IAPE '19, Oxford, United Kingdom
ISBN: 978-1-912532-05-6

RELaTED, An Approach to a decentralized Ultra Low Temperature District Heating

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ABSTRACT

Trends for heating energy in European Cities are the decarbonization of energy sources and the reduction of heat loads. District heating (DH) networks are key systems to reach the targets due to the cost competitiveness and high performance levels they show. However, DH networks require a conversion to adapt for the need of the future. It is necessary to reduce the operation temperature so that it is possible to increase the performance of renewable systems and operation criteria needs to be adopted for the introduction of weather-dependent, distributed heat sources such as solar systems.

In this paper is presented the RELaTED, a novel DH networks scheme with decentralized Ultra-Low Temperature performance. This way, it is possible the adaptation of new and existing networks to several operational schemes. Transitory phases for the conversion of actual DH and how this affects the whole system are discussed along the paper.

Keywords

Solar thermal systems, thermal energy, energy efficiency

1. INTRODUCTION

District heating (DH) systems are one of the most energy efficient heating systems in urban environments, with proven reliability within many decades already. DH of today and older ones are based on large Combined Heat & Power (CHP) or large Gas boilers reaching supply temperatures near to 100ºC. Future DH networks must develop other characteristics to reach some targets that makes them feasible. Comparing with actual DH networks, those for the near future must reduce grid losses and they must find synergies that increase efficiency of the whole system.

DHs are identified as key systems to achieve the de-carbonization of heating energy in European Cities. (European Commission, 2016) Renewable and waste heat sources are foreseen at the same time as de-carbonized heat sources and the way to guarantee competitive energy costs with limited influence of fossil fuel supply price volatility. To achieve this, a transition is needed in DHs, comprising not only measures to improve overall performance (temperature level reductions, improvement of substations, etc.), but to guarantee system viability as a whole in a context (Harrestrup & Svendsen, 2015) of reduced heat loads with the transition to NZEB (Near Zero Energy Buildings).

RELaTED deploys a novel concept where Ultra-Low temperature (ULT) DH networks are developed. The reduction of supply-line temperature guarantee the incorporation of low-exergy heat sources with minimal constraints. At the same time, it enlarge the renewable energy sources based (RES) heat and a reduction in operational cost due to the reduction of heat losses in distribution pipelines. All this leads to a better overall performance of heat generation plants and extensive use of de-carbonized energy sources at low marginal costs.

In the transition towards NZEB and PEH (plus energy houses), RELaTED allows for a prosumer scheme, where positive buildings deliver energy to the grid.

2. DE-CARBONISED HEAT SOURCES

Modern DH networks are one of the most resource efficient heat production systems. In some countries, DHs are linked to intense use of Combined Heat and Power (CHP) and Heat pump technologies, linked to renewable energy sources such as geothermal fields, biomass and waste incineration.

Along the last decade, already in several EU locations, large ST systems have been successfully connected to DH networks under commercial operation. (SDHplus, 2015)

Linked to variations of solar resources and electricity costs-for heat pump heating-, over the year, several DH networks have incorporated large scale thermal storage systems. (Gadd and Werner, 2015),)

In fact, for some concept districts such as the (Drake Landing Solar Community) full solar cover of heating loads has been achieved with a mixture of ST and seasonal storage even in cold climates in continental Canada at 50ºN.

Although very dependent on local availability, waste heat streams from industrial and commercial (e.g. supermarkets) sources, are relatively stable sources of heat. Large scale industrial processes are active all year-round, resulting in minimally carbon intensive processes.

(Vesterlund et Al., 2017) studied the configuration of the DH network in Kiruna, SE, where a large iron mining setting provided

DOI: http://dx.doi.org/10.17501.......................................

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a de-carbonised heat recovery source. In all calculations where industrial waste heat was introduced, the optimal situation made use of the maximum capacity of the industrial waste heat (15MW), it provided. The relative relevance of this heat source was 30% of the winter peak load (49MW) and 38% of the winter average load (39MW).

