Technology Collaboration Programme
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IEA DHC|CHP

International Energy Agency
Technology Collaboration Programme on
District Heating and Cooling
including Combined Heat and Power

SUMMARY FOR NON-TECHNICAL AUDIENCES

BEYOND SUBSTATION

COST BENEFIT STUDY ON THE BUILDING SECONDARY NETWORK FOR IMPROVING DH PERFORMANCE

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ABOUT THE INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) is an intergovernmental organisation that serves as energy policy advisor to 28 member countries in their effort to ensure reliable, affordable and clean energy for their citizens. Founded during the oil crisis of 1973-1974, the IEA was initially established to coordinate measures in times of oil supply emergencies.

As energy markets have changed, so has the IEA. Its mandate has broadened to incorporate the "Three E's" of balanced energy policy making: energy security, economic development and environmental protection. Current work focuses on climate change policies, market reform, energy technology collaboration and outreach to the rest of the world, especially major consumers and producers of energy like China, India, Russia and the OPEC countries.

With a staff of nearly 200 who are mainly energy experts and statisticians from its 28 member countries, the IEA conducts a broad program of energy research, data compilation, publications and public dissemination of the latest energy policy analysis and recommendations on good practices.

ABOUT IEA DHC

The Energy Technology Initiative on District Heating and Cooling including Combined Heat and Power was founded in 1983. It organizes and funds international research which deals with the design, performance, operation and deployment of district heating and cooling systems. The initiative is dedicated to helping to make district heating and cooling and combined heat and power effective tools for energy conservation and the reduction of environmental impacts caused by supplying heating and cooling.

CONTENT

INTRODUCTION

District Heating (DH) is an efficient solution to decarbonize building heating by using renewables and industrial waste heat sources. However, one cannot increase the share of these thermal energy sources, which are mostly low-temperature energies, without decreasing primary network return temperatures. Unfortunately, most district heating (DH) systems have been connected to existing buildings with their own heating distribution system, which is generally not optimised for reducing return temperatures. A study undertaken on 135 Swedish substations has shown that 74% of them were faulty (Gadd and Werner, 2015). Moreover, a survey has been carried out on 56 Swedish DHN to investigate the faults that occur in the current DH system (Månsson et al. 2019). The results have shown that DH operators encounter faults frequently, on customers' internal heating systems (31% of faults on substations). Another study on district heating in Sweden (Walletun, 1986) has shown that about 60% of malfunctions in substations stem from buildings' internal heating systems, 30% stem from Domestic Hot Water systems, and the last 10% come from a failure of a substation component (circulation pump, control valve, heat exchanger).

Thus, there is a strong potential for improving the performance of existing and new DH by acting on substations and, in particular, on the secondary side. A better operation of substations reduces the return temperatures on the DH network and consequently improves the DH system's efficiency. Indeed, low return temperatures allow reducing the primary flow rate and so the pump consumption, to decrease the heat losses on the network, but above all to improve the energy and environmental performance of the heating production, for instance, by increasing the rate of use of low-temperature renewable energies (geothermal, solar...). However, it is often difficult for DH operators to implement performance actions on customer installations, as they are generally not in charge of their operation and maintenance.

This project aims to bring out some recommendations to improve the design and operation of second heating systems in order to lower the return water temperatures and to identify heat tariff models in order to foster building owners to improve the building-side hydronic systems.

To achieve these objectives, a state-of-the-art study of substations has been undertaken with the aim of selecting common technical architectures that offer high improvement potential as well as technical upgrades for space heating and Domestic Hot Water systems. Hence, a dynamic thermo-hydraulic modeling tool including all parts of a DH network has been developed. The tool enables one to investigate the energy gains that can be reached by upgrading substations, as well as to analyse the malfunctions and their consequences. First, fault diagnosis indicators have been developed for the ongoing commissioning of substations. Then, a decision tree is proposed to select retrofit actions on secondary heating systems. Finally, based on the simulation results and a literature review, recommendations on heat tariffs to encourage building owners to improve their installations and reduce water return temperatures are proposed.

STATE OF THE ART

A district heating network is composed of heat generation plants where water is heated up and a hot water distribution network composed of pipes that supply substations. The substations separate the distribution network, also called the primary network, from the secondary network supplying domestic hot water (DHW) and the space heating in buildings.

The state of the art is focused on district heating systems in France. Most of the substations have a basic design using a unique heat exchanger for space heating and DHW. Moreover, secondary heating systems are often inefficient when using hydraulic compensators and radiators with a fixed flow rate and a three-way valve. Thus, there are some opportunities for improvement in the performance of substations.

