# THE INVESTIGATION OF THE EFFICIENT OPERATING MODES OF VARIOUS SOURCE HEAT PUMPS IN THE HEATING SYSTEMS OF INDIVIDUAL RESIDENTIAL HOUSES IN KHANKENDI

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**Abstract**

*The article investigates the efficiency of various-source heat pumps in the heating system of an individual residential house located in the Nagorno-Karabakh economic zone, specifically in Khankendi. The parameters characterizing the heating supply scheme, along with all the equipment and components related to the scheme, have been calculated utilizing the GeoT*SOL simulation software. This program is one of the modern simulation tools used for the planning and design of heating pump systems. As an example, a private residence in Khankendi has been studied, and schematic diagrams for four different-source heat pump systems for the house's hot water supply and heating have been proposed. Seasonal performance indicators, energy efficiency, losses, solar contributions, efficiency, and more have been computed through computer simulations. The most efficient system has been identified.*

**Keywords:** alternative energy, heating equipment, GeoTSOL, ground-source, air-source, soil-source heat pump, modeling, simulation

## I. Introduction

The 29th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP29) will be held in Azerbaijan this year. In 2024, hosting COP29 in Azerbaijan, one of the largest and most significant international events in the world, marks yet another notable triumph for President Ilham Aliyev. This stands as the most significant success of the Republic of Azerbaijan's foreign policy following our leadership in the Non-Aligned Movement and membership in the Security Council. The Republic of Azerbaijan aims to reduce greenhouse gas emissions by 35% by 2030 compared to the 1990 levels, with even more ambitious targets set for the period after 2030, aiming for a 40% reduction by 2050.

President of the Republic of Azerbaijan has declared the liberated territories as the "Green Energy" zone, with the goal of transforming these areas into a "Net Zero Emission" zone by 2050. This initiative reflects Azerbaijan's commitment to sustainable and environmentally friendly practices [1,2,3].

Within the framework of creating Green Energy Zones in the liberated territories, various measures are planned, including the production of electricity from restored energy sources, energy efficiency initiatives, installation of energy devices (especially solar panels) on building roofs,

utilization of solar energy-based LED lamps for street and road lighting, use of recovered energy technologies in heating, cooling, and hot water supply, implementation of smart energy management technologies, and measures for the energy-efficient management of traffic lights.

Despite Azerbaijan's wealth in oil and gas reserves, special attention is being given to the development of the renewable energy sector. In the near future, Azerbaijan aims to transform into an exporter of green and hydrogen energy. Based on agreements and memorandum of understanding signed with leading international green energy companies and external investors, the restored energy production in Azerbaijan is projected to reach 10 gigawatts in the coming years.

Global issues and tasks are addressed and analyzed by extensively studying world experience. In the realm of science, modern advancements, particularly in technology, are applied to the utilization of alternative energy. Research findings are applied to relevant areas, results are analyzed, and effective methods and approaches are selected.

## II. Results

The aim of this research is also to address the heating demand of individual residential houses in the city of Khankendi through the use of heat pumps. There are several methods for researching the effective operating modes of heat pumps. Among them, the most modern and effective method providing rapid results is computer simulation.

There are several simulation programs available for the calculations of heat pump systems. Programs used for the calculation of heat pump systems include GeoT*SOL, EnergyPlus, TRNSYS, DesignBuilder, HAP, HEAT2, RETScreen, etc. Each simulation program has its own specific features. In this research, the process of heating the individual residential house in the city of Khankendi through the use of a heat pump system has been investigated using the GeoT*SOL simulation program [4]. This program is a professional tool widely applied in developed European countries for the planning and design of heat pump systems. GeoT*SOL allows selecting various system types and components to achieve the best possible seasonal performance. It enables the calculation of energy consumption and costs to achieve optimal seasonal performance. GeoT*SOL simulates heat pump systems alongside solar thermal collectors and conventional boilers as required.

