RELaTED

D2.1 – Low temperature concepts

Date: 2018/11/26

Version: 3.3

Deliverable	D2.1
Name	Low temperature concepts
Website	www.relatedproject.eu
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 768567

PROJECT SUMMARY

Project Acronym	RELaTED
Project Title	REnewable Low TEmperature District
Project Coordinator	Roberto Garay. TECNALIA roberto.garay@tecnalia.com
Starting date	2017/11/01
Duration in months	48
Topic	EE-04-2016-2017 New heating and cooling solutions using low grade sources of thermal energy

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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DOCUMENT HISTORY

Work Package	WP 2 – System Architectures		
WP Lead	Danish Technological Institute, DTI		
Deliverable	D2.1 Low temperature concepts		
Date	2018/11/26		
Due date	2018/10/31		
Status	DELIVERED		
Date	**Version**	**Person/Partner**	**Comments**
2017/12/01	0.1	R. Garay (TECNALIA)	Template
2018/07/13	1.4	C. H. Christiansen (DTI)	List of content
2018/09/26	1.8	M. K. Pedersen (DTI) / C. H. Christiansen (DTI)	1st draft report
2018/10/12	2.0	M. K. Pedersen (DTI) / C. H. Christiansen (DTI)	2nd draft report
2018/11/02	3.0	M. K. Pedersen (DTI) / C. H. Christiansen (DTI)	Final draft for review
2018/11/15	3.2	M. K. Pedersen (DTI) / C. H. Christiansen (DTI)	Proof read version
2018/11/15	3.2.1	O. Macias (TECNALIA) & R. Garay (TECNALIA)	Revision & addition of IURRETA
2018/11/26	3.3	M. K. Pedersen (DTI)	Addition long term implementation

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ABOUT RELATED

RELaTED is a joint initiative of 14 industrial companies and research institutes across from various countries in Europe, aimed at pushing forward Low Temperature District Heating networks with increased use of Renewable Energy Sources.

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DE-CARBONISING DISTRICT HEATING SYSTEMS

District heating (DH) systems are one of the most energy efficient heating systems in urban environments, with proven reliability within many decades already. DHs are identified as key systems to achieve the de-carbonization of heating energy in European Cities.

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 of reduced heat loads with the transition to NZEB (Near Zero Energy Buildings).

RELaTED deploys a decentralized, Ultra-Low Temperature (ULT) DH network concept, which allows for the incorporation of low-grade heat sources with minimal constraints, larger shares of renewable energy sources (RES) and distributed heat sources. ULT DH reduces operational costs due to fewer heat losses, better energy 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.

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LIMITATIONS OF CURRENT DH NETWORKS

DH systems were designed many decades ago. In most cases, they are designed and operated to distribute heat at about 80 °C to consumers. Their capacity to reduce operational temperatures is related to radiator capacity to deliver sufficient heat to meet comfortable temperatures in buildings and to allow for the safe preparation of domestic hot water (DHW) preparation. DHW limits potential temperature reductions due to the need to avoid legionella-related issues. Depending on specific national regulations, storage temperatures in the range of 55-75 ºC are prescribed.

OVERALL RELATED CONCEPT

RELaTED pursues the development of DH networks with service temperature levels as low as 40-50 ºC. 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.

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 to adapt them to 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.).

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ULT DH

Even before the consideration of further technological improvements, ULT temperature levels substantially improve the performance of heat production systems. 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 framework for the integration of BIST into the main ULT DH concept.

With lower fluid temperature when compared with regular BIST integration levels, performance levels are expected to rise by 20%, due to lower heat loses. An additional 80% 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.

DHRHP systems allow for the de-coupling of temperature levels in DH network and building level HVAC systems. With the DH as heat source, stable temperatures at 35-40 ºC 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.

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Acronyms

3FS	Triple-function substation
BILTST	Building Integrated Low-Temperature Solar Thermal System
CHP	Combined Heat and Power
DCS	District Cooling System 10/15 °C
DER	Distributed Energy Resources
DH	District heating
DHRHP	District Heating Reversible Heat Pump
DHW	Domestic Hot Water
EC	European Commission
H2020	Horizon 2020 EU Research and Innovation programme
HT	DH High Temperature 100/50 °C
LT	DH Low Temperature 80/40 °C
NZEB	Nearly Zero Energy Buildings?
PM	Project manager
RELaTED	Renewable Low Temperature District
RES	Renewable Energy Sources
TL	Task Leader
ULT	DH Ultra Low Temperature 45/30 °C
VLT	DH Very Low Temperature 60/30 °C
WP	Work Package
WPL	Work Package Leader

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1. Executive summary

In RELaTED Task 2.1 the low temperature district heating concept is being defined, and some of the possibilities for integrating distributed energy recourses into a low temperature district heating network are being analysed and compared.

The low temperature concept is defined by temperature levels, the possibilities to improve renewable share/CO_2-emission with a more diversified production with distributed heat sources, the ability to expand the district heating networks to new districts without changing the existing network and optimize the performance of the network and thereby operate more feasibly.

Different technology options and barriers to achieve low temperature networks are being discussed on both building, network, and energy source level. On building level, the barriers are about heat emitters and domestic hot water production. On network level optimizing the pipe system length, dimension and insulation level are addressed. Some of the energy sources options for distributed heat sources in ultra-low district heating systems (ULT DH) are discussed.

For each of the four demo sites the development activities within RELaTED are presented and thoughts about how the RELaTED concept can be implemented and evolve on a longer term are shared.

The collected data about the networks in the demo sites are analysed and the heat loss on subnet level are calculated.

Selected development activities for distributed energy sources and temperature levels are analysed and the calculated cases for each site are compared on the parameters: share of distributed energy consumption, total energy consumption, share of solar energy and waste, performance indicator factors for primary energy, CO2, and renewable energy ratio.

These results will be used in the succeeding work packages of RELaTED to investigate further the architecture of the ULT concept (WP2), design and adaption of subsystems to facilitate the use of distributed energy resources (WP3), analyse the economic feasibility and business case (WP4) and prepare and conduct demonstrations (WP5), of the RELaTED project.

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2. Introduction

This deliverable will report on the activity carried out under RELaTED Task 2.1. It will define the RELaTED low temperature concepts, considering potentialities and limitations imposed by distributed energy sources (DER), low temperature (LT) and ultra-low temperature (ULT) distribution systems as well as heat and domestic hot water demand. This report is part of a set of reports that define the system architecture of the RELaTED concept. The reports are:

- **D.2.1 Low temperature concepts**
- D.2.2 Interconnection schemes for consumer installations
- D.2.3 Interconnection schemes for producer installations
- D.2.4 Energy flexibility and district heating control
- D.2.5 Development schemes for new DH developments
- D.2.6 Transition schemes for district heating in operation

2.1. Objective

The objective of task 2.1 is to analyse and propose the most energy efficient and carbon-dioxide reducing low-temperature concepts covering the variety of energy sources available and the preconditions given by the demonstration areas of the project.

Based on the available renewable energy sources and current operational temperatures and pressures of the participating district heating networks, different low temperature concepts are analysed. This includes the main components:

1. Analysing the efficiency of distributed energy resources (DER), e.g. solar thermal and heat pump DH production in relation to energy source and supply temperatures including different waste heat source temperature levels
2. Analysing low temperature distribution systems and temperature levels in relation to cooling and heating demand of buildings, different heating/cooling densities, and different designs of domestic hot water, heating, and cooling installations
3. Combining the two analyses above and proposing the most energy efficient and carbon-dioxide reducing low-temperature concepts.

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2.2. Methodology

To carry out task 2.1 the following methodology was used:

1. A sub-report template, see Annex C, was sent to the partners for getting basic and specific characteristics of the four district heating systems of the RELaTED projects representing typical but very different climate data, heat demands, design criteria and heat generating facilities.

2. Based on the returned sub-reports and a close dialogue with the partners, potential distributed energy sources and temperature levels of the district heating systems were identified and analysed considering the specificities of the existing systems.

3. Different low temperature concepts where then evaluated using performance factors defined in the European standard EN 15316-4-5:2017 [1]. The evaluation comprises calculation of primary energy factors, CO_2-emmission factors, and renewable energy ratios for concepts fitting the four district heating systems of the RELaTED project.

This provides and overview of the performance of the different combinations of low temperature and distributed energy resources. In the succeeding work packages WP3, WP4 and WP5, of the RELaTED project, the concept will be detailed further.

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2.3. Report content

The content of this report is sectioned as follow:

1. **Executive summary**: Contains a summary of the report.
2. **Introduction**: Introduces the report, the objective and the methodology
3. **Technology options and definitions**: Definition of ultra-low temperature, distributed energy sources, heating and cooling demand, hot water systems and demand, DH network systems and primary energy, CO_2 and renewable energy factors
4. **The RELaTED ULT concept**: This section describes the basic ULT-concept of RELaTED and the benefits, the framework for the concept, technical options for ULT on building, sub-net and system level, and the general preconditions of implementing the ULT concept at the four demo sites of RELaTED.

5-8. **Description of each of the four demo sites**: These sections describes possible short and long-term implementation of the ULT concept at each demo site, analysing of building systems, distribution networks and energy resources and overall concept evaluation for each demo site.

9. **Conclusion**

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3. Technology options and definitions

This section is explaining the different definitions and most used terms RELaTED to district heating and cooling in general. It also defines ultra-low temperature district heating, distributed energy resources as well as the idea of using primary energy factors, CO_2-factors, and renewable energy ratio at district heating system level. The aim is to give the reader not familiar with district heating the background of reading the report.

