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# EVALUATING THE INTEGRATION OF APARTMENT BUILDING HEATING SYSTEMS WITH LOW-TEMPERATURE DISTRICT HEATING NETWORKS

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**Abstract.** Any renovation of apartment buildings by replacing or keeping their heating devices usually means that high temperatures of the heat carrier are maintained, which restricts boosting the efficiency of a central heating supply system. This also limits the scope for a switch to more efficient systems such as low-temperature district heating systems. To assess the impact of reducing the heat carrier temperature on indoor heating with a constant radiator area, the article investigates several alternatives alongside a base case scenario. In one scenario, the modernization of a building is examined, either by retaining the current heating devices or by substituting them with devices of equal size. Another scenario explores the modernization of a building by exchanging the heating devices and adjusting the building's heating system to accommodate ultra-low temperatures. The possibility to reduce the temperature of the heat carrier in the heating system without any renovation of the building has been addressed as well. This led to seven alternatives. The analysis of the hourly data of the heating system model for two typical months in a heating season has revealed that when the building retains its existing area of heating devices post-renovation, the temperature can be brought down to 60/40/20 °C. It was also discovered that lowering the heat transfer temperature to ultra-low parameters (45/25/20 °C) cannot be achieved by refurbishing the buildings without increasing the number of radiators, as the heating devices will fail to deliver adequate heat for space heating.

**Keywords:** district heating (DH), building modernization, heating system, low-temperature.

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## 1. Introduction

The European Union (EU) aims for climate neutrality by 2050, with decarbonizing the heating sector as a key challenge. District heating (DH) offers significant economic and environmental benefits, making it essential for transitioning to a low-carbon heating sector (Paardekooper, 2018). DH networks are widely accessible, providing cost advantages through economies of scale while efficiently delivering heat (Persson & Werner, 2011). They also facilitate the integration of renewable energy (Werner, 2017) and waste heat sources (Abokersh et al., 2020; Pompei et al., 2022), enhancing environmental benefits (Krikser et al., 2020) and sustainability (Mazhar et al., 2018).

According to the Lithuanian Association of Heating Suppliers, 57% of buildings have DH supply (Lukoševičius, 2024). Lithuania's National Energy Independence Strategy aims to boost renewable energy adoption and expand DH systems by 2050. Key directions for transforming the DH sector include shifting to low-temperature operation, digitalizing DH systems, expanding DH in urban areas, replacing polluting individual heating, enhancing heat consumption efficiency, upgrading multi-apartment building systems, and improving maintenance efficiency (Aukščiausioji audito institucija, 2022; Parliament of the Republic of Lithuania, 2024).

Renovation of old buildings and the strict energy performance requirements for new buildings have led to a reduced demand for space heating. Existing DH systems with predominantly high heat carrier design temperatures (at 115–60 °C for Vilnius, Lithuania) face the challenge of growing relative heat losses in the system. High temperature still makes the application of excess heat from low-temperature sources difficult. Currently, more than 80% of heat is produced from renewable energy sources in Lithuania. Only Sweden uses more renewable resources for DH than Lithuania (The Lithuanian District Heating Association [LDHA], 2024). The DH system is approaching the limit of its efficiency. Upgrading the system to any further and boosting its efficiency may be quite difficult without making some radical technical changes first. Ever since 2014, the EU states have been increasingly considering the so-called fourth- and fifth-generation (4GDH and 5GDH) ultralow temperature DH systems (Buffa et al., 2019; Lund et al., 2018, 2021).