Some retrofit actions studied can be undertaken on four components of the secondary side, and among all the possibilities, only the most common ones have been selected:

- Substation heat exchanger: using two parallel heat exchangers for DHW and space heating instead of a unique heat exchanger.
- Pump and valve: using a variable flow rate pump coupled with two-way valves instead of a variable mass flow rate pump coupled with two-way valves or an even worse system, which is a constant flow rate pump coupled with two-way valves.
- Radiators: using low-temperature radiators instead of high-temperature radiators.
- DHW: using an instantaneous system instead of a bypassed tank architecture or an even worse system, which is a storage tank architecture.

Finally, by combining all these different retrofit actions, 36 cases have been studied. All case studies have been modeled through a thermo-hydraulic dynamic model in the environment MODELICA/DYMOLA.

ENERGY CONSERVATION MEASURES

All the different retrofit action combinations are compared through the primary return temperature. Indeed, a low primary return temperature allows reducing the heat losses in the distribution network, reducing pump consumption, and enhancing the use of low-temperature renewable energy. Thus, the lower the primary return temperature, the better the performance of the DH network.

All the results are summarized in a decision tree. This one is separated into four layers, representing the four types of retrofit actions. On each layer, several options are possible. The best option(s) are represented by a green line, while the worst option(s) are represented by a red line. The best options are those that lower the return temperature of the substation on the primary side. The black dotted arrows represent the gains (on the return temperature) that can be obtained by switching from one combination to another.