3.1. Ultra-low temperature district heating

District heating companies, equipment manufacturers, consultants and researchers have discussed definitions of district heating temperature levels intensively in recent years.

In [2], the following indicative temperature levels and definitions were specified:

- DH High Temperature System (HT), 100/50 °C
- DH Low Temperature System (LT), 80/40 °C
- DH Very Low Temperature System (VLT), 60/30 °C
- DH Ultra Low Temperature System (ULT), 45/30 °C
- District cooling systems (DCS), 10/15 °C

The HT/LT definitions of this work were based on Euroheat & Power's guideline on district heating substations [3]

Other references [4] are using different generations (periods in time) of district heating to define the temperature level:

- 3rd Generation District Heating (3GDH): Temperature level < 100 °C
- 4th Generation District Heating (4GDH): Temperature level < 50-60 °C (70) °C. The brackets indicate the temperature can go up to 70 °C in winter.

This implies that both the VLT and the ULT definitions introduced above are contained in the definition of 4th generation district heating.

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The RELaTED concept will define ultra-low temperature district heating systems as:

District heating systems that supply district heating to the customers at a temperature level where production of domestic hot water requires a supplementary heat source to deliver satisfactory domestic hot water temperatures. The supply temperature limit will depend on national requirements set to prevent legionella bacteria growth in domestic hot water systems. Though, all district heating systems supplying district heating at temperatures below 50 °C will be considered ultra-low temperature district heating systems (ULT DH).

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3.2. Ultra-low temperature distributed energy

Distributed energy sources (DERs) are energy sources which are not a large central production facility. The term is widely used for photovoltaics, wind turbines or micro-CHPs feeding electricity into electric distribution grids. The term has been adopted by the district heating sector for which the DERs can be sources like industrial waste heat, excess heat from cooling applications or solar thermal heating among others. As for electric distribution grids, the district heating networks facilitate the use of DERs and it is expected DERs will replace a large part of the district heating production as Europe moves towards a zero-carbon society.

The efficiency and capacity of most DERs will benefit from supplying into the district heating network with as low temperature as possible. Figure 1 is an illustration of how the thermal yield of solar heating is affected by lowering the flow temperature in a DH network from 60 °C to 45 °C. The example shows an annual yield improvement of 36% for the same solar collector field.

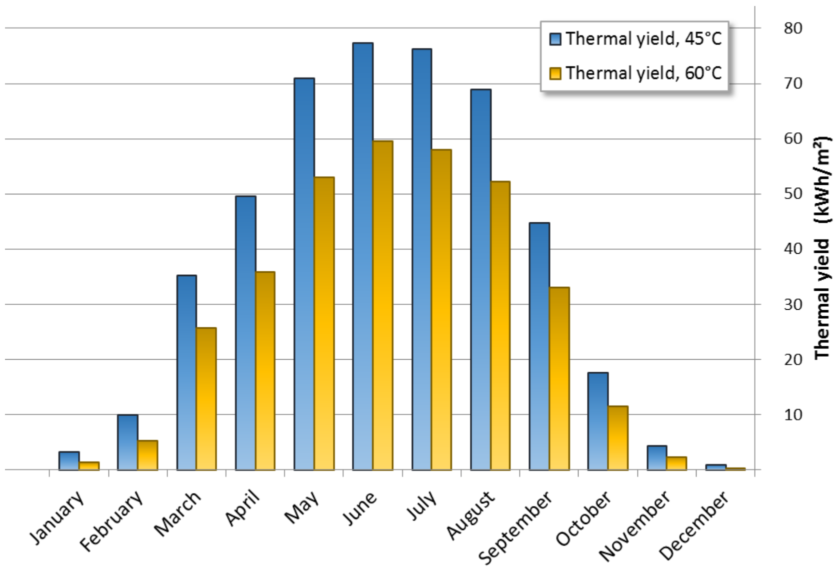

Figure 1. Thermal yield from solar thermal heating in relation to flow temperature in DH network, Stockholm climate conditions [13]

The low temperatures of ULT makes it more evident to use DERs with low temperature, which would not otherwise have been used because of the need for an energy demanding temperature boost, to obtain the required flow temperature in the DH network thus making it more feasibly.

The use of DERs within RELaTED are a motivation for lowering the network system temperature.

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3.3. Space heating

Outdoor design temperatures for space heating varies across Europe. Within the RELaTED project, they range from (~0ºC) in Iurreta (Spain), over (-12 °C) in Vinge (Denmark) to (-28 °C) in Tartu (Estonia). Because of this, and the use of different DH temperatures in each country, the size of heat emitters is different in each country for the same room sizes.

Space heating demand for new buildings are optimized for low energy consumption but not necessarily for low DH temperature. There are different building regulations in each country and therefore the space heating demands are very different.

Space heating demand for existing building stock is a lot higher than in new low energy buildings and the heat emitters in older buildings are often sized for higher supply temperatures.

Nearly zero energy buildings (NZEB) are introduced in European building codes minimizing the heat demand for new buildings. NZEB-requirements is a national issue and different approaches are seen throughout Europe.

The following temperature sets for DH network and internal heating systems indicate the optimal heating solutions:

- DH 60-100 °C (flow)/30-50 ºC (return) -> Heating system 55-90 °C (flow)/30-50 ºC (return) -> System type: Radiators.
- DH 45 ºC (flow)/30 ºC (return) -> Heating system 35 ºC (flow)/30 ºC (return) -> System type: Floor heating, other systems coupled to DH by means of DHRHP (e.g. fan-coil systems, Air Handling Units, etc.)

3.4. Cooling demand

Knowing the cooling demands of buildings in a ULT DH area can be useful to make use of the waste heat from the cooling systems. Cooling demands can vary in different countries and are depending on solar radiation and humidity. Outdoor design temperatures for cooling in Denmark are 26 °C/60% RH according to Danish regulations. In Denmark, typical applications for cooling are supermarkets, office buildings, data centres, cold stores, and process cooling. Dwellings, day care, and schools are usually not cooled.

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3.5. Domestic hot water systems

Minimum hot water temperature in DHW systems are generally around 45-50 °C to prevent bacterial growth primarily legionella while at the same time keeping a moderate energy consumption

Circulation pipe temperature requirements are generally above 50 °C and often around 55 °C also to prevent bacterial growth and at the same time keep the energy consumption moderate. There are national standards that dictates this in different ways. These temperature limits are determining the district heating temperature requirements. This will be discussed further in the D2.2 report Interconnection schemes for consumers.

DH networks with very low temperature (VLT) 60 ºC (flow)/30 ºC (return) will typically have the capacity to produce domestic hot water with a traditional water heater without any additional energy sources.

In case of DH ultra-low temperature systems (ULT), 45 ºC (flow)/30 ºC (return), the domestic hot water production need a boost from another energy source to ensure the correct DHW temperature.

Typical DHW-installations of existing systems are seen in Table 1.

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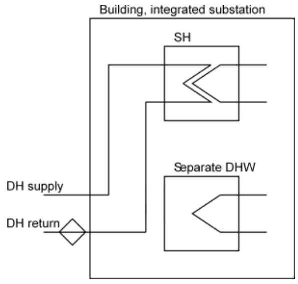
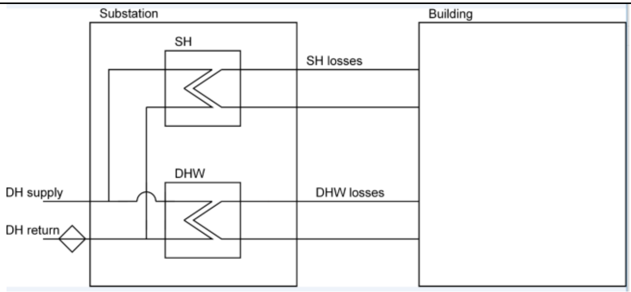
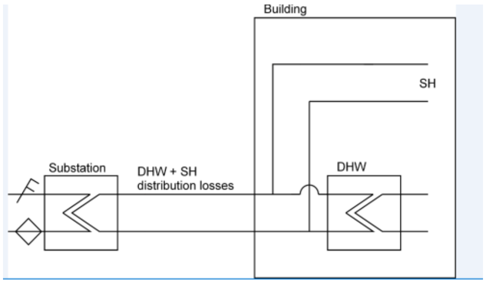
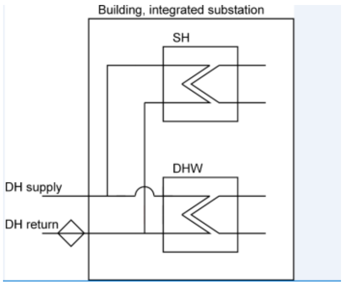
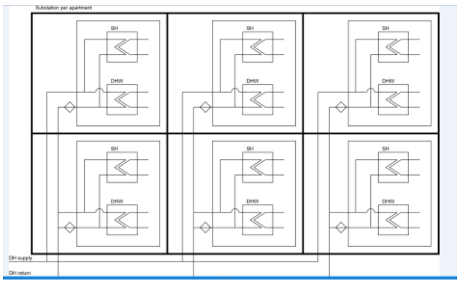
DHW Type identification	Installation type
DHW-0	
DHW-1	
DHW-2	
DHW-3	
DHW-4	

Table 1. Domestic Hot Water Systems

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DHW-0	Building integrated substation with DH only for SH. DHW is produced with and other energy source for example electricity.
DHW-1	Substation for both SH and DHW in a separate building. SH and DHW are distributed in separate pipes to the building where it is consumed.
DHW-2	Substation for DH in a separate building. DH is distributed to the building where it is consumed and separated in a substation for DHW production.
DHW-3	Building integrated substation. Both SH and DHW productions is placed in the building.
DHW-4	Substation per apartment. Both SH and DHW productions is placed in the apartments. DH is distributed to each apartment.