A fourth-generation system is defined by the low temperature of the heat carrier supplied to the users (60 °C and lower) and a greater integration of renewable energy sources (e.g. heat pumps) (Sporleder et al., 2024; Volkova et al., 2022) and excess heat in renovated and low-energy buildings (Mateu-Royo et al., 2020; Popovski et al., 2019). Heat pumps in DH systems are one of the most promising technologies for increasing heat supply efficiency by using renewable energy sources and reducing the temperature of the heat transfer fluid in networks (Mateu-Royo et al., 2020; Kutzner et al., 2022). In addition, geothermal heat pumps are able to cover the amount of cooling during the summer period (Kutzner et al., 2022). 4GHD systems have gained attention as a promising solution to the challenges faced by traditional high temperature DH systems (Abokersh et al., 2020). These older systems often suffer from significant heat losses, high installation costs (Lund et al., 2021), and reduced profitability as heating demand decreases due to renovations of buildings (Elhafaia et al., 2023). However, adopting 4GDH requires further research to overcome technological and economic challenges (Elhafaia et al., 2023) and to ensure reliable service delivery (Rugieniūtė & Bielskus, 2024) optimal scheduling of heating resources (Potočnik et al., 2015). Thus, through renovations of old buildings, heat losses in the system can be mitigated even when new buildings (low-energy users) are connected to the system by way of expansion. The lower temperature of the return flow heat carrier results in a higher level of efficiency in the integration of renewable resources (solar panels, biofuel boilers), excess heat and combined heat and power plants (Arabkoohsar & Alsagri, 2019; Østergaard & Svendsen, 2016). Therefore, Arabkoohsar and Alsagri (2019) mention that DH systems are undergoing a transition to their next generation, presenting significant opportunities for innovative designs that tackle the challenges and meet the demands of future energy systems, with a focus on achieving both high efficiency and cost-effectiveness (Arabkoohsar & Alsagri, 2019). The rise in studies on the subject of fourth generation DH systems since 2014 shows that this is an important direction in which systems can develop (Wahi et al., 2023). Scandinavian countries already have functioning pilot systems of this kind in place (LDHA, 2024). This is believed to be the future of the DH system, which will inevitably also have to be implemented in Lithuania.

Vilnius is the largest user of DH in Lithuania, accounting for 30% of total demand. AB Vilniaus šilumos tinklai seeks to transition to 4GDH system, but faces challenges with existing building heating systems, which are designed for high temperatures. Additionally, summer domestic hot water supply requires a regulated outlet temperature of 55 °C, necessitating high heat carrier temperatures in the DH system. Reducing heat carrier temperatures may not maintain adequate indoor climate conditions during colder months, as some heating systems may be undersized. However, research (Østergaard & Svendsen, 2016; Wahi et al., 2023, 2024) indicates these systems can meet required temperatures, with strategies for reducing return temperatures at the end-user level discussed in recent studies (Tol & Madessa, 2024).

As Lithuania and other post-Soviet countries shift towards low-temperature DH networks, there is a need to analyze the operational temperature modes of heating systems in modernizing buildings. This research aims to assess the potential for temperature reduction in the heating systems of apartment buildings undergoing renovation in Vilnius, exploring various upgrade options. The study includes an analysis of whether to retain or replace existing heating appliances, leading to seven alternative solutions. Following the introduction, the paper outlines the research object and methodology, and concludes with a discussion on the feasibility of each option and their potential integration with renewable energy sources. The findings highlight both the opportunities and challenges that lie ahead.

## 2. Research object and analysed scenarios

The research focuses on a five-storey large panel system building constructed in 1969, with a heated area of 1.714 sq. m, two stairwells, a basement, and a superposed roof. It holds an energy class E rating and uses the Vilnius DH system for heat through an independent setup. Fresh air enters naturally and is expelled via vents in WCs, bathrooms, and kitchens, while hot water is generated in the boiler room. To explore the potential for lowering supply and return temperatures, actual data must be analyzed and recalibrated to normative conditions. Heating demand analysis separates heating and warm seasons, as illustrated in the heating capacity versus outdoor temperature graph (Figure 1b).

It can be seen (Figure 1a) that the actual collected data are quite scattered, but a linear dependence can be identified. At lower temperatures (–17 to –5 °C), there are fewer data, due to the short duration of the heating season in this range of outdoor temperatures, while at higher outdoor temperatures, the data are spread over a wide area. This depends on the proportion of the total demand that is accounted for by the capacity of the hot water system. At lower temperatures, the heating demand dominates, while at higher outdoor temperatures the capacity of the hot water system (for circulation and hot water production) can have a rather large impact. Similarly, Figure 1b shows that the scatter in the recorded data is more pronounced in the higher (positive) temperature zone, which can be can explained by the influence of solar radiation on the heat demand. The linear dependency equation presented in the Figure 1b reproduces actual heat consumption for heating with nearly 78% confidence and is used for the subsequent calculation of heating demand under normative conditions.

