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


**SUMMARY FOR NON-TECHNICAL AUDIENCES**

# LEAVE 2ND GENERATION BEHIND:

## COST EFFECTIVE SOLUTIONS FOR SMALL-TO-LARGE SCALE DISTRICT HEATING NETWORKS

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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

# 1 INTRODUCTION

## 1.1 CONTEXT

Various large-size and middle-size district heating networks in the world are currently of 2nd generation type and operate with superheated water at temperatures higher than 100°C. To meet long-term decarbonization targets, rapid pathways to transform existing networks into low-temperature systems in a cost-effective manner are required. Low temperature networks provide multiple benefits. The main are a) the improvement of the efficiency of the production units; b) the possibility of exploiting waste heat from industrial processes and renewable plants that are usually available at low temperatures; c) the reduction of thermal losses. Supply temperature reduction of 2nd generation district heating (DH) is hampered by three main types of barriers, depending in the considered infrastructure.

- The first issue is related to the fact that when reducing the supply temperatures lead to smaller temperature differences between supply and return; to keep the power exchanged constant is thus necessary to increase of the mass-flow rates. This increase could be to potentially unsustainable increase of *network* flow rates to cover the same demand. The problem is exacerbated in large networks (~ 100 km or more), where supply flow rates are inherently large to comply with large thermal demands.

- The second issue concerns the capability of the *substation* to provide the required amount of heat to the heating device when it is supplied at lower temperature. In this case the limiting factors are both on the thermal and fluid dynamic operation, namely the heat transfer area of the heat exchanger and the cross section of the fluid paths (pipes, valves, heat exchanger).

- The third issue is related to the limitation on the exchange area of the *heating devices* installed in the indoor environment.

## 1.2 AIM OF THE PROJECT

In this context, the overarching aim of this project is to identify transformative cost-effective routes for reducing the supply temperature of existing district heating, and to indagate to what extent these barriers can be overcome. This is done by analysing two existing case studies, with the specific aim of proposing/developing and testing proper actions to face the issues concerning the DH's operators related to the distribution network and the substation.

# 2 CONSIDERED STRATEGIES

In the project, the actions that have been taken into account to tackle limitations due to network and substations are:

- Optimal exploitation of the existing infrastructure through the adoption of optimal operation of the available pipelines/loops/pumps (as concern the network infrastructure) and the thermal substations. This also includes the possible use of a proper supply temperature setting during the year in order to achieve, in all the climatic conditions, the lowest supply temperature as possible.

- Focused substitution of the existing infrastructure. This includes the thermal substations, when limiting the supply temperature reduction, the intervention on specific fluid-dynamic bottlenecks (e.g. pipeline diameter change) or the modification of the network topology through installation of additional pipes or booster pumping stations.

- Proper analysis of the potential for the demand modification. Demand-side management is considered to shave peaks in order to extend the number of hours the supply temperature reduction is applied as well as analysis of the retrofitting status of the building stock to predict the trend in consumption reduction as well as to estimate the effects of incentives.

- Proper installation of thermal storages and heat pumps. The first is done with the aim of reducing water congestion issues in the most critical parts of the pipe network (reduction of mass flow rated in peak hours and increase in off-peak hours e.g. during the night). The second is used to locally increase the water temperature by recirculation of mass flow rates from the return side (also by mixing supply and return when required).

The benefits of the proposed solutions have been estimated by relying on validated models. Tests have been performed considering existing medium-to-large networks that urgently need interventions to reduce supply temperature. The specific case studies analysed are a large-scale network, Turin (800 km, 2000 GWh/y) and a small-scale network, e.g. a part of the Metz network (170 km, 720 GWh/y).

# 3 METODOLOGY/RESULTS OF THE PROJECT

## 3.1 METZ CASE STUDY

The first case study supporting the methodology is a subnetwork of the DH system of the city of Metz (France). This is a second-generation DH network operated at typical primary temperature levels ranging from 110 °C to 160 °C. The topology of the network consists in a main central network linked to a satellite subnetwork through a feeder equipped by a set of booster pumps. What is considered here is a virtual system consisting only of this part of this network, with the original connection to the feeder being replaced by a virtual production unit. The assumption is made of a production consisting in a CHP plant with a central set of hydraulic pumps. The operation of the network is simulated on a given scenario, assuming a target for the primary inlet temperature. Simulation results are then used as input for problem identification, using a set of criteria and successive steps. An optimizer has been adopted to reach the reduction of the supply temperature through the optimal modification of the DH infrastructure. The component decision parameters are the direct outcomes of the ‘bottleneck’ identification procedure:

- The modification of some of the thermal substation.
- The choice of a different piping coming from a pre-set catalogue.
- Addition and simple dimensioning of booster hydraulic pumps
- Possible upgrade for the central pump (for the maximal head attainable).