The analysis of simulation results revealed the significance of pre-calculating parameters characterizing the heating system during the modeling and exploration of "smart village" and "smart city" projects in developed countries [5-9]. As a result of the simulation, it has been clarified through the comparison of the obtained results which scheme will operate more effectively.

The heating pump environment has been selected to include geothermal probes, geothermal collectors, air, and groundwater. Over the course of one-year, dynamic minute-by-minute simulations have been conducted to calculate seasonal performance factors, energy consumption, losses, solar fractions, efficiency, and other relevant parameters for the entire heating pump system. The simulation process was conducted for one system type and four different heat sources. The operating mode of the heat pumps was accepted in monovalent mode. The simulation results yielded the following insights.

The city of Khankendi is located at approximately -46.77° E longitude and 39.83° N latitude. The annual sum of global irradiation has been calculated through simulation and is determined to be 1,498,465 Wh/m². Four different heating equipment schemes relying on various heat sources have been selected for an individual residential house with the same parameters. The aim of the research is to investigate which heat source is more effective for space. For this purpose, all parameters of each scheme were calculated, and all values were compared. According to the schemes provided in Figure 1, the following heating equipment configurations have been selected:

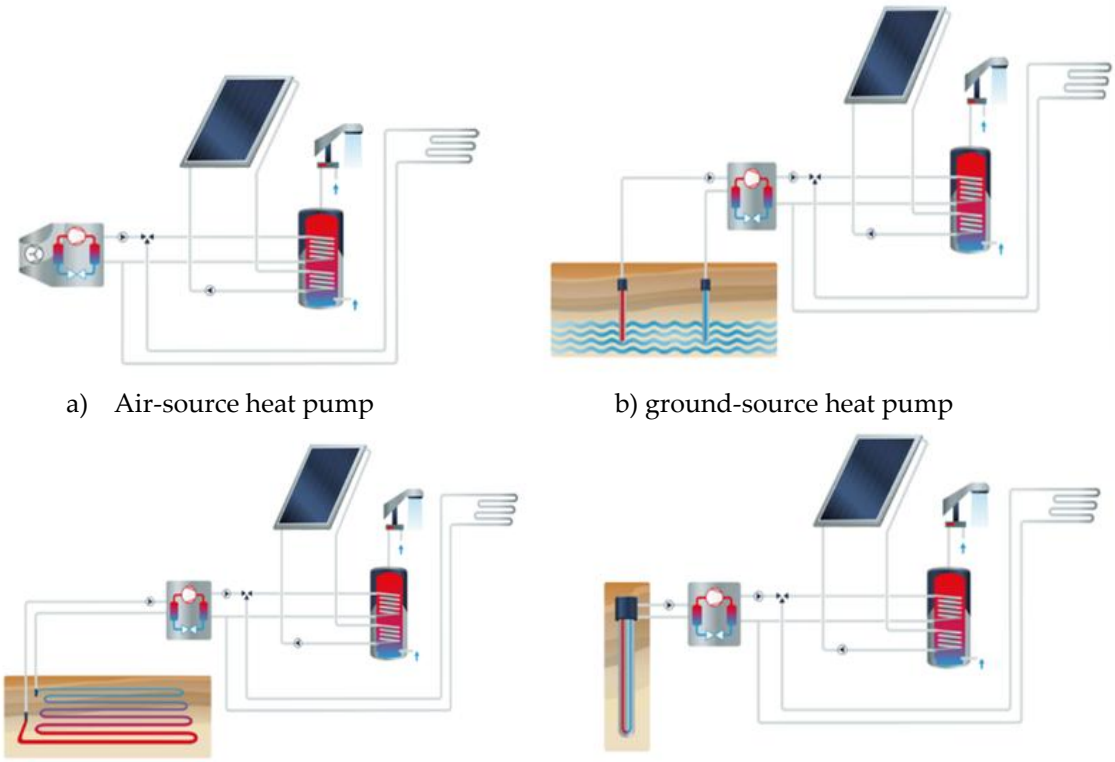
a) Air-source heat pump for hot water supply and heating system,

b) Ground-source heat pump for hot water supply and heating system,

c) Soil-source, collector-type heat pump for hot water supply and heating system,

d) Soil-source, probe-type heat pump for hot water supply and heating system.