In newer buildings, the demand for DHW account for a bigger amount of the total energy consumption as buildings get more and more energy efficient. In Denmark, the DHW consumption in new office buildings are around 10-15%, in older apartment buildings around 25-30% and over 50% in dwellings.

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3.6. District heating network

A DH system consist of a network of pipes from the heat source to the consumers. These are the three most commonly used pipe systems:

- Pair of pipes insulated in channels. This system is no longer being used for new DH systems as it is more expensive, and the insulation levels cannot be as good as pre-insulated pipes. Channels can be re-used for new pipes as an alternative to dig. The insulation in channel systems are exposed to moist and in some cases, water fills up the channel. This will reduce the effect of the insulation.

- Pair of pipes, pre-insulated. Commonly used and comes in dimensions from DN20 to DN1200. The bigger dimensions often have a lower insulation class because of space restrictions.

- Twin pipes, pre-insulated. Commonly used and comes in dimensions from DN20-DN200. Requires less space than pair of pipes and has a lower heat loss than a pair of pipes with the same insulation class. It can be more complicated to make branch connections with a pair of pipes.

- Branch pipes are often made with pre-insulated flexible pipes. These can be pair of pipes or twin pipes.

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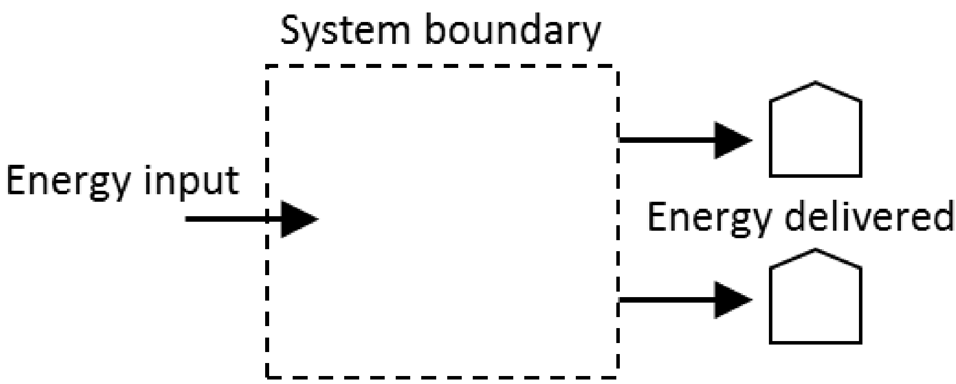
3.7. Primary energy factors, CO_2-factors and renewable energy ratios

The European standard EN 15316-4-5:2017 “Heating systems and water-based cooling systems in buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-5: District heating and cooling” [1] provides calculation methods for the performance indicators primary energy factor, CO_2-emission factor and the renewable energy ratio in district heating systems. These performance indicators are generally determined based on the ratio of weighted energy input to the system and energy delivered from the system (outputs). In its most simple form, the only output from the system is district heating. Such system is sketched in figure 2.



$$Performance\ indicator = \frac{\sum energy\ input\ * \ \text{energy source weighting factor}}{Energy\ delivered}$$

Figure 2. How energy performance indicators are calculated in their simplest form

The standard further specifies methods to allocate primary energy, CO2-emmissions and renewable energy ratio to multiple outputs of a system e.g. both electricity and heat from a combined heat and power plant (CHP). The allocation method which will be used in RELaTED is the so-called Power Bonus Method.

Different types of primary energy factors exist. The non-renewable primary energy factor specifies the fossil energy component of the primary energy source. The renewable primary energy factor specifies the renewable energy component. The sum of the two is called the total primary energy factor. Which type of primary energy factor to be used is a national decision [5], [6], [7], [8]. RELaTED uses the total primary energy factor in the present report.

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In RELaTED, the performance indicators are used to compare and evaluate the impact of integration of different DERs in existing and new systems. Further, the methods are used to consider the temperature related heat losses from the district heating distribution network.

To be able to compare the solutions across the different district heating systems, the same reference of fuel-based and electricity-based primary energy factors and CO2-emissions are used in the present report. The reference is found in Annex 1 and 2. Note, a renewable fuel may have a non-renewable component if e.g. fossil energy has been used in the processing or transportation of the renewable fuel. Further, solar thermal energy and energy from the environment e.g. ambient air used for an air-source heat pump is treated equally when supplied directly to the district heating network and when supplied to the building behind the heat meter.

This reference of RELaTED may be different from what is used nationally in the partner countries. Further, some factors will change with changes in the EU energy mix - until now the EU-reference total primary energy factor of electricity has been 2.5 but may change in the future to a value close to 2.0 [9]. Even though the references of Annex 1 and 2 are used in this report, the national decided performance indicators may have massive influence on the decision to use low temperature or ultra- low temperature district heating solutions in practice e.g. when the performance indicators are used for calculations related to the Energy Performance of Buildings Directive [10]. This national influence may be analysed further in WP 5 as part of the preparation of different demonstrations.

In the evaluation of the different cases from each demo site the performance indicators are shown for each case for easy comparison of different energy sources and flow temperatures.

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To show the differences in between the cases, a set of parameters is used to indicate the part of energy from different sources:

Total consumption:	Energy used for SH and DHW production.
Heat delivered ‘an net’:	Energy delivered from the source including distribution losses.
Distribution loss:	Part of the energy that is lost during transmission to the end user
Distributed electricity consumption:	Electricity used for temperature boosting of DHW and space heating at the end user or temperature boost of distributed energy sources.
Total electricity consumption:	Total electricity used for production at the heat source, transmission and distributed electricity consumption.
Solar thermal energy:	Energy produced form a solar thermal array
Waste heat:	Waste heat from cooling, industry etc.

Table 2 shows an example of how the parameters are presented in the report:

	Case 1.1 60-30°C	Case 1.2 45-30° Direct electricity	Case 1.3 45-30° Microbooster
Total Consumption (KWh)	155.350	155.350	155.350
Heat delivered an net (KWh)	237.572	220.570	236.972
Distribution heat loss (%)	34,6%	29,6%	27,5%
Distributed electricity consumption (kWh)	0	20.130	3.728
Total electricity consumption (KWh)	90.365	77.650	65.774
Solar thermal energy (kWh)	0	0	0
Waste heat (kWh)	0	0	0
Primary energy factor	0,95	0,88	0,75
CO2 emission factor (g/kWh)	159,8	147,9	125,2
Renewable energy ratio	0,08	0,08	0,08

Table 2. Example of presentation of calculation results

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4. The RELaTED ULT concept

This section is introducing the ULT/VLT concept of RELaTED. In the subsequent sections (5-8) details are given about the specific four district heating systems of RELaTED, where particular adaptations of the whole concept are presented.

4.1. The basic RELaTED ULT concept

The basic RELaTED ULT DH concept is a visionary model for implementing and improving DERs efficiency and capacity, and at the same time gain the benefits of reduced distribution heat losses when operating at ULT temperatures. ULT is defined by temperature levels below 50 °C where it is necessary to use supplemental heating for DHW production.

The concept can be used for long term considerations/plans of including DERs, as well as a tool/basis for evaluation of shorter term site possibilities.

The demonstration of the concept will comprise adaptions aiming at lowering network temperatures to optimize network performance and easier integration of distributed heat sources, including finding appropriate solutions for building installations, distribution network and energy sources and introducing new products and solutions like 3FS substations and DHRHP heat pumps to facilitate the integration.

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4.2. Benefits of the RELaTED ULT concept

There are many benefits of combining distributed renewables or waste heat energy sources with low network temperatures:

1. Integration of distributed renewable or waste heat energy resources to:

a. Improve renewable share/CO_2-emission

b. Integrate with society e.g. by opening the network for new independent suppliers of heat

c. Demonstrate district heating as responsible heat source

d. Diversify production

e. Operate feasibly

2. Reducing the network temperatures to:

a. Improve performance – specially in low heat density areas e.g. with NZEB-buildings

b. Expand the network to new districts

c. Facilitate integration of distributed energy sources

d. Optimize performance of energy resources.

e. Operate feasibly

The challenge is to determine and facilitate the best combination of the available DERs and the optimal low temperature level of a specific network. Some solutions are site-specific, other solutions are generic.

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4.3. Framework for low-temperature concepts

To be able to analyse the low temperature concepts, a schematic or framework model of a district heating system will be used, see figure 3.

