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Authors The authors bear the entire responsibility for the content of this report and for the conclusions drawn therefrom.	Speich, Matthias, ZHAW-INE, matthias.speich@zhaw.ch Ulli-Beer, Silvia, ZHAW-INE, silvia.ulli-beer@zhaw.ch
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Summary

This report links technological insights on temperature reduction in Swiss district heating grids to municipal energy policy and utility strategy. A literature review combined with desk research shows that few cities in Switzerland have explicit temperature reduction strategies, and only three are explicitly pursuing such strategies with the primary goal of integrating low-temperature renewable energy sources. Drawing on insights from a case study of Geneva's temperature reduction strategies, we present a simulation model connecting technical potentials to strategic and policy levers. Results show that temperature reduction has clear socio-economic benefits, in the form of lower annual costs for consumers, in a scenario where low-temperature renewables are being integrated into an existing DH grid. However, these benefits are not always proportional to the degree of temperature reduction achieved. These results will form the basis for the participatory elaboration of guidelines on incorporating temperature reduction in municipal energy strategies.

Zusammenfassung

Dieser Bericht verknüpft technologische Erkenntnisse zur Temperatursenkung in Schweizer Fernwärmenetzen mit der kommunalen Energiepolitik und der Strategie der Versorgungsunternehmen. Eine Literaturrecherche in Verbindung mit Sekundärforschung zeigt, dass nur wenige Städte in der Schweiz über explizite Strategien zur Temperatursenkung verfügen und nur drei solche Strategien ausdrücklich verfolgen, wobei das vorrangige Ziel die Integration von erneuerbaren Niedertemperatur-Energiequellen ist. Auf der Grundlage von Erkenntnissen aus einer Fallstudie zu den Temperatursenkungsstrategien der Stadt Genf stellen wir ein Simulationsmodell vor, das technische Potenziale mit strategischen und politischen Hebeln verknüpft. Die Ergebnisse zeigen, dass die Temperaturreduktion in einem Szenario, in dem niedrigtemperaturige erneuerbare Energien in ein bestehendes Fernwärmenetz integriert werden, klare sozioökonomische Vorteile in Form von niedrigeren jährlichen Kosten für die Verbraucher mit sich bringt. Diese Vorteile stehen jedoch nicht immer im Verhältnis zum Grad der erreichten Temperaturreduktion. Diese Ergebnisse bilden die Grundlage für die partizipative Ausarbeitung von Leitlinien zur Einbeziehung der Temperaturreduktion in kommunale Energiestrategien.

Résumé

Ce rapport établit un lien entre les connaissances techniques relatives à la réduction de la température dans les réseaux de chauffage urbain suisses et la politique énergétique municipale ainsi que la stratégie des services publics. Une analyse documentaire combinée à des recherches théoriques montre que peu de villes suisses disposent de stratégies explicites de réduction de la température, et que seules trois d'entre elles poursuivent explicitement de telles stratégies avec pour objectif principal l'intégration de sources d'énergie renouvelables à basse température. En nous appuyant sur les enseignements tirés d'une étude de cas consacrée aux stratégies de réduction de la température de Genève, nous présentons un modèle de simulation reliant les potentiels techniques aux leviers stratégiques et politiques. Les résultats montrent que la réduction de la température présente des avantages socio-économiques évidents, sous la forme d'une baisse des coûts annuels pour les consommateurs, dans un scénario où des énergies renouvelables à basse température sont intégrées dans un réseau de chauffage urbain existant. Cependant, ces avantages ne sont pas toujours proportionnels au degré de réduction de température atteint. Ces résultats serviront de base à l'élaboration participative de lignes directrices sur l'intégration de la réduction de la température dans les stratégies énergétiques municipales.

List of acronyms

°C	Degree Celsius
CHF	Swiss Francs
CHP	Combined heat and power
CRG	Cost reduction gradient
DH	District heating
DHN	District heating network
DHW	Domestic hot water
ESCO	Energy service contractor
HVAC	Heating, ventilation and air conditioning
K	Kelvin
MCHF	Millions of Swiss Francs
RES	Renewable energy sources
SCOVILLE	Strategy Cockpits for the Orchestrated implementation of thermal grids in cities and municipalities
WtE	Waste-to-Energy

1. Introduction

1.1. Aims of this report

As a whole, WP7 aims at providing utilities with actionable insights on return temperature reduction measures in DHN. The focus lies on a subset of all possible temperature reduction measures, which was identified as particularly promising in previous case studies in Switzerland: the monitoring, optimization and possibly the replacement of substations. According to a utility representative involved in the project, the expectation from the industry's side is not so much to obtain a detailed optimization of the energy system, but rather a simple, but still science-based, evaluation of the costs and benefits of options. In particular, the goal is to avoid making big mistakes in the implementation of temperature reduction measures. WP7 leverages data from the operation of DHN in Geneva to generate insights on the feasibility, costs and benefits of interventions at the level of substations.

Task 7.4 places the findings from Tasks 7.1, 7.2 and 7.3 in the context of municipal energy policy. Based on an existing simulation framework for the implementation dynamics of thermal grids in municipalities (SCOVILLE: Strategy Cockpits for the Orchestrated implementation of thermal grids in cities and municipalities), the impact of selected strategies for temperature reduction on the following KPIs is evaluated over time: 1) market share of DH in planned supply areas, 2) GHG emissions from space heating and DHW use, 3) annual costs of heating.

2. Literature and State-of-the-Art Review

2.1. The significance of temperature in DHNs

The principle of DH is to distribute heat via a heat transporting medium (usually water) pumped through a network of pipes. These pipes connect one or several heat generation facilities with buildings, where the heat is used for space heating, DHW production and sometimes process heat. In European DHNs, the heat distribution in buildings occurs through a system of pipes (the secondary network) that is physically separated from the DHN (the primary network) (Werner, 2017). The interface between the primary and secondary sides is referred to as the substation, consisting primarily of one or more heat exchangers, control equipment and a heat meter. The role of the substation is to supply the secondary side with heated water compatible with the specifications of the building regarding temperature, pressure and flow rate (Nussbaumer et al., 2018). The substation is installed so that the specifications of the technical connection requirements are respected, such as design temperature, flow rate and temperature difference. These requirements are reflected in the physical installations (e.g., type and dimension of the heat exchangers) and in the control settings (Nussbaumer et al., 2018). Often, the substation heat exchanger is owned by the DH utility, whereas the secondary-side installations belong to the building owner. In some networks, however, the substation also belongs to the building owner.

Most existing DHNs consist of two parallel systems of pipes: the supply pipe brings the water to the substation and the return pipe brings the water, cooled by the heat exchangers, back to the heat generation plants. A common substation configuration is represented schematically on Figure 1, based on an analysis of substations in a Swiss DHN (Callegari et al., 2023): a heat exchanger (labeled "SST HX") received heat from the primary side and supplies two distinct circuits within the building: the space heating circuit ("SH") supplies space heating installations (e.g., radiators), whereas a second heat exchanger supplies a tank used to heat and store DHW. In this configuration, the building's heat consumption is metered by measuring the temperature and flow rate at two points: before the water from DHN enters the substation heat exchanger from the DHN supply line, and after the water exits the substation heat exchanger towards the DHN supply line. Whereas the supply temperature is controlled by the DH operator, the network return temperature (as the water flows back to the heat

generation plant) depends on how well the substations and secondary-side installations extract heat from the supplied hot water. We note that this example represents the simplest configuration encountered, whereas many other configurations are possible (e.g., multiple buildings per substation, sub-networks, alternative substation architectures, etc.). However, this example demonstrates the significance of the substation and secondary-side installations for network temperature.

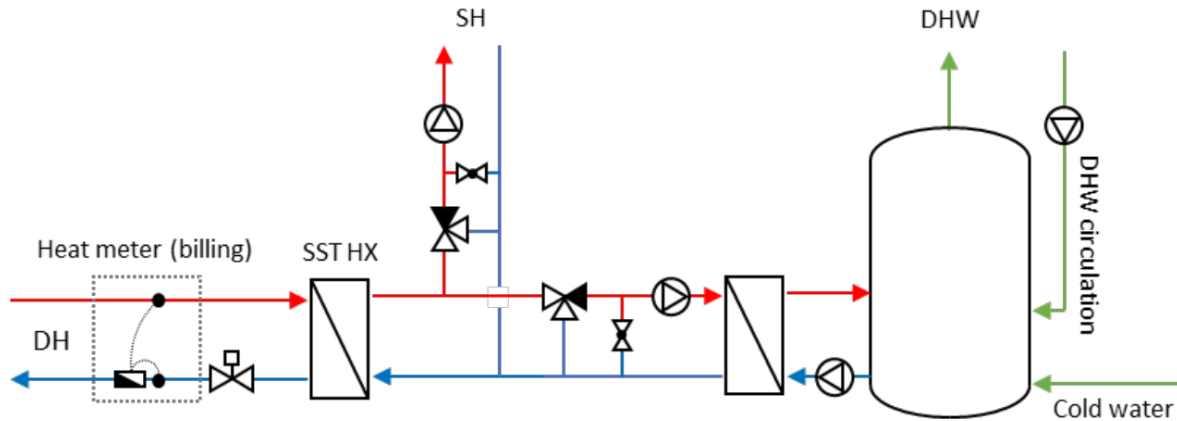


Figure 1: Schematic visualization of a commonly encountered substation in a Swiss DHN. Source: Callegari et al. (2023)

For several reasons, it is in the interest of the DH utility to keep system temperatures as low as possible. In particular, reducing return temperatures has been identified as a key lever (Zinko et al., 2005). The potential benefits of lower temperatures occur at different points in the DHN: at the network, generation and building levels. As represented schematically on Figure 2, several potential benefits at network level can be achieved (Geyer et al., 2021): since the transport capacity of water depends on the difference between supply and return temperature (referred to as the “temperature spread”), reducing return temperatures can increase the transport capacity of existing infrastructure. Indirectly, this enables an increased integration of high-temperature heat sources, such as high-grade excess heat. Alternatively, the resulting increase in temperature spread can be exploited to reduce mass flow, which leads to lower operating costs due to less energy required for pumping. These two options take advantage of an increased temperature spread.

Alternatively, the reduction of return temperatures can enable a reduction of supply temperatures, which comes with its own benefits. At network level, lower system temperatures help minimize distribution losses of existing infrastructure and enable the use of cheaper pipes for future expansions, which lowers investment costs and brings about various technical benefits that reduce the need for maintenance (Guelpa et al., 2023). In addition, lower supply temperatures improve the efficiency of several heat generation technologies, such as CHPs (by increasing the power-to-heat ratio), or heat pumps (by reducing the heat pumps’ sink temperature and thus improving its COP). Without reducing return temperatures, supply temperature reduction may require expensive measures such as infrastructure expansion i.e., larger or additional pipes) (Guelpa et al., 2023). It should also be noted that some heat generation technologies benefit directly from a reduction in return temperature, such as flue gas condensation.

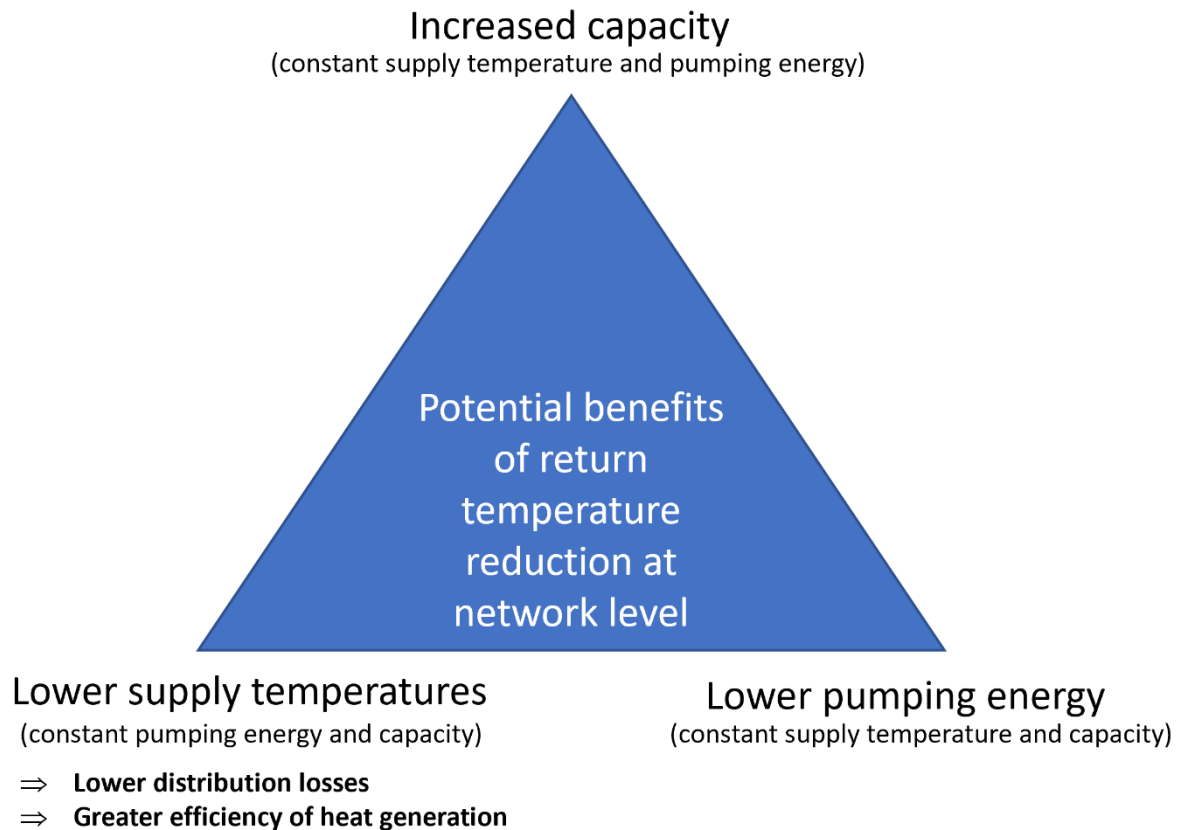


Figure 2: Potential benefits of reducing DHN return temperatures at network level. Own elaboration based on Geyer et al. (2021).

To summarize, system temperatures have an increasingly crucial role in DHNs. While temperature reductions were considered as a nice-to-have in the past, they are essential to enable the integration of various types of RES, as is foreseen by many cities and utilities to reach their net-zero policy goals. There is a widely shared understanding that reducing return temperature is a key lever for a sustainable reduction of supply temperature. However, unlike supply temperature, return temperature is not controlled directly by the DH utility but depends on how well the substations and buildings extract heat from the hot water supplied to them. Therefore, reaching a desired temperature level may require interventions on the substations and secondary-side interventions.

2.2. Costs and benefits of temperature reduction measures

As described above, reducing network temperature has various benefits for the operation of a DHN, which translate into lower costs. The metric typically used to quantify these benefits is the cost reduction gradient (CRG), expressed in currency per unit of energy and temperature reduction (e.g., CHF/(MWh*K)). Assuming a linear relationship, the CRG indicates how much the specific costs of the DHN can be reduced with each degree of temperature reduction. The CRG is usually estimated for a given configuration and (hypothetical) temperature reduction. Indeed, published values show vast differences between different heat generation technologies. For example, while assessing the economic benefits of transitioning from 3GDH to 4GDH temperature levels (represented in their study by supply/return temperature levels of 80/45 °C and 55/25 °C, respectively), Averfalk & Werner (2020) found CRG in the order of 0.1 €/ (MWh*K) for conventional heat generation technologies (waste incineration and biomass) and 0.36 €/ (MWh*K) for RES not yet commonly integrated in DHNs (geothermal, solar, industrial excess heat, heat pumps). This difference between generation technologies was confirmed by Geyer et al. (2021), who found CRG in the order of 0.08 - 0.1 €/ (MWh*K) for conventional technologies (CHP and flue gas condensation), and values up to 0.6 €/ (MWh*K) for

alternative RES. This difference between technologies shows that for DHNs supplied by conventional heat generation technologies, there is little incentive to plan and implement temperature reduction strategies. This was found to be a barrier for the transition to lower temperature regimes that would enable the integration of RES and the realization of the above discussed benefits (Averfalk & Werner, 2020).

Geyer et al. (2021) quantified the three distinct benefits of return temperature reduction at the level of the distribution network: increasing transport capacity, reducing mass flow and thus pumping energy, and reducing heat losses. In their study case, these benefits were estimated as follows:

- If additional heat demand can be connected, the utility may decide to exploit the greater temperature spread to increase capacity. In this case, the CRG is estimated at 0.55 €/ (MWh*K).
- Alternatively, the greater temperature spread may be exploited to reduce mass flow and thus pumping energy, whereas capacity is kept constant. This yields a CRG of 0.11 €/ (MWh*K).
- Finally, if the return temperature reduction is accompanied by an equal reduction of supply temperature, the economic benefits translate into lower network losses. In this case, the CRG is estimated at 0.07 €/ (MWh*K).