There are several operating modes for a heat pump: monovalent mode, monoenergetic mode, bivalent mode, bivalent parallel mode. In the investigated heating equipment system, the heat pumps operate in monovalent mode. In this mode, the heat pump serves as the sole heat source for both space heating and domestic hot water. The heat source should be designed to operate throughout the heating season; in monovalent mode, the heat pump heats the entire space to the lowest external temperature. In this mode, a solar collector is used as the secondary heat source.



a) Air-source heat pump b) ground-source heat pump

c) Soil-source, collector-type heat pump d) soil-source, probe-type heat pump

**Figure 1:** *Schemes of heating equipment with various heat sources*

The use of solar collectors in heat supply is related to the abundance of solar energy, its inexhaustibility, accessibility, and environmental cleanliness. For the heating equipment of residential buildings, primarily small solar systems are employed. Such systems include solar collectors, storage tanks, circulation pumps, and other auxiliary devices. Computer simulation has been utilized to calculate all specific characteristics of the solar collector for Khankendi.

The energy used for space heating and domestic hot water supply, measured in kilowatt-hours per hour (kWh/h), based on various sources, is shown in Fig. 2. Since the same space is selected for each scheme, all parameters are identical for this position.

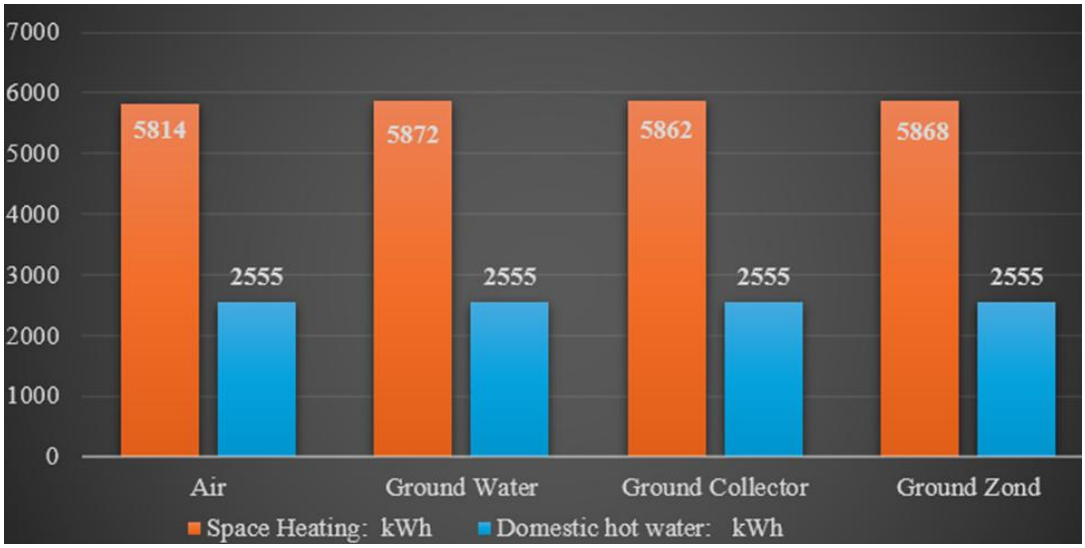



**Figure 2:** *Energy Used for Space Heating and Domestic Hot Water Supply (kWh/h)*

For each heat source, annual produced energy values have been calculated. The analysis of the results indicates that, although with slight differences, ground-source heat pumps are theoretically preferable.

