Digitalization of the demand side: How does the end-user's behavior influence the operating temperatures in district heating networks?

Tunzi, Michele; Diget, Tom; van der Veer, Kees ; Nielsen, Anders

Published in:
Hot Cool

Publication date:
2024

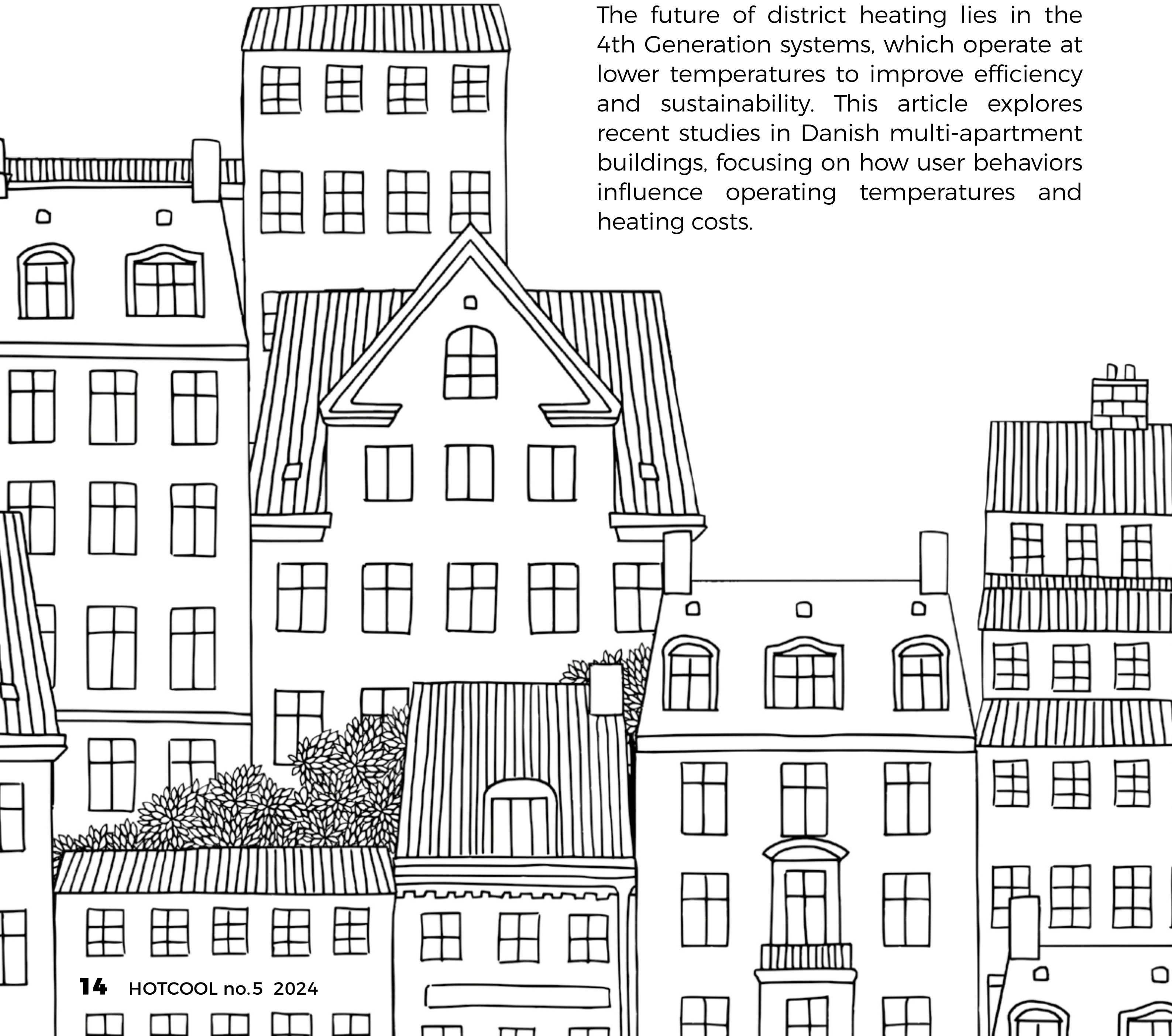
Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Tunzi, M., Diget, T., van der Veer, K., & Nielsen, A. (2024). Digitalization of the demand side: How does the end-user's behavior influence the operating temperatures in district heating networks? *Hot Cool*, *2024*(5), 14-18.