These numbers allow a rough estimate of the potential benefits of temperature reduction strategies in Swiss urban DHNs. A typical unit price (sum of standing and energy price components, expressed per kWh) is in the range of 100-150 CHF/MWh, with an upwards trend. Since these grids predominantly use heat from waste incineration plants and other conventional thermal heat generation technologies, the expected CRG for heat generation is rather low. Since the focus of this report is on temperature reduction with the purpose of integrating new RES, it must be assumed that any reduction of return temperature will be accompanied by a reduction in supply temperature. As a result, the immediate economic benefits at network level stem from reduction of heat losses. Under the assumption (yet to be verified) that the CRG at generation and distribution level are additive, the attainable CRG is in the order of 0.2 CHF/(MWh*K) (accounting for somewhat higher costs in Switzerland than in northern European cases). Therefore, a reduction of 20 K (at the network level from e.g. 110 to 90° C) would allow a cost reduction of approximately 2.5 – 4%, which is in line with the estimation of Averfalk & Werner (2020), as well as a recent, detailed modeling study (Kotilainen et al., 2025). Some caveats apply for this estimation: first, the reported CRGs were estimated in the context of transitioning from 3GDH to 4GDH. In Swiss cities, the aim is rather to transition from 2GDH to 3GDH (see Section 2.4). Due to the greater temperature difference, it is possible that the network CRG is somewhat higher. On the other hand, detailed analyses in Geneva showed that the losses are already low (see D7.3.1), which limits the potential for further savings.

While the economic benefits can be estimated at the system level, the costs of return temperature reduction measures stem from individual measures in buildings, which can be highly diverse. In a German DHN, Bergstraesser et al. (2021) identified 13 problematic substations using the excess flow method and performed an inspection on those. For each substation, they identified the faults and recommended measures to eliminate those. In some cases, the indicated measures are minor and cheap, such as hydraulic balancing or change of the settings in substations. Other cases would require major interventions, such as a complete renovation or replacement of the substation. As a result, the estimated costs range from €400 to €32'500. As can be seen on Figure 3, there is no clear relationship between the costs and impact on network return temperature: some measures costing over €10'000 have a comparable impact to the cheapest measures. Of note, Kotilainen et al. (2025) cite a similar price range for the upgrade of a substation in one building (€10'000 – 25'000).

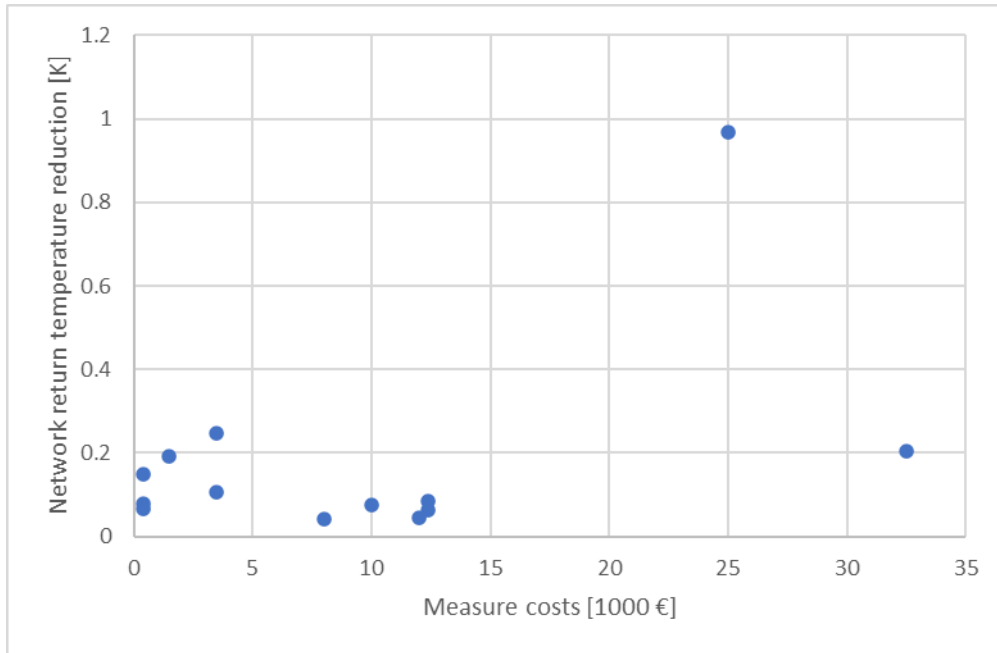


Figure 3: Estimated costs of intervention on substations and impact on network return temperature in a German urban DHN. Data source: Bergstraesser et al. (2021).

Bergstraesser et al. (2021) further calculated the specific costs of network return temperature reduction, thus enabling a direct comparison with the CRG discussed above (Figure 4). It appears that for most substations, the costs would vastly outweigh the economic benefits at system level. Indeed, only three substations show costs within the range of the attainable CRG for conventional DHNs (i.e., less than 0.2 €/MWh*K). Two more substations show costs within the range of the attainable CRG for alternative energy sources (less than 0.7 €/MWh*K). For almost half of these substations, the specific costs are an order of magnitude higher than these CRGs. It should also be noted that for three additional substations, no measures for fault repair could be found. In conclusion, Bergstraesser et al. (2021) suggest that the focus of temperature reduction strategies should be on those substations where fault repair is economically viable, also because these mostly require minor interventions that can more easily be standardized.

Setting these numbers into the same context as above, we find that if the most advantageous specific cost of 0.08 €/MWh*K found by Bergstraesser et al. (2021) could be applied throughout all substations to reach a 20K temperature reduction, this could be obtained at an increase in levelized costs of 1.6 €/MWh, i.e. approximately 1%. By contrast, if an average cost of 4 €/MWh*K applied, a temperature reduction of 20K would cause an increase in levelized costs of 80€/MWh, or 50-80%. Since more moderate price increases have recently been flagged by authorities (Preisüberwacher, 2023), it should be assumed that such price increases would be politically disputed.

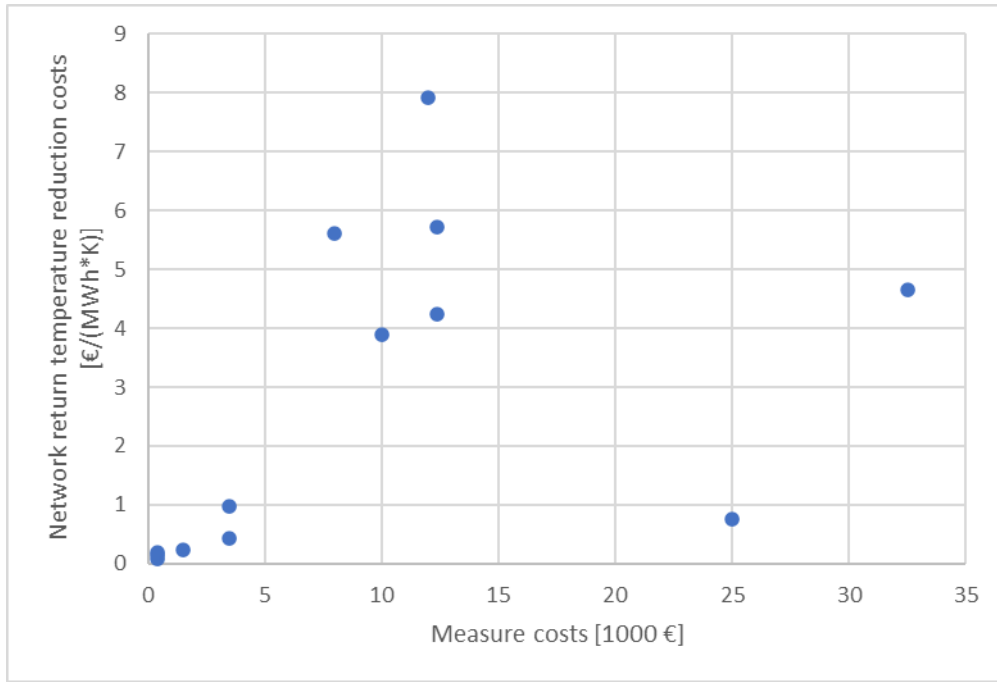


Figure 4: Estimated absolute costs and specific temperature reduction costs for the fault removal measures proposed by Bergstraesser et al. (2021).

This overview of estimated costs and benefits has two important implications for the planning and implementation of temperature reduction strategies in the context of Swiss cities. First, in conventional DHNs (2GDH networks with CHP as heat source), the immediate economic benefits of temperature reduction are likely to be minor. This is especially the case when the purpose of temperature reduction is to enable the integration of low-temperature RES. Rather, the substantial economic benefits occur once alternative RES are connected to the grid. This raises the issue of timing and calls for appropriate strategies to overcome the lock-in effect caused by low CRGs in conventional DHNs. The second implication is that the known technical measures for return temperature reduction differ widely in terms of economic rentability: some measures are viable even in conventional DHNs, other measures are likely to be viable in future DHN configurations, whereas other measures will generate substantial additional costs. To plan a temperature reduction strategy, it is therefore essential to know not only the technical optimization potential of substations in a DHN, but also the cause for their suboptimal functioning and the costs of optimization measures.

2.3. Transitions to lower DH temperature regimes

As noted before, reducing return temperatures is a key lever to transition to a lower temperature regime. However, return temperature cannot be controlled directly by the DHN operator. Rather, it depends on the characteristics of the connected buildings, secondary-side installations and substations. Since these elements are often not under direct control of the utility, the planning and execution of temperature reduction strategies is often uncertain and time-consuming. A transformation roadmap was proposed by Averfalk et al. (2017) based on working experience from various European countries. In their view, the first step is to eliminate errors in the existing substations and network components, which yields first temperature reduction potentials. A next step is the replacement of heat exchangers in substations: heat exchangers with a longer thermal length enable further temperature reductions. Energy efficiency measures in buildings, such as envelope retrofits and improvements of secondary-side installations, are the third pillar of the proposed roadmap. Crucially, the authors note that these steps cannot all be carried out by the DH utility alone. For a selection of concrete measures, Table 1 indicates the importance of different actor groups in initiating them, as identified by Averfalk et al. (2017). It appears from this compilation that while the DH utility is the central actor, the contributions

of equipment producers, energy professionals, building owners and policymakers are central to the implementation of temperature reduction strategies.

Table 1: Measures of a DH temperature reduction strategy, with the role of each actor group in initiating each measure (○ low; ◐ medium; ● high). Source: adapted from Averfalk et al. (2017)

	DH Utility	Equipment producers	Energy planners	Consultants	HVAC service providers	Building owners	Policymakers
Introduce return temperature dependent DH tariff	●		◐				○
Identify malfunctioning substations and remove errors	●	●			●	○	
Develop and install new thermostatic radiator valve with return temperature controller	●	●			●	○	
Provide service to educate customers how to properly use the heating system	●				●	○	
Replace single string system with double string, reduce bypass and circulation losses in buildings	○	◐			●	○	●
Operate the network with optimal temperatures with respect to lowering the return temperature to 90°C	●		◐				
Eliminate the use of thermal bypass in the network	●	○		○	●	●	
Reduce energy use and upgrade heating system when renovation of the building is needed	◐			●	●	○	
Replace central DHW storage tank with decentral heat exchanger	○			●	●	○	
Exploit low temperature renewable and waste heat	●	◐	●	○			●
Operate the network with optimal temperatures with respect to lowering the supply temperature to 55°C	●				●		

It is also apparent from table Table 1 that the measures can occur at different levels. Following Bahadori et al. (2025), we distinguish the following types of measures, which often complement or enable each other and thus form the building blocks of a coherent strategy:

- Supply-side improvements (e.g. production and distribution infrastructure optimization).
- Interventions at the level of substations.
- Building energy retrofits (e.g., improvements of the building envelope or secondary-side system).
- Incentivization of customers through tariff models.
- Regulatory and policy measures.

In the following, we focus on reviewing the organizational and policy measures. For a thorough review of technical options, we refer to Callegari et al. (2023).

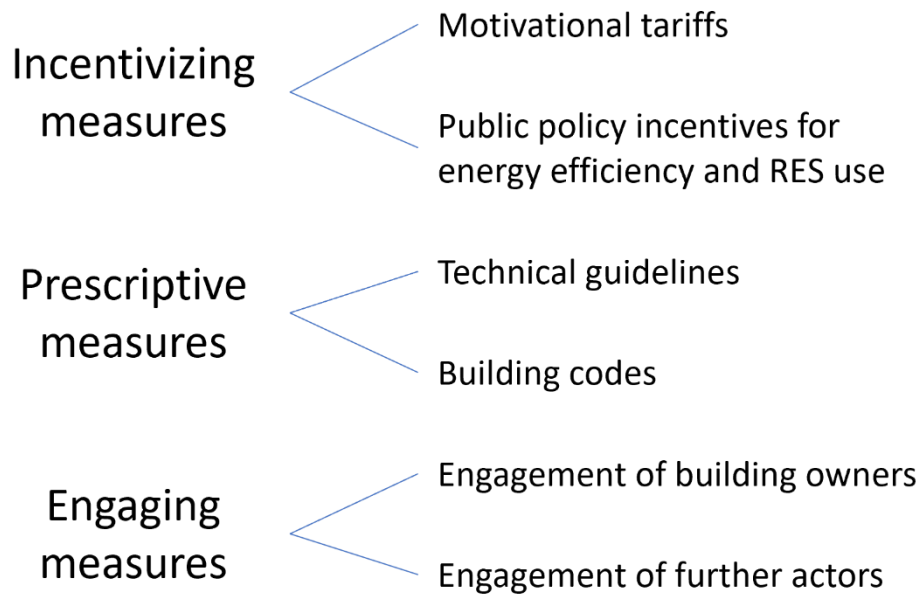


Figure 5: Overview of reviewed organizational and policy measures that may form part of a temperature reduction strategy.

We broadly distinguish between incentivizing, prescriptive and engaging measures (Figure 5). The first group of measures sets incentives for building owners to invest into building and substation retrofits, e.g., through DH tariffs, taxes or subsidies. Prescriptive measures set mandatory standards, e.g., through building codes. Engaging measures proactively engage building owners, e.g., through the utility's customer relation management or new, targeted offers.

Various examples of incentivizing tariff models have been applied in different countries. The most common categories are (Leoni et al., 2020; Lygnerud et al., 2023):

- Flow-component tariffs, where the customer pays a price for each m³ of water passing through the substation.
- Bonus-malus tariffs, where customers are penalized or rewarded depending on their return temperature.
- Discounts for drawing heat from the return line instead of the supply line.
- Feed-in tariffs, incentivizing prosumers.

The analysis of past low-temperature transitions shows that motivational tariffs have played an important role (Lygnerud et al., 2023). However, several challenges were identified: customers may not understand the implications, so that communication efforts are necessary for such tariffs to work. Also, motivational tariffs may be perceived as untransparent or unfair (Lygnerud et al., 2023). Furthermore, the split incentive issue may limit the effectiveness of price-based incentives. In particular, the regulatory framework was found to counteract the idea of motivational tariffs in rented buildings: while tenants pay the DH bill, optimization measures would be at the charge of the building owner (Leoni et al., 2020). In addition to tariffs, public policy measures aimed at increasing energy efficiency and RES use may also play in favor of temperature reduction strategies (Pakere et al., 2021).

Two types of prescriptive measures are discussed in the literature: measures that directly impact the buildings' connection to a DHN, and measures aimed at improving building energy efficiency in general. For the first category, technical guidelines were mentioned as an instrument where the DH utility can directly specify the ranges for supply and return temperatures (Overbye, 2025). Regarding building energy efficiency, building codes are mentioned as an instrument, but their concrete role in this

context is rarely discussed (Averfalk et al., 2017; Overbye, 2025). In general, prescriptive elements of temperature strategies seem to be less discussed in research than incentivizing elements.