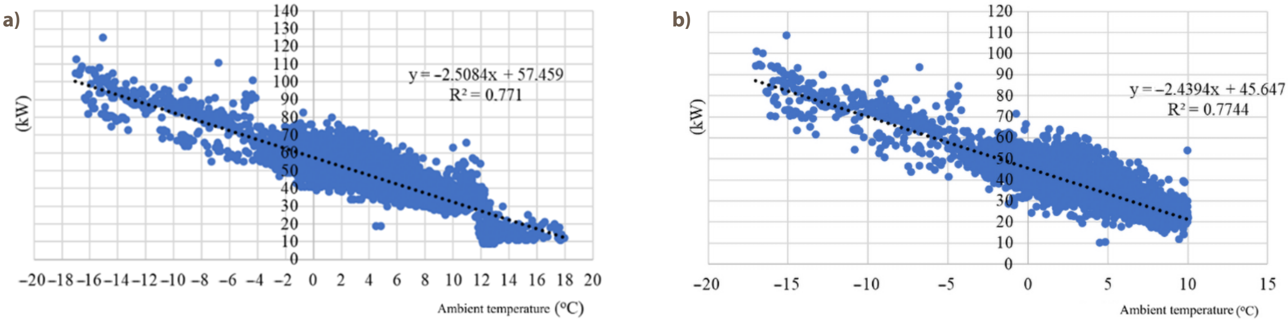


**Figure 1.** Dependencies of the total capacity (for heating and hot water systems): a) and the heating capacity; b) of the apartment building on the outdoor temperature

During the analysis period, total heat consumption was around 206 MWh, including 46.6 MWh consumed for hot water preparation and 33 MWh to ensure circulation in summer. The heat consumption in the year covered by the study amounted to 125.8 MWh (47.7 kWh m$^{-2}$). The building is in a climate zone where the rated duration of the heating season is 218 days (from September 26 to May 2), the average temperature during the heating season is 0.1 °C, and the number of degree days is 3,902. Adjusted for the rated conditions, the heating consumption increases to 160 MWh (60.6 kWh m$^{-2}$).

The building's design thermal capacity for heating is 143 kW (83.43 W m$^{-2}$). The analysis of the factual data has shown that the capacity for heating at the design temperature of –23 °C was just 102 kW (59.5 W m$^{-2}$). The design temperatures in the heating system are 95/70/18 °C (supply heat carrier temperature/return-flow heat carrier temperature/indoor air temperature, °C), and the factual temperature schedule is 70/50/20 °C.

To assess the potential of implementing a low-temperature DH system within a residential block in Vilnius, various scenarios are chosen and assessed within the examined apartment complex: the block of flats is modernized by replacing heating devices while maintaining current heating system temperatures (the baseline scenario). The existing or equivalent-sized radiators are kept, and the water temperature is lowered to provide adequate heating, not dropping below 65 °C for hot water supply. During renovations, heating devices are replaced, and the system is adjusted for low temperatures (45–25 °C). A heat pump will be installed to raise the heat transfer medium temperature for hot water to 65 °C, with a mixing device installed at the DH system entrance. The following scenarios have been developed to evaluate the baseline option and A-F alternatives (Figure 2).

As observed, the building itself undergoes upgrades in most scenarios, but in some instances, the heating device area remains unchanged from before the renovation, while in other situations, it is modified and diminished. Every option explores the potential to lower the heating system's temperature.