Digitalization of the demand side:

HOW DOES THE END-USER'S BEHAVIOR INFLUENCE THE OPERATING TEMPERATURES IN DISTRICT HEATING NETWORKS?

The future of district heating lies in the 4th Generation systems, which operate at lower temperatures to improve efficiency and sustainability. This article explores recent studies in Danish multi-apartment buildings, focusing on how user behaviors influence operating temperatures and heating costs.



By Michele Tunzi,
Associate Professor, Technical University of Denmark, DTU Construct

Tom Diget,
Chief Operating Officer, Viborg District Heating Company

Kees van der Veer,
Vice President, IT and Software, Brunata

Anders Nielsen,
Application Manager, Grundfos

Introduction

The current technological challenge of district heating is to develop new solutions to sustain the 4th Generation DH (4GDH) transitions. The core idea is to secure the expected comfort and hygiene for space heating and domestic hot water systems in buildings with low average supply and return temperatures in the range of 55 °C and 25 °C in the networks. Reducing network operating temperatures can secure the phase-out of fossil-fuel-based heat generation, integrate low-grade heat sources, minimize distribution heat losses, and reduce overall heating costs.

This article aims to share the latest knowledge from surveys in typical Danish multi-apartment buildings with water radiators used as heating elements for space heating systems. In particular, to highlight the impact of common user behaviors on the overall operating temperatures and their effect on the heating bills.

Can existing buildings be operated with lower temperatures?

Contrary to a common belief, existing buildings can operate effectively at temperatures lower than their original 'design' temperatures during most of the heating season without undergoing extensive retrofitting of their heating systems or building envelopes. [1]

Heating systems are designed to maintain indoor comfort even during extreme outdoor temperatures with no heat gains. However, the heat demand during the heating season can fluctuate significantly, rarely close to the calculated design heat demand. Additionally, commercial components are available in discrete sizes, and the heating elements and heat exchangers are typically oversized.

A survey conducted in ordinary apartment buildings connected to the Viborg district heating network in Denmark highlighted that existing buildings from the 1940s to 1990s can be comfortably heated with a supply temperature of 40-55 °C for the majority of the heating seasons. Even during cold spells, the supply temperature in those buildings was below the "design" radiator supply temperature of 70 °C.

Figure 1: Existing apartment buildings connected to the Viborg district heating network, Denmark

Normally, the total energy delivered for space heating during very low outdoor temperatures (below -5 °C) only accounts for 3-5% of the total share. Hence, in line with 4GDH requirements, it will not be an issue for district heating operators to increase the supply temperatures in the networks only for a limited number of hours while maintaining a low supply temperature profile for most of the year.

How does the digitalization of the demand side help our understanding?

Historically, the absence of comprehensive data from substations and heating systems led to buildings being viewed as 'black boxes'. This perception hindered the advancement of strategies for optimal control and operation of these systems, restricting the potential for achieving low-temperature operation.

While the degree of digitalization on the demand side varies among countries, implementing the new European Energy Efficiency Directives (EED) in recent years has accelerated the adoption of remotely accessible digital devices. This development has led to innovative monitoring and control, facilitating low-temperature operations and enhancing end-user billing transparency. It is expected that all energy meters and submeters (heat cost allocators for space heating and hot water consumption) in large buildings with central heating or connected to district heating networks will soon be remotely readable.

Lessons learned from heating system operations in existing apartment buildings in Viborg

The basic knowledge is that to heat a flat, all available radiators must be in operation and controlled locally with thermostatic radiator valves to secure the expected indoor temperature according to the end user's preferences.

However, analyzing data from energy meters, heat cost allocators mounted on each radiator (see Figure 2), and a few temperature sensors allowed us to gain insight into the standard ways of controlling and operating the space heating systems in apartment buildings. It was found that, on average, 30 to 40% of the radiators are normally closed and not active.

Figure 2: Typical radiator in apartment buildings with thermostatic control valve and heat cost allocator

The main reasons can span from the end-users believing they can reduce energy consumption to having unoccupied flats in the buildings.

The effects are the same independent of the cause. First, this leads to a non-uniform heating distribution among flats. Flats with fewer operating radiators and different indoor temperatures can enhance heat transfer from neighboring flats, "stealing" heat from each other.