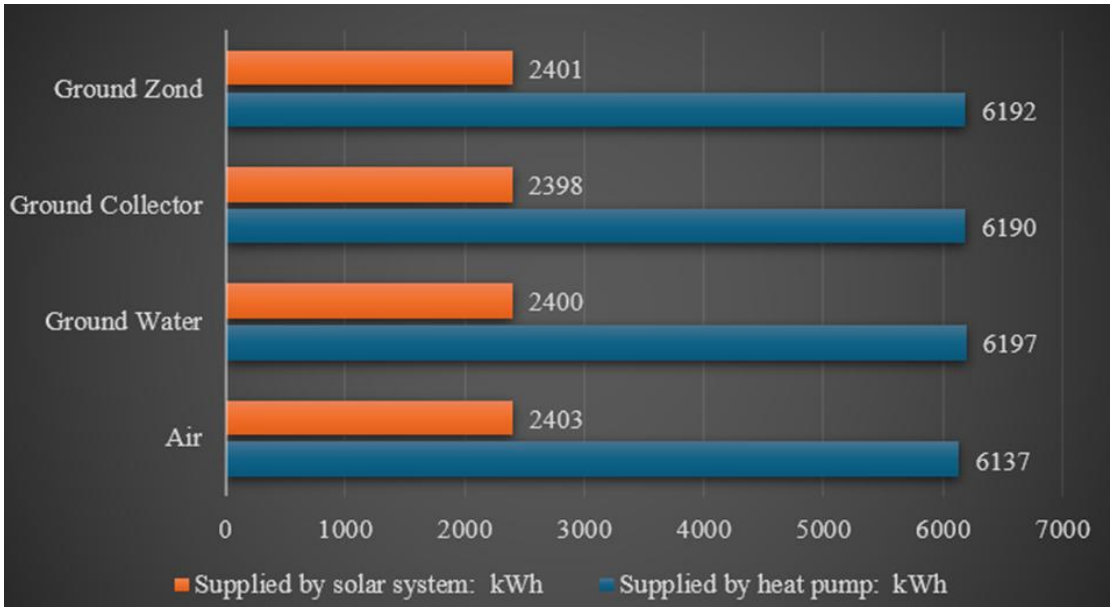



**Figure 3:** *Energy values produced by various heat sources (kWh/h)*

The efficiency of the heat pump operation is characterized by its performance factor. Fig. 4 illustrates the results obtained from computer simulation for the performance factor of the heat pump, the heat pump system, and generator system with the heat pump.

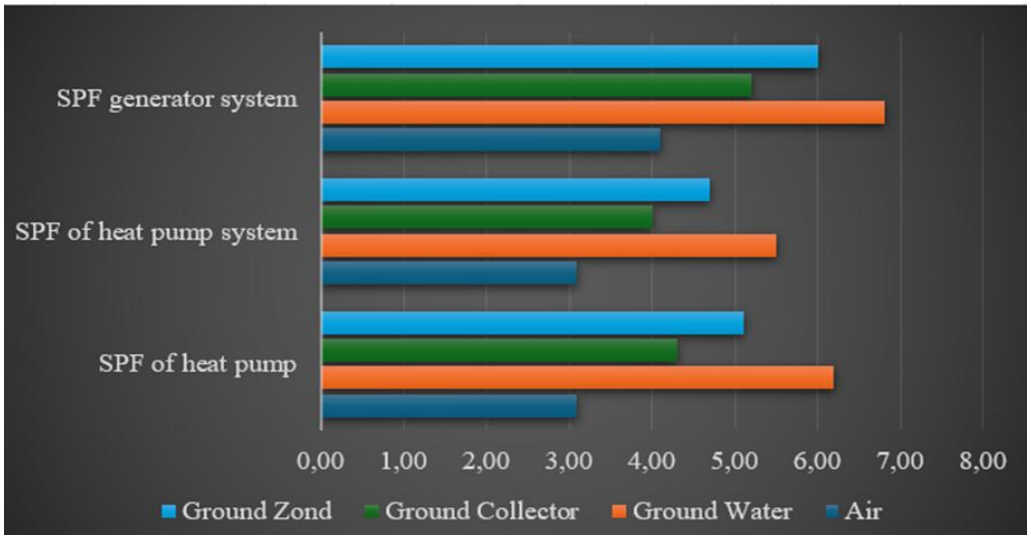



**Figure 4:** *Performance factor values*

In the comparison of performance values based on schemes, the position related to the ground-source holds an advantage. Namely, the calculated values for the ground-source heat pump, the heat pump system, and the generator system are lower than the others.