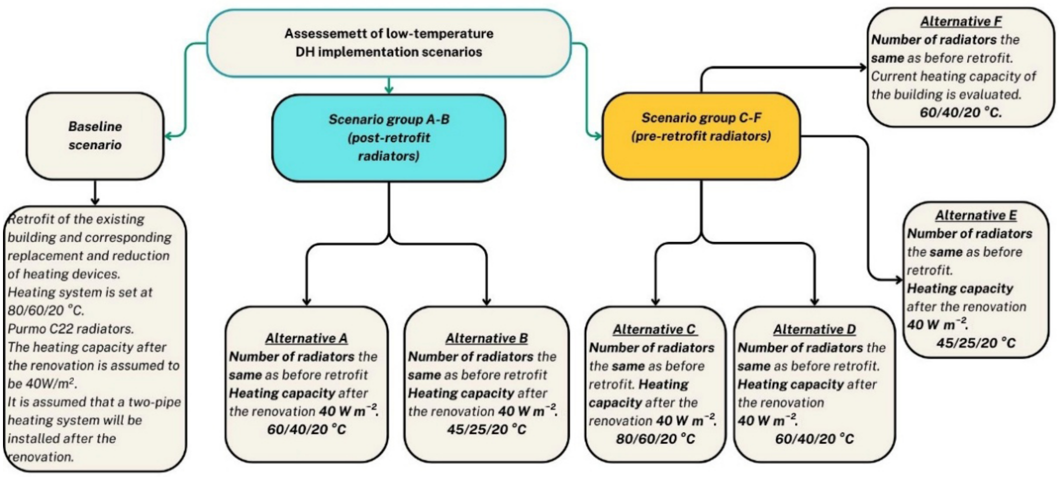


**Figure 2.** Scenarios developed to evaluate alternatives

## 3. Methodology for assessing alternatives

This section explains the calculation method used to assess the possibility to lower the heat carrier temperature when the area of the radiators remains steady. The analysis is done in reliance on the method for radiator capacity recalculation. The following assumptions are made:

- The building is equipped with MC-140-AO cast-iron radiators with the capacity of 178 W per element, when $\Delta t$ = 70 K ($\Delta t$ is the logarithmic difference in temperatures under Equation (4)).
- The number of radiators in the building matches the number of windows (stairwell windows excluded). The building under analysis has 110 windows.
- The type of cast-iron radiator is chosen for the building when the heat losses in the building amounts to 100 W m$^{-2}$, with a temperature schedule of 95/70/18 °C. The choice of radiators is based on a 10% buffer margin. As a result, a typical radiator consists of 11 elements.

The capacity of a typical radiator in the building is as follows: its section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn

$$Q_{rad} = \frac{Q_{building}}{N}, \quad (1)$$

where $Q_{rad}$ is the capacity of the typical radiator at different outdoor air temperatures, W, when the size of the radiator remains steady but its capacity changes at different outdoor air temperature; $N$ is the number of heated premises in the building, pcs.; $Q_{building}$ is the heating capacity of the building, W.

The capacity of the heating system in the building is derived from an analytical equation based on the actual dependence of the heating capacity on the outdoor temperature (Figure 1b):

$$y = -2.4394x + 45.647, \quad (2)$$

where $x$ is a variable, in this case – the outdoor air temperature; $y$ is the unknown, or the heating capacity of the building.

The thermal output released by the radiator is calculated as follows:

$$\phi = \phi_n \cdot \left[\frac{\Delta t}{\Delta t_n}\right]^n, \quad (3)$$

where $\phi_n$ is the thermal output of the radiator at a given logarithmic difference in temperatures, W; $\Delta t_n$ is the logarithmic difference in temperatures as calculated on the basis of a relative point of reference, K (taken from catalogue); $\Delta t$ is the logarithmic difference in temperatures, K; $n$ is the typical degree indicator of a particular type of radiator (for cast-iron radiators it is assumed to be 1.3).

The logarithmic difference in temperatures is calculated under the Equation (4):

$$\Delta t = \frac{t_{supply} - t_{return}}{\ln\left(\left(t_{supply} - t_{indoor}\right) / \left(t_{return} - t_{indoor}\right)\right)}, \quad (4)$$

where $t_{supply}$ is the temperature of the heat carrier supplied to the radiator, °C; $t_{return}$ is the temperature of the heat carrier flowing out of the radiator, °C; $t_{indoor}$ is the indoor air temperature, °C.

For the analysis of the heating season to be done properly, it is critical to define a schedule of temperature regulation for the heat carrier in the heating system. The current temperature schedule is shown in Figure 3, where the temperature regime is 70/55/20 °C.

In Figure 3, $T_1$ is the temperature of the heat carrier supplied from the DH system; $T_2$ is the temperature of the heat carrier as it flows back to the DH system; $t_3$ is the temperature of the heat carrier supplied to the heating system ($t_{supply}$); and $t_4$ is the temperature of the heat carrier as it flows back from the building's heating system ($t_{return}$). The figure shows a schedule of heat carrier temperatures, when the indoor air temperature is 20 °C and the design outdoor air temperature is –23 °C. In that case, the temperature of the heat carrier supplied from the Vilnius city DH system is 115 °C, and that of the heat carrier flowing back to the CHS system, 60 °C; the temperature of the heat carrier supplied to the heating system, 70 °C, and that of the carrier flowing back from the system, 55 °C.