As noted before, building owners cannot be expected to react to incentives on their own. Therefore, various approaches for customer engagement have been implemented and described. In the experience of Swedish utilities, an existing close customer relationship was a key success factor in persuading building owners to take action (Månsson et al., 2019). Concretely, this may take the form of service agreements or free inspections (Månsson et al., 2019). Utilities may therefore strengthen customer relationships, but this takes time and effort. However, this can be seen as an opportunity to strengthen the service aspect of DH, which was suggested as necessary to maintain competitiveness of DH (Lygnerud et al., 2021). Besides customers, the engagement of further actors has been discussed: according to the actors interviewed by Skjølstrup (2019), installers hold a key role, since they face customers directly and can influence their decision. However, installers often lack both the skills and the incentives to propose solutions aligned with the need to reduce temperatures. Also, Leoni et al. (2020) suggest involving an ESCO if the DH utility is not able or willing to invest into optimization measures. These measures may be financed by other actors with an interest in lowering DH temperatures, such as prospective heat providers or technology providers. Ultimately, there is high agreement that any solution should fairly distribute the costs and benefits of temperature reduction across involved actors (Leoni et al., 2020; Lygnerud et al., 2023). Such a scheme was sketched by Leoni et al. (2020), with virtuous circles where the benefits from temperature reduction are reinvested to finance additional measures or further customer engagement (Figure 6). However, it seems that such multi-actor solutions have so far been described conceptually, but practical applications are rare.

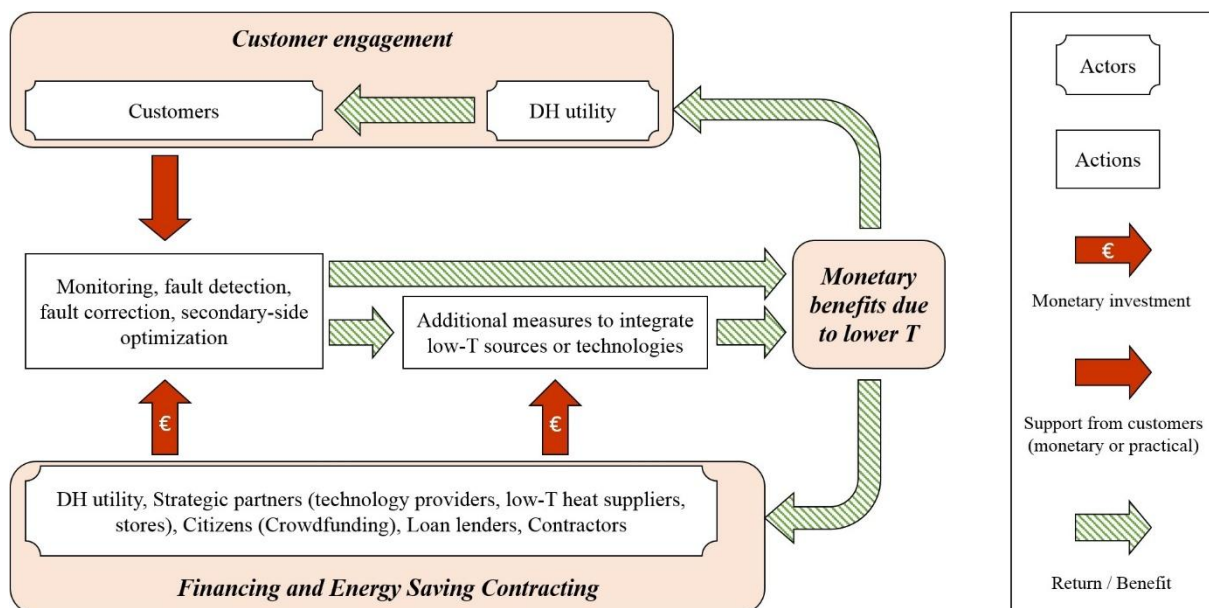


Figure 6: Suggested mechanism for a multi-actor business model to enable temperature reduction in DHN. Source: Leoni et al. (2020).

2.4. DH and temperature reduction in the context of the Swiss energy transition

Following a series of momentous political decisions at federal, cantonal and municipal levels (e.g., the acceptance of the energy strategy 2050 in 2017; the adoption of a national net-zero target by 2050 in 2019; cantonal energy laws banning new fossil-fueled heating systems; municipal net-zero strategies), Swiss cities and municipalities have greatly expanded their plans to develop DH in the coming years (Speich et al., 2024). This includes new developments, but also the modernization of existing DH grids. Historically, the development of DHN in Switzerland was primarily driven by opportunity, such as the availability of a cheap and easily exploitable heat source. As a result, DHN fed by the excess heat of

waste incineration plants were developed in many cities and regions. These grids typically operate at temperature levels above 100 °C. However, municipal energy strategies aiming for net-zero emissions often foresee the integration of additional renewable heat sources, such as ambient heat, low-grade excess heat or geothermal energy, which occur at lower temperature levels. Although heat pumps can be used to raise temperatures to the supply temperature in modern DHN, it is often uneconomic to directly integrate these energy sources into a high-temperature network. Also, with the greater role of DHN in future energy systems, it is increasingly critical to realize the efficiency potentials in these networks to ensure an affordable and decarbonized heating supply. As a result, temperature reduction has been recognized as a critical step (Swiss Federal Office of Energy, 2021). As an example for its relevance, the widely used planning handbook for DHN (Nussbaumer et al., 2018) was completed in 2021 with a chapter on the planning of substations.

Despite its relevance, temperature reduction has not yet been widely implemented. One explanation is that the topic was not critical enough yet, so that utilities used their limited personnel resources for other time-critical purposes, such as the roll-out of new developments (Speich et al., 2024). Also, the dependence on the decision-making of external actors (building owners, but also planners and building professionals tasked with dimensioning and configuring substations) represents potentially high transaction costs for utilities. Table 2 summarizes activities of pioneering Swiss cities for temperature reduction in terms of goals, stated purpose and implemented measures. This list is not exhaustive but represents those examples known to the authors where concrete measures have been taken. Also, since municipal energy policy is currently fast-moving, the situation presented here is a snapshot and may change in the near future. This list shows that the goals differ across cities: while Geneva, Lausanne and Martigny aim for temperatures that allow the integration of renewable energy sources, Zurich, Winterthur and Basel use temperature reduction primarily as a way to increase the system's efficiency. In the interviews carried out by Speich et al. (2024), informants from two additional Swiss German cities stated that no concrete measures had been taken in their city yet. In one case, while the utility had recognized substation optimization as a way to increase capacity, this topic had only become critical recently, so that it had not yet been prioritized. In the second case, the city's energy strategy did not foresee the integration of RES at lower temperatures in the DHN, since a net-zero compatible system configuration can be obtained with high-temperature excess heat and decentral solutions. It appears from this comparison that the strategy of integrating lower-temperature RES into existing DHN is pursued more in French-speaking than in German-speaking cities. With the information available, it is not possible to assess whether this is coincidental or indicative of region-specific approaches to planning. In any case, we stress that other cities with less ambitious temperature reduction initiatives may pursue alternative strategies to deploy RES and to comply with municipal decarbonization policy. For example, in Zurich, the integration of various RES (e.g., lake water, sewage) takes place in separate grids, rather than being integrated directly in the high-temperature DHN. Also, Winterthur foresees the construction of a separate grid to valorize the excess heat of a data center.

Table 2: Temperature reduction goals and implemented measures in selected Swiss cities.

City	Temperature reduction goals	Purpose of temperature reduction	Measures
Geneva	Supply/return temperatures of 90/45 °C on the whole DHN (Callegari et al., 2023).	Integration of renewable energy sources (Callegari et al., 2023).	Contracts, regulation and guidelines; Control and monitoring; Information, education and partnerships (Bucheli, 2024b).
Lausanne	Reduction of the supply temperature from 130 to 85 °C in a part of the DHN.	Integration of renewable energy sources (Municipalité de Lausanne, 2023).	Partial decoupling of DHNs, construction of new heat generation

	Design of new extensions with a supply temperature of 85 °C.		plants (Municipalité de Lausanne, 2023). Energy cascading in a new, energy efficient district.
Martigny	Reduction of the DHN's supply/return temperatures from 110/68 to 90/50 °C.	Integration of geothermal energy (Carron & Sartori, 2023).	Interventions in SST of connected buildings (Carron & Sartori, 2023)
Zurich	Reduction of the waste incineration DHN's supply temperature from 113 to 104 °C by 2040.	Ensure the DHN's transport capacity; increase the DHN's efficiency; harmonize temperature levels; (Stadtrat Zürich, 2018).	Construction of bypass pipes (Stadtrat Zürich, 2018). Penalty for high return temperatures in DH tariff (ewz, 2025).
Winterthur	Reduction of the DHN's return temperature from about 60 to 50 °C.	Increase the DHN's efficiency, especially to realize the expected potential of the integration of flue gas heat recovery (Stadtrat Winterthur, 2025)	Amendment of the technical connection conditions (Technische Anschlussbedingungen, TAB) (Stadtrat Winterthur, 2025)
Basel	Reduction of the DHN's supply temperature from 170 to 90-115 °C.	Increase the DHN's efficiency and reduce grid investment and construction costs (IWB, 2025).	Financial support to building owners for the purchase of new substations or for energy coachings (Basler Zeitung, 2012).
Bern	No reduction of the supply temperature of the main network (175 °C) is foreseen, but sub-grids are operated at lower temperature.	The temperature spread of 110 K ensures a high transport capacity, which is critical for the security of supply (Bucheli, 2024a).	-

The concrete measures applied in each case differ: for example, in Lausanne, substantial infrastructural measures are required, such as the construction of a new heat generation plant to allow the autonomous operation of the sector of the network for which a temperature reduction is foreseen. These changes were presented by the city government as part of a request for an investment credit of 170 MCHF for the development and modernization of the municipal DHN. By contrast, in Zurich, the construction of bypass pipes was a minor intervention (2 MCHF) that could be decided directly by the city government. A critical point of intervention are the substations in connected buildings: in Winterthur and Basel, the responsibility to configure and possibly replace substations to reach necessary return temperature levels is delegated directly to the building owners, e.g., by adjusting the technical connection conditions¹. In Basel, this was accompanied by measures to financially compensate building owners in cases where the substation had to be replaced. By contrast, in Zurich, optimization of substations is intended to be incentivized with a penalty in the tariff model: for every K of return temperature in excess of 50 °C, the energy price is increased by an additional percentage

¹ In Winterthur, it is worth noting that the technical connection conditions, which were so far under responsibility of the municipal utility, are now decided upon by the city government. This follows a change in the regulation on municipalities at cantonal level, which excludes the administration's employees from taking law-making decisions (Stadtrat Winterthur, 2025). This example highlights the relevance of the topic for municipal energy policy.

point (with a maximum increase of 20%). A key success factor identified in the implementation of advanced temperature reduction strategies is the ownership of substations by the utilities (Callegari et al., 2023)(Callegari et al., 2023). Indeed, ownership gives the utility direct control on the substation, facilitating interventions such as monitoring, optimization or replacement. However, this configuration is not universal: in other cities (e.g., Basel²), the substation is owned by the building owner. The concrete effect of ownership on the cost and feasibility of interventions is not fully known and will become apparent with the implementation of such strategies in different cities.

2.5. Previous research in SWEET-DeCarbCH WP7

SWEET-DeCarbCH, **Task 7.1** provides a detailed study of substations in two Swiss DHNs, with a focus on the potential for temperature reduction (Callegari et al., 2023). The studied cases are examples of two contrasting configurations: the CAD-SIG DHN in Geneva is a 2G urban network (with a supply/return temperature around 110/70 °C), whereas the rural DHN Le Marais-Rouge is a 4G network (80/40 °C). CAD-SIG is representative of the large DHN in Swiss cities, which primarily use high-temperature heat sources such as waste incineration and fossil fuels. As SIG and the Canton of Geneva foresee the integration of various RES, the question of temperature reduction has become salient. By contrast, Le Marais-Rouge, which was built in 2007, stands out as an innovative edge case in Switzerland. In particular, buildings connected to Le Marais-Rouge are equipped with substations specifically designed to optimize return temperatures and reduce peak loads from DHW production. By contrast, the substations in CAD-SIG are heterogeneous and their properties and connection typologies had not been studied so far. Hence, part of the work in Task 7.1 was to characterize the existing substations in CAD-SIG.

These analyses have produced the following insights:

- In both DHNs, analyses revealed a sub-optimal functioning of several substations, suggesting that there is substantial potential to improve the efficiency of the networks by optimizing substation performance. An extensive measurement campaign on selected substations of the CAD-SIG network further revealed that high return temperatures were mostly caused at the level of heat exchangers in substations, rather than on the secondary side in the buildings. This further highlights the importance of the substation as a point of intervention for temperature reduction strategies. Concretely, monitoring substations is recommended to quickly identify malfunctioning or inefficient substations.
- Numerical simulation, informed by monitoring data from the Marais-Rouge case, suggest that the adoption of the cascading substation architecture used in that network could be beneficial in Geneva. However, differences in climate reduce the potential benefits of these substations in Geneva.
- Furthermore, regardless of substation architecture, the Marais-Rouge case study highlights the benefits of a homogenous substation architecture within the network: for example, maintenance and repair costs can be reduced.

Task 7.2 aims at estimating the temperature reduction potential in a DHN with the existing configuration, i.e. without replacing any substations or heat exchangers. The analyses focus on the case study of Le Lignon, Geneva, which is a subset of the CAD-SIG grid studied in Task 7.1. Based on a year of measured data at a 10-minute resolution and a thermal model of the substations and buildings, the study assesses whether the existing heat exchangers can still operate effectively (i.e., the simulated pressure drop on the primary side, mass flow on the primary side and mass flow on the secondary side are all within an acceptable range) under various temperature reduction scenarios. The analysis

² See: https://www.gesetzessammlung.bs.ch/app/de/texts_of_law/772.600/versions/6527, §29

concluded that, given a reduction of design power by 20%, a reduction of DHN supply temperature by 10 K appears feasible without needing to replace any heat exchangers.

Task 7.3 evaluates the interactions of temperature reduction strategies with other targets of strategic energy planning, also based on data from Le Lignon. The analyses revealed that currently, thermal losses on the distribution network amounted to 3.5% of annual demand, which is a low figure for high-temperature networks. This is explained by the very high heat demand density in Le Lignon. Nevertheless, temperature reduction offers further savings potential: a reduction of supply and return temperature by 15 K would lead to a reduction of network losses by about 15%. Furthermore, scenarios developed by SIG and the Canton of Geneva foresee the installation of a large-scale heat pump on the DHN, in the vicinity of Le Lignon subgrid. According to calculations in Task 7.3, reducing network temperature by 15 K would lead to savings of 15% in the heat pump's electricity consumption, compared to a scenario without temperature reduction.

2.6. Insights from the existing literature and previous research in DeCarbCH

- There appears to be a gap between the state of the art in international literature on temperature reduction and the plans of Swiss cities and DH utilities: whereas the literature describes a transition to 4GDH, the identified Swiss cities who foresee temperature reduction plan to reach 3GDH temperatures, or simply to make the operation of 2GDH networks more efficient. Where 4GDH temperatures are considered, they are usually envisioned in separate networks, which may or may not be connected to the existing high-temperature DHNs.
 - This is consistent with the goal-gap mechanism with which Speich & Ulli-Beer (2024) explain the adoption of technological innovations for DH: cities and utilities consider new solutions to the extent that these are seen as necessary to reach public policy goals, especially net-zero targets. In the cities mentioned above, the comparatively modest temperature reduction goals were found sufficient to enable a DH system compatible with net-zero targets.
 - Nevertheless, this does not imply that Swiss cities are not ambitious enough: assessing the costs and benefits of a transition towards lower temperatures should be undertaken with a detailed, case-specific analysis.
- The analysis of the current situation in Geneva allows an assessment of the multiple constraints on the achievable network supply temperature:
 - Some substations show problematic behavior, leading to high return temperatures on the primary side. The reasons for this are heterogeneous, such as control or design issues of the heat exchangers. The implication is that a targeted monitoring and heat exchanger upgrade program allows some reduction of the network's return temperature. As a caveat, the heterogeneity of substation configurations represents a challenge for assessing the performance of SST.
 - An analysis of a subset of SST suggests that a supply temperature reduction of 10K is feasible without major interventions on the heat exchangers, assuming a minor decrease in required peak power. This analysis revealed that the mass flow on the secondary side was often the limiting factor.
 - Building envelope retrofits only had almost no effect on the return temperature from the retrofitted buildings.
 - Even when building envelopes, substations and the primary network allow a further decrease of network temperature, temperature requirements for DHW represent a further limiting factor for temperatures below 60 °C.

3. Methods

3.1. Adaptation of the SCOVILLE framework to the question of temperature reduction

This study uses the SCOVILLE simulation framework, adapted to explore the impact of temperature reduction strategies and building retrofit policies on the KPIs of sustainable rollout and operation of DHN. Concretely, this report focuses on the following KPIs:

- Heating prices for consumers (CHF/kWh) and annual energy costs for heating (CHF/Year).
- Annual GHG emissions from heating in the simulation area.
- Market share of DH in the designated supply area [% of heating demand].