With unprecedented performance levels in fuel-based heat production processes, improvements in performance levels will only have minimal impact in the route to DH de-carbonisation. The transition will require the large scale integration of ST systems, and waste heat resources. Linked to load reduction in the progressive transition to NZEB performance levels, with progressive connection of BIST into the DH, a de-carbonised DH environment can be achieved

3. LIMITATIONS OF CURRENT DH NETWORKS

DH systems date back more than 100 years. Originally with steam as heat carrier, DH has evolved through the 20th century into systems at lower temperature. With most of the systems in Europe developed over the decades of 1970 & 80, typical DH systems deliver presurized water at about to about 80°C to consumers. In Nordic countries, district heating developed rapidly in the nineties into areas with lower heat density, requiring more efficient distribution networks. Supply temperatures were reduced even further. In these systems, heat is supplied at 60-70ºC, supported by modern building codes in those regions, where new radiator systems are sized for operation at 60°C/30°C.

DHs deliver heat for space heating (SH) and domestic hot water (DHW) preparation. With the trend towards more insulated buildings-NZEB, heat loads for SH are steadily decreasing, which, in combination with improved substation design, allow for even further temperature reductions of the supply temperature. However, the preparation of DHW imposes limits to this temperature fall, due to the need to avoid legionella-related issues. Depending on specific national regulations, storage temperatures in the range of 55-75ºC are prescribed, depending on storage size and DHW preparation method.

(Olsen et Al.,2008) and (Christiansen et Al. 2012), among others, have investigated in alternative DHW preparation methods with DH service temperature as low as 50ºC. In many alternatives, traditional DHW preparation methods are substituted by “innovative methods”. In these concepts, mains water is primarily heated by the DH, and then complemented by electric heaters/boosters up to the required temperature levels. In more advanced alternatives, heat pumps are used for such purposes.

4. CONCEPTUAL DEVELOPMENT OF THE RELATED ULT DH SYSTEM

RELaTED builds over existing evidence (Brand et al.,2016 and Gudmundsson, et al., 2014) that DH supply temperatures as low as 45ºC, are suitable for heat supply to define its ULT DH concept.

In RELaTED every single building is converted into an energy node, where so-called triple function substations (3FS) allow for bi-directional heat exchange between the building and the network, with the additional functionality of grid injection of excess local solar heat. In fact, adaptations are made to Building Integrated Solar Thermal (BIST) systems in order to adapt them to

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Low Temperature (BILTST), with reduced local storage, as the connection to the DH makes it redundant.

Additionally District-heating connected Reversible Heat Pump systems (DHRHP) allow for recovery of exhaust heat from cooling applications (e.g. air conditioning, ventilation, etc.).

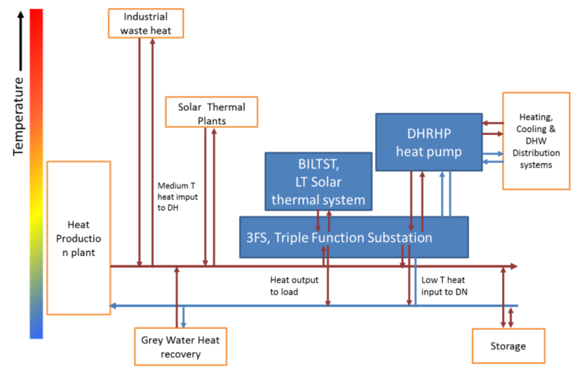

Figure 1. Overall RELaTED concept

Even before the consideration of further technological improvements, ULT temperature levels substantially improve the performance of heat production systems. It is estimated that CHP performance can be improved by a factor 2 to 5, considering (Lowe, 2011). Furthermore, ULT allows for the integration of virtually any waste heat source from industry, sewage, etc.