The variation of the temperatures of the heat carrier supplied to the heating system is assumed to mirror linear dependences:

$$y = -1.0552x + 46.28, \quad (5)$$

where $x$ is a variable (the outdoor air temperature), °C; $y$ is the unknown (the temperature of the heat carrier supplied to the heating system).

The Equation (5) features a linear dependence generated on the basis of Figure 1b. The regressive dependence ($R^2$) as calculated amounts to 0.9991; as a result, this equation mirrors the $t_3$ line in Figure 1b almost identically.

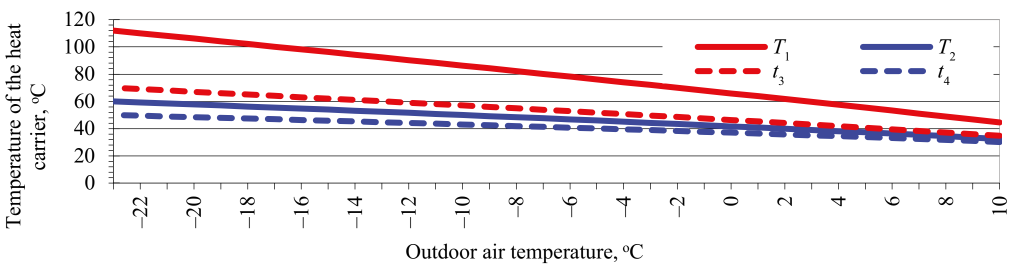


**Figure 3.** Relationship between heat carrier temperatures and outdoor air temperature

The heating capacity of the building after renovation is as follows:

$$Q_{building.renovated.} = 40 \cdot A_{building} \cdot \frac{\left(t_{indoor} - t_{outdoor}\right)}{\left(t_{indoor} - t_{des.outdoor}\right)}. \quad (6)$$

where $A_{building}$ is the heated area in the building, sq. m; $t_{des.outdoor}$ is the design outdoor air temperature, –23 °C; $t_{outdoor}$ is the outdoor air temperature, °C.

The following Table 1 shows the dependence of the temperature of the supply heat carrier on the outdoor air temperature for different temperature regimes: 80/60/20 °C; 60/40/20 °C; 45/25/20 °C.

**Table 1.** Analytical equations describing the relationship between the heat carrier supplied to the heating system and outdoor air temperature, along with the corresponding regression model

| No | Temperature schedule, °C | Equation | $R^2$ |
|---|---|---|---|
| 1 | 45/25/20 | $y = -0.5434x + 32.696$ | 0.9996 |
| 2 | 60/40/20 | $y = -0.8543x + 40.741$ | 0.9993 |
| 3 | 80/60/20 | $y = -1.2687x + 51.467$ | 0.9991 |

In Table 1, $x$ is a variable – in this case, the outdoor air temperature; $y$ is the unknown, or the temperature of the supply heat carrier. The regressive dependence ($R^2$) of the analytical equations shown in the table always approximates 1.

The main condition that a radiator has to satisfy is that it should cover the heat losses, meaning that the assessed heat losses must be equal to the losses of the radiator: $Q_{heat.losses} = Q_{rad.heat.losses}$. The calculations are done using Equations (3) and (4). The temperature of the supply heat carrier is calculated on the basis of the equations in Table 1, while the temperature of the return-flow heat carrier is unknown. For the purposes of the calculations, the temperature of the return-flow heat carrier is varied until the equation of $Q_{heat.losses} = Q_{rad.heat.losses}$ becomes true – this is done by way of iteration, or repetition of approximations.

## 4. Results and discussion

This chapter covers the results of the calculations for different alternatives, when the outdoor air temperature matches the rated climatic conditions, and the indoor temperature is 20 °C. The heating system operation is simulated with Microsoft Excel at intervals of one hour during all heating season. The results of the simulation cover more than 100,000 data points (not considering the analysis of real data), so a systematic graphical interpretation is presented. The outcomes are displayed solely for the coldest month, January, as these findings indicate that if the radiator's output area is adequate for January, it will also be adequate for the other months.

