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Simulations regarding the Modernization of the District Heating System in Timisoara by Controlling the Supply and Regulating the Temperature of the Heating Agent

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Abstract: *The current context of climate change requires the efficiency of district heating systems. The article proposes the implementation of modernization solutions for district heating systems in order to reduce heat loss on the distribution system and implicitly CO2 emissions at the level of thermal agent production. The case study analyses the supply of the Forestry Technical College from Timisoara, which has a heat demand for the building of 1MW and is located at a distance of 1200m from the nearest thermal point. Simulations were performed for several efficiency stages of the central heating system, which before efficiency, operated without any control over the supply with thermal agent.*
The first stage of efficiency involves the transition from the uncontrolled continuous supply of the final consumer to an adjustable supply according to the thermal energy requirement, and the second stage represents the reduction of supply temperatures on the supply and return pipes from the high temperature regime (t_t = 80°C and t_r = 60°C), to an average temperature regime (t_t = 60°C and t_r = 40°C).

Keywords: *District heating, modernization, efficiency, reduction of heat loss*

1. Introduction

District heating systems have been known since the 14th century, and have been using various energy sources since the beginning: geothermal, fossil fuels, biomass and waste incineration. The thermal transport agent for heat for district heating systems until the 1930s was steam. This system used pipes made of concrete and was characterized by high energy losses through the transport system [1].
The second generation of district heating systems appeared after 1930 and used hot water under pressure at temperatures above 100 ° C, systems characterized by high consumption of materials with poor thermal properties (pipes in concrete ducts, massive counter current heat exchangers). These systems have shown an inability to control heat demand, but have shown improved fuel economy [1], [2], [3].
In the 1970s, the third generation of centralized energy transmission systems was developed. It also used pressurized water, but at lower temperatures than the previous generation and was often referred to as the "Scandinavian district heating technology" [1], [2]. During this period, the switch to prefabricated components buried in the ground (pre-insulated pipes) and to plate heat exchangers, which generated a reduction in material consumption was made [1], [2], [3].
The fourth generation of systems is a natural evolution of the previous one which, in the context of the requirements regarding the quality in constructions, regarding energy saving and thermal insulation, highlights both the characteristics oriented towards efficiency and sustainable use of natural resources. The main features of this generation refer to the fact that the temperatures of the thermal agent for transporting or distributing thermal energy continue to decrease (40-60 ° C), the equipment used is more and more modular, and the materials are increasingly flexible and have low energy losses, but the most important aspect is that the system makes it easier to integrate renewable energy sources (heat pumps, solar panels) and excess heat from communities and industry [3], [4].
The evolution of district heating systems is presented in Table 1 in terms of the method of heat production and energy source associated with the technological period [1].

Table 1: Production and energy sources for district energy [1]

Characteristic	1st Generation	2nd Generation	3rd Generation	4th Generation
Peak Technology Period	1880–1930	1930–1980	1980–2020	2020–2050
Heat Production	Steam boilers	CHP and heat- only boilers	Large-scale CHP	Heat Recycling
Energy Source	Coal	Coal and oil	Biomass, waste and fossil fuels	Renewable sources

Today, district heating systems allow the long-distance distribution of thermal energy and the increasing use of renewable energy, thus increasing the fight against global warming and the energy crisis. For this reason, sustainable district heating systems will have to provide planning structures, low costs correlated to efficient operation and strategic investments, an aspect illustrated in Fig. 1 [2].

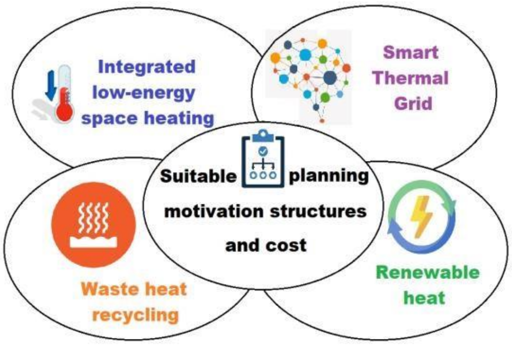


Fig. 1. The concept of 4th Generation District Heating [2]

Given both the massive expansion of newly built areas characterized by buildings equipped with low temperature heating systems, and the existence of consumers located at a great distance from the thermal points, but also the current issue of central heating systems in Romania and in particularly of the district heating system in Timișoara (pipes with an advanced degree of wear, insulated in the classical solution), which even in the case of massive investments to replace existing pipes with pre-insulated pipes, some problems remained unresolved [3].
In this sense, for the transition from generation III to generation IV, the article proposes as efficiency solutions the zoning of the centralized system according to the type of consumer, in the sense that the primary distribution network to transport heat on a main route at a maxim temperature necessary for the most disadvantaged consumer, from which areas with a lower temperature requirement are supplied, or certain isolated consumers (at a great distance from the thermal point) [3].