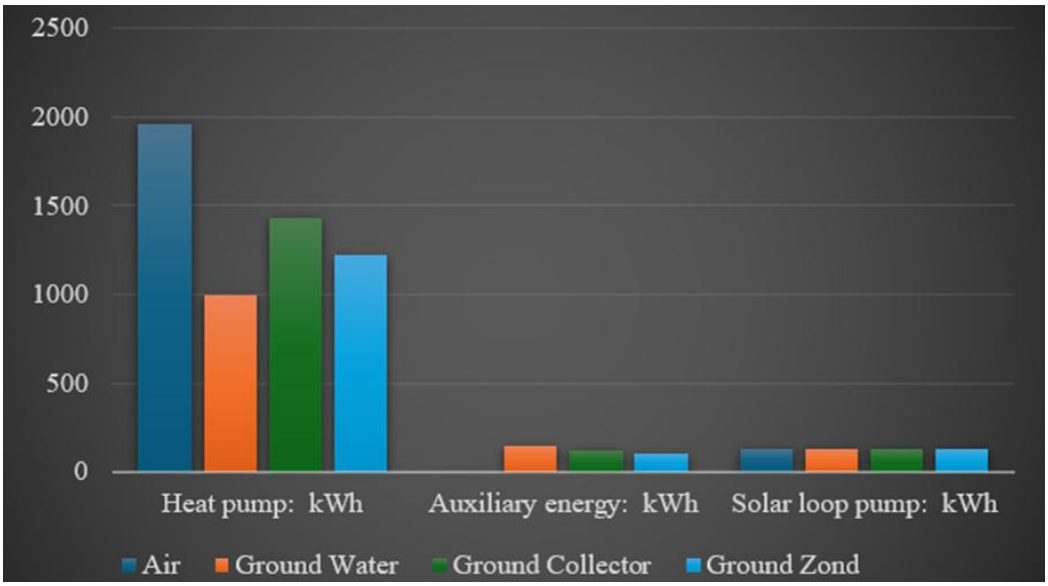



**Figure 5:** *Annual energy consumption of heat sources*

In each scheme, the heat source consumes electrical energy. According to the simulation, the energy consumed by each energy source in each scheme was calculated and compared. In terms of these parameters, the ground-source heat pump scheme stands out. The annual energy consumption of the energy sources in the corresponding schemes is minimal here (Fig. 5).

Table 1 presents the values of system losses. One of the parameters characterizing the efficiency of the system is the annual tank losses. In this regard, there is not much variation in tank losses among various source heat pump systems.

**Table 1:** *System losses*

| | Air | Ground Water | Ground Collector | Ground Zond |
|---|---|---|---|---|
| Tank losses: kWh | 379 | 379 | 380 | 379 |
| ...fraction of solar tank losses: kWh | 157 | 158 | 158 | 157 |
| Solar loop piping indoors: kWh | 400 | 400 | 400 | 400 |
| Solar loop piping outdoors: kWh | 70 | 70 | 70 | 70 |

Using various source heat pumps in the heating supply scheme, all parameters related to the solar component have been calculated, as presented in Table 2.

**Table 2:** *Solar fraction of the heating equipment system*

| | Air | Ground Water | Ground Collector | Ground Zond |
|---|---|---|---|---|
| Solar fraction: % | 28,10 | 27,9 | 27,9 | 27,9 |
| Solar fraction DHW: % | 87,40 | 87,3 | 87,3 | 87,4 |
| Efficiency of solar system: % | 23,30 | 23,3 | 23,3 | 23,3 |

The energy gain of each system is one of the main factors influencing its efficiency. In Fig. 6, the primary energy gain values of the system, including the energy transferred by the collector and through the collector loop, are compared. Here, the most favorable values belong to the ground-source heat pump scheme.