But, if the outdoor temperature drops and the heat transfer from adjacent flats is reduced or the supply temperature is controlled under the assumption that all radiators are in operation, increasing the number of active radiators is the only way to maintain the same comfort. This was evident from an ongoing test in one of the buildings with 156 radiators. It was found that during 16-18 December 2023, the average outdoor temperature in Viborg was around 8°C, and the number of radiators in operation was 94. Whereas, during 5-8 January 2024, the outdoor temperatures dropped to - 9°C, and the number of radiators in operation increased by almost 10%, as highlighted in Figure 3.

Secondly, fewer radiators heating the entire flat inevitably increases the overall return temperature because the valve controlling the flow in the radiators will open more (or fully) to

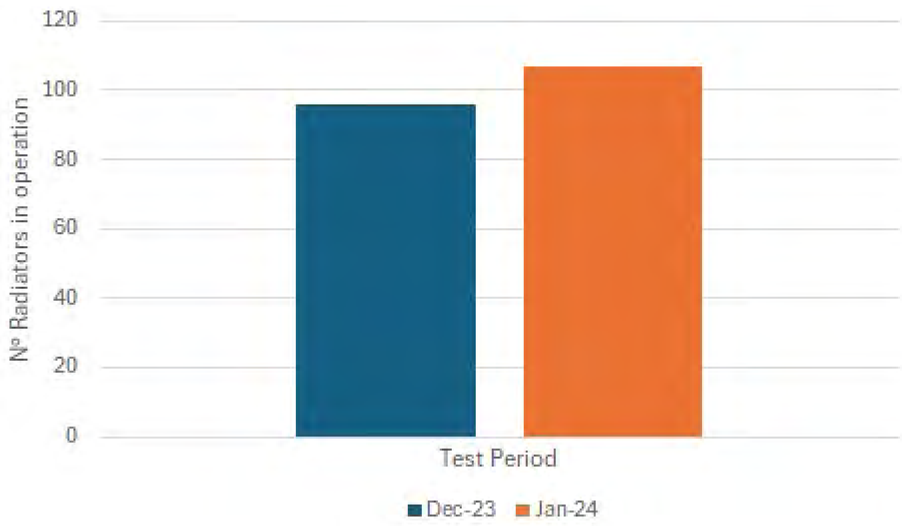


Figure 3: Number of radiators in operation for December 2023 and January 2024.

compensate for the lack of heat emitted from the non-active radiators. The difference is evident from the extra temperature measurements from the sensors mounted on the distribution pipelines in two staircases of one building part of the survey, as presented in Figure 4. Higher temperatures were observed when more radiators were turned off in the apartments connected to the distribution pipelines in Staircase 1, resulting in an overall return temperature of 45 ˚C. On the contrary, on Staircase 2, where the users have good habits in keeping most radiators in operation, the overall return temperature in the distribution pipelines was as low as 28 ˚C.

The economic impact of return temperature on the end-users energy bills

While the magnitude of the impact may differ depending on local conditions, in a building equipped with 175 radiators, the presence of just two poorly performing valves within those radiators could increase the overall building return temperature by 5˚C [2]. Such an increase in the overall return temperature at the building level inevitably influences heating bills.

Danish district heating operators incorporate penalties or bonuses into the final heating bills based on the yearly average return temperature from each building. These price adjustments are linked with the motivation tariffs part of their heating price structure. [3]

For example, in a common residential apartment building in Viborg, Denmark, with a yearly heating consumption of 314 MWh(30 apartments), a yearly average return temperature of 37 ˚C can secure a discount on the overall heating bill of 940 EUR. The yearly bonus can be increased to 3,200 EUR if the average annual return temperature can be reduced to 32˚C – equivalent to a discount on the heating bill of 107 EUR per apartment. On the contrary, an annual average return temperature of 45˚C corresponds to a yearly penalty of 1,930 EUR.