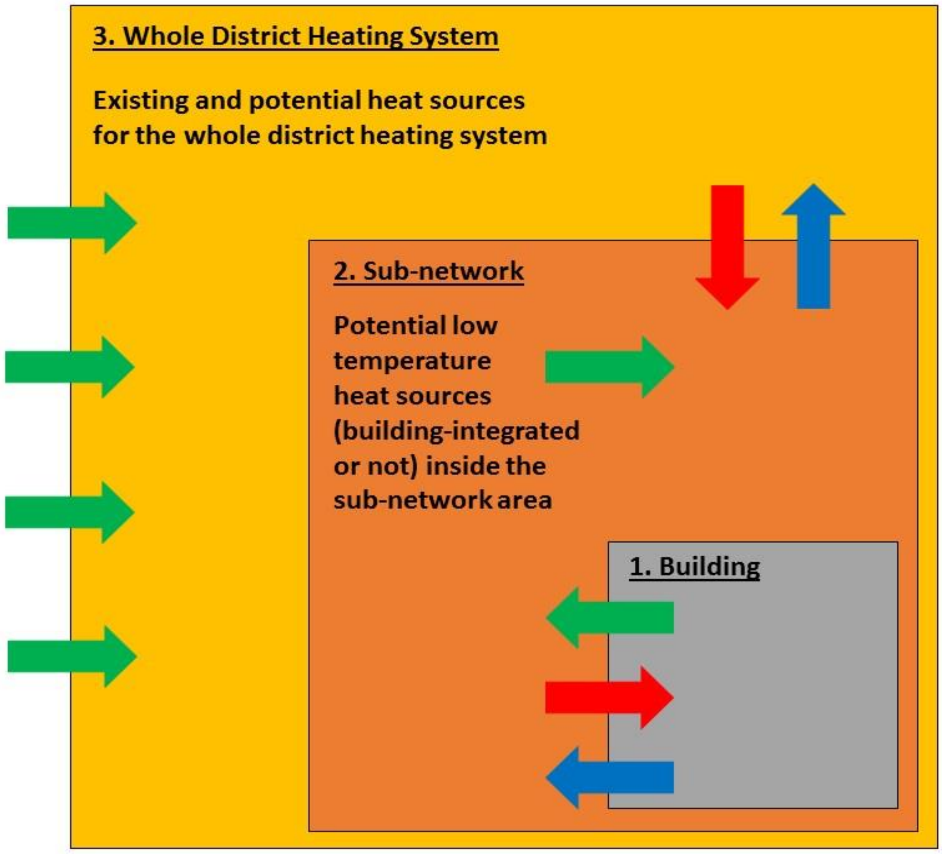

Figure 3. Schematic model of district heating system levels

The model is describing three levels of a district heating system:

1. Building level (consumer)
2. Sub-network level
3. Whole district heating system level

At building level, district heating is supplied and the cooled-off water is returned to the network. Further, building-integrated resources may be able to supply district heating to the network as well. The sub-network level is a section or part of the network where the temperatures are reduced. Distributed energy resources may be supplied to the network at this level as well. Finally, the model includes the whole district heating system level. At this level, large scale energy resources are supplied.

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Each level will address the measures to design, optimize or convert a system to low temperature. Required technologies to be adapted and demonstrated in the RELaTED-project are:

- Building integrated low temperature solar thermal systems (**BILST**)
- District heating reversible heat pump (**DHRHP**)
- Triple function substations (**3FS**)

The next sub-sections will introduce these technologies in the context of the three levels of the district heating systems (Building, Sub-network, and Whole system) of the four RELaTED sites.

4.4. Building-level

4.4.1. Building-integrated heat sources

Building integrated low temperature solar thermal systems (BILST) is a way to use low temperature solar collectors to inject heat into the DH system without the need for storage facilities normally used in solar heating systems. Because of the low distribution temperature in the DH system it is possible to make use of the solar heat with lower temperatures for a longer period than in a traditional system. The low temperature solar collectors can be used as façade systems and thereby using areas not normally used for solar heating. To both deliver and use heat from the DH system BILST must be combined with a 3FS substation described later in this report.

District heating reversible heat pump (DHRHP) will make it possible to inject the reject heat from cooling systems into the DH system while at the same time using the heat pump to boost the low DH temperature for DHW production and/or other higher temperature demanding HVAC applications for example air handling units and fan coil systems. To both deliver and use heat from the DH system DHRHP must be combined with a 3FS substation described later in this report.

A Micro-booster is a technology where a heat pump is used as an alternative to direct electric heating to boost the low DH temperature to produce DHW. Micro-boosters can be built in different ways. In some products, the heat pump is used to boost the DH water on the primary side of a plate heater. In other products, the heat pump is used to boost the temperature in a DHW storage tank. The storage tank can be preheated with a DH coil in the bottom of the tank and thereby reducing the use of the heat pump and the electricity consumption. At 45 °C DH

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supply temperature a well sized coil can cover about 50% of the DHW heating under normal use.

4.4.2. Building installations

To ensure a working ULT system in a building the heat emitters must be sized for the right capacity at low temperature. This is important for radiators and heating coils in ventilation plants. Floor heating usually runs at lower temperatures 30-35 °C and should not be a barrier for ULT. DHW systems need a boost system to ensure the right hot tap water temperature. The boost system can be a direct electrical heating element or a micro-booster heat pump for lower energy consumption. Balancing of the heating system in the building is important to ensure that all heat emitters have the full capacity and can heat all rooms at peak loads. Smart meters can make it possible to prioritize for example production of DHW in a storage tank when the DH prize is low and thereby even out peak loads in the DH system.

Triple function substations (3FS) are an upgrade of the traditional substation concept which will allow bi-directional heat flow. The 3FS substation will make it possible to extract heat at high temperature from the supply pipe, inject heat at high temperature to the supply pipe and inject heat at low temperature to the return pipe. Injecting heat into the return pipe will require either the use of the return water in other parts of the network or a very small part of heat injected so the return water does not get to warm.

The 3FS substation is a requirement for the use of BILST and DHRHP in a ULT DH network. For the 3FS substation to work probably it will depend on data from smart meters to choose whether the produced heat is stored locally or injected into the DH network when it is economically beneficial.

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4.5. Sub-net level

4.5.1. Other distributed heat sources

Industrial waste heat can be injected into the DH system as a supplement at high temperature to the supply pipe. Because of the use of ULT it is possible to make use of waste heat that could not be used in a traditional DH system without boosting it. The waste heat sources must be chosen so the capacity fits with the other sources in the system or else there will be periods with overcapacity.

Medium-scale solar thermal plants can produce heat to inject into the DH system. A plant under 1.000m² can normally work without a storage tank. It might be beneficial to size a solar thermal plant for covering the whole or part of the distribution loss in the sub-net.

Air-to-water or ground source heat pumps can both be used as base production or in larger DH systems as supplement heat. The use of heat pumps fits well with the ULT concept as the COP of the heat pumps is better at low DH temperatures.

4.5.2. Network layout and operation

To make an ULT system an important focus point is the DH network. The network must be simplified to reduce heat loss thereby making it easier to keep a low network temperature even at the outer end of the system. In existing DH systems, it can be beneficial to make temperature sectioning so older building stock with high temperature demands can continue unaltered while newer building areas can work with the lower temperatures. Sub-networks can with advantage be interconnected to make better use of distributed heat sources in the system. Bypasses can be optimized with temperature control or even shut down, so the system is not short circuited. Introduction of smart metering at the consumers and sensors in the network will make it possible to make better load controls and prioritize the distributed heat sources in the DH network.

Investigate the option of using return water of larger network for supplying heat to sub-network. In older city areas with the need for a high DH supply temperature the return water can be used as a supplement source in a new nearby ULT DH area. The warm return water can be used as source for the DHRHP system which can operate over a vast range of supply temperatures while ensuring service temperatures in the building side. This way it is possible to use more of the energy from the water before reheating it and at the same time reducing the heat loss at the return pipe.

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4.5.3. Network heat losses and electricity consumption

Pipe dimensions and insulation level

In the design of a new DH system it is important to focus on optimizing the pipe network with small dimensions and minimum length for a low distribution loss especially in NZEB building areas with low building density.

The use of twin pipes instead of pair of pipes if possible can lower distribution loss around 25-35% [2] depending on dimension and insulation level.

Insulation class 3 are preferred for the main pipe traces where the necessary space is available, but for the branch pipes to each house insulation class 2 might be necessary for easier handling of the pipes at the insertion point.

Hydraulics and pumps

Lowering the DH temperature from for example 60-30 °C to 45-30 °C in an existing system will result in a higher flow because of the lower temperature difference. The higher flow will require more pump energy. In new DH systems the pipes must be optimized according to the low DH temperature difference considering both heat loss and pressure drop. Larger pipes give lower pressure drop but larger heat loss, while smaller pipes give larger pressure drop but lower heat loss. Choosing the right pump for the system with a low energy consumption and automatic capacity regulation can be a more economical solution than choosing a larger pipe dimension especially in existing systems.

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4.6. System-level

4.6.1. Potential large-scale heat sources

Alternatives to heat pumps as base production in ULT systems can for example be:

- Biomass (solid) boiler with biofuel
- Biomass (gaseous or solid) CHP
- Large-scale solar thermal plant with a storage. Storage must be sized to cover the consumption as long part of the year as possible before using supplemental heating supply.
- Deep geothermal plant. Depending on depth and geology it can be necessary to combine it with a heat pump to boost the temperature for use in a DH system.

4.6.2. Overall system operation

Heat source management based on machine learning, weather forecast, historical demand and online measurement in the system can be used to control and prioritize the use of heat sources and storage systems. Based on the input data the system will automatically improve how it predicts the DH usage and adapt to the actual situation. This will help keeping an efficient and economical DH production.