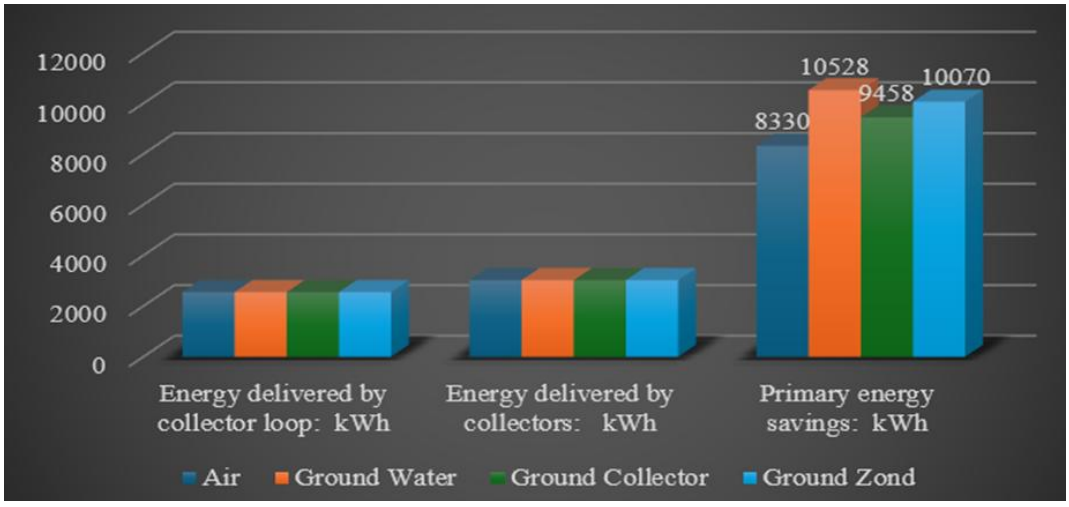



**Figure 6:** *Primary energy gains in systems*

The world reached a new anti-record in $CO_2$ emissions into the environment from energy production in 2022. The implementation of these schemes significantly reduces the amount of $CO_2$ emitted into the environment. In this context, the ground-source heat pump scheme holds an advantage (Fig. 7).