2. Solutions for reducing energy consumption by regulating the temperature, in the transition from the 3rd to the 4th generation

The district heating system in Timișoara is part of the category of third generation systems that use as solid energy source solid fuel (coal) with natural gas contribution. The thermal agent used by district heating plants is hot water (90°C-115°C) transported through the primary circuit to the zonal thermal points where the energy is transferred to the secondary circuit using plate heat exchangers. From the thermal points the thermal agent is transported to the final consumers [3].
District heating with low temperature of the thermal agent offers new possibilities for a higher energy efficiency and a lower consumption of energy produced from fossil fuels. In terms of demand, low temperature thermal agent is commonly available as a basis for energy efficient heating of the building and preparation of hot water for consumption. Low temperature heat can be integrated into district heating by using large-scale efficient heat pumps, solar thermal collectors and combined heat and power plants on biomass.

In general, the use of lower temperatures reduces pipeline transport losses and can increase the overall efficiency of the total energy chains used in district heating. In order to achieve maximum efficiency, not only district heating networks but also energy conversion must be optimal, and indoor installations of final consumers must be adapted to allow the use of low temperatures provided by the network (e.g., by radiant heating). For this reason, the implementation of solutions based on high levels of renewable energy requires an adaptation of the technical infrastructure and buildings. A typical district heating network supplies areas with different temperature needs for heating buildings, such as individual residential areas or condominiums characterized by old buildings with a high temperature demand, administrative buildings and residential areas of individual type or condominium characterized by new buildings with a lower temperature demand (Fig.2a). If we consider the entire district heating system, the total heat loss is significant, as well as the potential for savings. In each zone, the afferent supply network is practically a branch of the main primary network (Fig. 2a), and in these branching points it is proposed to change the temperature by installing a mixing loop (Fig. 2b) [5], adapting the temperature to correspond to the real heat demand in the area, minimizing the heat loss on the respective branch [3]. Another common situation is that we have a zonal thermal point that produces thermal energy for nearby consumers or for more distant consumers (Fig. 3a). The temperature regulation solution for the distant consumer is for it to be supplied on a dedicated route from the nearest thermal point, thus having the possibility to regulate the temperature according to its energy requirement (Fig. 3b).