SCOVILLE is a System Dynamics-based simulation framework aiming at exploring the impact of strategy and policy interventions on the socio-economic KPIs of DH mentioned above. The original formulation of SCOVILLE focused on the effects of the rollouts of DH networks, which are a major part of municipal net-zero strategies in many Swiss cities and municipalities. In this report, we present a revised formulation of the model aimed at reflecting the effect of supply temperature reduction. This is part of an ongoing effort to assess the effect of innovative technological solutions for DHC beyond technical potential studies. The changes made to the model (compared to the June 2025 version available under <https://www.aramis.admin.ch/Default?DocumentID=73685>) are described below.

3.1.1. Disaggregation of old and retrofitted buildings

At the core of a SCOVILLE model are stocks representing the buildings, grouped by heating system (Figure 7). The flow from one stock to another is determined by the assumed lifetime of a heating system, as well as the perceived utility of each heating system (oil, gas, heat pump, DH) by building owners. Each stock further has a subscript “area”, so that stocks are disaggregated by geographical area (representing e.g. different expansion phases of a DH grid).

In this revised formulation, buildings are further disaggregated into old and retrofitted buildings. Therefore, an additional subscript “retrofit status” was added. As a result, the choices of building owners are more complex: they may decide to switch to a different heating system (or not), and owners of old buildings may further decide to renovate the envelope. Also, the perceived utility of heating systems is calculated for both old and renovated buildings. Heating system switches within a renovation category are treated as in the previous version, using the respective utility function for old and renovated buildings. Envelope retrofits (either together with a heating system switch or not) are driven by a prescribed deep retrofit rate (set to 1.5% of old buildings renovating each year), instead of the heating system lifetime. This implicitly recognizes the role of deep retrofits as triggers for heating system switch.

As another result of this disaggregation, the thermal performance of buildings (heat loss coefficient) is simulated separately for old and renovated buildings.

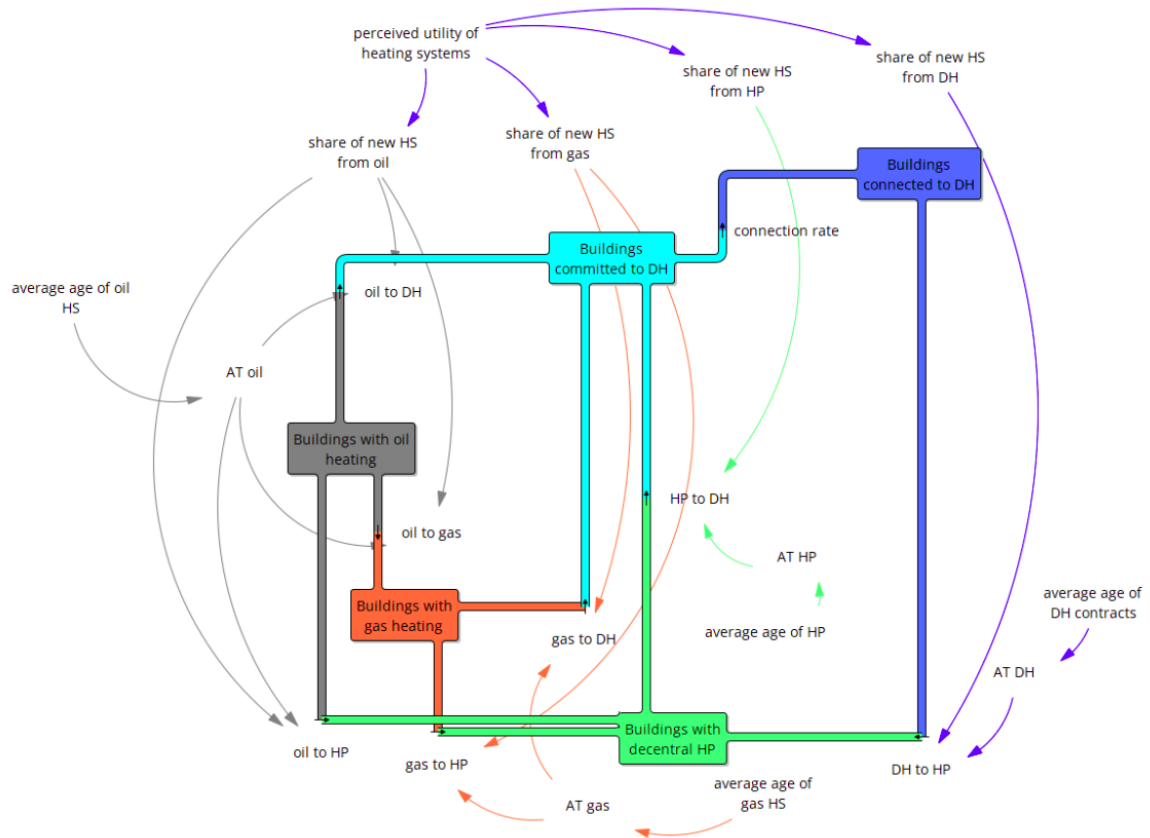


Figure 7: Building stocks as represented in the SCOVILLE simulation framework.

3.1.2. Tariff model and financing

In the original SCOVILLE formulation, the tariff was calculated with a heuristic based on a long-term estimation of costs and energy sales, as well as a short-term financing need (e.g., to close a gap between desired and current annual net cash flow). Based on further model testing and stakeholder feedback, the formulation of tariff was revised:

- The long-term and short-term component heuristic was abandoned. Instead, the price signal to the customer is divided between a power-based component (per kW) and an energy-based component (per kWh). The indicated value for these price components is obtained by dividing annual cost recovery need by overall connected power and also, separately, by annual energy sales. Each component is then weighted by the policy lever “infrastructure orientation” (Dimensionless 0-1, with 0 meaning that all costs are recovered through the energy component and 1 meaning that all costs are recovered through the power component). The default value for this parameter was set to 0.3.
- The price calculation no longer relies on long-term forecasts. Instead, the costs to be recovered reflect actual costs in the current years, i.e. OPEX (energy procurement and regular maintenance costs) and CAPEX (annuitized investment costs with interests).

3.1.3. Constraints on supply temperature reduction

Supply temperature is treated as a stock (Figure 8). Starting from an initial value (set here to 110 °C), supply temperature is reduced to match an indicated value, which represents the maximum of two constraints: the thermal needs of buildings, and the return temperature of the network. To account for delays (e.g., the utility does not immediately have the necessary information on substations, or may choose to lower supply temperature gradually to avoid problems with customers), the adjustment is slowed down with an adjustment time parameter, set here to 5 years.

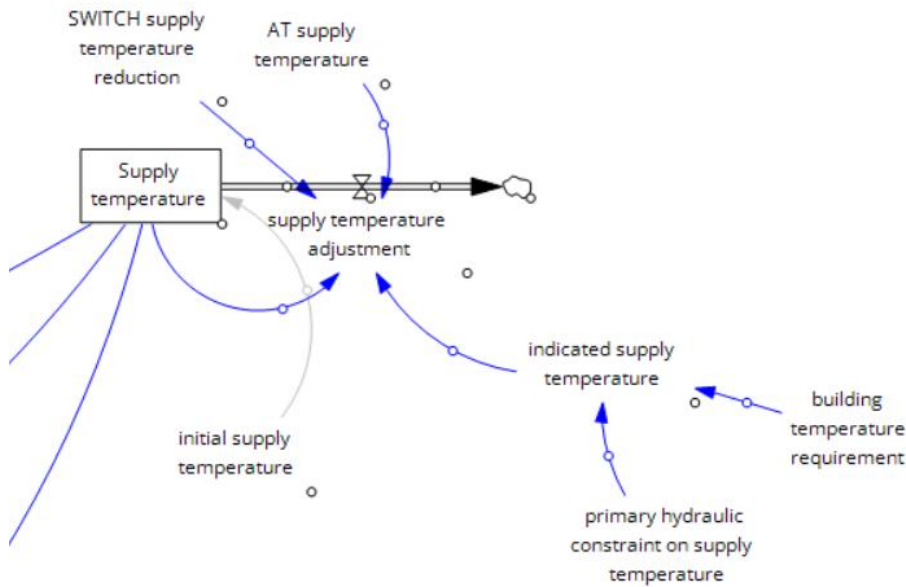


Figure 8: Simulation of supply temperature as a stock.

The temperature requirements of buildings are defined by the worst performing buildings in the network. Since buildings are not modelled individually but as (homogenous) stocks, the requirements of the worst buildings are not simulated explicitly. Instead, the model uses a look-up function to parametrize this: under a targeted retrofit policy as applied in Geneva (e.g. buildings with a certain thermal performance are obligated to renovate by a fixed date), it can be assumed that the thermal constraint of buildings relaxes fast (Figure 9). By contrast, without such a mandate (but assuming the same deep retrofit rate), it can be assumed that the worst buildings will not be renovated for a long time, thus leading to a much flatter decrease (Figure 10). While the profile for targeted policies is informed by the empirical results of Task 7.3, the profile for a “random” renovation policy represents an educated guess and will require further validation.

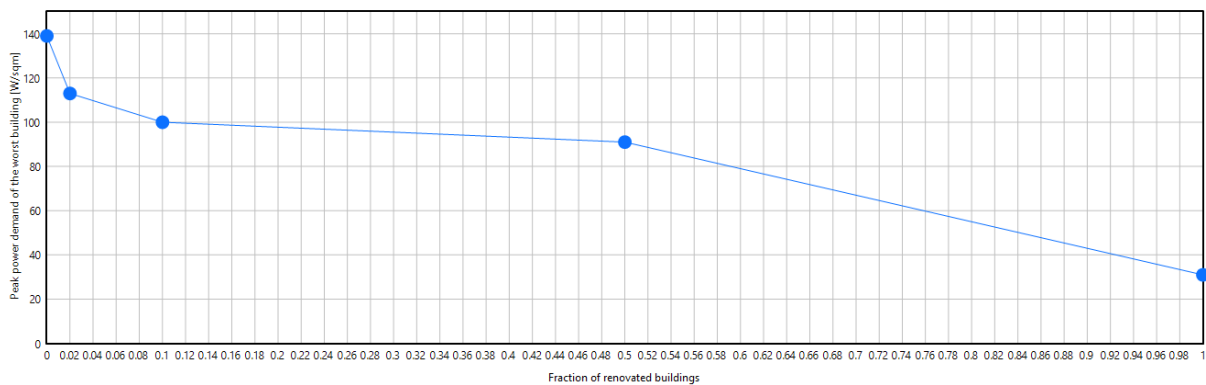


Figure 9: Parameterisation of the current peak power of the worst building under a "targeted" retrofit policy.

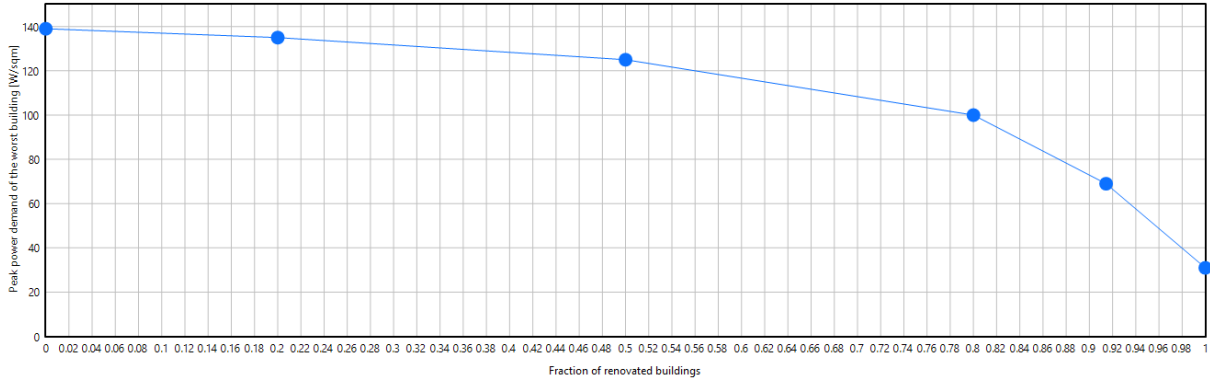


Figure 10: Parameterisation of the current peak power of the worst building under a "random" retrofit policy.

The thermal requirements of the current “worst” building’s radiators is estimated with as:

$$\text{room temperature} + (\text{design radiator temperature} - \text{room temperature}) \\ * \left(\frac{\text{power required by current worst building}}{\text{historical worst case power requirement}} \right)^{1/1.3}$$

This formulation scales the peak power requirement based on the ratio of the current “worst” building’s peak power demand and a historical worst case. This carries the implicit assumption that the pipes and radiators can be considered equivalent in all old buildings, whereas the envelope varies to some degree.

In addition, the model accounts for the effects of substations on the thermal requirements of buildings: The fraction of optimized substations is modelled as a stock, with an annual deterioration rate as well as an annual optimization rate. This entails both the replacement of substation heat exchangers with larger units, as well as minor technical fixes (e.g. resetting operational settings, cleaning, etc.). The temperature difference from substations is added to the radiator thermal requirements mentioned above, with a value between 11 K (if the fraction of optimized substations is zero) and 3K (if the fraction of optimized substations is one).

The network hydraulic constraint is based on return temperature, calculated by the weighted return temperature of deteriorated and optimized substations. We assume here a return temperature of 70 °C from deteriorated substations and 45° from optimized substations. For a given network return temperature, the lowest possible supply temperature is given as:

$$\text{network return temperature} + \frac{\text{target transmission capacity}}{\text{maximum grid mass flow} * 4.18}$$

The target transmission capacity [MW] can be e.g. the current connected peak demand, or the foreseen peak demand at the end of the grid rollout. The maximum grid mass flow reduces the network’s pipe layout to a single scalar, with the simplifying assumption that there is one main transmission pipe that dictates the hydraulic constraint for the whole network.

3.1.4. Energy mix in the DH network

In the original SCOVILLE formulation, the energy mix of DH was static and represented only implicitly through (constant) energy procurement costs and the emission factor for DH. Since this study focuses on temperature reduction as a prerequisite for the integration of low-temperature, renewable energy sources, it is necessary to explicitly and dynamically model the energy mix. Consistent with the case study setup (see below), the model needs as input the installed capacity for three generation units: a waste-to-energy (WtE) baseload, a large-scale heat pump and a natural gas boiler for peak loads.

The energy required from these generation plants (i.e. the sum of energy delivered and network losses) is allocated to each of these sources based on an exponential approximation of a typical load duration curve (Cueni et al. (2026), Figure 11). The share of energy from each energy source is calculated as the area, delimited by the curve, where the installed capacity of WtE and of the heat pump (dashed horizontal lines on Figure 11), respectively, intersect with the load duration curve.

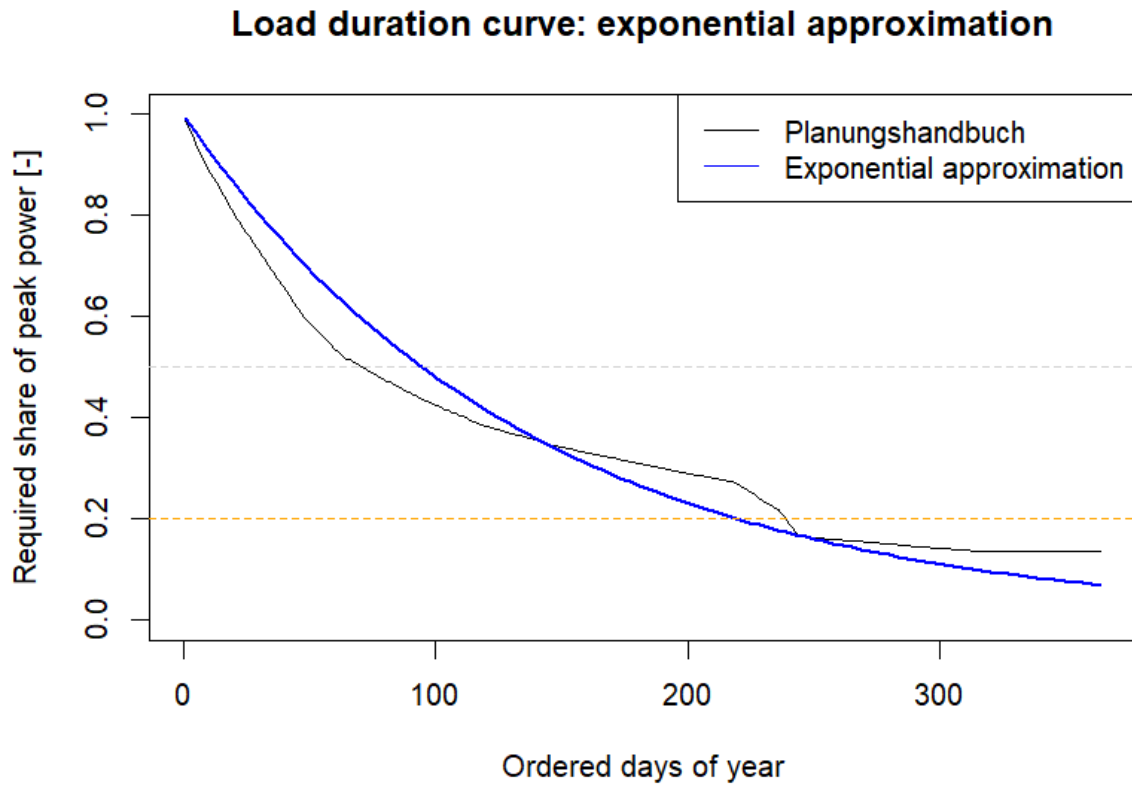


Figure 11: Exponential approximation to the load duration curve used in the model.

