Technology Collaboration Programme
by iea

IEA DHC

INTERNATIONAL ENERGY AGENCY
TECHNOLOGY COLLABORATION PROGRAMME ON
DISTRICT HEATING AND COOLING

SUMMARY FOR NON-TECHNICAL AUDIENCES

CASCADE

A COMPREHENSIVE TOOLBOX FOR INTEGRATING LOW-TEMPERATURE SUB-NETWORKS IN EXISTING DISTRICT HEATING NETWORKS

This page is empty on purpose.

Disclaimer notice (IEA DHC):

This project has been independently carried out within the framework of the International Energy Agency Technology Collaboration Programme on District Heating and Cooling (IEA DHC).

Any views expressed in this publication are not necessarily those of IEA DHC. IEA DHC can take no responsibility for the use of the information within this publication, nor for any errors or omissions it may contain.

Information contained herein has been compiled or arrived from sources believed to be reliable. Nevertheless, the authors or their organizations do not accept liability for any loss or damage arising from the use thereof. Using the given information is strictly your responsibility.

Disclaimer Notice (Authors):

This publication has been compiled with reasonable skill and care. However, neither the authors nor the DHC Contracting Parties (of the International Energy Agency Technology Collaboration Programme on District Heating and Cooling) make any representation as to the adequacy or accuracy of the information contained herein, or as to its suitability for any particular application, and accept no responsibility or liability arising out of the use of this publication. The information contained herein does not supersede the requirements given in any national codes, regulations or standards, and should not be regarded as a substitute.

Image Source (Frontpage):

LTDH-consumers in Sønderby, Høje Taastrup (extract from Google Maps 2021)

Citation:

Please refer to this report as:

Moser S, Puschnigg S, Jauschnik G, Linhart M, Volkova A, Siirde A, Kauko H, Schmidt R-R, Reuter S and Leitner B. CASCADE – A comprehensive toolbox for integrating low-temperature sub-networks in existing district heating networks. IEA DHC/CHP Summary Report, 2022.

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

Lowering the temperatures of district heating networks (DHNs) can contribute to a more sustainable energy system. Compared to conventional high temperature DHNs (up to 130 °C), a supply flow temperature of only 30 °C to 70 °C can better integrate renewable heat sources such as solar or geothermal energy, low temperature waste heat, or even ambient heat with heat pumps. However, conventional DHNs cannot easily be transformed into a low-temperature network. This is the reason why sub low-temperature DHNs (sub-LTDHNs) are analysed within this project, as they can be integrated within an existing superior high-temperature DHN. Thereby, an energy cascade is built and a more efficient operation of the overall network achieved, thus initializing and contributing to a transformation of the superior DHN. This option can be considered as one of the possibilities for the district heating (DH) transition to 4th generation DH. Within this study, sub-LTDHN supply temperatures in the range of 50 – 70°C have been used and analysed.

METHODS

In the beginning, the project team derived a generic definition of a sub-LTDHN (refer to Figure 1). The key requirements include (i) the connection of a sub-LTDHN to a superior DHN that exhibits relatively high network temperatures, (ii) the heat has to be mainly extracted from the return line of the superior DHN, (iii) supply flow temperature of the sub-LTDHN is around 30 °C to 70 °C (only indicative values), (iv) and it has to be a network (i.e., more than one customer).

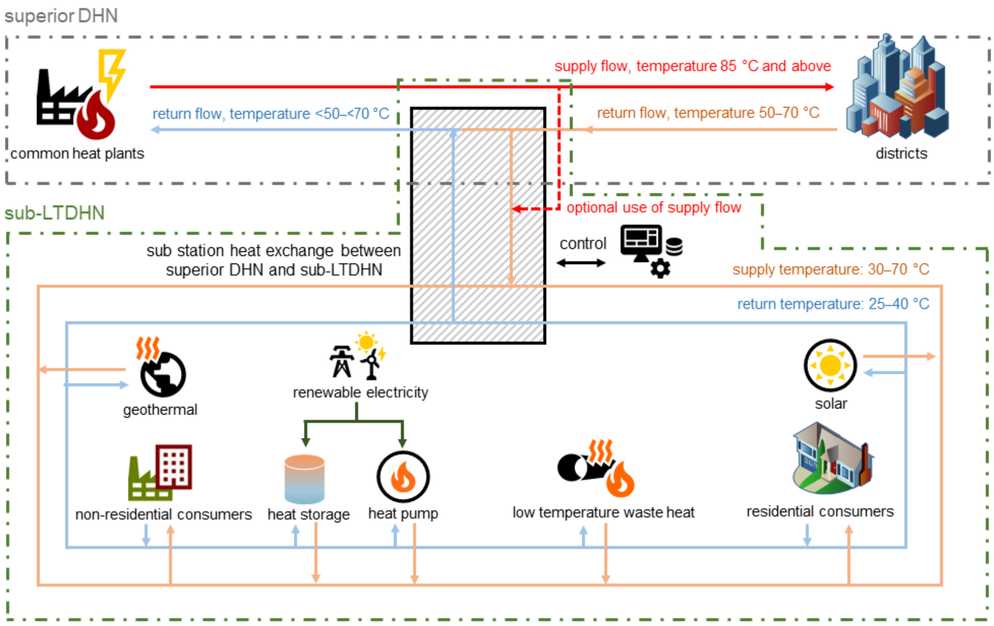

Figure 1: Graphic definition of a sub-LTDHN, its system boundaries and potential components