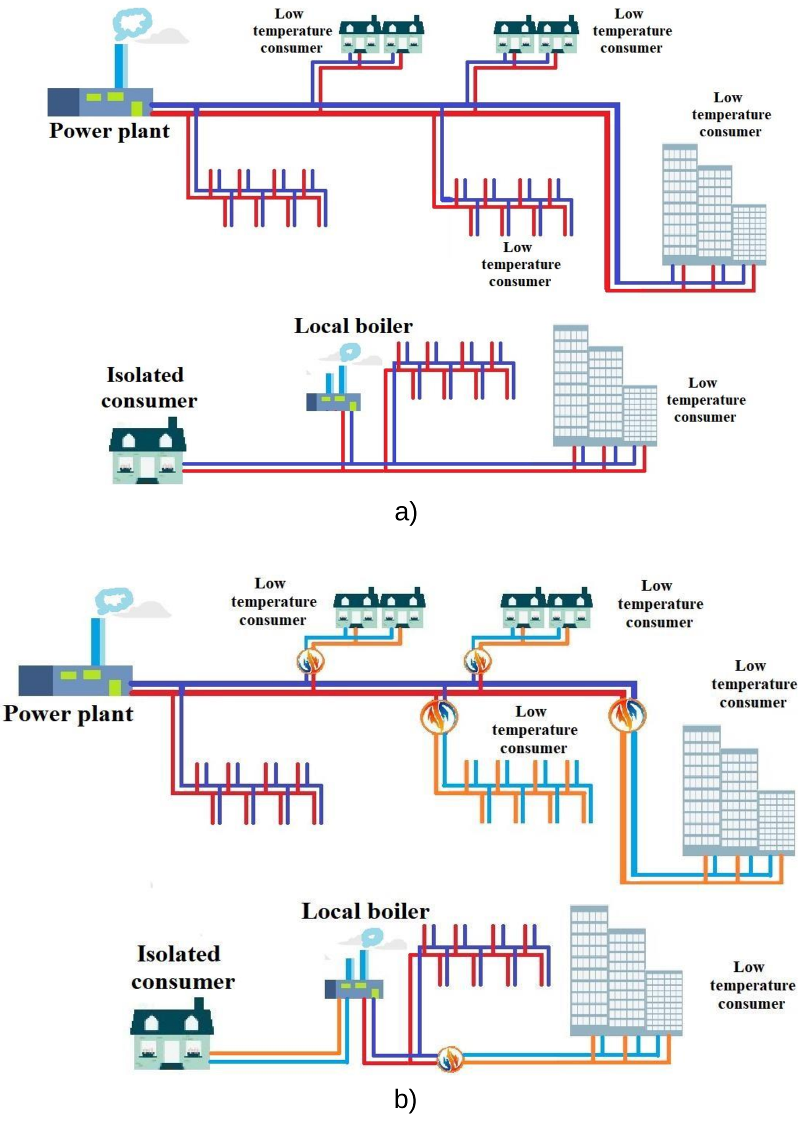


Fig. 2. Temperature regulation solutions for the district heating network
a) Before temperature regulation, b) After temperature regulation [5]

3. Adapting the existing system and transitioning from the IIIrd to the IVth generation, for an isolated consumer from Timisoara. Case Study

In general, the district heating systems in our country (which contain in interdependence, the source, the hot water network, the connection installations and the powered buildings) use two temperature regulation steps. Thus, at the source the temperature in the supply pipe in the primary network is fixed based on the forecast data (outdoor temperature and wind speed for a period of 612 hours). At the thermal points, a second regulation step is operated by correlating the temperature of the thermal agent in the indoor installations with the outdoor temperature.
Therefore, from the thermo-hydraulic point of view in the heat supply using in practice, the qualitative-quantitative (mixed) regulation based on the use of the theoretical quality graph at sources and on the correction of the thermal power taken from the final consumers by modifying the thermal points, automatically or manually the primary heat sink flow.
This change of flow aims both to correlate the temperature of the secondary thermal agent with the temperature of the outside air and to achieve the condition regarding the temperature of the hot water for consumption. Thus, it can be said that the adjustments in the two stages regarding the temperature / flow of the thermal agent finally ensure an additional correction of the heat consumption at the final consumer. In the operation of the system, a correlation is actually established between the temperature of the thermal agent and the climatic factors (especially the temperature of the outside air) [6].
The reason for this correlation, contained in the adjustment chart, is related to the heating process of the buildings. The process of preparing hot water, as a result of the connection schemes of the consumers, contributes to the decrease of the water temperature in the return pipe but also to the lower limitation of the water temperature in the supply pipe, to the value of 65°C, as a result of the requirement to be able to obtain even during the relatively warm transition periods hot drinking water at a temperature of 50 - 55°C [3].
Given the fact that the primary and secondary thermal network does not cover the total area of the city of Timisoara, which is constantly developing and expanding, there is the problem of finding solutions that are as economical and technically efficient as possible, with which to feed the new buildings or neighborhoods to the needs of final consumers. One of the classic solutions is the extension of the primary heating network and the creation of a new heating point to serve as the connection for new area of buildings. Given that the primary thermal circuit supplies the entire city, the thermal agent transported through the primary network has a fairly high temperature, with a variation between 90-115^oC on the supply pipe and 50-65^oC on the return pipe, generating a considerable energy loss. [3].
The evolution from the 3rd to the 4th generation district heating system requires a decrease in the temperature of the transport thermal agent, so we have to choose a supply solution that supports this principle. In Timisoara, at the moment, the temperature regulation of the thermal agent is made from the unit thermal point for the whole served consumption area, and the supply regime is 24 hours.
The case study analyzes the heat supply of the Forestry Technical College from Timișoara, which has a heat demand of 1MW [7]. The proposed modernization aims both to reduce energy losses through the transport of thermal agent and to reduce CO2 emissions.
The Forestry Technical College is supplied from the PT UMT thermal point, as can be seen in (Fig. 3), through a dedicated route, made with pre-insulated steel pipes D.139.7x250mm with insulation class "1 x reinforced" [7], with a length of 1200 meters, through which the thermal agent is transported with a flow temperature of 80^oC and a return temperature of 60^oC, Heat exchange between the thermal agent delivered from the UMT thermal point and the thermal agent circulated through the consumer's indoor installation it is made with the help of a thermal module [7].