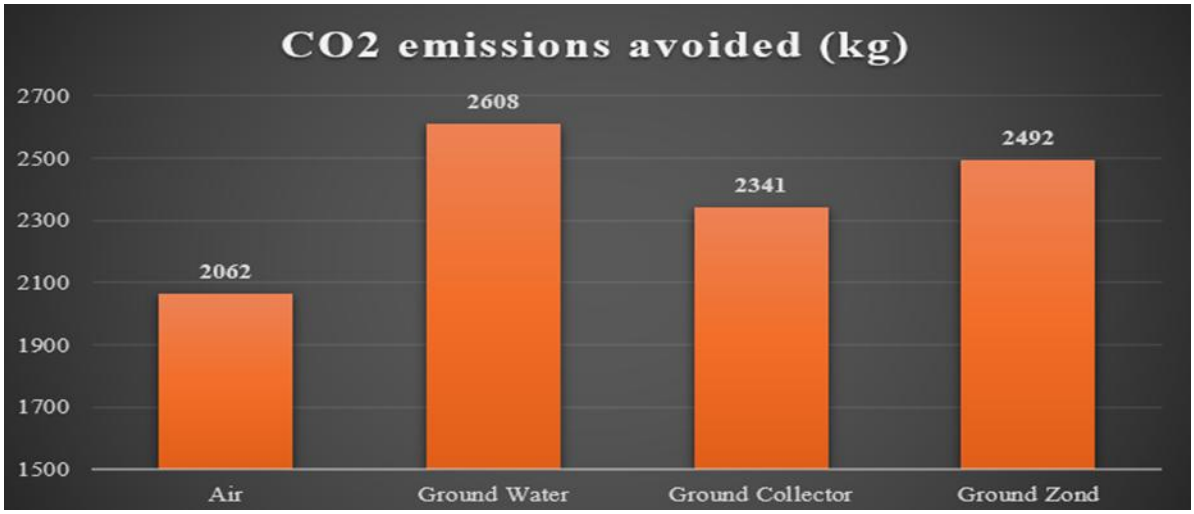



**Figure 7:** *Amount of captured $CO_2$ emissions*

Global warming has currently turned into a human catastrophe, primarily due to the disruption of the atmospheric heat balance. The problem arises from the increasing pollution of the environment. One of the main factors contributing to environmental pollution is the emission of flue gases from the combustion of fossil fuels used to obtain electricity and heat energy [7]. In addition to being energy-efficient in utilizing alternative energy, including heat pumps in heating systems, the simulation method prevents a significant amount of carbon emissions from being released into the atmosphere. The advantage of research conducted through the simulation method lies in the rapid and accurate acquisition of results. Heat pump systems do not have a negative impact on the environment during their operation. Combustion of fossil fuels is eliminated during their use, and no noise is emitted during their operation. There is no need for additional expenses during their utilization, and their operational lifespan is long. The application of heat pumps in the heating systems of buildings and for space cooling will lead to a reduction in heating and cooling expenses. There will be a high demand for heat pumps in the economic zone of Karabakh, especially considering the forecasts for the increase in electricity and fuel prices and the abundance of individually constructed houses in this region.

## Conclusion

1. The heat pump system is an environmentally friendly heating and cooling system from an ecological perspective. The applied heat pump does not pose an ecological threat to the people living in the environment.
2. The heat pump operates continuously and does not require special attention.
3. In the Karabakh region, specifically in Khankendi city, the possibilities of using heat pumps from various sources for the heating equipment of individual residential houses have been explored, identifying the type with high energy potential.
4. In the Karabakh region, in Khankendi city, the research has shown that the use of ground-source heat pumps is more effective in heating supply, considering the climatic conditions.

5. The fundamental scheme of the heat pump system is provided through computer simulation. Each characteristic parameter of the devices constituting this system has been calculated, and devices produced by the factory have been selected.

6. As a result, energy produced and used, required power, losses, etc., have been calculated for both the system and each component.

## References

[1] Presidential Decree of the Republic of Azerbaijan: On declaring the year 2024 as the "Year of Solidarity for a Green World" in the Republic of Azerbaijan. December 25, 2023.

[2] Ilham Aliyev. (February 2, 2021) "Azerbaijan 2030: National Priorities for Socio-Economic Development."

[3] Ilham Aliyev. (January 5, 2022) "Presidential Decree on declaring 2022 as the 'Year of Shusha' in the Republic of Azerbaijan."

[4] GeoT*SOL Basic Version 1.0. "Design and Simulation of Heat Pump Systems User Manual."

[5] Anarbayev A.I., Koroli M.A. "Development and Implementation of a Combined Solar Heat Pump System." "Energeticheskaya Bezopasnost : Sb. Nauch. St. III Mezhdunar. Kongressa," Kursk, October 16-17, 2020. Vol.2. - Kursk, 2020. - P.374-378. - Bibliography: 1 title.

[6] Sadiyev U.A., Normominov M.T. "Use of Pumps in Heat Supply Systems." // International Journal of Academic Engineering Research (IJAER) ISSN: 2643-9085 Vol. 5 Issue 4, April - 2021, Pages: 49-51.

[7] Babayeva S.Sh. "Prospects of using heat pumps in the heating system of an individual residential building in Kalbajar city." / International Conference on Reconstruction and Recovery in Post-Conflict Situations RRPCS 2022. February 24-25, 2022. Baku, Azerbaijan.

[8] International Energy Agency. "Net Zero by 2050: A Roadmap for the Global Energy Sector."

[9] Babayeva S.Sh. (2022) "Research on the operation of heat pumps working in monovalent mode in the heating system." // "Problems of Energy" scientific and technical journal No. 1, Baku, pp. 25-31.