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Investigation of the Efficiency of Monovalent Regime, Land-Source Collector-Type Infiltration Pumps in the Karabakh Economic Zone

Abstract: *The article explores the efficiency of land-source collector-type heating pumps in the economic zone of Karabakh. The heating equipment scheme and all characteristic parameters related to this scheme were calculated using the GeoTSol modeling program. Four types of collector-type heating pump system schematics have been proposed, and for each scheme, a computer simulation has been conducted to determine the scheme that operates most efficiently based on characteristic parameters in the optimal mode.*

Streszczenie: *W artykule zbadano efektywność gruntowych kolektorowych pomp ciepła w strefie ekonomicznej Karabachu. Schemat urządzeń grzewczych oraz wszystkie charakterystyczne parametry związane z tym schematem obliczono za pomocą programu do modelowania GeoTSol. Zaproponowano cztery typy schematów układu kolektorowych pomp ciepła, a dla każdego schematu przeprowadzono symulację komputerową w celu określenia schematu, który działa najefektywniej na podstawie charakterystycznych parametrów w trybie optymalnym. (**Badanie efektywności monowalentnego systemu pomp infiltracyjnych typu kolektora lądowego w strefie ekonomicznej Karabachu)***

Key Words: GeoTSOL collector-type heating pump, modeling, simulation
Słowa kluczowe: GeoTSOL, kolektorowy ogrzewacz ciepła, modelowanie, symulacja

Introduction

Efficient energy utilization is an indicator of a society's scientific, technical, and economic potential. Simultaneously, this factor determines the developmental level of society. The application of energy-efficient technologies is crucial for the rapid development of society in this field. This particularly pertains to the heating and cooling supply system of buildings and installations, which is one of the most energy-demanding sectors. The superiority of heating and cooling energy technologies utilizing renewable energy sources over traditional energy technologies lies not only in the reduction of energy expenses but also in being environmentally friendly and automatic. Consequently, in recent years, the application of heat pumps for heating and cooling systems has gained widespread popularity globally. Research activities and literary analyses in this field are essential for exploring the effective operational modes of heat pumps.

Various heat pumps from different sources are used in heating and cooling systems. These include air, ground-source waters from the upper layer of the soil, water basins and natural water flows, ventilation wastes from buildings and structures, sewage wastes, and heat generated from technological processes [1].

To ensure heating and cooling provision for any space, the first step is to choose the heat source, followed by determining the operational mode and scheme of the pump. For the investigated heat pump, the selection of a ground heat source has been decided. This is because the soil serves as an unlimited heat accumulator, and its heating regime is mainly influenced by two key factors: solar radiation and the radiogenic heat flux from the depths of the earth. Such systems are widely used in countries such as the United States, Canada, Sweden, Switzerland, Germany, and Austria. Switzerland, in particular, has emerged as a global leader in this field [2].

Problem setting

Executing the design of the heating and cooling system for a particular object and assessing the efficiency of the heating pump's operation are crucial steps. Various methods are available for this purpose, including simulation programs, which are the most modern and providing accurate results. These programs rely on theoretical knowledge and mathematical modeling. GeoTSol is one of the professional programs used for the research and design of heating pumps [3].

Solution of problems

The selected research object is located in the Xocavand district within the Karabakh economic zone. This choice is motivated by the alignment with the state strategy of the Republic of Azerbaijan, aiming to supply the Karabakh economic zone with green energy [4].

For the analysis of the operation of heating pumps in providing hot water and heating for an individual residential house, four different schemes were selected for computer simulation. According to the schemes presented in Fig. 1, a) Hot water supply and heating system through the heating pump (K1), b) Hot water supply with a solar collector and heating system with a heating pump (K2), c) Heating pump system with joint usage of radiator and solar heating support (K3), and d) Bivalent regime heating pump system with buffer tank, solar panel, and cool water station (K4) have been investigated.

All parameters characterizing the operation of each system related to each scheme have been calculated using the GeoTSol simulation program. This professional program has been selected for its accuracy and expertise in accurately characterizing the performance of the systems under consideration.

The energy used for space heating and domestic hot water supply for the K1, K2, K3, and K4 systems is illustrated in Table 1, expressed in kilovolt-hours per hour (kWh/h).

Table 1. The energy utilized for space heating and domestic hot water supply, expressed in kilovolt-hours per hour (kWh/h).