In order to identify good practice examples of sub-LTDHNs, literature research was conducted, oriented on the generic definition. In addition, direct contact to DH suppliers was established to gain (i) further information about identified examples and (ii) to ask for more good practice examples they might know. Build on that, their conditions and technical solutions were analysed and categorized and some initial lessons learnt derived. Afterwards, barriers and drivers of sub-LTDHNs were analysed and elaborated. Based on the previous evaluations, technical concepts and dynamic load conditions were discussed, exemplarily applied for two case areas located in an Austrian and in a Nordic city. In addition, a techno-economic scalability and an operational dynamics analysis were conducted. Finally, generalizable lessons learnt and recommendations were derived as obtained from the conducted research.

IDENTIFIED EXAMPLES

In the course of the research process, 31 sub-LTDHNs have been identified. Only 4 examples were found to be implemented and to fully match the generic definition. Further 13 examples were implemented, but meet the definition only to a certain extent. In many cases, these similar examples supplied only one customer, and thus were not a network. Another 5 sub-LTDHN examples were identified, which are only theoretically elaborated, i.e., they are not implemented/operational. The status of the remaining 9 sub-LTDHN examples remains unknown, as no further information could be obtained although it was tried to establish contact to the companies. Of those 31 identified examples, 13 were identified in Germany, 9 in Denmark, 5 in Austria and 4 in other countries. Despite careful and in-depth research, this is probably not a complete list of sub-LTDHNs implemented in Europe, as we recognized during in the engagement with the practitioners and experts that the operators do not necessarily consider the use of return line-based sub-networks innovative and thus do not disseminate the implementation.

BARRIERS AND ENABLERS

The 9 sub-LTDHN examples, i.e., the 4 practically implemented and the 5 only theoretically elaborated, were analysed regarding potential barriers and enablers. In addition, a thorough literature review, interviews with district companies and experts of research organizations, and a survey on barriers and enablers was conducted. The barriers were classified as technical and non-technical barriers. The non-technical barriers include economic, regulatory and information barriers.

The main technical barriers identified in both scientific literature and survey results are related to low return temperatures in the superior DHN and the necessity to boost the supply temperature locally, along with barriers related to mass flow (limited mass flow rate and hydraulic issues) and more complex regulation. The main obstacle from an economic point of view is the lack of clarity about the return on investment in this solution, that is why tariffs that do not take into account network temperatures, high investments, and lack of business models were studied in this report.

TECHNICAL CONCEPTS

To evaluate technical concepts of sub-LTDHNs, a model implemented in Dymola for simulating sub-LTDHNs connected to a superior DHN was developed, and applied to two different case study areas: a new planned residential area in a Nordic city and a smaller new neighbourhood in a typical Austrian city. For both case study areas, three supply temperature levels for the sub-LTDHN were evaluated: 50, 60 and 70 °C. In both cases, there was a clear, expected decrease in the share of total heat demand covered from the return line with increasing supply temperature level in the sub-LTDHN. In the Austrian case, the entire heat demand could be covered from the return line in the lowest supply temperature case. For the Nordic case, the supply temperature, and consequently the return temperature in the superior DHN, remains high for the entire year and shows little correlation with the heat demand. Consequently, the peak heating demand from the supply line has only a moderate increase with increasing supply temperature level in the sub-LTDHN, and peak heating demand from the return line remains almost constant. In the Austrian case, the assumed return temperature level was constant and much lower, leading to a more prominent increase in the peak heating demand from the supply with increasing supply temperature to the sub-LTDHN. Moreover, in the Austrian case, the mass flow in the superior DHN was very high compared to the mass flow in the sub-LTDHN, resulting in a negligible impact on the temperature in the return line of the superior DHN after cascading. In the Nordic case, the mass flow in the nearby branch of the superior DHN was relatively low, less than twice the mass flow in the sub-LTDHN. This resulted in a clear decrease in the temperature in the return line, in particular with the lowest supply temperature in the sub-LTDHN, as a higher share of the heat demand is covered from the return line.