The range of possible values is to be specified by the user for each optimization. The optimization is done with respect to two objectives:
1) the investment cost (CAPEX), and the operational cost (OPEX) that corresponds to the sum of the investment costs for each of the proposed modifications on the network.
2) the second objective function is the operational cost (OPEX), calculated through the aggregation of heat production costs and hydraulic operation (pumping operation, powered by electricity with a given efficiency).
The tool allows to achieve Pareto fronts for different decision parameters. Significant supply temperature reduction (about -10 °C) can be achieved with minor interventions, adopting different set of modifications in the infrastructure. The multi-objective nature of the optimization leaves the engineer with a general latitude in decision on different contexts: examples are uncertainties on economical parameters, or some unexpected constraint preventing the use of a previously identified solution. The engineer is provided with a bunch of possible designs from which the solution would be selected to suit his/her final needs.

## 3.2 TURIN CASE STUDY

The Large-Scale DH analysed in this work is the Turin system, among the largest in Europe and the largest in Italy (total length of the pipeline 1452 km). The Turin network is topologically divided in two parts (a main transport network and 182 distribution networks, connecting the transport to the buildings) and is supplied by two cogeneration plants. Booster pumps are adopted to boost pressure along the transport line.

A cascade approach has been adopted to analyse potential of supply temperature reduction in large-scale case networks. At first, an analysis on demand response is done to shave thermal peaks, and to focus, in the following analysis, on the steady-state conditions (off peak time). Two specific analyses with two validated approaches have been used to estimate potential on temperature reduction for substation and network infrastructure;

- The substation analysis is based on a model of substation and user that allows to estimate the relation among supply temperature, mass flow and thermal power exchanged; given a maximum flow rate per each substation it is possible to find the minimum supply temperature required for each thermal power required (and so for each weather condition). The substation analysis shows that in 400 analysed substations, the network, as is could potentially be supplied at 104 °C and that only about 20 % of the substations require supply temperatures larger than 90 °C.

- The network model allows to find the best operation of booster pumps that guarantees the maximum mass flow increase, with the constraints of maximum velocity and maximum pressure in the pipes. The network model provides, in a typical operation of thermal plants in a cold winter day, a possible mass flow increase of 47%. This corresponds to a supply temperature of about 100°C. In particular, the bottlenecks is located in a pipe connecting the thermal plant with the city centre. Therefore, with the introduction of the distributed generation, this value is expected to significantly reduce.

An analysis on the installation of heat pumps, recirculating the distribution network water, has been addressed. Considering a proper regulation setting, in the Turin network, heat pumps with a production temperature of 90°C (30 °C lower than current operations) could be exploited to supply distribution networks for about a half of the heating season, without any other intervention. This also helps in the reduction of the mass flow circulating in the transport line, with a consequent further supply temperature reduction in the entire system. Exploitation of different types of thermal storages (sensible, latent, thermochemical) has been indagated. If considering a profitable exploitation of the low temperature heat, the results show a payback time much smaller respect to the lifetime of the system.

The investment required to perform the transition, varies depending on the degree of modification expected. Concerning the thermal substations, the following indication of 1 k€/eq_subst can be estimated for reduction up to 90 °C (70 €/°C eq_subst) and 3.5 k€/eq_subst for a reduction up to 80 °C (146 €/°C eq_subst) (the total cost is estimated by multiplication per the total number of DH substations). About 20°C of supply temperature reduction can be achieved with limited investment costs. While the goal of supply temperatures reductions lower than -30°C in the cold winter condition are reachable only with significant investment costs.

# 4 CONCLUDING REMARKS

The supply temperature reduction of existing DH systems represents a unique way to guarantee a smart exploitation of renewable sources, mainly available at low temperature, for space heating and domestic hot water production in urban areas, as well as reducing thermal losses and increasing the efficiency of CHP and heat pumps. The analyses of the results obtained in the investigation performed in this project, for the two different case studies, provides some insights that can constitute a beacon on the supply temperature reduction of the existing systems.

- The s*upply temperature reduction* that can be achieved in current systems without modification of the infrastructure is non negligible (in the large-scale case study-15°C). *The regulation of the supply temperature* as a function of the climate conditions is mandatory to achieve satisfactory results in the reduction of supply temperature of existing DHNs. Results show that temperature can be significantly decreased without any system modifications, for a large period of the heating season.

- Considering the *retrofitting of the existing infrastructure*, with reasonable investments, in both the analysed cases, it is possible to reach further supply temperature reduction (-10 °C and -30°C) and, in one case, make the operating condition suitable, for the use of heat pumps.

- The *centralized production* can be the main limitation in the supply temperature reduction, from the network perspective. It could be interesting to exploit prosumers (discussed in points below), renewable sources available in large plants (e.g. solar, geothermal, biomass) or installation of heat pumps and thermal storages (discussed in points below); proper analysis should be performed to analyse the inclusion of distributed generations since current pipes could be not always suitable and provide too larger values of velocity and pressures.

- The *adoption of proper analyses and tools* is crucial to properly plan actions for supply temperature reduction in existing district heating systems. This allows avoiding investments that do not provide the expected outcomes, as well as focusing the attention on the aspects that are crucial to unlock supply temperature reduction. This also allows quantify the possible drawbacks in the reduction of supply temperature, as the increase of pumping cost, that can be not negligible. The same applies to *suitable technologies/techniques*, such as, heat pumps, that allows recirculating water further reducing the mass flow in the network, as well as thermal energy storages and demand response, for a suitable management of the thermal peaks.