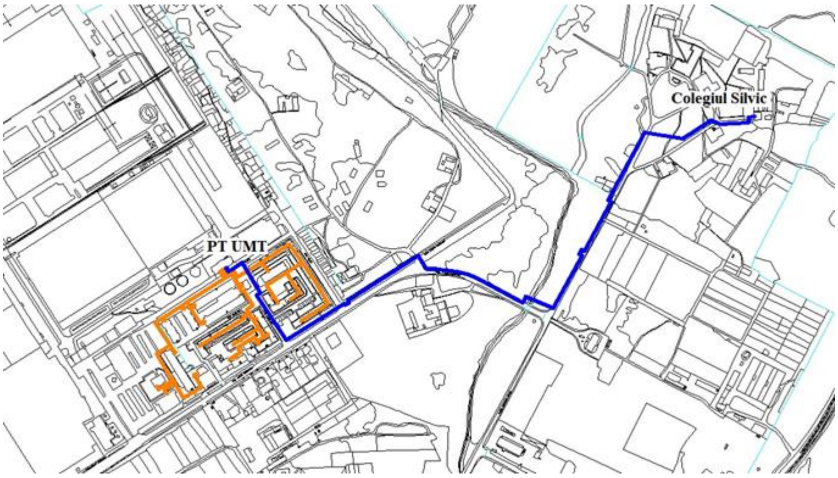


Fig. 3. Heat supply of the Technical Forestry College from Timișoara [7]

Thermal supply network of the Forestry Technical College
Thermal supply network of the residential buildings

The reduction of thermal energy loss on district heating pipes can be done in two ways, the use of thermally insulated pipes and reducing the temperature of the thermal agent to a temperature as low as possible without affecting the necessary thermal parameters to the final consumer. Considering the fact that the thermal network route we are referring to in this case is made from good quality pre-insulated pipes, we propose a solution to reduce energy loss by lowering the transport temperature of the thermal agent.

In the studied situation considering the long length of the district heating route to the final consumer, as well as the destination of the educational building, we identified a first stage of modernization of the district heating system which involves the transition from a continuous supply of heat during the day to a supply correlated with the final consumer's requirement.

The simulation for the supply with thermal agent of the Forestry Technical College was performed with the help of the Polysun calculation program [8] which is based on the analytical relation (1), according to the design regulations of the heating installations [9], [10].

$$Q = m \cdot c_p \cdot (t_1 - t_2) \qquad (1)$$

where:

m - mass flow, in kg / s;

c_p - specific heat of water, in kJ / kg · K;

t_1 - indoor water temperature, in ° C;

t_2 - outdoor ambient temperature, in ° C.

The principle diagram of the consumer supply installation in the existing situation is presented in Fig. 4.