D7.3.1 established the dependency of the heat pump's COP on supply temperature. We therefore parameterize the COP accordingly (Figure 12). We assume that 90 °C represents the heat pump's maximum sink temperature. Therefore, the COP does not decrease further above 90°C, which is the upper limit of the temperatures analyzed in D7.3.1. Rather, above this temperature, it is assumed that the heat pump requires additional energy from the gas boilers to achieve the required temperature. The split between electricity and gas input is accounted for in the calculation of energy procurement costs and of the emission factor.

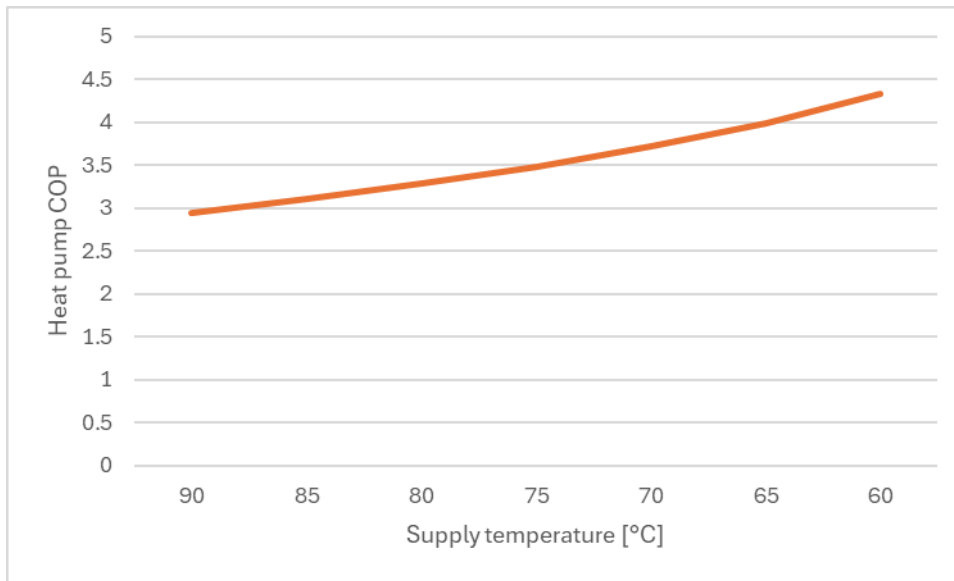


Figure 12: Parameterisation of the heat pump's COP (based on results from D7.3.1).

Additionally, D7.3.1 investigated the dependency of network thermal losses on supply temperature in the case of Geneva-Le Lignon. This parameterization is used here, with linear extrapolation for supply temperatures above 90 °C (Figure 13).

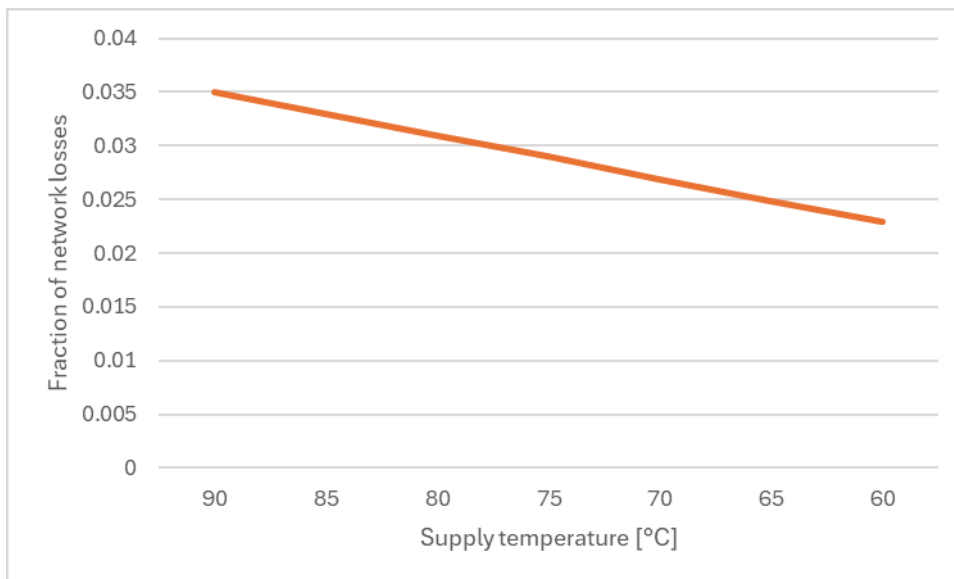


Figure 13: Parameterisation of network losses as a function of supply temperature, based on results from D7.3.1.

3.2. Application to a synthetic case study

(Speich & Ulli-Beer, 2025) The model is applied to a synthetic case study representing the planned DH supply area in a stylized Swiss city to emphasize generic insights of the analyzed strategies and policies. The case is similar to the one presented in D2.3.2 and discussed in a stakeholder workshop in November 2025 (Speich & Ulli-Beer, 2025): an existing district heating grid is set to be expanded in five successive phases over more than a decade. The initial grid has a connected demand of 87 MW, and each of the five expansion phases target a connected demand of 35 MW.

In addition to the estimated power on the demand side, the current model formulation requires an explicit input on the connected heat generation power. This case assumes the following units:

- Baseload WtE: 40 MW

- Large-scale heat pumps: 3 units of 30 MW each, installed between 2030 and 2034.
- Natural gas peak boilers: 150 MW.

Also, electricity prices are scaled based on the Swiss Energy Perspectives 2050+ (Prognos/Infras/TEP Energy/Ecoplan, 2021). For gas prices, accounting for various cost drivers (increased dependence on more expensive biogas and synthetic gases, carbon pricing), a linear annual increase of 0.0032 CHF/kWh was assumed.

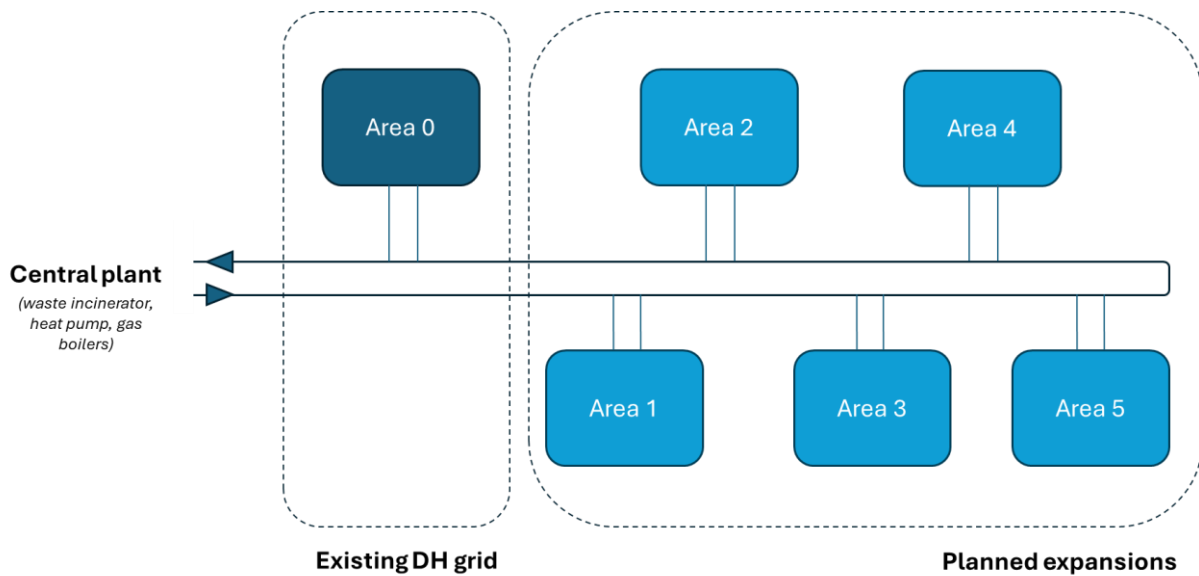


Figure 14: Schematic layout of the stylised case study

In accordance with the case study's objective, the stylized case is loosely based on the example of Geneva. In particular, the following aspects are based on the Geneva example:

- The explicit strategy to reduce supply temperatures in the whole city's grid to enable the integration of renewable energy sources, which is rare in Switzerland (cf. Section 2.4).
- The type of energy sources used: WtE and natural gas for peaks, not complemented with heat pumps.
- The ordering of these energy sources as baseload, mid and peak load, respectively.
- The exploration of a targeted building renovation policy.
- Empirical results from Tasks 7.1-7.3 are used to parameterize the model.
- As in previous model applications (Speich & Ulli-Beer, 2025) the scenarios all foresee a ban on new fossil based heating systems, which comes close to Geneva's quasi-ban policy.

Nevertheless, this study cannot be taken as a model study of Geneva. In particular, the following aspects differ:

- The area characteristics do not represent data from Geneva or any other city, but correspond to the synthetic case defined earlier.
- In Geneva, the existing high-temperature grid is physically interconnected with other grids (e.g. the low-temperature grid Genilac) and tariffs are fixed over the entire DH system. In this synthetic case, the grid is treated as stand-alone in this respect.

3.3. Simulation experiments

The aim of this study is to compare different socio-technical variants for the implementation of temperature reduction strategies in the context of transitioning from a 2GDH network with conventional heat sources (waste incineration CHP and fossil fuels) to a 3GDH network integrating a

range of RES. The selected variants should reflect plausible policy and strategy mixes by the municipality and DH utility in a Swiss context. An overview is given in Table 3

First, a simulation without any temperature reduction is carried out (*noTred*). The remaining simulations differ to analyze the impact of the following aspects:

- For the calculation of the network hydraulic constraint: does the target transmission power represent the current peak demand (based on currently connected loads) or the long-term foreseen target peak demand?
- Does the city have a targeted building retrofit policy, as in Geneva, or is building retrofit happening without targeting the worst buildings first (“random”)?
- In addition to the assumed deep retrofit rate of 1.5% (1.5% of old buildings get renovated every year), scenarios include a low and a high rate.

Table 3: Overview of simulation experiments.

Simulation name	Supply temperature reduction approach	Building retrofit policy	Deep retrofit rate
noTred	None	-	1.5%
toCurrent_random_mid	Based on current peak demand	Random	1.5%
toCurrent_random_low	Based on current peak demand	Random	1%
toCurrent_random_high	Based on current peak demand	Random	2%
toCurrent_targeted_mid	Based on current peak demand	Targeted	1.5%
toCurrent_targeted_low	Based on current peak demand	Targeted	1%
toCurrent_targeted_high	Based on current peak demand	Targeted	2%
toMax_random_mid	Based on foreseen peak demand	Random	1.5%
toMax_random_low	Based on foreseen peak demand	Random	1%
toMax_random_high	Based on foreseen peak demand	Random	2%
toMax_targeted_mid	Based on foreseen peak demand	Targeted	1.5%
toMax_targeted_low	Based on foreseen peak demand	Targeted	1%
toMax_targeted_high	Based on foreseen peak demand	Targeted	2%

4. Results

The result section presents different simulation results that highlight interaction of constraint relaxations and required supply temperature (4.1), their dynamic impact on techno-economic benefits, e.g. COP of central heat pump (4.2) and socio-economic impact on KPIs e.g. annualized heating costs and GHG-emissions (4.3).

4.1 Constraints on supply temperature reduction

Relaxation of the constraint of the building temperature requirement: The first constraint on supply temperature reduction, building temperature requirement, differs markedly between targeted and random retrofit policy scenarios (Figure 15). Targeted scenarios allow a reduction to less than 80 °C already at the beginning of the simulation, whereas random scenarios start around 90 °C and reach 80°C only at the end of the simulation period (2050), and only for high renovation rates.

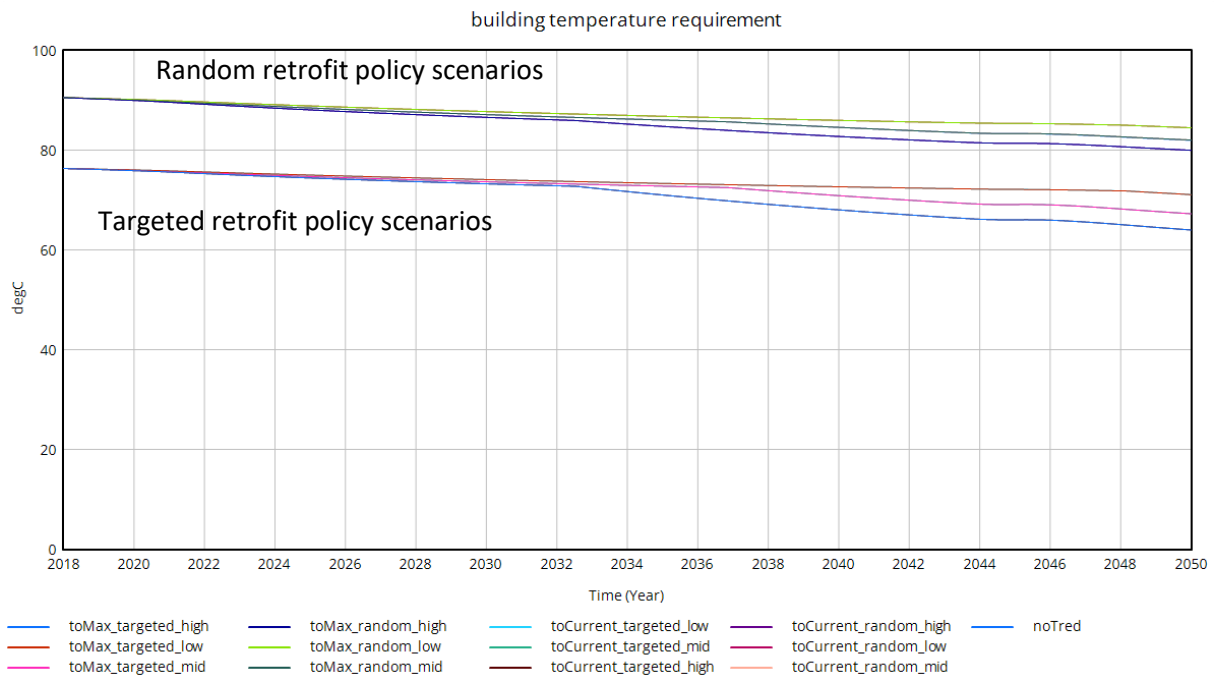


Figure 15: Simulated temperature requirements of buildings in the DH grid.

Relaxation of the constraint due to transmission capacity: On the network side, there is a marked difference between setting the target transmission capacity based on current or future loads (Figure 16): in the former case (toCurrent), this constraint drops below 70°C initially (i.e. the network has ample hydraulic leeway to reduce supply temperature) but increases over time as more loads are connected to the grid. Under the second approach (toMax), this constraint is initially around 90 °C, and drops gradually to slightly more than 80 °C, as old substations are optimised and new connections (with substations optimised from the beginning) are connected. The building retrofit policy only has a very marginal effect here.