Figure 4 presents the analysis results for alternatives C, D, E, and F in January. The solid black, blue, grey, and red lines indicate the supply heat carrier temperatures, while the dotted lines represent the return-flow temperatures. The analysis is divided into two sections: one with a constant number of radiators (prior to upgrades) and the current heating capacity, marked by the blue dotted line, and another reflecting a building heat loss of 40 W m$^{-2}$, shown by the black dotted line.

An evaluation was conducted to assess the feasibility of transitioning to a reduced temperature schedule of 60/40/20 °C (Alternative F), given the building's heating capacity. In Figure 4, the supplied heat transfer medium (black line) shows a lower temperature than the return (red line) when the heat demand exceeds the existing heating area capacity. During calculations, the supply heat transfer fluid temperature is referenced from Table 1, adjusting only the return fluid's temperature. To enhance radiator heat output, the logarithmic temperature differential must increase, which means the return temperature must always remain above room temperature. Thus, as the temperature difference grows, the return temperature is raised to exceed the supply temperature.

When outdoor temperatures drop to around –20 °C or lower, the supply heat transfer medium is warmer than the return medium, but the temperature difference is minimal. This suggests that the heat transfer through the radiator cools only slightly, requiring a significant increase in flow rate, which raises hydraulic resistance, may produce noise, and can lead to excessive return temperatures to the DH system. Thus, implementing alternative F, which maintains current capacity without replacing radiators or reducing heat transfer parameters, is not feasible.

Alternatives C, D, and E keep existing radiators while retrofitting the building, reducing heating capacity to 40 W m$^{-2}$. Options C (blue line) and D (red line)

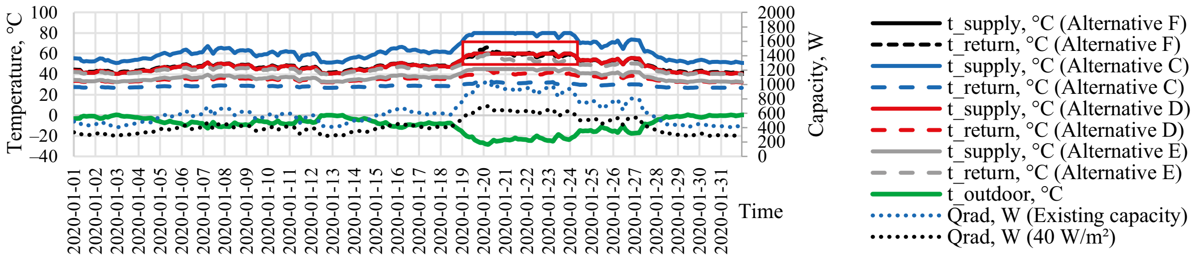


**Figure 4.** Results for alternatives C, D, E, and F in January

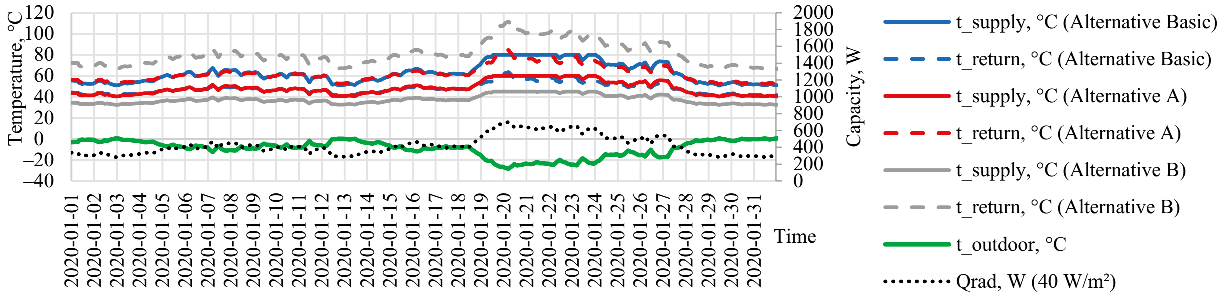


**Figure 5.** Results for alternatives Basic, A, and B in January

maintain adequate heat delivery with flow temperatures of 80/60/20 °C and 60/40/20 °C, as the flow temperature remains above the return temperature. Alternative E investigates if the supply temperature can be reduced to 45 °C (45/25/20 °C), but data shows that, during January, the supply temperature is consistently lower than the return temperature, making this arrangement impractical.