Heat load and network temperature-based control. Monitoring of temperature in critical points of the DH network can help keeping the temperature low, to prevent heat loss, while at the same time keeping the temperatures sufficiently high to heat the buildings in the network. In combination with pumping optimization this will help keeping down distribution costs.

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4.7. Implementing the RELaTED ULT concept

Implementing the RELaTED ULT concept into new and existing DH networks will meet different challenges based on region specific barriers, existing energy sources, economy etc.

The integration of DERs and the reduction of network temperatures have some generic characteristics but must also be adapted to the specific site and system.

There exist a variety of different types of district heating system and a great deal of these types are reflected in the four demonstration sites:

Vinge: New DH network in a green field development with NZEB

Main heat source: Free choice from a number of renewable heat sources

Heat density: Low

Climate: Denmark

Tartu: Operational medium sized DH network with high share of heat production based on biomass CHP

Main heat sources: Central CHP with excess heat in summer exceeding demand

Heat density: Medium

Climate: Estonia

Belgrade: Operational large DH network with heat production based on gas boiler but plans for a mix of substituting heat sources

Main heat sources: Gas boiler

Heat density: Medium

Climate: Serbia (Inland)

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Iurreta: Operational small corporate DH network

Main heating sources: Boiler + heat pumps

Main cooling sources: Air-conditioners

Heat density: High (for South-European Standards)

Climate: Spain (North coast)

Proposing energy efficient and carbon-dioxide reducing low-temperature concepts for the above systems based on the input from the templates received from partners of Tartu, Belgrade, Vinge and Iurreta will comprise the RELaTED ULT/VLT concepts, see four next sections (one section per site).

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5. New DH network in a green field development with NZEB (Vinge)

5.1. Overall description of DH system

Vestforbrænding (VESTFOR) is the largest waste management company in Denmark and the largest waste incineration company for DH in Northern Europe. VESTFOR produces 295.000 MWh electricity and 1,25 million MWh heat in CHP plants 100% based on waste and biomass. VESTFOR delivers waste and DH services to more than 900,000 individuals and 60,000 businesses in the region, and all its activities have an environmental certification. VESTFOR is going to operate a new small and separate district heating system, supplying new low-energy single-family houses in Vinge.

Vinge is a green field development and the largest urban development project in Denmark. Located near Frederikssund, Vinge will have its own train station (35 minutes to Copenhagen), and will be fully developed in a 20-year time frame. It is expected to comprise 20,000 inhabitants and 4,000 new jobs within its 370 hectares' new development. Vinge is designed as a green and smart city with a sustainable energy infrastructure. All buildings in Vinge must be low energy or passive houses and heated by renewable energy.

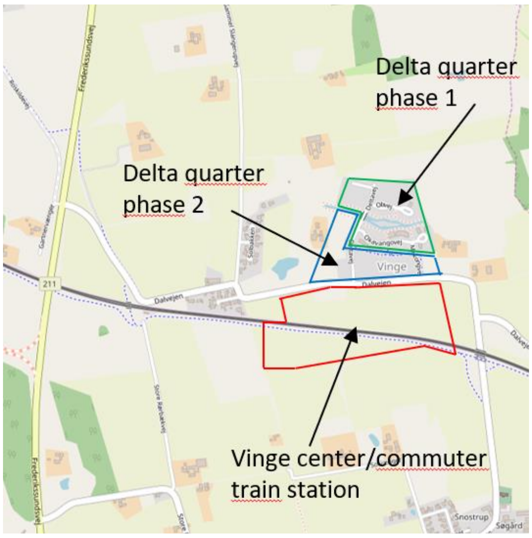

Figure 4. Overview Vinge (Map data © OpenStreetMap Contributors)

In phase 1, in the Delta quarter, 23 interconnected townhouses of a total of 36 planned and 31 detached houses of a total of 38 planned is built in 2017 and

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2018. The DH network is already established for the 36 townhouses and the 38 detached houses, with mandatory connection for the 36 townhouses and voluntary connection for the 23 detached houses. Till now 8 of the owners of the detached houses have chosen to have their own energy supply and are therefore not connected to the DH network. For now, the DH, heat is provided by a 200kW air-to-water heat pump with two 1,500-liter water storage tanks and a 100kW inline electric heating element.

5.2. Long term implementation of ULT concept

In a foreseeable future but not yet fully planned the expansion of Vinge is expected to evolve into [11]:

Phase	Site area	potential building area	Potential building density
Delta Quarter phase 1	≈ 43.000m²	≈ 12.500m²	≈ 30%
Delta Quarter phase 2	≈ 43.000m²	≈ 12.500m²	≈ 30%
Vinge Center when fully developed	≈ 172.000m²	≈ 184.000m²	≈ 107%

Table 3. Expected future expansion of Vinge

In phase 1 of the Delta quarter around 7.000m² of houses are already built.

Part of Vinge Centre will be a new commuter train station with possibly a 200m² shop.

Concerning the rest of Vinge Centre, the following is estimated:

Dwellings ≈120.000m²
Business ≈58.500m²
Retail shops ≈3.500m²
Other shops ≈2.000m²

A large museum storage facility is planned in 2019. This building might not need or produce a lot of heat since most of the storage is based on passive heating from the ground and humidity control.

Based on these numbers there is a large potential for integrating distributed energy resources into the DH system from the start and to optimize network for ULT. Vinge is expected to evolve further in the future.

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5.3. Developing activities within RELaTED

RELaTED will demonstrate its ULT DH system for new low-energy developments with large shares of renewable energy with the best possible fiscal solution for homeowners and district heating company and minimal environmental impact.

Vinge will demonstrate the scalability of the ULT DH concept for new urban developments, where network design should adapt to steady increases in energy loads by connection and diversification of energy sources, particularly of renewable nature.

Figure 5. Delta quarter phase 1 (Map data © OpenStreetMap Contributors)

Within RELaTED, the DH system in Vinge will convert its LT DH system operational at 60/30 ºC to the RELaTED 45/30 ºC ULT concept. Electric booster units will be used to guarantee that DHW peak consumption periods are covered correctly while maintaining overall low operational temperature.

Also, within RELaTED, energy planning, extension of DH, connection of further RES, etc. will be performed to ensure the development of its low carbon DH concept over its 20 years deployment period.

In further development phases, other renewable energy supplies such as heat pumps, waste heat, solar thermal, biomass etc. are expected to be connected to the network and are therefore analysed in this deliverable.

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5.4. Analysing buildings and installations

5.4.1. Building energy performance

The current buildings in the Delta Quarter in Vinge are designed and constructed within a period of 4 years. In this period the Danish Building Regulations have been updated twice. Until 2015 it was mandatory to use energy class A2010 and voluntary to use either energy class A2015 or A2020 with a transition period to mid-2016. Since then it is mandatory to use energy class A2015 and voluntary to use energy class A2020. All three energy classes are represented in the Delta Quarter divided on both interconnected townhouses and detached houses. Energy class A2020 are closes to NZEB level.

The Danish energy classes are divided into dwellings, dorms, hotels etc. and other buildings. In other buildings lightning is also calculated into the energy classification. The Danish energy classes are defined as seen in the table below

Danish Energy Classes:

Energy class	Dwellings, dorms, hotels etc.	Other Buildings
A2010	52,5+ A/1650 kWh/m² per. year	71,0+ A/1650 kWh/m² per. year
A2015	30,0+ A/1.000 kWh/m² per. year	41,0+ A/1.000 kWh/m² per. year
A2020	27,0 kWh/m² per. year	33,0 kWh/m² per. year

Table 4. Danish energy classes

The analyses are performed with data according to the energy classes and with a share of 15 kWh/m² per. year for DHW since there is not yet enough data about the actual DH consumption in the Delta quarter. DHW consumption is not considered for houses with ventilation exhaust air heat pump for DHW production. The analyses are based on data from the interconnected townhouses because only few of the planned detached houses are built and many of them are not even connected to the DH network since it is only mandatory for the interconnected townhouses.

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5.4.2. Heating systems

Underfloor heating is a very widespread heating system for new residential houses in Denmark and is also used in all the houses in the Delta quarter. In some cases, primarily in the ground floor supplied with radiators on the first floor. Underfloor heating is very good in terms of low temperature systems as the normal distribution temperatures are around maximum 30-35 °C in order not to make discomfort and to preserve floor material. As for underfloor heating systems there are no barriers for lowering the DH supply temperature to 45 °C.

In some of the houses radiators are used for heating on the first floor. Changing the DH temperature from 60-30 °C to 45-30 °C will reduce the heating effect of the radiators to around 70%. In most cases radiators are a little oversized as they are often rounded up to nearest standard size or to fit the width of a window. In small rooms in NZEB residential housing like those in the Delta quarter it may not be a problem to lower the temperature. But it is important to consider for new buildings and for buildings that are dependent on the radiator capacity to reheat a building after a night time drop.

The ventilation systems in some of the houses in the Delta quarter have a DH based heating coil. This is not used as primary heating system but only to ensure comfort temperature for the ventilation air. If the heating coil is not dimensioned for ULT there can be problems delivering the necessary effect. In this case it might be little to no problem as many ventilation systems for residential houses in Denmark are made only with heat recovery for heating of the air.

In other buildings with larger ventilation plants for example office buildings it is important to focus on a correct sized heating coil to ensure the necessary effect for heating of the ventilation air.

5.4.3. Domestic hot water systems

A traditional DHW plate heater is used for DHW production I the A2010 row houses in the Delta quarter. The plate heaters are well sized, but the DH supply temperature cannot be lowered under 50-55 °C for these houses to maintain a DHW temperature at 45-50 °C. Therefore, the need for an alternative system to boost the DHW temperature is necessary.