	K1	K2	K3	K4
Space Heating: kWh	5939	5966	6037	6037
Domestic hot water: kWh	4656	4656	4648	4586

The heating supply system's energy sources include the heating pump, solar collector, and boiler. In the case of the K1 scheme, only the heating pump serves as the energy source. For the K2 and K3 schemes, both the heating pump and solar collector contribute to the energy supply, while in the K4 scheme, the energy sources include the heating pump, solar collector, and boiler. The energy values produced for each scheme by each source are presented in Table 2. As a result of the analysis presented in Table 2, the K2 scheme stands out in terms of this indicator. Despite the significant energy production by the solar system in the K3 scheme, there are substantial losses in the well. Additionally, the energy produced by the heating pump is lower in the K3 scheme compared to the K2 scheme.

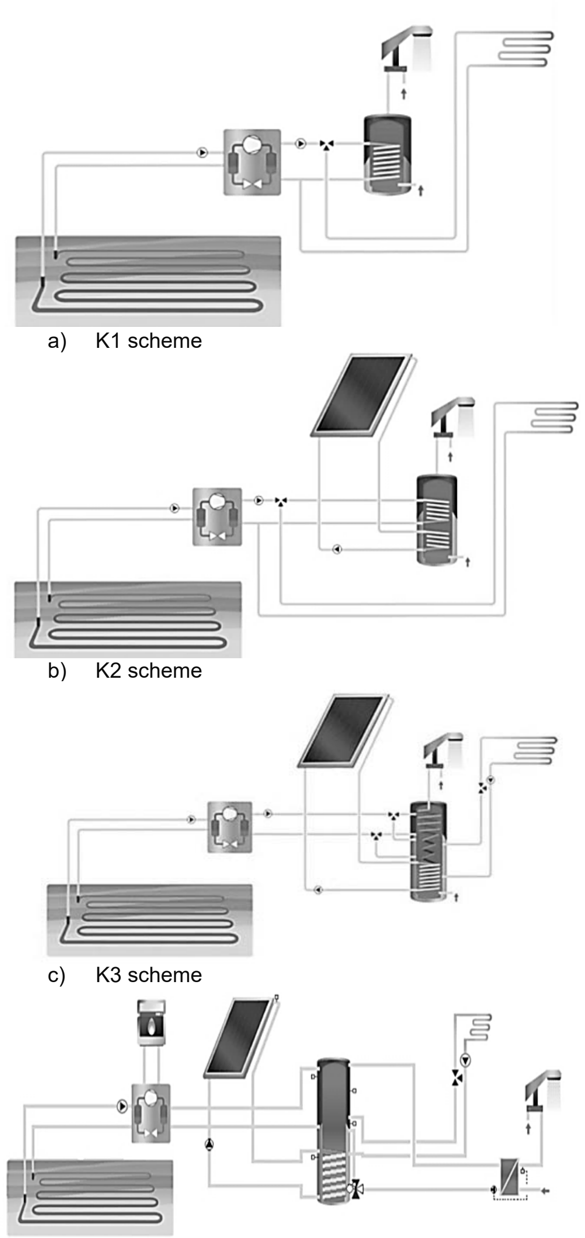

Fig. 1. Schemes of collector-type ground-source heat pumps' heating supply systems.

The efficiency of the heating pump's operation is characterized by its performance factor. The results obtained from computer simulations for the performance factors of the heating pump, the heating pump system, and the combined solar thermal system with the heating pump are presented in Table 3.

In the comparison of performance values based on schemes, K2 demonstrates superiority. The calculated values for the heating pump, the heating pump system, and the heating pump combined with solar thermal systems are higher in K2 than in others.

Table 2. Energy values produced by different sources (kWh/h).

	K1	K2	K3	K4
Supplied by heat pump: kWh	10812	7430	7349	7636
Supplied by boiler: kWh	0	0	0	75
Supplied by solar system: kWh	0	3305	3641	3206

Table 3. Performance factor values.

	K1	K2	K3	K4
SPF of heat pump	3,8	4	3,3	3,3
SPF of heat pump system	3,6	3,7	3,1	3,1
SPF generator system	0	5	4,4	4,1

In each scheme, the heating source consumes electrical energy. According to the simulation results, the energy consumption of each heating source in each scheme has been calculated shown in Table 4. K2 scheme stands out. The annual total energy consumption of heating sources in K2 scheme is minimal among the considered schemes for these parameters.