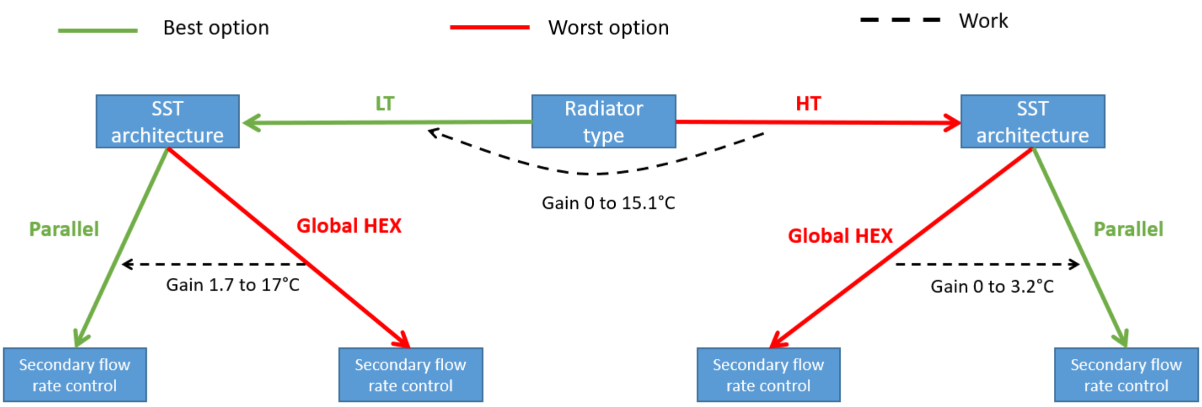

Figure 1 Decision tree summarizing the numerical results

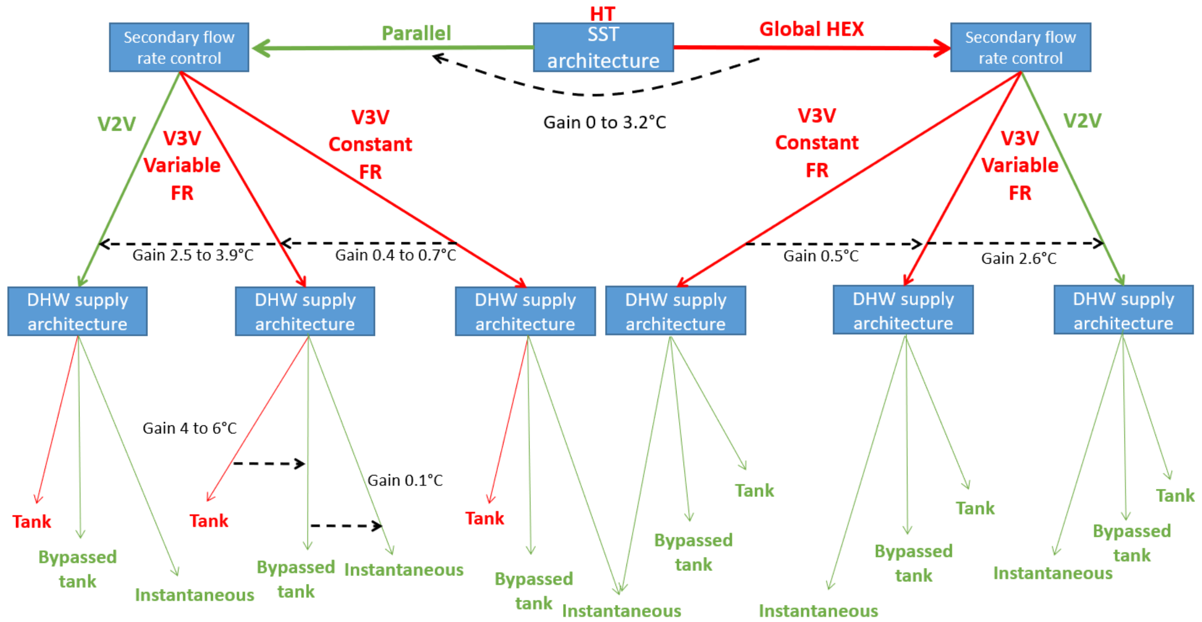

Figure 2 Decision tree summarizing the numerical results in the case of HT radiators

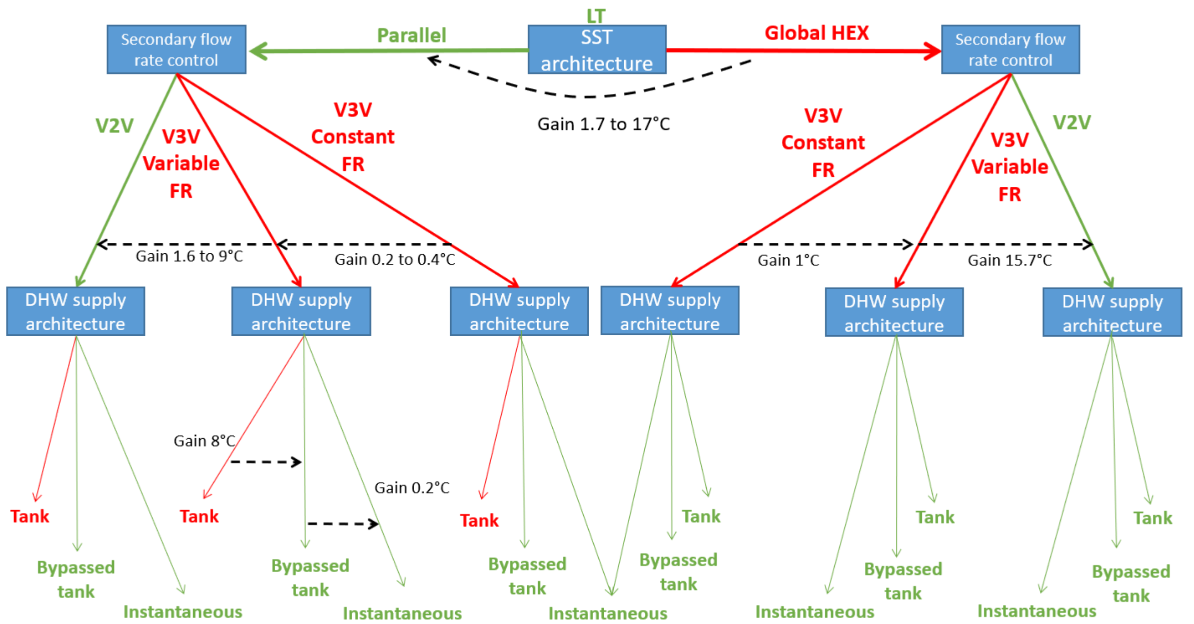

Figure 3 Decision tree summarizing the numerical results in the case of LT radiators

According to the numerical study, the best combination of retrofit actions is composed of a parallel substation connected to a secondary network using LT radiators, two-way valves, and a variable mass flow rate pump without a DHW storage tank. Indeed, the return temperature could be reduced by 17 °C.

FAULT DIAGNOSIS INDICATORS

Moreover, fault diagnosis indicators on substations and on the second side of substations have been developed for ongoing commissioning of installations. These indicators complement existing ones found in the literature. Their aim is to identify the origin of a decrease in substation performance. The indicators are created to detect four common malfunctions:

- A faulty primary valve (the valve controlling the flow passing through the primary side of the substation)
- A faulty secondary valve (the valve controlling the flow passing through the radiators)
- A substation heat exchanger fouling
- A DHW system with an unsuitable recirculation flow rate.

Besides, these indicators are designed to be easily used with measurable data.

HEAT TARIFF MODELS

Based on simulation results, the decrease in return temperature thanks to retrofit actions has translated into annual energy gains for the DH. This, along with the cost of retrofit actions, allowed us to assess the payback times for an action (or combination of actions) and the monetary savings resulting from the lower gas demand that the action enables. In the figure below, the payback time for the best combination of actions is visualized for one, two, three, and four actions. As the results indicate, a situation with the upper level of natural gas prices leads to a significantly lower payback time for the actions, ranging from 0.9–1.3 years, whereas gas prices at lower levels yield payback times of around 6–9 years. Assuming that the reduced costs are fully transferred to the customer, all these combinations of actions could be considered good investment opportunities.