Ventilation systems with an exhaust air heat pump DHW heater are used in some of the A2015 and A2020 houses. Some of them are therefore not dependent on the DH network for DHW production at all. In one group of houses there is a DH

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coil in the bottom of the DHW storage tank to preheat the DHW and minimize the use of the heat pump.

For new houses or for existing houses with a plate heat exchanger a micro-booster DHW heater can be a solution to lower the DH temperature. This solution is not yet used in the Delta quarter but could be an alternative to the ventilation exhaust air DHW heater. Combined with a DH coil in the storage tank the electricity consumption for heating DHW can be kept to a minimum.

5.5. Analysing distribution network

5.5.1. Hydraulics and pump power

In the calculations, pump power for the DH network is set to 1% of the total energy consumption for both temperature sets.

5.5.2. Distribution heat losses

The heat loss from the distribution pipes to the interconnected townhouses in the Delta quarter is calculated to around 35% of the calculated DH consumption at 60-30 °C. Lowering the temperature set to 45-30 °C, while at the same time reducing the total consumption to DHW heating because of local boosting for producing DHW, will result in a calculated heat loss from the distribution pipes at around 28-30%.

The relatively low building density in the Delta quarter and the NZEB houses low heat consumption and distributed DHW production, causes the distribution heat loss to be relatively high compared to areas with higher building density.

Since only the interconnected townhouses are obligated to connect to the DH system the areas with detached houses, with only a few of them connected to the DH network, will make the distribution loss even higher than the analysed data assume.

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5.6. Analysing energy resources

5.6.1. Building-integrated heat sources

As of now there are no new building projects in the Delta quarter in Vinge and therefore there are no projects to try the building-integrated heat sources on currently. There will be a follow up on this subject later in the project

5.6.2. Other distributed heat sources

The following cases for distributed heat sources have been calculated for the temperature sets 60-30 °C and 45-30 °C. In the cases with temperature set 45-30 °C there is always a supplemental local heat source in form of direct electricity or a micro-booster heat pump for boosting of DHW temperature.

Air-to-water heat pump

Case 1.1 Heat source is an Air-to-water heat pump at temperature set 60-30 °C. Yearly COP is 2,7. This is the existing setup in the Delta quarter.

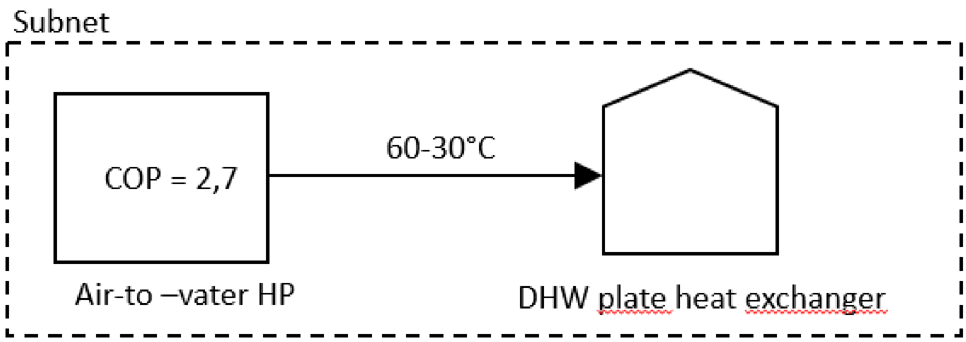

Figure 6. Vinge Case 1.1

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Case 1.2 Heat source is an air-to-water heat pump. Temperature set is lowered to 45-30 °C. Yearly COP is 3,6. DH is supplied with direct electric heating of DHW at consumers

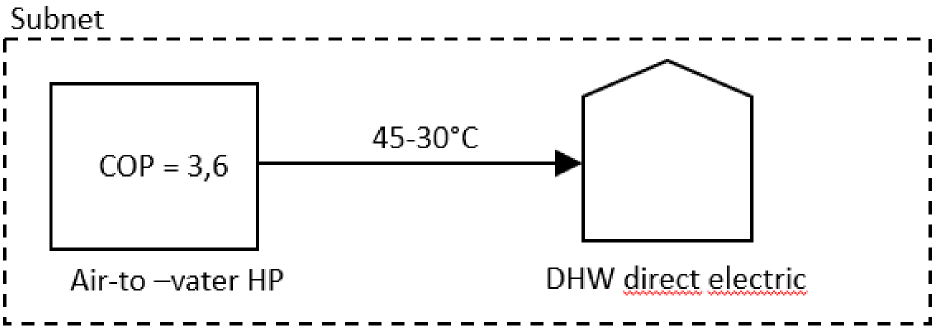

Figure 7. Vinge Case 1.2

Case 1.3 Heat source is an air-to-water heat pump. Temperature set is lowered to 45-30°. Yearly COP is 3,6. DH is supplied with a micro-booster, with a DH heating coil in the storage tank for heating of DHW at consumers. Micro-booster yearly COP is 5,4.

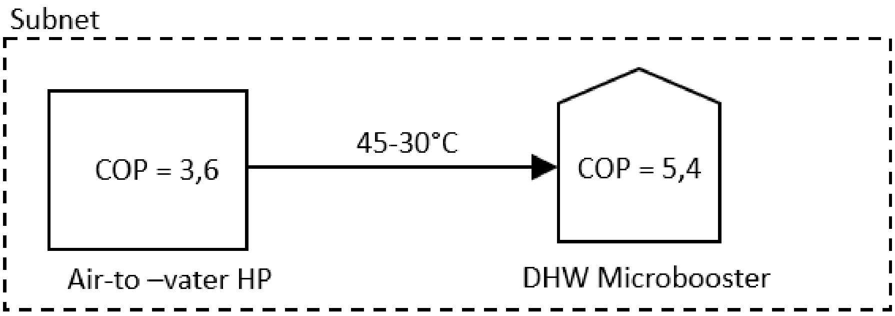

Figure 8. Vinge Case 1.3

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Biofuel Boiler

As an alternative to air-to-water heat pump the heat source is a solid biofuel boiler supplied with solar heating in two of three cases.

Case 2.1 Heat source is a solid biofuel boiler at temperature set 60-30 °C. Boiler efficiency is 92%.

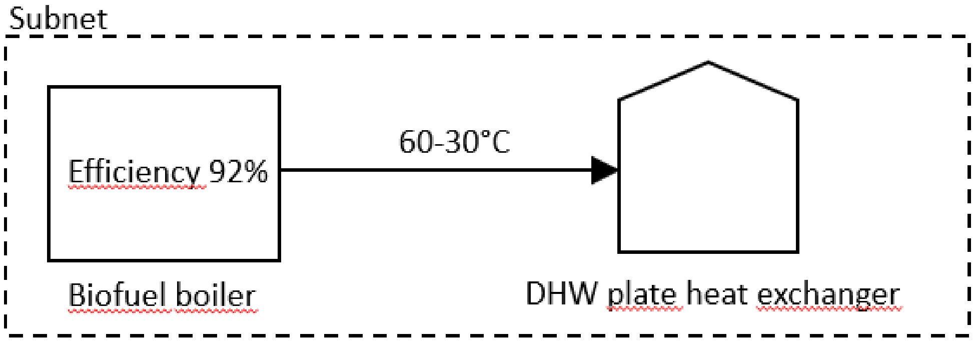

Figure 9. Vinge Case 2.1

Case 2.2 Heat source is a solid biofuel boiler at temperature set 60-30 °C. Boiler efficiency is 92%. The boiler is supplied with 175m² solar thermal heating panels for 100% coverage in June.

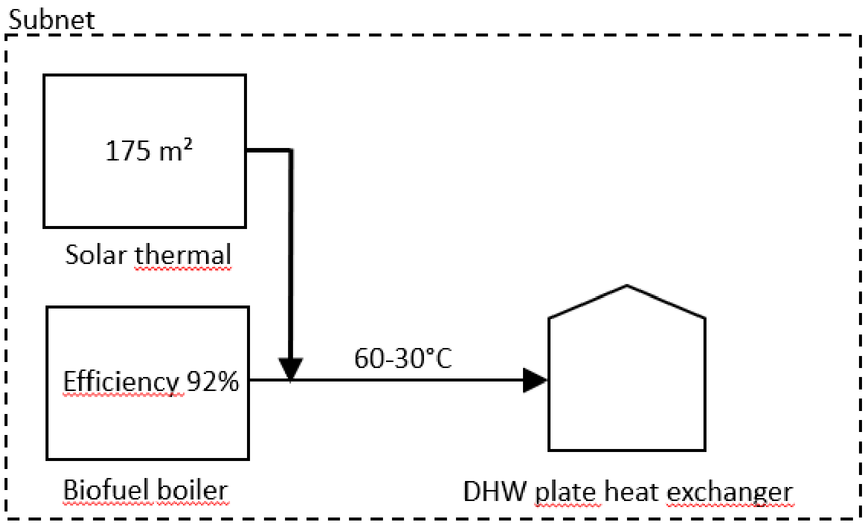

Figure 10. Vinge Case 2.2

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Case 2.3 Heat source is a solid biofuel boiler. Temperature set is lowered to 45-30 °C. Boiler efficiency is 92%. The boiler is supplied with 115m² solar thermal heating panels for 100% coverage in June. DH is supplied with a micro-booster, with a DH heating coil in the storage tank for heating of DHW at consumers. Micro-booster yearly COP is 5,4.