Table 4. Annual energy consumption of heating sources.

	K1	K2	K3	K4
Heat pump: kWh	2819	1862	2223	2343
Auxiliary energy: kWh	215	148	156	164
Solar loop pump: kWh	0	153	122	159
Boiler (fuel): kWh	0	0	0	83

Table 5 provides the values of system losses. One of the parameters characterizing the system's efficiency is the annual tank losses. In the K2 scheme, the annual tank losses are minimal.

Table 5. System losses.

	K1	K2	K3	K4
Tank losses: kWh	299	266	456	367
...fraction of solar tank losses: kWh	0	97	100	49
Solar loop piping indoors: kWh	0	333	309	352
Solar loop piping outdoors: kWh	0	59	55	74

The following table illustrates the statistics of the share of solar fraction. In the K2 scheme, the share of the solar portion in the heating supply system is the highest, constituting 68.9%. The efficiency of the solar system in this scheme is 32.5%.

Table 6. Share of solar fraction in the heating supply system.

	K1	K2	K3	K4
Solar fraction: %	0	30,8	33	29,1
Solar fraction DHW: %	0	68,9	50,9	43,4
Efficiency of solar system: %	0	32,5	35,8	31,7

The energy saving of each system is one of the main factors influencing its efficiency. Table 7 compares the values of the primary energy saving, along with the energy transferred by the collector and the collector loop. Here, the most favorable values belong to the K2 scheme. Specifically, the primary energy saving is 11,644 kWh/h.

Table 7. Main energy saving in the systems.

	K1	K2	K3	K4
Energy delivered by collector loop: kWh	0	3402	3741	3255
Energy delivered by collectors: kWh	0	3794	4105	3682
Primary energy savings: kWh	9102	11644	11085	10429

In 2022, global carbon dioxide (CO_2) emissions from energy production reached a new record, posing environmental challenges. However, the implementation of these schemes significantly reduces the amount of CO_2 emitted into the environment. In this context, the K2 scheme demonstrates superiority (Table 8).

The maximum power extracted from the ground influences the efficient operation of the heating pump in this scheme. The maximum power extracted from the ground is equivalent to 11,662.7 Watts.

Table 8. Maximum power extracted from the ground and corresponding CO_2 emissions.

	K1	K2	K3	K4
CO2 emissions avoided: kg	2253	2882	2743	2581
Max. power extracted from the ground: W	9740,8	11662,7	9670,5	9311,7

Global warming has now turned into a catastrophe for humanity, primarily due to the disruption of the Earth's heat balance. The main cause behind this problem is the increasing pollution of the environment. Emissions from the combustion of fossil fuels for electricity and heating, especially the gases emitted, contribute significantly to environmental pollution. The utilization of alternative energy, including heat pumps in heating systems, not only provides energy efficiency but also helps mitigate the significant carbon emissions released into the atmosphere. The advantage of research conducted through simulation methods lies in the rapid and precise acquisition of results. Heating pump systems do not have a negative impact on the environment. During their operation, no fossil fuels are burned, preventing the release of harmful emissions [5, 6]. The use of heating pumps does not contribute to noise pollution, and there is no need for additional expenses during their application. Moreover, their operational lifespan is long. The application of heat pumps in the heating system of buildings will contribute to the reduction of expenses both in terms of heating supply and cooling. There will be a significant demand for the use of heat pumps in the Karabakh economic zone. This is mainly due to the forecasts of an increase in the cost of electricity and fuel, along with the high number of individual houses to be constructed in this region [7 - 14].

Result

- In the Qarabagh region, the utilization of renewable energy sources in the heating provision of houses is among the priority issues.
- For heating the houses in Xocavand, the use of ground-source, collector type heat pumps and solar collectors is suitable.
- The characteristic parameters of all appliances associated with the heating supply schemes have been calculated and selected.
- As a result of the comparison, it has been determined that the heating supply scheme executed through a solar collector for hot water provision and a heat pump system (K2) for heating is more effective.
- The primary energy source in the K2 heating supply system amounts to 11644 kWh.
- The implementation of the K2 heating supply scheme has mitigated the release of 2882 kg of CO_2 into the atmosphere.

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