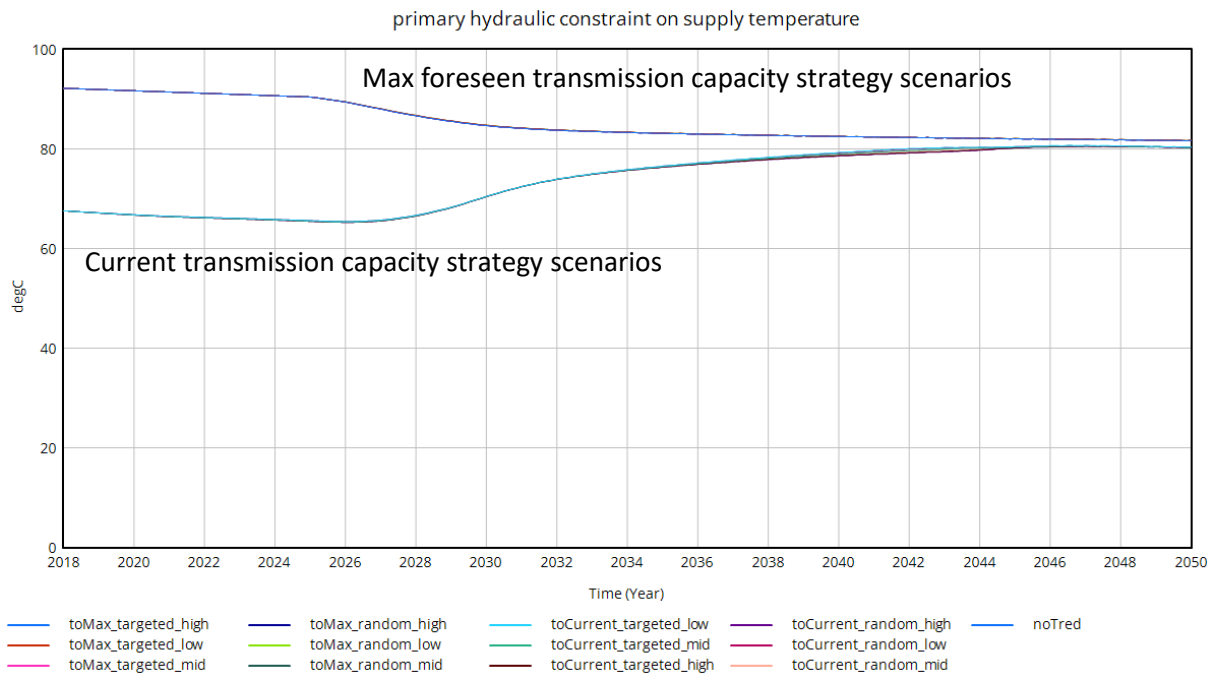


Figure 16: Simulated hydraulic network constraint on supply temperature.

Impact of the constraints on the required supply temperature: The supply temperature, based on the maximum of these constraints and accounting for delayed decision-making, follows a similar pattern for most scenarios: a gradual descent towards 80–85 °C at the end of the simulation, which is steeper at the beginning. All these scenarios reach 90°C by 2030 or shortly thereafter, meaning that there is barely any need for additional energy from gas boilers to lift the temperature of the heat pump sink. Only the combination of the two more favorable approaches enables further temperature reductions: in the *toCurrent_targeted* scenarios (i.e. there is ample hydraulic leeway in the network and the buildings with the greatest thermal requirements are renovated fast), the supply temperature drops below 80°C by 2028. Due to increasing hydraulic constraints with additional connected loads, the supply temperature rises again slightly in the second half of the simulation.

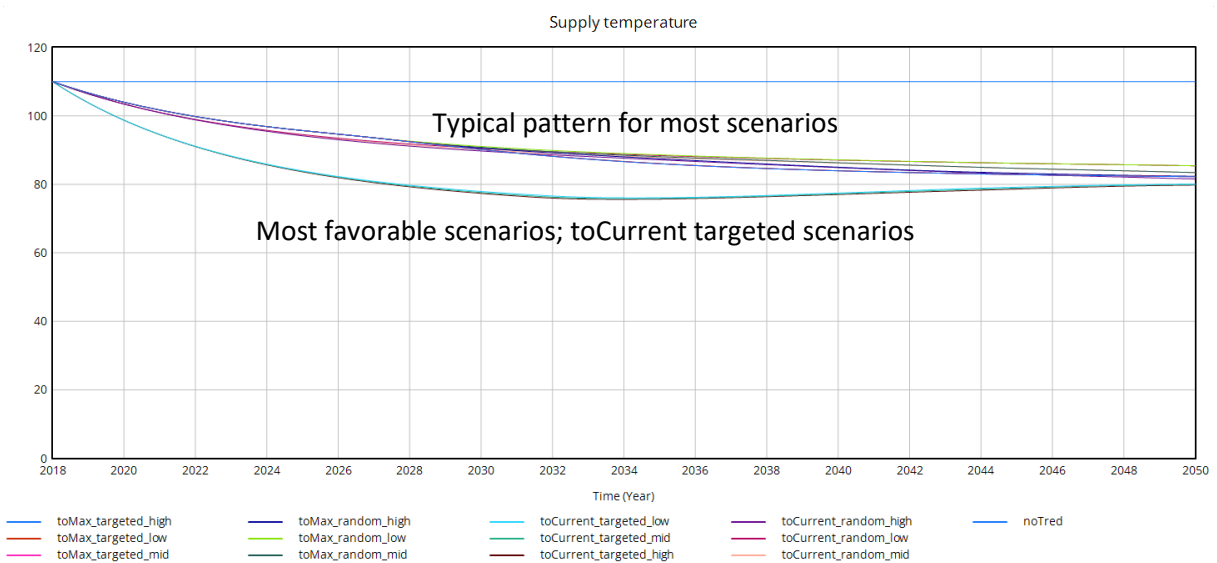


Figure 17: Simulated supply temperature in all scenarios.

4.2 Technical benefits of supply temperature reduction

Supply temperature reductions provide distinct techno-economic benefits: the following five simulation results show the dynamic benefits of the scenarios on 1) COP of central heat pump, 2) network losses, 3) share of gas in heat pump energy, 4) effective energy procurement costs and 5) effective GHG emission factor.

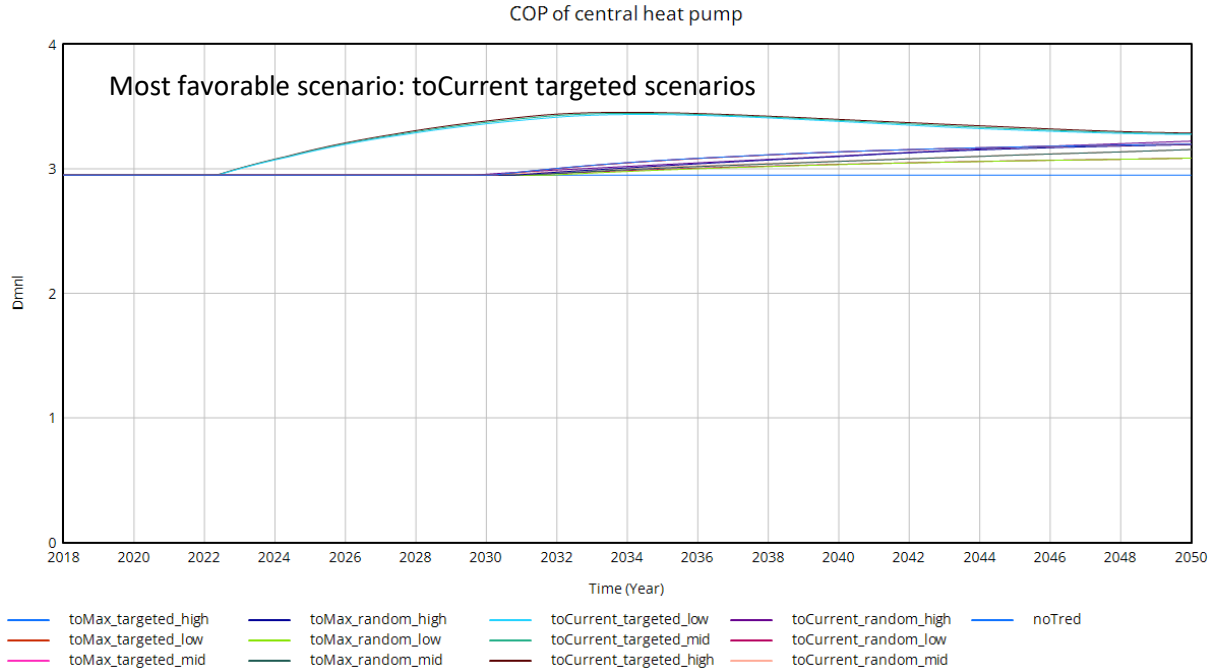


Figure 18: Simulated COP of the central heat pump.

The differences in supply temperature translate into different benefits for the integration of renewable energy sources and for energy efficiency, i.e. in substantially higher heat pump COP (Figure 18) and lower network losses (Figure 19) for the *toCurrent_targeted* scenarios.

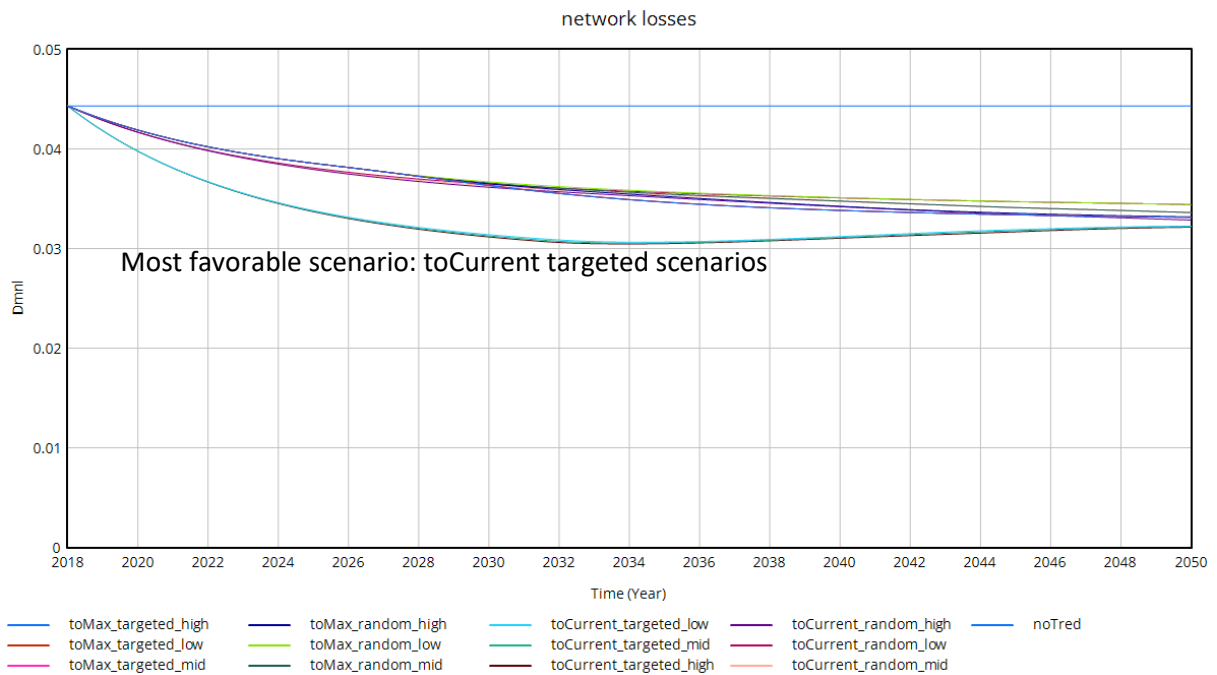


Figure 19: Simulated network losses (fraction of total energy requirement from generation plants).

As mentioned above, in all scenarios (except *noTred*), the supply temperature drops fast enough to avoid a substantial share of additional natural gas use by the time the first heat pump is installed in 2030 (Figure 20).

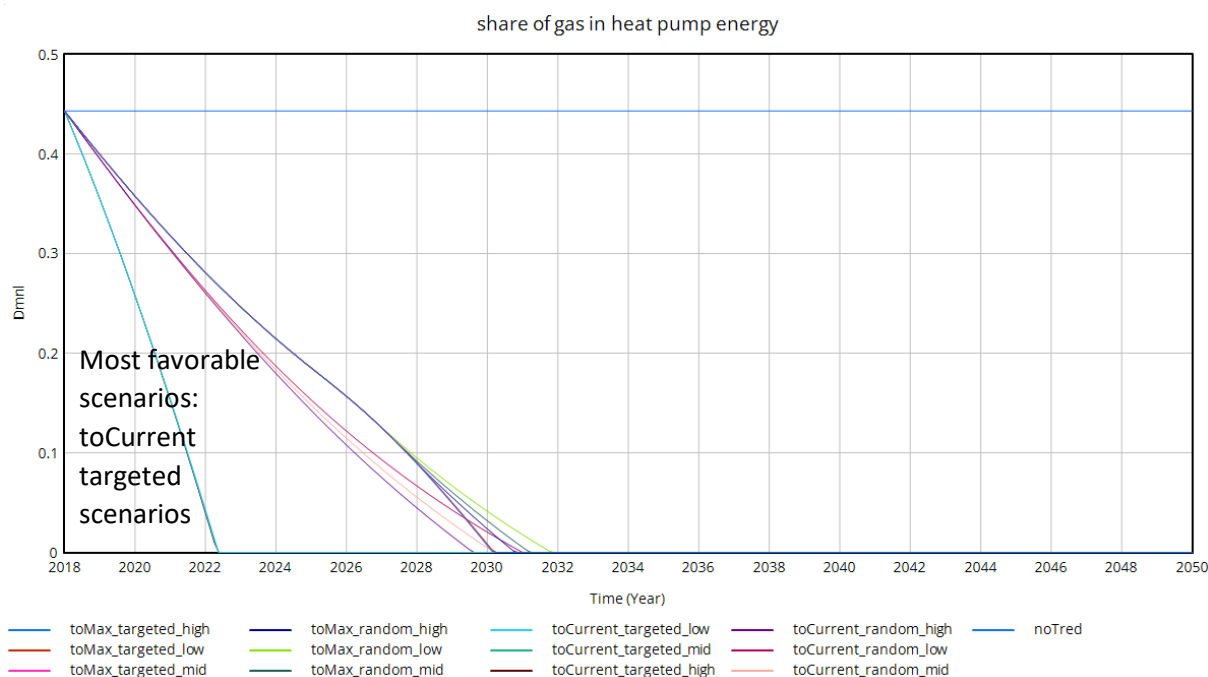


Figure 20: Simulated share of gas (for temperature lift) in the share of energy provided by the large-scale heat pump units

The energy procurement price is impacted by the energy mix, and thus by temperature reduction (Figure 21). In the beginning of the simulation, all scenarios show an accelerating increase. This is explained by the increased use of the gas boilers for peak load as demand increases (more buildings being connected). The integration of heat pumps helps mitigate this, albeit to a different extent: under the *noTred* scenario, the economic benefits of heat pump integration are much smaller than under the other scenarios, particularly the *toCurrent_targeted* scenarios. In the second half of the simulation, the price rises again, reflecting the prescribed rise in electricity and gas prices.

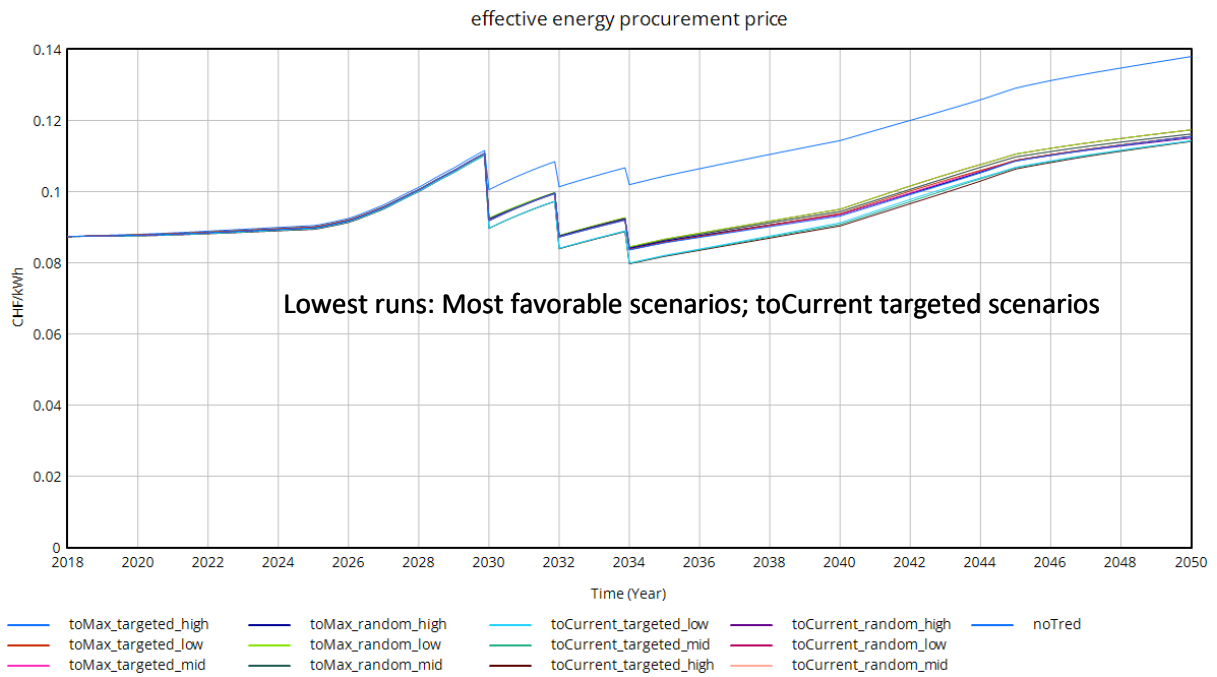


Figure 21: Simulated energy procurement price based on the annual energy input share of waste incineration excess heat, electricity and natural gas.