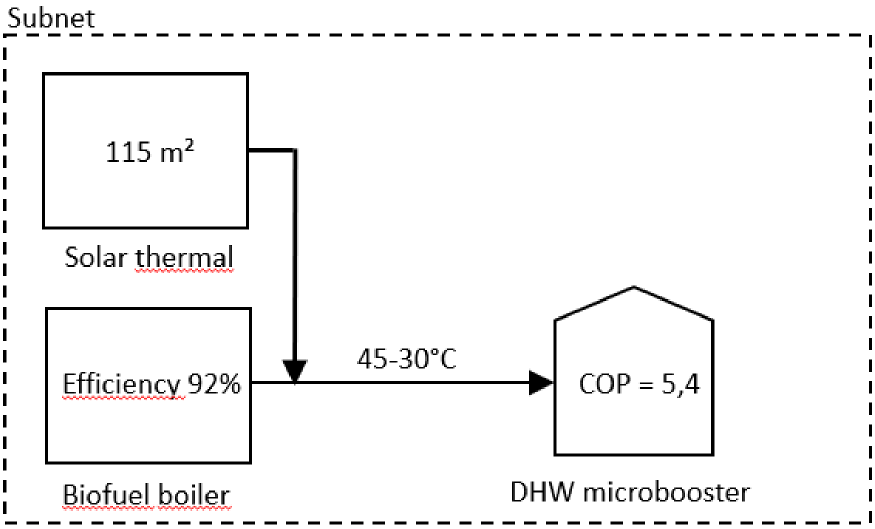

Figure 11. Vinge Case 2.3

The calculation results for the nine cases can be found in section 5.7.

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5.6.3. Potential large-scale heat sources

The following cases for large scale heat sources for long term implementation in Vinge have been calculated for the temperature sets 45-30 °C. In both cases, there is a supplemental local heat source in form of a micro-booster heat pump for boosting of DHW temperature.

Case 3.1 Heat source is a ground source heat pump at temperature set 45-30 °C. Yearly COP is 4,0. The heat pump is supplied with industrial waste heat covering 30% of the yearly DH consumption. DH is supplied with a micro-booster, with a DH heating coil in the storage tank for heating of DHW at consumers. Micro-booster yearly COP is 5,4.

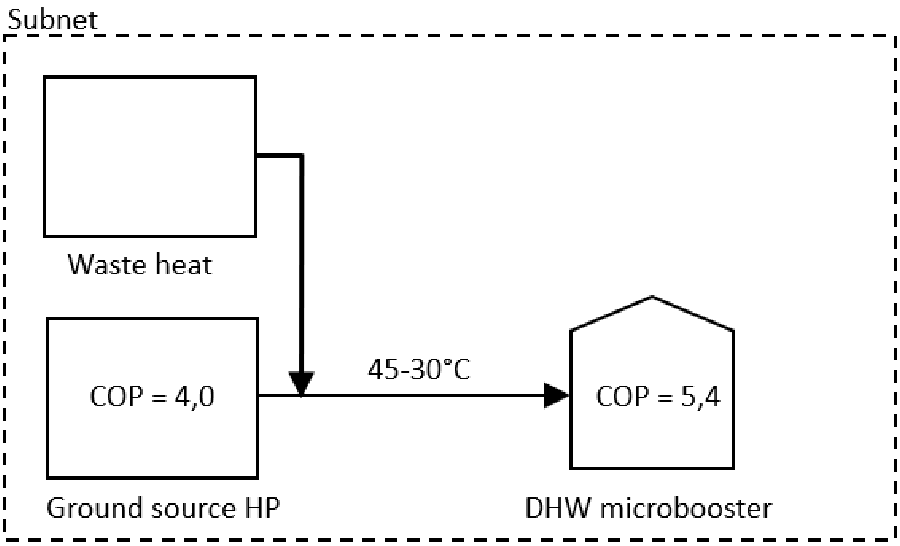

Figure 12. Vinge Case 3.1

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Case 3.2 Heat source is a solid biofuel boiler at temperature set 45-30 °C. Boiler efficiency is 92%. The boiler is supplied with industrial waste heat covering 30% of the yearly DH consumption. DH is supplied with a micro-booster, with a DH heating coil in the storage tank for heating of DHW at consumers. Micro-booster yearly COP is 5,4.

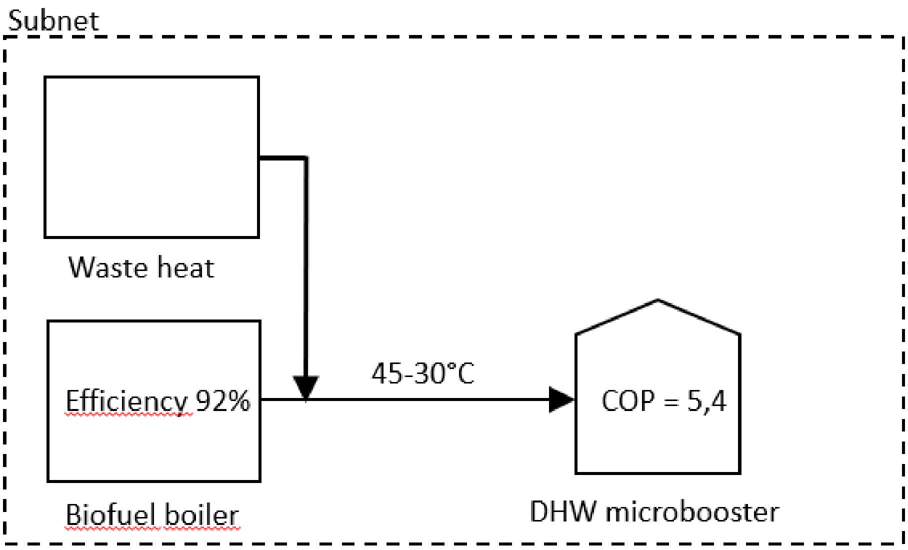

Figure 13. Vinge Case 3.2

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5.7. Overall concept evaluation

Evaluation of the cases are based on primary energy factors (PEF), CO_2 emission factors and renewable energy ratio according to EN 15316-4-5.

In the evaluation tables the part of distributed heat sources is defined to show the effect of these in each case.

5.7.1. Distributed heat sources

Air to water heat pump

In this scenario, the network temperature produced by the air-to-water heat pump is reduced from 60/30 °C in case 1.1 to 45/30 °C in case 1.2 and 1.3. To boost the temperature for DHW production a direct electric heating coil is used in case 1.2 and a DHW micro-booster heat pump supplied with a DH heating coil is used in case 1.3.

	Case 1.1 60-30°C	Case 1.2 45-30° Direct electricity	Case 1.3 45-30° Microbooster
Total Consumption (KWh)	155.350	155.350	155.350
Heat delivered an net (KWh)	237.572	220.570	236.972
Distribution heat loss (%)	34,6%	29,6%	27,5%
Distributed electricity consumption (kWh)	0	20.130	3.728
Total electricity consumption (KWh)	90.365	77.650	65.774
Solar thermal energy (kWh)	0	0	0
Waste heat (kWh)	0	0	0
Primary energy factor	0,95	0,88	0,75
CO2 emission factor (g/kWh)	159,8	148,5	125,2
Renewable energy ratio	0,66	0,69	0,74

Table 5. Air to water heat pump case 1.1-1.3

In case 1.2 the distribution heat loss is lowered because of the lower system temperature set in relation to a lower DH consumption. The total electricity consumption is lowered because of the lower system heat loss. The primary energy factor and the CO_2 emission factor are lowered compared to case 1.1. The Renewable energy ratio is higher because of the better COP for the heat pump.

In case 1.3 the distribution heat loss in relation to the DH consumption is even lower because of a higher DH consumption as it is used as source for the micro-booster. The total electricity consumption is lower than case 1.2 because the micro-booster uses less electricity than the electric heating coil. The lower

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electricity use is in the buildings. The primary energy factor and the CO_2 emission factor are lowered compared to case 1.2. The Renewable energy ratio is higher because of the micro-booster instead of direct electricity for DHW heating.

Biofuel Boiler + solar

In this scenario, a biofuel boiler is used with a network temperature 60/30 °C in case 2.1. In case 2.2 the network temperature is unchanged 60/30 °C and the biofuel boiler is supplied with a 175m² thermal solar array to cover 100% in June. In case 2.3 The network temperature is reduced to 45/30 °C and the thermal solar array is reduced in size to 115m² to cover the total consumption in June.

	Case 2.1 60-30°C	Case 2.2 60-30°C 175 m² Thermal solar	Case 2.3 45-30° 115m² Thermal solar + Microbooster
Total Consumption (KWh)	155.350	155.350	155.350
Heat delivered an net (KWh)	237.572	237.572	236.972
Distribution heat loss (%)	34,6%	34,6%	27,5%
Distributed electricity consumption (kWh)	0	0	3.728
Total electricity consumption (KWh)	2.376	2.376	5.933
Solar thermal energy (kWh)	0	57.974	52.200
Waste heat (kWh)	0	0	0
Primary energy factor	1,33	1,01	1,04
CO2 emission factor (g/kWh)	47,7	37,1	43,8
Renewable energy ratio	0,83	0,87	0,81

Table 6. Biofuel + solar thermal case 2.1-2.3

In this scenario, a biofuel boiler is used with a network temperature 60/30 °C in case 2.1. In case 2.2 the network temperature is unchanged 60/30 °C and the biofuel boiler is supplied with a 175m² thermal solar array to cover 100% in June. In case 2.3 The network temperature is reduced to 45/30 °C and the thermal solar array is reduced in size to 115m² to cover the total consumption in June.