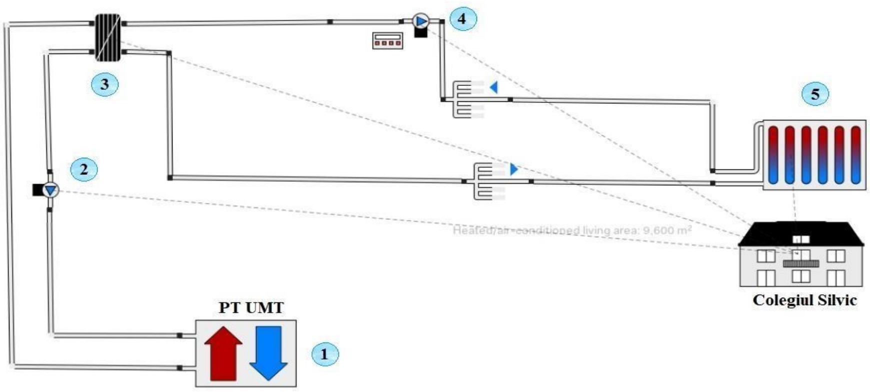
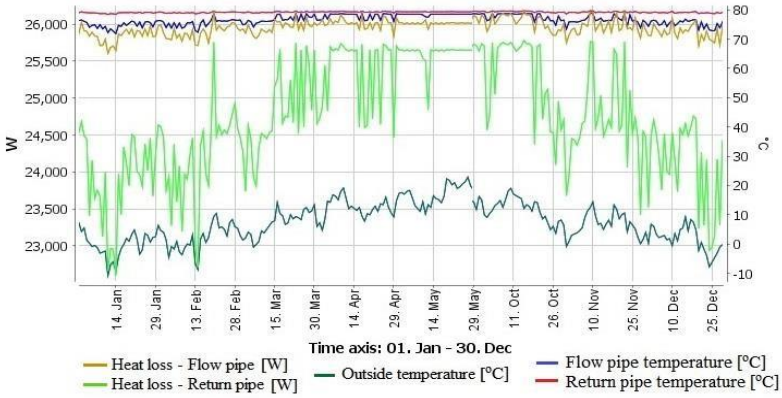
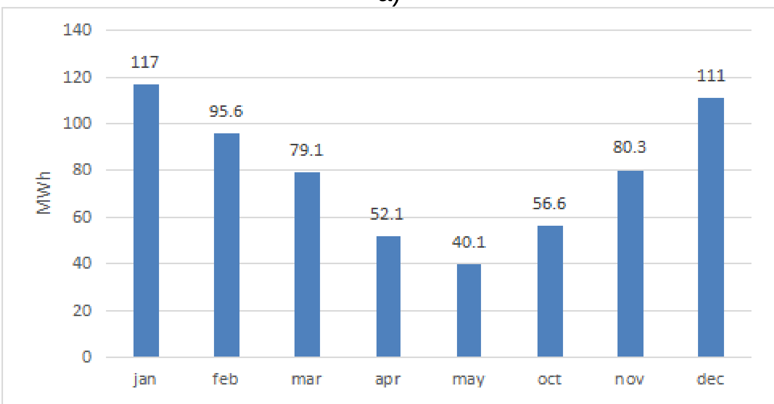


Fig. 4. Schematic diagram of the existing installation
1 – District Heating Substation, 2 – Circulating pump DH, 3 – Heat exchanger
4 – Circulating pump end-user, 5 – End-user

For the existing heat supply situation of the Forestry Technical College, at the supply / return temperatures of 80/60 ° C, the heat losses were simulated according to the average outdoor temperature for Timișoara [11], [12], for the year 2022. Fig. 5 shows the variation of heat loss (Fig. 5a) and the monthly energy consumption (Fig. 5b).



a)

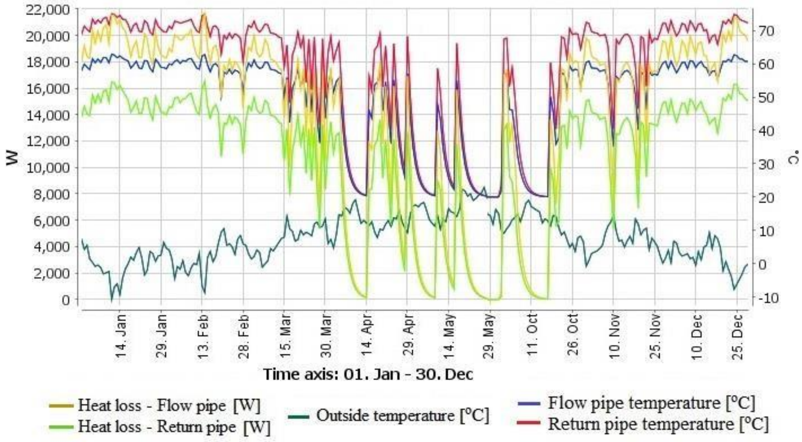


b)

Fig. 5. Heat loss and energy consumption for the existing situation [8]

The first stage involved a modernization of the PT-UMT thermal point by introducing an automation for the circulation pump of the thermal agent to the studied consumer, so that on the transmission network the circulation of the thermal agent is realized only during the period when there is circulation in the interior heating installation of the consumer.