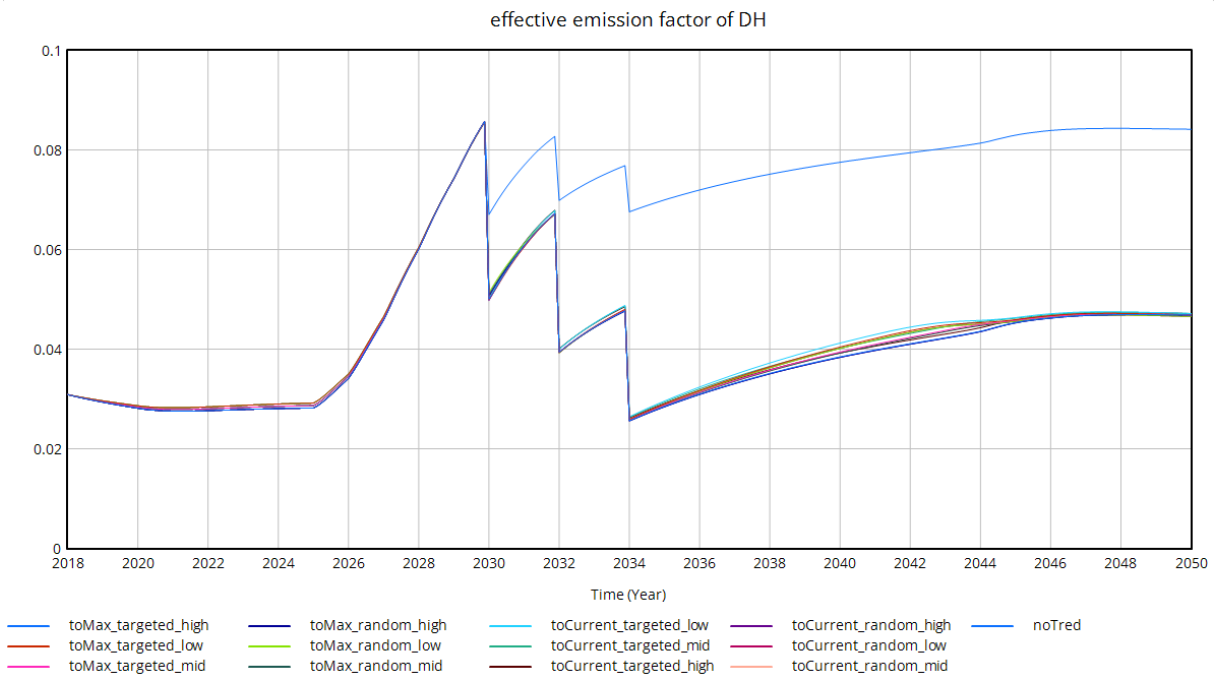


Figure 22: Simulated emission factor of the DH grid [kg CO₂e/kWh]

A similar effect is seen for the emission factor (Figure 22), which is driven primarily by gas energy input. As a result of the increased need to use gas boilers to satisfy a growing demand, the emission factor almost triples within a few years for all scenarios before the heat pumps are installed.

4.3 Impact on socio-economic KPIs

The model simulates consumer prices disaggregated in a power and an energy component. For the evaluation of results, however, the model also outputs an average price enabling a comparison with other heating systems (Figure 23). This output highlights the economic benefit patterns of temperature

reduction: after the heat pumps are installed, the price stays comparatively high under the noTred scenario, whereas it substantially drops under the temperature reduction scenarios. In all scenarios, the price rises at the end of the simulation, reflecting the prescribed rise in electricity and gas prices, but also improved energy efficiency and thus reduced demand from connected buildings.

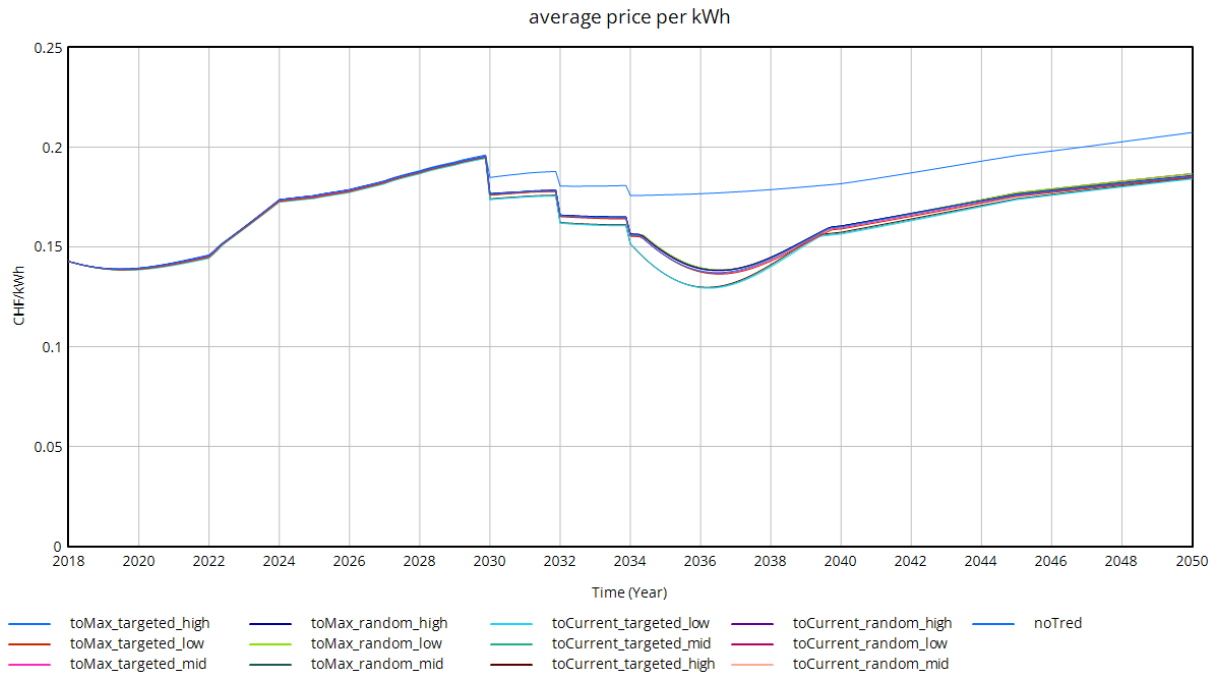


Figure 23: Simulated average price per kWh (output variable only: in the model, the price signal to consumer is based on connection, standing and energy prices).

Translating this price into annual heating costs for a typical apartment shows a frequently encountered pattern: district heating is cost-competitive with heat pumps, but more expensive than fossil fuels (not shown, since fossil fuels are banned in all scenarios). The benefits of temperature reduction become apparent in the second half of the simulation, where all scenarios enable annual savings of up to CHF 500 for old apartments (Figure 24) and CHF 200 for renovated apartments (Figure 25) on heating costs compared to *noTred*.

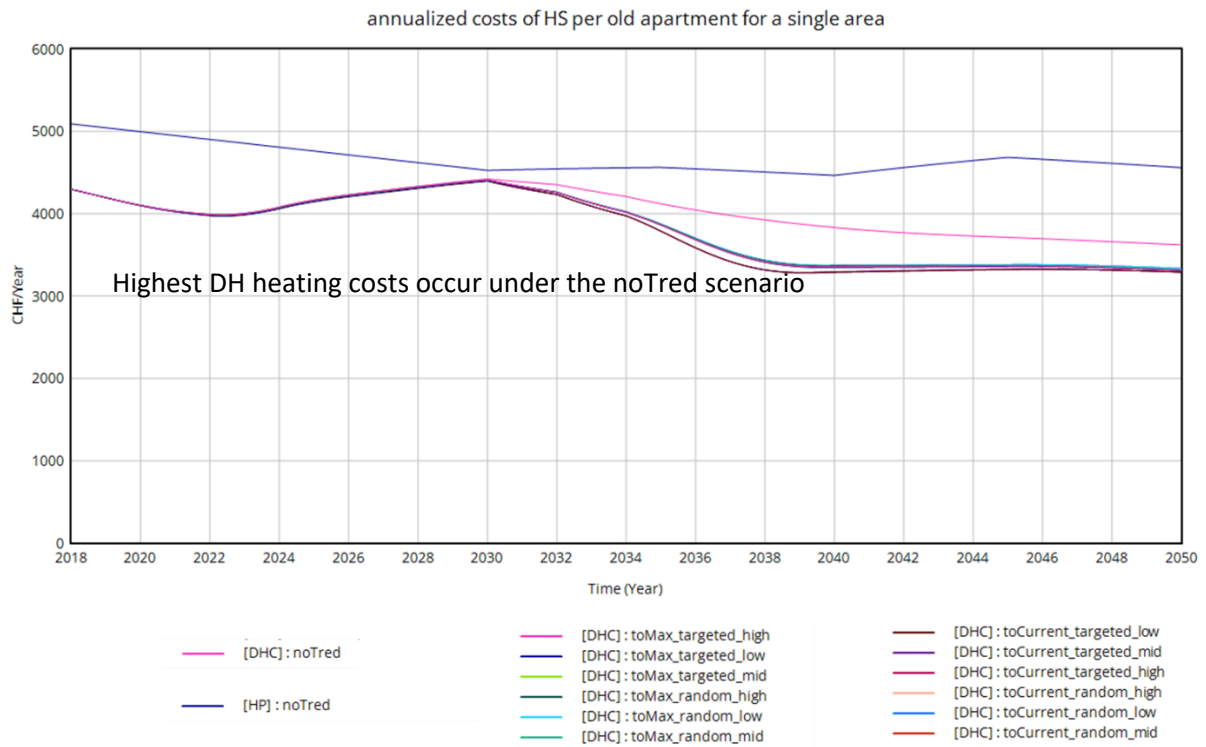


Figure 24: Simulated annualised heating costs for an old apartment.

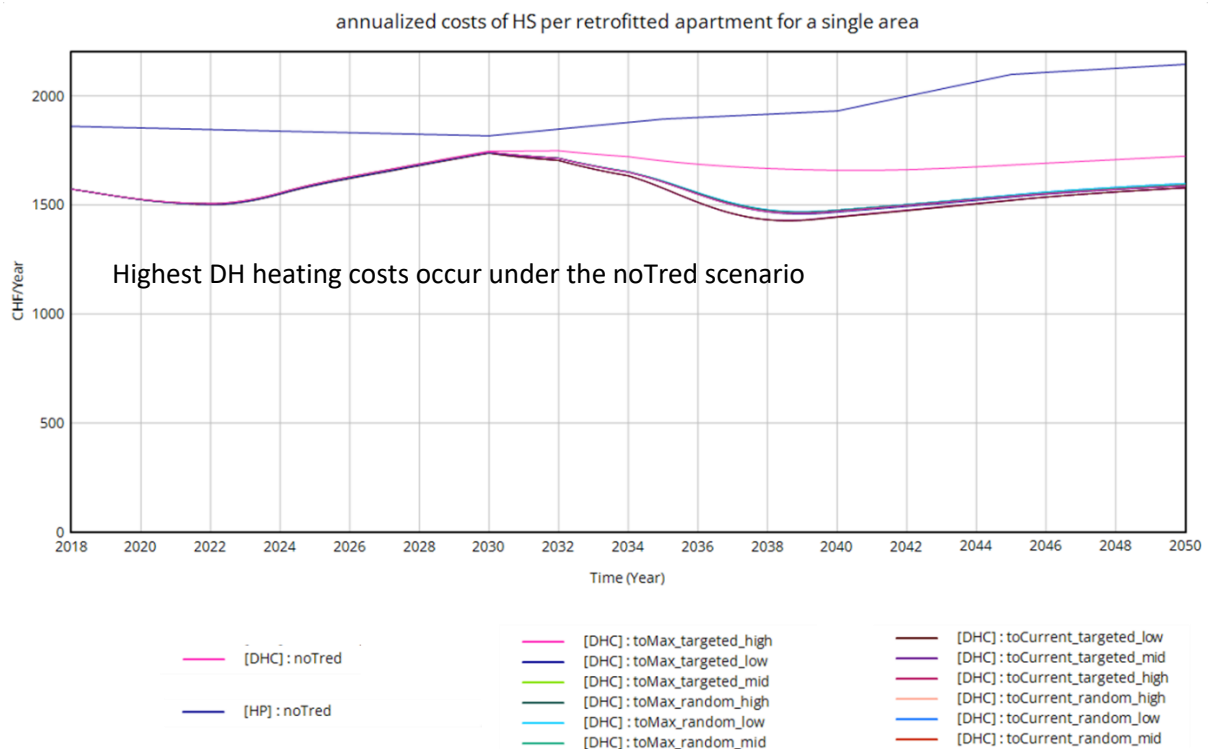


Figure 25: Simulated annualised heating costs for a retrofitted apartment.

The environmental impact of temperature reduction measures, and of DH rollout in general, principally concerns the reduction of GHG emissions. GHG emissions go down much faster than in the previous model application (Speich & Ulli-Beer, 2025), since this case explicitly includes a large-scale heat pump in the generation mix (Figure 26). While the *noTred* scenario reaches a remaining 20 kT CO₂eq by 2050,

the temperature reduction scenarios allow some more emission reduction due to lower gas consumption. GHG emission reduction is rather insensitive to temperature reduction strategies (*toCurrent* vs. *toMax*) and building retrofit policies (*targeted* vs. *random*), whereas different deep retrofit rates influence the results somewhat.

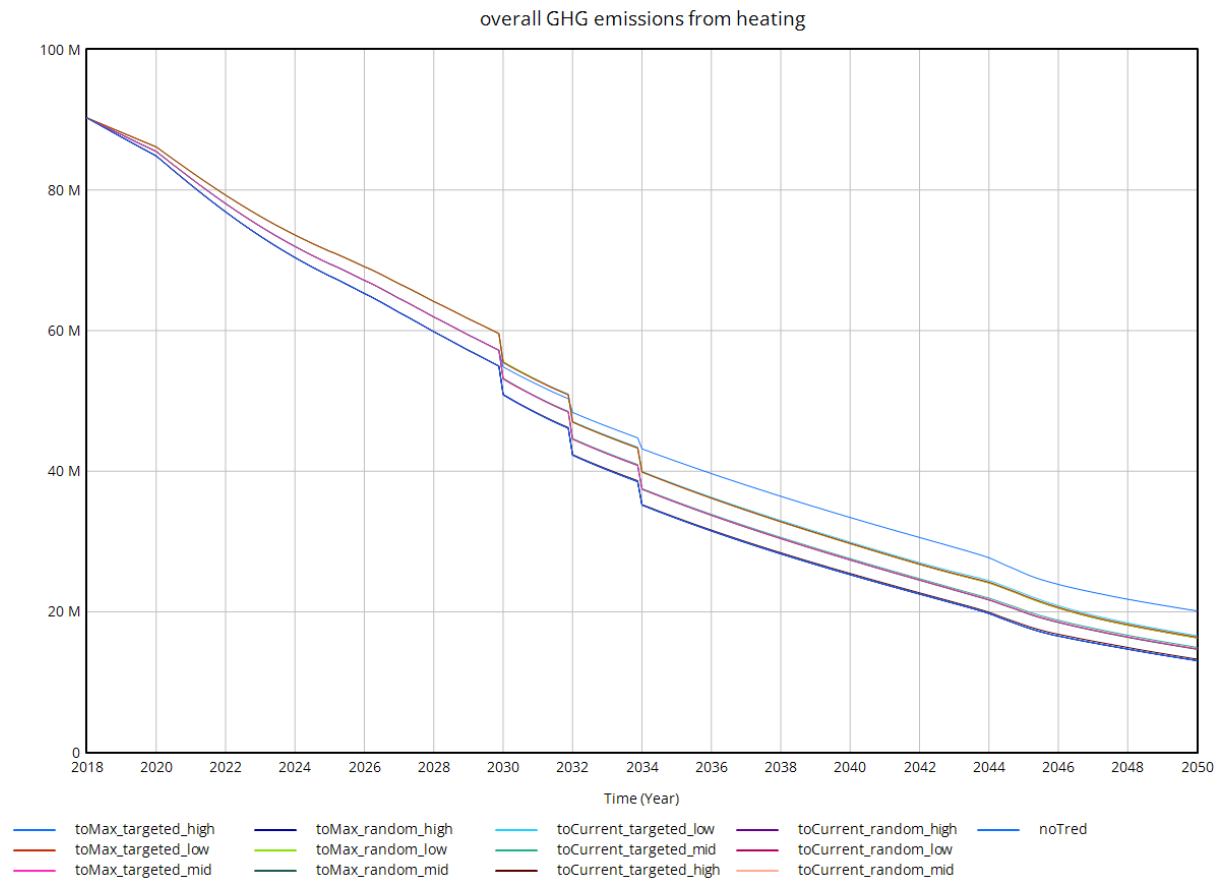


Figure 26: Simulated GHG emissions over the whole simulation area (connected and non-connected buildings) [kg CO₂eq].