RELaTED builds atop of the existing trend for integration of large solar thermal plants systems in DH networks, some of them comprising large seasonal storage systems. RELaTED incorporates large ST plants, but also provides the famework for the integration of BIST into the main ULT DH concept. With lower fluid temperature when compared regular BIST integration levels, performance levels are expected to rise by 20%, due to lower heat loses. An additional 20% rise is calculated when avoiding local storage due to direct DH connection. The RELaTED ULT network acting as a perfect heat sink avoids storage stagnation situations, thus allowing for larger ST performance levels.

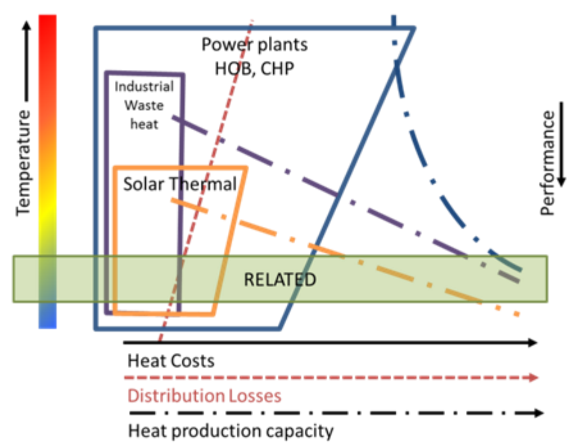

Figure 2. Temperature & performance range, cost of heat & other critical variables in heat production for DH

DHRHP systems allow for the de-coupling of temperature levels in DH network and Building level HVAC systems. With the DH

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as heat source, stable tempertures at 35-40ºC ensure stable COP levels of 6-7 for the DHRHP all-year-round. These units provide an economic way for the preparation of DHW, while at the same time allowing for the connection of buildings with higher temperatures in their HVAC design (i.e. older buildings).

The RELaTED concept, when implemented with a substantial share of RES provides a robust framework to ensure the economic viability of DH networks, in the context of the transition of the building stock to NZEB along the following decades.

5. RELATED IN NEW DH NETWORKS

The RELaTED ULT DH concept is directly applicable to DHs in the context of new urban developments. In these cases, previous experiences are directly applicable, allowing for SH at 45ºC. Sizing of heating networks in buildings and the overall DH infrastructure would be made according to the expected heating temperature, with standard calculation procedures.

As defined before, DHW loads are key issues, where, electric heating would be applied, either by means of electric boosters or heat pumps (depending on the rated power). (Brand et Al., 2016) tested an electric booster system connected to a DH network at 40ºC. In this experimental work, the use of electricity accounted to 30% of the DHW perparation energy, or 3% of the overall energy consumption.

RELaTED proposes an advanced 3FS substation concept, where local ST systsms can be connected into the DH network, and substations allow for LT distribution systems, with the potential use of electric boosters. In some cases, where cooling loads are present or high temperature heating systems are used, DHRHP systems provide an alternative to electric boosters.

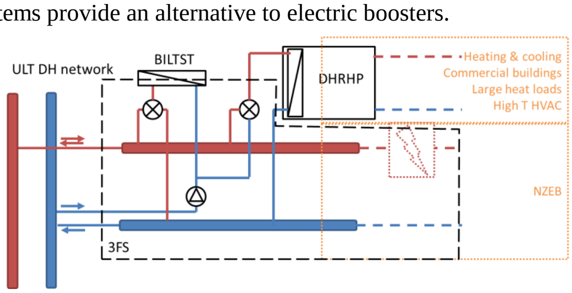

Figure 3. 3FS cponcept & connection with ULT networks

In this scheme, RES systems are integrated since the beginning of the system, according to the possibilities, requirements, and interest in each particular building. 3FS allow for the integration of sparse BILTST systems into the network, without the need of specific investment at DH level.

6. RELATED IN EXISTING DH NETWORKS

Intetgration of ULT in existing networks is a complex mission. Existing networks are commonly composed by many subnetworks, each serving buildings constructed over decades according to different energy codes.