At this stage of modernization at the flow / return temperatures of 80/60°C, heat losses were simulated under the same conditions depending on the average outside temperature. In Fig. 6 shows the variation of heat loss (Fig. 6a) and the monthly energy consumption (Fig. 6b).



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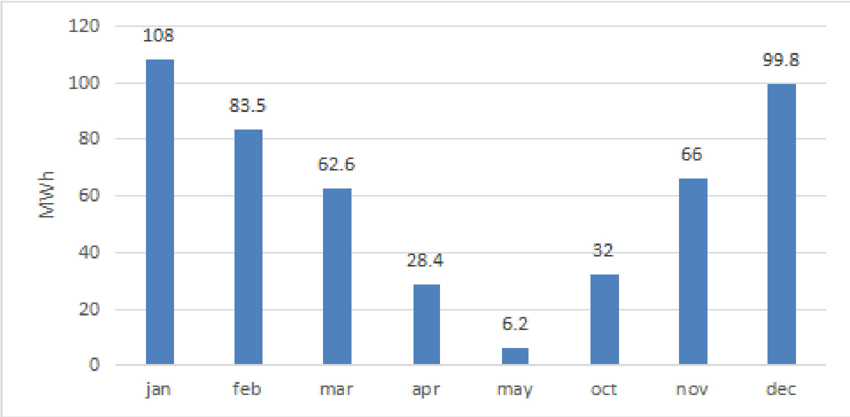
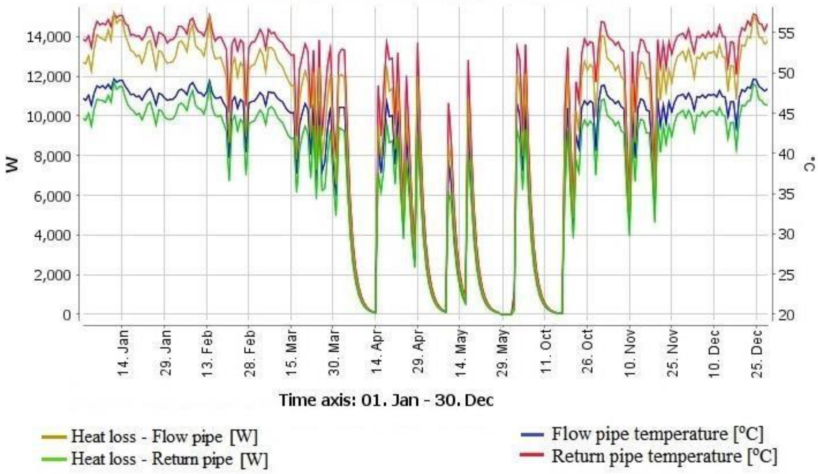


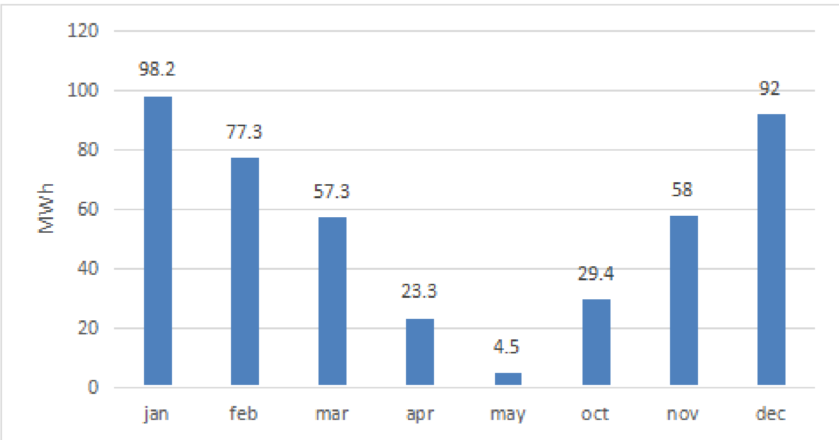
b)

Fig. 6. Heat loss and energy consumption for modernization situation (pumping automation) [8]