Figure 5 shows the analysis of the January baseline, alternatives A (60/40/20 °C temperature schedule) and B (45/25/20 °C temperature schedule). The blue, red, and grey solid lines represent the supply temperatures, and the dashed lines represent the return temperatures. This figure shows the results when the building is retrofitted with a heat loss of 40 W $m^{-2}$ (represented by the output of a typical radiator in Figure 4, black dotted line) and the radiators are replaced. In the baseline a Purmo C22 450 500 (Purmo, 2025) radiator has been selected according to the 80/60/20 °C temperature schedule. Alternatives A and B use the same radiators as in the baseline variant, but the temperature schedule is changed (lowered).

Figure 5 shows that alternatives A (red line) and B (grey line) do not provide the required heat output to the room throughout the period considered, as the supply flow temperatures are lower than the return flow temperatures (the reason why the return temperature is higher is given in the analysis of Figure 5). The analysis for January shows that only the baseline option can provide the required heat input to the room, and therefore it can be concluded that the radiator can only operate at its best under the design conditions.

The initial analysis of the building has shown that alternatives A, B, F and E cannot provide adequate heat transfer to the space and will not be assessed in the next stages of the analysis. The baseline, C and D are used for further analysis. After discarding the unsuitable alternatives, the optimal temperature regimes for the different cases considered have been established:

- Existing building heating capacity, retaining old radiators;
- Retrofitted building (heat loss 40 W $m^{-2}$), retaining old radiators and a design temperature difference of 20 K between supply and return;
- The building is being renovated (heat loss 40 W $m^{-2}$) and the old radiators are being replaced with new ones (Purmo C22 450 500).

The calculations follow the same methodology as above, except that in this case the temperature of the supply heat transfer medium is changed by approximation and the temperature of the return is calculated according to the dependence:

$$y = -0.4651x + 9.3023, \quad (7)$$

where $x$ is the variable (outdoor air temperature), °C; $y$ is the quantity to be searched for (return heat transfer medium temperature).

The equation considers an outdoor air temperature of –23 °C with a 20 °C temperature difference between supply and return heat streams, while at 10 °C, this difference is 5 °C. Figure 6 illustrates the calculations for the baseline, C, and D scenarios. The red lines depict the temperature dependence of the supply (thick) and return (thin) heat transfer mediums for a building heating capacity of 40 W $m^{-2}$ using a Purmo C22 radiator. The black lines represent the existing heating capacity and old radiators. This correlation matches the actual data in Figure 3, validating the methodology used.

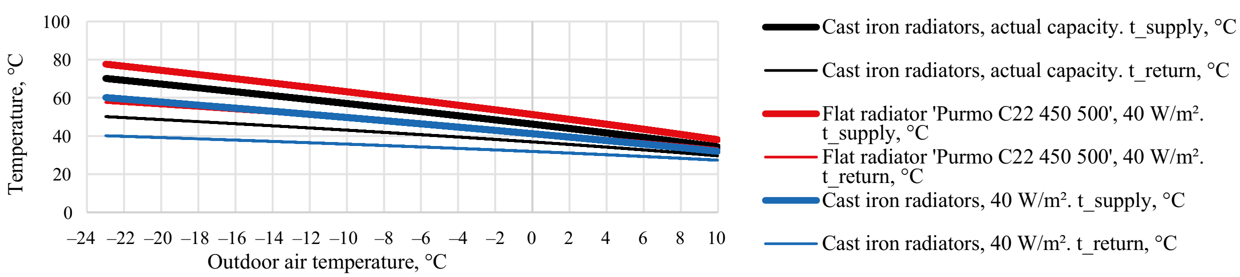


**Figure 6.** Optimal temperature regimes to be calculated

The blue line illustrates the temperature dependence of the supply (thick line) and return (thin line) heat flux based on outdoor air temperature for a building heating capacity of 40 W $m^{-2}$ using Purmo radiators. For the 80/60/20 °C regime, Figure 6 shows that the heat transfer medium should be around 76 °C at the inlet and 58 °C at the outlet at design outdoor temperatures, aligning with the selection criteria. This suggests that choosing a radiator for a specific temperature regime is ideal.