Finally, the market share shows only some marginal differences between scenarios (Figure 27), driven mostly by differences in the deep retrofit rate. The effects shown in D2.3.2 and Speich & Ulli-Beer (2025) is apparent again: first, technical improvements, even substantial, to an existing grid are likely to only have a marginal effect on market share, since the choice of building owners is to a large extent already “baked in” by the time the benefits of these measures become apparent. Second, a reduction in heat demand across the whole building park leads to an increase in the market share of DH.

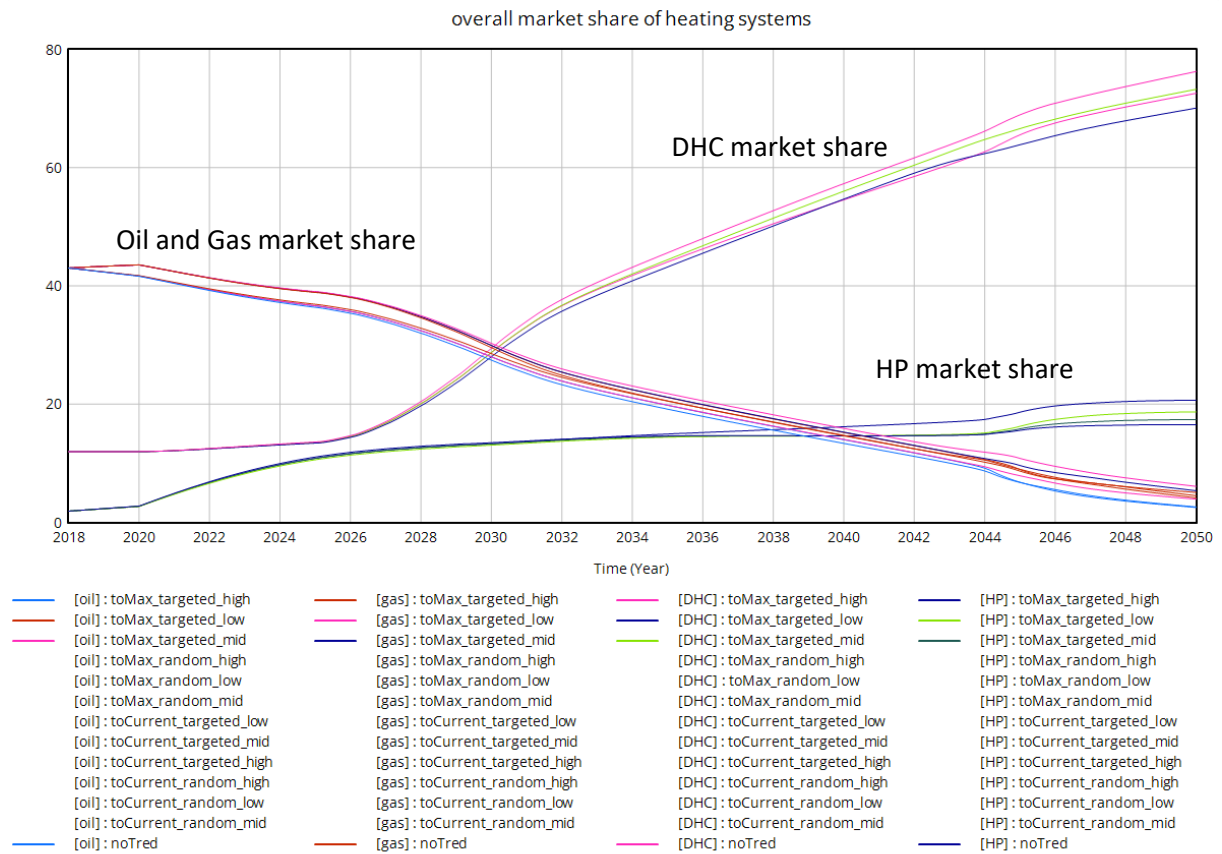


Figure 27: Simulated market share of heating systems (oil, gas, heat pumps, DH) in the simulation area (selected scenarios only).

5 Discussion, Outlook and Conclusion

This report aims to link technological insights on temperature reduction in DH networks to KPIs and policy levers at the level of municipal energy policy and utility strategy, using the SCOVILLE simulation framework. Its results are based on a synthetic case study and therefore cannot be directly translated into case specific policy recommendations. However, its aim is to provide a common framework for discussing the generic insights of temperature reductions strategies and policies in stakeholder workshops to jointly discuss the implications of the insights for policy and strategy formulation.

The case study offers some preliminary insights which, if validated by stakeholders, can inform cities, municipalities and utilities in the future:

- In a DH network integrating large-scale heat pumps, there are important socio-economic benefits in reducing network temperatures (in particular lower heating costs for customers). Therefore, the contribution of temperature reduction strategies to alleviating the trade-off between decarbonization goals and socio-economic impacts (Speich & Ulli-Beer, 2025) can be considered positive.
- Targeted building retrofit policies can substantially help achieve temperature reductions, especially if the DH network has some hydraulic leeway to enable these reductions within the physical bounds set by existing infrastructure.
- However, these levels of temperature reduction do not necessarily translate into much greater socio-economic benefits compared to more modest temperature reduction measures.

Finally, the limitations of this study should be noted. First, the cost of temperature reduction measures (e.g. substation optimization) was neglected in this study. A screening of the relevant literature suggests that these costs are rather small compared to the cash flow of a DH utility. Nevertheless, a more detailed cost-benefit analysis should verify this. Second, the simulation rests on necessary simplifications and empirical parameterizations that should be plausibilized. Finally, the report stays within the range of measures currently foreseen in Switzerland, neglecting the potential of more ambitious temperature reduction goals seen abroad.

References

- Averfalk, H., & Werner, S. (2020). Economic benefits of fourth generation district heating. *Energy*, 193, 116727. <https://doi.org/10.1016/j.energy.2019.116727>
- Averfalk, H., Werner, S., Felsmann, C., Rühling, K., Wiltshire, R., Svendsen, S., Li, H., Faessler, J., Mermoud, F., & Quiquerez, L. (2017). *Transformation Roadmap from High to Low Temperature District Heating Systems. Annex XI final report*. <https://backend.orbit.dtu.dk/ws/portalfiles/portal/142164425/Untitled.pdf>
- Bahadori, R., Speich, M., & Ulli-Beer, S. (2025). Modernizing District Heating Networks: A Strategic Decision-Support Framework for Sustainable Retrofitting. *Energies*, 18(14), 3759. <https://doi.org/10.3390/en18143759>
- Basler Zeitung. (2012, August 7). *Die Basler Fernwärme soll sich abkühlen*.
- Bergstraesser, W., Hinz, A., Braas, H., Orozaliev, J., & Vajen, K. (2021). Lessons learned from excess flow analyses for various district heating systems. *Smart Energy*, 1, 100005. <https://doi.org/10.1016/j.segy.2021.100005>
- Bucheli, M. (2024a). Das Hochtemperaturnetz der Stadt Bern ist unglaublich leistungsfähig. *Aqua & Gas*. https://www.aquaetgas.ch/aktuell/interview/20240130_ag2_das-hochtemperaturnetz-der-stadt-bern-ist-unglaublich-leistungsf%C3%A4hig/
- Bucheli, M. (2024b). Optimierung thermischer Netze in Planung, Projektierung und Betrieb. *Aqua & Gas*. <https://www.aquaetgas.ch/svgw-news/gasfernw%C3%A4rme/20241119-fachtagung-optimierung-thermischer-netze/>
- Callegari, S. A., Novoa-Herzog, R., Schneider, S., Brischoux, P., Duret, A., Jobard, X., & Holzmüller, P. (2023). *Strategies and potentials of temperature reduction on existing district heating substations: two case studies*. <https://archive-ouverte.unige.ch/unige:172333>
- Carron, J., & Sartori, M. (2023). Chauffage à distance de Martigny. Apport énergétique par géothermie de moyenne profondeur. In *Présentation FDV*. https://www.sinergy.ch/files/Presentation-FDV_20231003.pdf
- Cueni, M., Nussbaumer, T., Thalmann, S., & Zaugg, D. (2026). *Planungshandbuch Thermische Netze*.
- ewz. (2025). *Tarif Fernwärme im Wärmeverbund KVA und Holz*. <https://www.ewz.ch/dam/ewz/meinewz/Dokumentencenter/now-fit/wv-kva-holz-tarifsysteem-2022.pdf>
- Geyer, R., Krail, J., Leitner, B., Schmidt, R.-R., & Leoni, P. (2021). Energy-economic assessment of reduced district heating system temperatures. *Smart Energy*, 2, 100011. <https://doi.org/10.1016/j.segy.2021.100011>
- Guelpa, E., Capone, M., Sciacovelli, A., Vasset, N., Baviere, R., & Verda, V. (2023). Reduction of supply temperature in existing district heating: A review of strategies and implementations. *Energy*, 262, 125363. <https://doi.org/10.1016/j.energy.2022.125363>
- IWB. (2025). *2024 Annual Report*.
- Kotilainen, J., Hellstedt, J., & Tolvanen, H. (2025). Determining economic feasibility of supply temperature reduction in existing district heating system through thermohydraulic modelling. *Energy*, 329, 136781. <https://doi.org/10.1016/j.energy.2025.136781>

- Leoni, P., Geyer, R., & Schmidt, R.-R. (2020). Developing innovative business models for reducing return temperatures in district heating systems: Approach and first results. *Energy*, 195, 116963. <https://doi.org/10.1016/j.energy.2020.116963>
- Lygnerud, K., Nyberg, T., Nilsson, A., Fabre, A., Stabat, P., Duchayne, C., & Gavan, V. (2023). A study on how efficient measures for secondary district heating system performance can be encouraged by motivational tariffs. *Energy, Sustainability and Society*, 13(1), 38. <https://doi.org/10.1186/s13705-023-00417-0>
- Lygnerud, K., Ottosson, J., Kensby, J., & Johansson, L. (2021). Business models combining heat pumps and district heating in buildings generate cost and emission savings. *Energy*, 234, 121202. <https://doi.org/10.1016/j.energy.2021.121202>
- Månsson, S., Johansson Kallioniemi, P.-O., Thern, M., Van Oevelen, T., & Sernhed, K. (2019). Faults in district heating customer installations and ways to approach them: Experiences from Swedish utilities. *Energy*, 180, 163–174. <https://doi.org/10.1016/j.energy.2019.04.220>
- Municipalité de Lausanne. (2023). Développement du réseau de chauffage à distance à l'ouest et au sud Financement des centrales de production de chaleur renouvelable locale à partir des eaux du lac à Ouchy et des eaux épurées à Vidy, des réseaux thermiques concernés et d'une nouvelle centrale de distribution et de production de chaleur à Malley. In *Préavis N° 2023 / 06*. <https://www.lausanne.ch/apps/agir/affaire/doc/42/4201cff3eacb4ac299ed9865ec8d56d1.pdf>
- Nussbaumer, T., Thalmann, S., Jenni, A., & Ködel, J. (2018). *Planungshandbuch Fernwärme* (1.2). https://www.verenum.ch/Dokumente/PLH-FW_V1.2.pdf
- Overbye, P. M. (2025). Low-Temperature DH: How to Reduce the Temperature in Existing District Heating Networks. *Hot Cool*. <https://dbdh.org/low-temperature-dh-how-to-reduce-the-temperature-in-existing-district-heating-networks/>
- Pakere, I., Gravelins, A., Lauka, D., Bazbauers, G., & Blumberga, D. (2021). Linking energy efficiency policies toward 4th generation district heating system. *Energy*, 234, 121245. <https://doi.org/10.1016/j.energy.2021.121245>
- Preisüberwacher. (2023). *Geplante Erhöhung der Leistungskomponente der Fernwärmearife von Energie Wasser Bern (ewb) per 1. Januar 2024; Empfehlung der Preisüberwachung*. [https://www.preisueberwacher.admin.ch/dam/pue/de/dokumente/empfehlungen/fernwaerm_e_ewb_24.pdf.download.pdf/Empfehlung Fernwärme ewb.pdf](https://www.preisueberwacher.admin.ch/dam/pue/de/dokumente/empfehlungen/fernwaerm_e_ewb_24.pdf.download.pdf/Empfehlung%20Fernw%C3%A4rme%20ewb.pdf)
- Prognos/Infras/TEP Energy/Ecoplan. (2021). *Energieperspektiven 2050+ - Kurzbericht*. Bundesamt für Energie. <https://pubdb.bfe.admin.ch/de/publication/download/10323>
- Skjølstrup, J. K. (2019). *Best Practices to Lower District HEating Supply Temperatures: Addressing Critical Heat Customers* [Aalborg Universitet]. https://vbn.aau.dk/ws/files/307156358/Final_Master_s_Thesis.pdf
- Speich, M., Chambers, J., & Ulli-Beer, S. (2024). Current and future development of thermal grids in Switzerland: an organizational perspective. *Frontiers in Sustainable Cities*, 6. <https://doi.org/10.3389/frsc.2024.1379554>
- Speich, M., & Ulli-Beer, S. (2024). Business implications of net-zero targets for heating and cooling. *42nd International System Dynamics Conference*. <https://proceedings.systemdynamics.org/2024/papers/O1263.pdf>

- Speich, M., & Ulli-Beer, S. (2025). *Herausforderungen des Ausbaus thermischer Netze im Rahmen kommunaler Klimastrategien*.
<https://digitalcollection.zhaw.ch/server/api/core/bitstreams/b491e4d4-7734-466a-9b7b-4266f001b2ac/content>
- Stadtrat Winterthur. (2025). Festlegung des Transferpreises für den Bezug der Fernwärme von der Kehrrichtverwertungsanlage und Teilrevision der Tarifordnung betreffend die Abgabe von Fernwärme vom 21. November 2018. In *Beschluss-Nr. 2025/379*.
- Stadtrat Zürich. (2018). *ERZ Entsorgung + Recycling Zürich, Fernwärme Zürich-Nord, NetzEntlastungsleitungen 2019–2021, Objektkredit* (p. 2). [https://www.stadt-zuerich.ch/content/dam/stzh/portal/Deutsch/Stadtrat %26 Stadtpraesident/Publikationen und Broschueren/Stadtratsbeschluesse/2018/Sep/StZH_STRB_2018_0802.pdf](https://www.stadt-zuerich.ch/content/dam/stzh/portal/Deutsch/Stadtrat%26%20Stadtpraesident/Publikationen%20und%20Broschueren/Stadtratsbeschluesse/2018/Sep/StZH_STRB_2018_0802.pdf)
- Swiss Federal Office of Energy. (2021). *Potenzial von Fernwärme- und Fernkälteanlagen*.
<https://www.news.admin.ch/news/message/attachments/69676.pdf>
- Werner, S. (2017). International review of district heating and cooling. *Energy*, 137, 617–631.
<https://doi.org/10.1016/j.energy.2017.04.045>
- Zinko, H., Lee, H., Kim, B.-K., Kim, Y.-H., Lindkvist, H., Loewen, A., Ha, S., Walletun, H., & Wigbels, M. (2005). *Improvement of Operational Temperature Differences in District Heating Systems*.
https://www.verenum.ch/Dokumente/2005_IEA_Improvement%20DT.pdf