TECHNO-ECONOMIC SCALABILITY

A techno-economic analysis revealed that cascading can be a scalable solution to increase the overall network efficiency. A quasi-static simulation of the integration of multiple sub-LTDHN within a superior network showed different advantages, depending on the specific cascading option. Multiple cascaded sub-LTDHNs within the same network branch result in significant reductions of the local return temperature. Therefore, decentralized renewable heat supply technologies can benefit from the large temperature spread between local return and supply flow to operate efficiently. Cascading multiple sub-LTDHNs in different branches result in a higher reduction of the total return temperature and the possible integration of more sub-LTDHNs that can be supplied without required mixing from the supply. A case study revealed that cost savings due to reduced return temperatures and resulting efficiency gains in the heat generators reach significant levels for heat supply systems that are based on renewable sources.

Technical difficulties were analysed by dynamic simulations and identified to be of most relevance in remote locations of the superior network. In areas where a supply of sub-LTDHNs cannot be guaranteed from the return line, technical backup solutions, such as an additional connection to the supply line of the superior network, are required.

LESSONS LEARNT AND RECOMMENDATIONS

This chapter serves to discuss lessons learnt experienced during the project and to derive recommendations. The aim is to provide DH companies and research organizations with general findings on heat cascading to raise the awareness of such solution, to further develop them, and to increase their market uptake. As with most technological solutions (especially when they are rather unknown), the probability of implementation increases by showing real practical solutions instead of theoretically elaborated studies. This report provides the required comprehensive information on best practice examples of sub-LTDHNs implemented through cascading, their barriers and enablers, their technical concepts, their techno-economic scalability and operational dynamics.

Identifiability of sub-LTDHN: As the technical implementation is not too complex, many experts and practitioners do not consider a sub-LTDHN to be something special. Thus, many sub-LTDHNs are probably implemented but information on them has not been published. Despite careful and in-depth research, this leads to the assumption that the number of case studies that corresponds to the definition is higher than identified.

DHN operator's organization: Innovation, such as implementation of a sub-LTDHN, often depends on one or a few people in the company. In addition, an inertia of change is observed, which is probably due to the investment-intensity and long lifetime of DHN assets.

Fields of sub-LTDHN applicability: In low demand density high temperature DHNs, sub-LTDHN can contribute to a significant reduction of heat losses. The improvement of the ratio of losses to consumption make DH supply in low-density areas more economic. Newly build city quarters and newer buildings with low heat demand and suitable heating equipment are most interesting for sub-LTDHNs implementation. However, there are limitations of position: The impact of cascaded sub-LTDHNs, e.g., reduced heat losses and increased network capacity, is limited if the sub-LTDHN is close to the heat generation site. However, if it is located at an end of the network, the return line's mass flow may be too little to provide the heat amounts necessary.

Capacity benefits and costs: Sub-LTDHNs increase the overall capacity of a DHN and thus are an opportunity to connect further customers cost-effectively. However, a more costly three-pipe system (i.e., backup from the supply flow if the return temperature of the HTDHN is too low) may be required to guarantee the required temperature level. But this system design is still more inexpensive than building a new heat generation plant.

Technical evaluation: Adding a sub-LTDHN to the superior DHN increases the complexity of hydraulic control. Moreover, measures to decrease the return mass flow of the superior network could inevitably lead to supply shortages for the sub-LTDHN connected to the return line. The main barriers are the sub-LTDHN supply temperature, the return temperature of the superior DHN, and the available mass flow of the local branch. When the supply temperature of the sub-LTDHN is higher than or close to the temperature of the return flow in the superior DHN, the benefits of cascading decrease.

Techno-economic scalability: Several sub-LTDHNs can be cascaded within one superior network, which increases the positive effects of sub-LTDHNs (especially the achievable return temperature reduction).

CONCLUSION

Sub-LTDHNs can contribute to the transition of high-temperature DH systems to low-temperature and eventually to 4th generation DH. Since the transition to low temperature DHN is an ongoing process, the feasibility of sub-LTDHNs may be questioned. However, the transition may still last for decades and thus the current and new generation of DH technologies will operate simultaneously. The successful integration of low-temperature networks into the heat market is required to realize a decarbonized energy system that relies on renewable and low-temperature heat sources.

Due to the arguments presented (location, technical restrictions, economic feasibility), sub-LTDHNs may still be and remain as a niche solution. However, they may be, due to cost and capacity reasons, a scalable option for lowering the return temperature in network branches near heat generation units. Sub-LTDHNs can be advantageous for supplying heating especially for modern buildings and newly built areas. Cost savings from reduced return temperatures are mainly beneficial when non-combustion heat sources are used.

The results elaborated within this report serve as knowledge base about sub-LTDHNs for DH organizations and in particular DH companies. In future, the obtained results, experiences, lessons learnt and recommendations can be a trigger for DH companies to further investigate their DHNs for the potential of integrating sub-LTDHNs.