## 5. Conclusions

A literature review has shown that renovating existing buildings and choosing the right size of heating devices allows reducing the temperature of the heating system to a certain extent. The research examines seven scenarios (alternatives) for reducing the heat supply to a typical building to determine the feasibility of such reduction. Upon completion of the analysis, four scenarios were dismissed, while three were deemed feasible (baseline and alternatives C and D). The research conclusions are as follows:

- Analysis of factual data has revealed that the current temperature schedule of the building in question is 70/50/20 °C and cannot be possibly reduced to 60/40/20 °C, for this would result in a failure to provide the necessary amount of indoor heat.
- The calculations have shown that the capacity of the building post-renovation goes down to 40 W $m^{-2}$ (with the number of the radiators as it currently is), and a lower temperature regime of 60/40/20 °C can be applied.
- It has been established that once the building has been renovated keeping the current number of radiators, the temperature regime of the heat carrier could not be reduced to ultra-low parameters (45/25/20 °C), for the radiators will not be able to provide the necessary amount of indoor heat.
- It has also been verified that selecting a radiator for a specific temperature regime ensures that this is the ideal temperature regime.

The study emphasizes the importance of improving building retrofit strategies and exploring alternative heating options, such as surface heating systems, to maintain low temperature conditions. It also suggests taking into account heat pumps and other renewable energy technologies, while ensuring comfort standards and economic considerations are factored in when assessing potential solutions.

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## Author contributions

Conceptualization, validation, JB, GS and VL; methodology, AR and JB; software, JB and AR; formal analysis, GS and VM; investigation, VM, JB and VL; resources, VM; data curation, JB and AR; writing – original draft preparation, JB, AR, GS and VL; writing – review and editing, VL, VM and GS; visualization, JB; supervision, GS and AR; project administration, funding acquisition, GS.

## Disclosure statement

The authors declare that there are no financial, personal, or other conflicts of interest that could have appeared to influence the work reported in this study. No competing interests are declared.

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## DAUGIABUČIŲ NAMŲ ŠILDYMO SISTEMŲ INTEGRAVIMO Į ŽEMOS TEMPERATŪROS CENTRALIZUOTO ŠILUMOS TIEKIMO TINKLUS VERTINIMAS

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Santrauka

Daugiabučių namų renovacija, keičiant ar paliekant jų šildymo prietaisus, paprastai reiškia, kad reikia išlaikyti aukštą šilumnešio temperatūrą, o tai riboja centralizuoto šilumos tiekimo (CŠT) sistemos efektyvumo didinimą. Be to, tai apriboja galimybę pereiti prie efektyvesnių sistemų, pavyzdžiui, žematemperatūrių CŠT sistemų. Siekiant įvertinti sumažintos šilumnešio temperatūros poveikį patalpoms šildyti, kai radiatorių plotas išlieka pastovus, straipsnyje išnagrinėtos kelios alternatyvos ir bazinis scenarijus. Pagal vieną scenarijų nagrinėjamas pastato modernizavimas, paliekant esamus šildymo prietaisus arba pakeičiant juos tokio pat dydžio prietaisais. Pagal kitą scenarijų nagrinėjamas pastato modernizavimas pakeičiant šildymo prietaisus ir pritaikant pastato šildymo sistemą itin žemai temperatūrai. Taip pat nagrinėta galimybė sumažinti šilumnešio temperatūrą šildymo sistemoje neatnaujinant pastato. Tai leido parengti septynias alternatyvas. Išanalizavus šildymo sistemos modelio valandinius dviejų tipinių šildymo sezono mėnesių duomenis paaiškėjo, kad, po renovacijos pastate išlaikant esamą šildymo prietaisų plotą, temperatūrą galima sumažinti iki 60/40/20 °C. Taip pat nustatyta, kad renovuojant pastatus neįmanoma sumažinti šilumos perdavimo temperatūros iki itin žemų parametrų (45/25/20 °C) nekeičiant esamo radiatorių skaičiaus, nes šildymo prietaisai nesugebės tiekti pakankamai šilumos patalpoms šildyti.

**Reikšminiai žodžiai:** centralizuotas šilumos tiekimas (CŠT), pastatų modernizavimas, šildymo sistema, žema temperatūra.