The 3FS scheme, with particular adaptations can be optimized to operate in three different environments:

- ULT DH networks
- Higher temperature DH network: 3FS can be integrated at higher tempeatures, while the (sub)network where it is integrated is not fully capable of operating at LT
- Temperature cascading concept: 3FS, when incorporated only in part of the DH subnetwork can be used to extract heat from the return pipe of the DH system. Thus allowing for the densification of a DH network without further changes to the pipes. For this purpose, an additional pump would be required This configuration could later be transformed into a general purpose 3FS when lowering the supply temperature in the DH.

7. TRANSITORY PHASES

The conversion of a DH network is a complex process, which needs to be performed stepwise in order to guarantee continous SH and DHW services. Although relatively long SH service interuption in summertime is possible, DHW is required all-year-round. Thus network conversions need to be carefully scheduled. Successful transitions require that all buildings within a network are equipped with an updated substation (ULT or 3FS), prior to temperature reductions in each subnetwork. As a further step, temperature in transmission pipes can be reduced, with inproved performance in heat production plants.

Along the process, waste heat streams an ST plants can be incorporated at any phase, as long as their compatibility with current temperature levels is ensured.

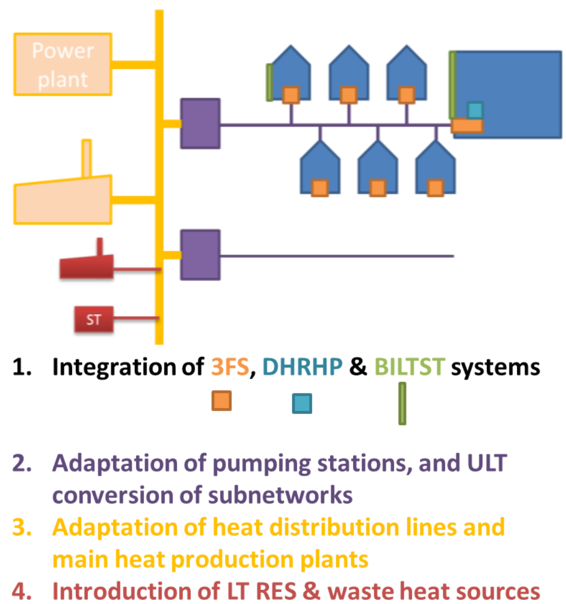

Figure 4. Conversion process from a DH into a ULT

8. EXPECTED DEVELOPMENT

RELaTED is an ongoing research & development, with expected demonstration activities along the 2018-2021 period. The overall ULT concept, integration of 3FS, BILTST & DHRHP subsystems, industrial waste heat, large ST & waste incineration plants will be demonstrated in 4 selected locations:

- Green field development in VINGE, DK
- DH network with large share of biomass in TARTU, EE

DOI: http://dx.doi.org/10.17501......................................

- Large DH network with incorporation of large RES resources in BELGRADE, SR
- Corporate DH network in IURRETA, ES

Successful demonstration of RELaTED in this context will show the potentialities of the system under various climatic conditions, heat production mix & DH design/operation cultures.

9. CONCLUSIONS

RELaTED presents a promising ULT DH concept, backed-up by existing evidence that large ST fractions, Industrial waste heat and ULT DH allow for substantial de-carbonisation of heat delivery in the context of DH networks.

RELaTED will implement this concept over a set of diverse DH networks, allowing for the validation of the concept prior to full scale implementation.

10. ACKNOWLEDGEMENTS

Research output presented in this paper has performed under project RELaTED (RELaTED, 2017). RELaTED project partners are: TECNALIA, Danish Technical Institute, Fortum Tartu, Beogradske Elektrane, Basque Government, Metro Therm, Nibe, Aventa, Industrias IMAR, Basque Energy Agency, Mazovia Energy Agency, Institute of Baltic Studies, FEDARENE, El Taller De Comunicación y CIA.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 768567.

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