Considering the supply solution of the final consumer on a dedicated route, the possibility of implementing a new stage of efficiency of the supply system was studied by reducing the temperature of the supplied thermal agent from the initial situation 80/60°C to 60/40°C. The results can be seen in Fig. 7 showing the variation of heat loss (Fig. 7a) and the monthly energy consumption (Fig. 7b).



a)



b)

Fig. 7. Heat loss and energy consumption for the efficiency situation (reduction of supply / return temperatures) [8]

Compared to the existing situation, the modernization stage can contribute to the reduction of energy loss on the supply route by a percentage of 51.12%, and the efficiency stage can contribute to the reduction of energy loss on the supply route by a percentage of 65.87%, according to Table 2. In addition, one can observe that for the modernization and efficiency stage, respectively, a saving of 145.3 MWh can be achieved by applying the pumping automation and 191.8MWh respectively by reducing the temperature of the thermal agent.

Table 2: Analysis of annual consumption and reduction of heat loss

Characteristics	Unit	Existing situation	Modernized situation	Streamlined situation
Annual heat loss	[MWh]	295.60	144.50	100.87
Heat loss reduction	[%]	-	51.12	65.87
Annual energy consumption	[MWh]	631.8	486.5	440
Annual energy reduction	[MWh]	-	145.30	191.80

A comparative analysis obtained by simulating the operating parameters, between the three variants of heat supply (during the cold period of the year) of the analysed isolated consumer is presented in Fig. 8.

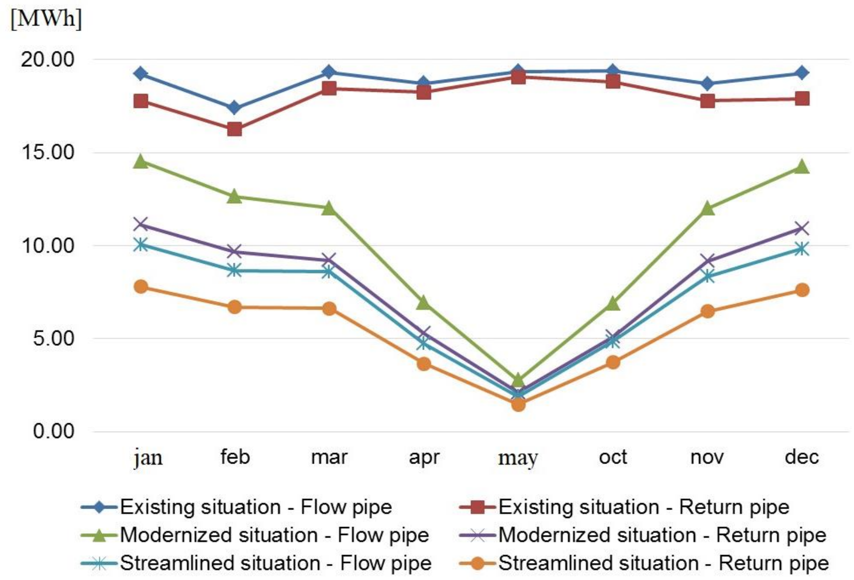


Fig. 8. The comparison between the heat losses of all three analysed variants

From the analysis of the graphical representation in Figure 8, one can notice that in the existing situation the heat loss curves on the supply and return of the system keep their allure throughout the year, while in the situation of the modernized system by automating pumping and the system considered efficient energetically, they change their shape, having a decreasing tendency as the outside temperature increases.

4. Conclusions

For the transition from generation III to generation IV, modernization and efficiency measures can be multiple and can be carried out in several stages depending on the particular situations of final

consumers, measures aimed at the realization and sustainable use of district heating networks, in accordance with policy to reduce energy consumption and CO_2 emissions.
For the case study, based on the results obtained by simulation, it can be seen that for the first stage of modernization a reduction of energy losses of 51.12% was obtained compared to the existing situation (continuous circulation), and for the efficiency stage by reducing the supply/return temperatures of the thermal agent obtained a reduction of energy losses of 65.87% compared to the existing situation. On the other hand, an important aspect is the reduction of the annual thermal energy consumption materialized by a reduction of 145.3 MWh by automating the pumping and respectively 191.8 MWh by streamlining the system by reducing the supply/return temperatures of the thermal agent.
As future directions, the authors intend to carry out a study on the use of heat pumps for the production of heat for this case study and to assess the reduction of CO2 emissions.

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