and newly constructed buildings in all sectors of the economy. Therefore, one of the main activities of the Energy Union is the development and implementation of medium- and long-term programs to reform inefficient heating (cooling) systems, which will reduce the use of fossil fuels and reduce import dependence of EU countries.

At the international level, it is proposed to discuss and approve a Climate Strategy, which would identify the main areas of work on GHG emissions management and activities in the field of adaptation to climate change. Ukraine also needs a more systematic approach to developing effective policies to combat and adapt to climate change.

3. Conclusions

In view of the above, it is necessary to make adjustments to the management system of many sectors of the economy of Ukraine, including communal energy, primarily heating of buildings and air conditioning of housing and communal services (Basok et al. 2021). Therefore, it is extremely important to develop measures to shape the policy of adaptation of municipal energy, ie to identify and justify the main directions of solving key problems of adaptation of municipal energy supply (heat and cold supply) to global warming, taking into account norms and standards in energy efficiency, public construction and reconstruction. It is necessary to harmonize the normative documents of municipal energy supply with the directives of the European Union on the field of municipal energy supply and energy efficiency of buildings. It is also necessary to change the applied temperature characteristics, especially the number of degrees-days of warm and cold periods, to improve engineering systems and equipment for energy supply of buildings, to optimize thermal characteristics of enclosing building structures, in particular in the construction of passive houses, zero-energy houses, "green" houses, improve the architecture of buildings, etc.

It is necessary to form a policy of adaptation to climate change to the conditions of Ukraine, to develop an appropriate regulatory document – a strategy for adaptation of municipal energy supply to climate change and control over its implementation. The main provisions of the strategy of adaptation to climate change of municipal energy supply should include:

- goals of the strategy of adaptation to global warming;
- characteristics of conditions and identification of global warming threat factors for municipal energy supply (heat supply and air conditioning);
- definition of indicators, indicators, their threshold values, exceeding which poses a threat to municipal energy supply;
- principles of ensuring adaptation to global warming;
- development of measures and mechanisms that eliminate or reduce the impact of negative conditions and factors due to global warming;
- creation of monitoring as an operational and analytical system for managing adaptation measures and mechanisms to eliminate emerging deviations from the threshold values of indicators that pose a threat to municipal energy supply.

Implementation of the strategy of adaptation of communal energy to climate change will contribute to the economy and rational use of fuel, energy and material resources; reduction of energy costs for the housing and communal sector; introduction of new architectural, innovative engineering and construction solutions; improving the comfort and standard of living of the population; reducing the country's dependence on imports of fuel and energy resources, and therefore will increase the country's energy security.

The first steps towards creating a framework strategy for the adaptation of the whole country to global warming are already planned. In particular, on January 24, 2020, the Cabinet of Ministers of Ukraine established an interagency group to overcome the effects of climate change. The purpose of its activities is to protect the health and well-being of citizens from the risks and consequences of climate change. A recent event is the adoption in Ukraine of the Energy Security Strategy for the period up to 2025 (Energy… 2021).

In the framework of the Paris Agreement, the EU policy "European Green Course" (COM 2019), the EU concept of "Carbon footprint" (Europarl. 2020) Ukraine, as a European country, together with the world will develop measures and mechanisms aimed at reducing emissions, including related to the operation of buildings, as provided for in (IEA, July 2021), scenario NZE2050. This is especially true on the eve of the next world climate summit in Glasgow this fall. Therefore, the physics and geopolitics of global warming have become one of the most pressing transdisciplinary problems of the modern world. It is necessary to develop and deepen the scientific, technological and organizational (for example, strategic energy management) bases of adaptation of life to current and expected climate changes.

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