The introduction of motivation tariffs helped, among other activities, to incentivize the improvement of the heating systems operations and reduce the yearly supply and return temperature in the Viborg district heating network from 80/50 ˚C in 2002 to 68/40 ˚C in 2023. However, there are two potential areas for improvement:

1. The penalties or bonuses are equally divided among all flats/tenants. In cases of rented properties, the building owner does not have any interest in investing to secure optimal operation of the heating systems

2. By equally dividing the fines or incentives, the heating bills do not fairly reflect the actual influence of each end-user in the overall average return temperature

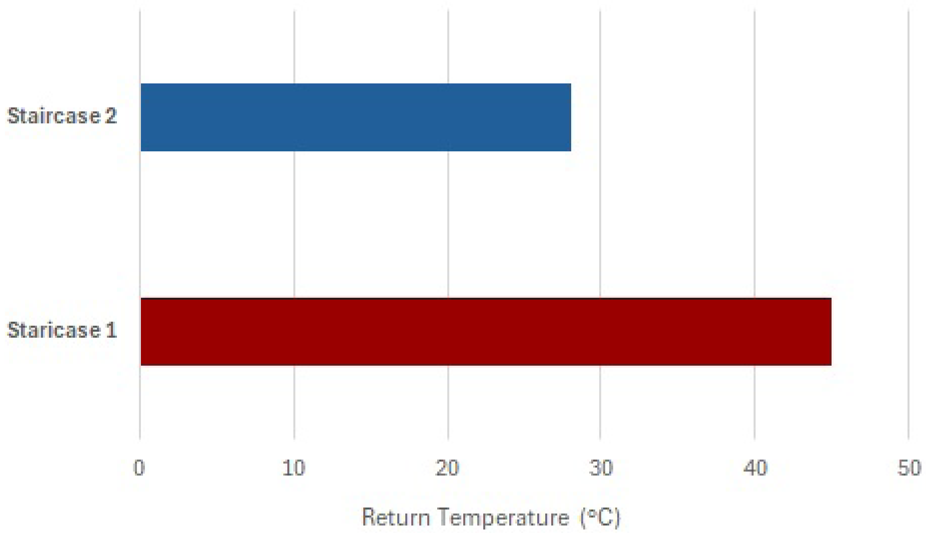


Figure 4: Impact of radiator operation on the overall return temperatures in two different staircases

According to the findings in the survey of the apartment buildings in Viborg, Denmark, the authors hope that a more open discussion can be initiated among all district heating stakeholders regarding fair end-user billing legislation. This may consider correctly disseminating the correlation between controlling and operating the radiators with higher return temperatures and unfair energy distribution among flats, using the data from energy meters, submeters, and sensors. For instance, in several countries, such as Poland, Hungary, and Slovenia, corrective measures for both low and high consumption are part of the national legislation/directive or integrated into the common market practices.

Recommendations and future outlook

The current level of digitalization on the demand side already offers a new opportunity to gain insight into the actual operation of space heating systems. The analysis shows that in many cases, the end-users tend not to use all radiators in their flats, keeping some of them closed. This negatively affects the correct operation of the entire system, leading to unnecessarily higher operating temperatures.

Therefore, one of the future challenges is to engage with the end-users and make them an active part of the green transition of the energy system. This is crucial because the end-users exclusively control the return temperature in district heating networks. To the best of our knowledge, in the vast majority of cases, they are not aware of the implications of their behaviors. Effective communication, enhanced by customized heating bills, can cost-effectively secure low operating temperatures without investing in deep building renovation.

Finally, in cases where apartments are not occupied or when the tenants may be away for extended periods, we believe that indoor temperatures should drop in no circumstances below 17 °C during the heating season. This will avoid mold formation inside flats, which will be more expensive for the building owners to renovate and affect the quality of the indoor environment. On the other hand, it will mitigate the negative effect of the non-uniform heat distribution among flats and help minimize the overall return temperatures. We believe these simple actions can secure a better economy for the utility company and end-users and pave the way for a smooth transition toward 4GDH and for the profitability of future green investments.

Acknowledgment

The authors thank the Danish Energy Agency and the EUDP program (Jr 64019-0545 and 64019-0554) for funding the investigation.

References

[1] O. , Antoni et al., "Optimised Operation and Maintenance of District Heating and Cooling Systems via Digital Process Management," 2023. Accessed: May 06, 2024. [Online]. Available: https://www.iea-dhc.org/the-research/annexes/2018-2024-annex-ts4

[2] M. Tunzi, D. S. Østergaard, and S. Svendsen, "Development and Test of a Novel Electronic Radiator Thermostat with a Return Temperature Limiting Function," Energies (Basel), vol. 15, no. 1, Jan. 2022, doi: 10.3390/en15010367.

[3] T. Diget, "Motivation Tariff - The key to a low-temperature district heating network.," Hot & Cool Magazine. [Online]. Available: http://www.e-pages.dk/dbdh/69/19

For further information please contact:
Michele Tunzi, mictun@dtu.dk