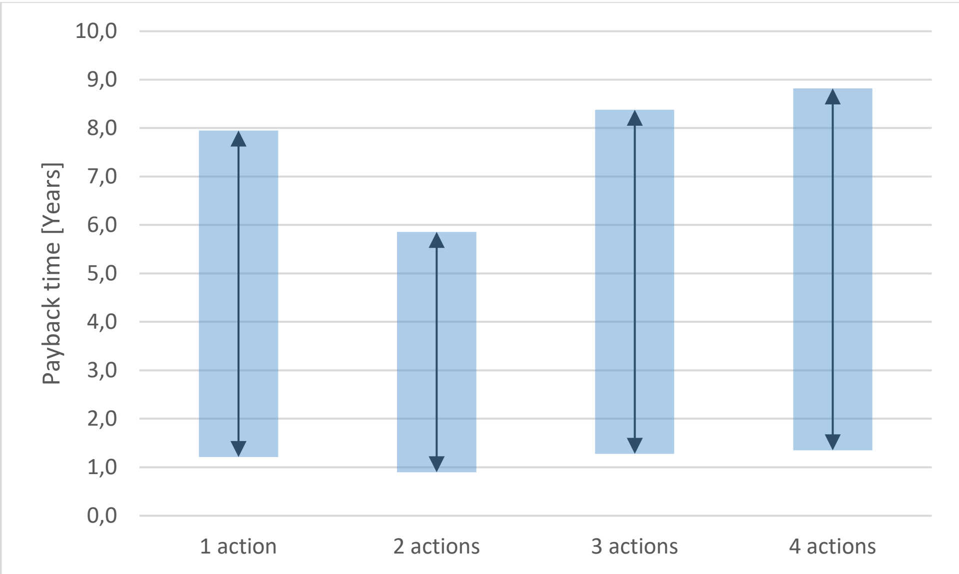

Figure 4. Payback time for the best combination of actions for a low (20 EUR/MWh) and high (130 EUR/MWh) gas price. Actions represented are 2V (for 1 action), 2V+LT (for 2 actions), 2V+LT+parallel (for 3 actions), and 2V+LT+parallel+instant (for 4 actions)

The question asked is how to help the heating customers retrofit their building heating systems to improve DH performance. Motivational heat tariffs have been studied as a solution to encourage building owners to retrofit their low-efficiency systems. From a literature review, some recommendations have been drawn up. A good DH price model from the customer perspective was described as easy to understand and “fair”. Moreover, it is essential to engage in a close dialogue with customers to explain the way that motivational tariffs can generate a win-win solution for both the customer and the energy company.

The most important factors to consider for motivational tariffs based on mature heat market motivational tariff practices identified in the literature are summarized in Table 1.

Table 1. Summary of motivational tariffs in use and the components that are measured

Tariff in use	Measured component
Flow/Bonus Malus	m^3/MWh
Bonus Malus	Return temperature can include a separate measurement of cooling performance through the substation
Discount	Customers using return line heat
Compensation	Feed-in tariff for waste heat deliveries

So, the heat tariff models proposed in this study include the classical heat tariff model and add new items such as the pricing of the consumed water volume per consumed energy, an incentive tariff for reducing the primary return temperature, and an incentive to make use of waste heat in the secondary circuit.

In this study, it is confirmed that motivational factors that have been tested on mature markets should be maintained (like the flow component and the charge related to installed capacity) and that news factors (lower temperature in the substation and waste heat available in the secondary system) should be added to the price model component of future business models.

CONCLUSION

In this study, the performance of 36 combinations of retrofit actions on secondary heating systems has been assessed on a numerical test bench. These simulations enabled us to identify the most interesting retrofit actions: the combination of better flow control on the secondary side coupled with the use of low-temperature radiators. The payback times of retrofit actions range between 1 and 9 years, according to gas prices and the type of action. Nevertheless, these results must be consolidated by in-situ case studies.

Moreover, it is important to engage in a dialog with the customers about their interest in motivational tariffs. The client's role as a provider of waste heat and the client's flexibility will help to develop motivational tariffs.

In order to continuously improve the performance of existing networks, it is essential to set up performance monitoring and then carry out retrofit actions. For this purpose, guidelines are provided, separated into three steps:

- The first step deals with the **maintenance operation on the primary side**. The first actions to undertake are on the primary side, because this side is handled by the operator. This step must be taken throughout the lifetime of the network.
- The second step is about the **maintenance operation on the secondary side**. This step must also be taken throughout the lifetime of the network.
- The third step deals with the **retrofit actions**. Once the network is functioning properly, upgrading actions can be made on the secondary network.

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