In case 2.2 the distribution heat loss and the electricity consumption are unchanged. The share of solar thermal cause the primary energy factor and the CO_2 emission to be lower than in case 2.1 and the renewable energy ratio is higher because of the solar share.

In case 2.3 the distribution heat loss is lower than case 2.1 and 2.2 because of the lower distribution temperature. The electricity consumption is higher than

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case 2.1 and 2.2 caused by the use of distributed electricity for the micro-booster. The part of solar energy is lower than case 2.2 because the need for 100% consumption in June is lower RELaTED to the lower network heat loss. The primary energy factor and the CO_2 emission is lower than case 2.1 but higher than case 2.2 because of the higher use of electricity for the micro-booster. The Renewable energy ratio is lower than case 2.1 and higher than case 2.2 because of the higher use of electricity.

5.7.2. Large scale heat sources

In this scenario in case 3.1 a ground source heat pump combined with waste heat covering 30% of total consumption is used as heat source with a network temperature 45/30 °C supplied with micro-booster.

In case 3.2 a biofuel boiler combined with waste heat covering 30% of total consumption is used as heat source with a network temperature 45/30 °C supplied with micro-booster.

	Case 3.1 45-30°C Ground source Heat pump + vaste heat + microbooster	Case 3.2 45-30°C Biofuel boiler + vaste heat + microbooster
Total Consumption (KWh)	155.350	155.350
Heat delivered an net (KWh)	236.972	236.972
Distribution heat loss (%)	27,5%	27,5%
Distributed electricity (kWh)	3.728	3.728
Total electricity consumption (KWh)	43.601	5.933
Solar energy (kWh)	0	0
Waste heat (kWh)	66.171	66.171
Primary energy factor	0,49	0,96
CO2 emission factor (g/kWh)	83,0	41,0
Renewable energy ratio	0,53	0,57

Table 7. Large scale sources 3.1-3.2

The distribution heat loss is the same for both cases. Case 3.1 has a higher electricity consumption than case 3.2 because of the heat pump. The part of waste heat is the same for both cases. The primary energy factor is lower for the heat pump than the biofuel boiler, but the CO_2 emission is higher in case 3.1 than 3.2 because of the higher use of electricity for the ground source heat pump. The

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renewable energy ratio is a little bit higher for the biofuel boiler than the ground source heat pump.

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6. Operational medium sized DH network with high share of heat production based on biomass CHP (Tartu)

6.1. Overall description of DH system

With about 100 000 inhabitants, Tartu is the second largest city of Estonia. Situated 186 kilometres (116 miles) southeast of Tallinn and 245 kilometres (152 miles) northeast of Riga, Tartu lies on the Emajõgi ("Mother River"), which connects the two largest lakes of Estonia.

Tartu is served by a DH system privately owned and operated by FORTUM TARTU and its subsidiary AS Keskkatlamaja, with a heat peak capacity of 250MW, comprising biomass CHP systems, biomass and gas boilers, and heat pumps systems connected to its heating and cooling network. Yearly 500GWh are delivered to over 1735 consumers in the city. 94% of this energy is obtained from biomass and peat.

Operational temperatures are 75/45 ºC to 110/60 ºC. Main consumers are collective apartment housing (44%), Industry and commercial buildings (26%), private individual houses (15%) and municipal, state buildings (schools, hospitals, university etc. 15%), with 40-60 new connections to the grid per year.

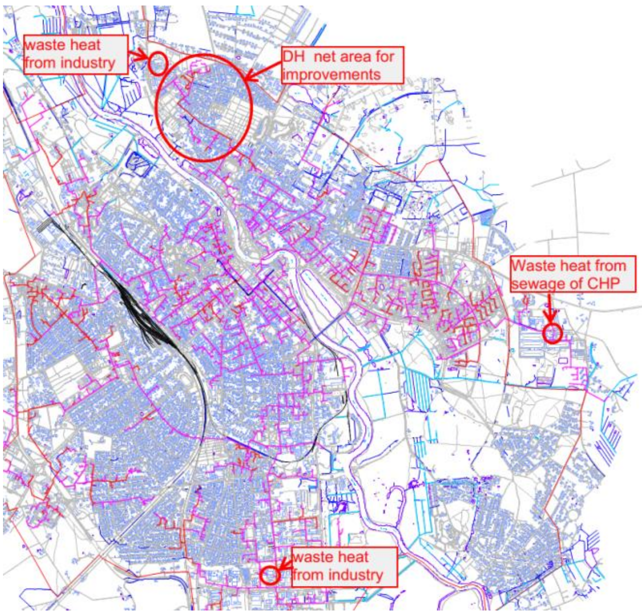

Figure 14. Overview Fortum DH network Tartu and potential distributed heat sources

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6.2. Long term implementation of ULT concept

Long term RELaTED concept results could be used for other parts of DH net. Technical limits for temperature reduction in other areas will be investigated. Possibly temperatures will be reduced in whole DH net of Tartu but technical limits as output from RELaTED project shall be considered.

In case of implementation of DH at existing residential or private house areas outside of the existing DH area, the LT concept could be used if it has advantage and gives savings in energy consumption.

New available waste heat resources will be implemented as DH heat source. Possible heat sources could be ice machines of Ice Arena, sewage of Waterworks Company after treatment plant, and also industry and business building, shopping malls and food markets outside of existing DC network. Feasibility and energy saving potential of all possible heat sources will be investigated separately. The amount of possible heat sources depends on results of RELaTED project, negotiations with potential customers and general market conditions.

More customers with bidirectional heat supply together with lower DH temperatures will lead to implementation of open DH concept in Tartu and better utilization of different heat sources

6.3. Development activities within RELaTED

Within RELaTED, FORTUM will develop the following implementations:

- LT conversion of the TARKON DH network area comprising 41 consumers consuming 6,8 GWh/y with a network length of 3,3 km. Technical limitations of the DH network will be investigated and associated feasible technical and economically viable conversion scenarios identified. Temperature reductions of 10 ºC are estimated to be achieved in this district, with network temperature levels being reduced from 75 ºC to 65 ºC (60 ºC during summer). The tested conversion solution will serve for further conversion of other subnetworks in the DH network in Tartu.
- Development of a technical solution and heat purchase strategy from one or several industrial waste heat producers with an estimated power of 0.5 to 1 MW. Possible heat sources are several printing and, food industries, condensate flue gas, etc.

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- Connection of excess heat from cooling applications to the DH network.

6.4. Analysing buildings and installations

6.4.1. Building energy performance

The buildings in the Tarkon area are from the period 1962 – 2017. About one third of these buildings are renovated in the period 2009-2017. The reason for renovation has been to reduce energy consumption for heating purpose. Mainly the renovation consisted of additional insulation of walls and full renovation of internal heating systems. Energy savings have been about 10-40% from initial heat consumption. The savings are different house by house and depends on the kind of renovations that have been made, what was the initial level of energy consumption etc.

Heating systems

Heating systems in buildings are built as indirect systems for connection to SH system. The secondary side of the heating system is designed mainly with temperature set 70/50 °C for radiators.

Radiator and ventilation systems are dimensioned for temperature set primarily 70/50 °C, but old buildings, which are not renovated are designed for 85-90/65 °C. Readings from heating meters indicate that the heating systems generally have some capacity margin.

Floor heating systems are designed with secondary side temperature set 40/35 °C.

6.4.2. Domestic hot water systems

Traditional DHW plate heaters is generally used for DHW production.

In some buildings, the DWH production is separate and not coupled to the DH network.

Substations are designed for a minimum DH supply temperature of 65 °C. Hot water design temperature is 55 °C. There are no specific rules for hot water circulation temperature.

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6.5. Analysing distribution network

6.5.1. Hydraulics and pump power

According to Fortum the existing pipe network is of a larger dimension than needed. Lowering the supply temperature in the network can result in a larger flow in the system, but the larger pipe dimension could mean that the rise in pressure loss will not be to excessive. More on the indications on the capacity margins in heating systems also might help that the temperature difference between supply and return won't differ much from now and therefore the flow might not increase a lot.

In the calculations pump power is set to 1% of the total heat consumption

6.5.1. Distribution heat losses

Total length of the DH net in Tartu is around 170 km. Approximal 70% of DH net is pre-insulated single and twin pipes and they are constructed or renovated during the last 20 years.

During summer and mild weather, the supply temperature today is around 75 °C. During extra cold weather the supply temperature is up to 110 °C.

Since the network supply temperature is not lowered under 65 °C there will not be need for distributed energy sources to boost the DHW temperature and therefore this will not affect the primary energy and CO_2 emission factor and the renewable energy ratio.

The heat loss from the DH network in the Tartu area is estimated to 13% by Fortum. In the Tarkon area the heat loss is calculated to around 17% of the DH consumption in this area. Lowering the temperature 10 °C in the Tarkon area in both summer and winter will result in a calculated lower temperature loss around 1.5%.

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6.6. Analysing energy resources

6.6.1. Building-integrated + distributed heat sources

Within the Tarkon subnetwork some of the possible distributed heat sources are excess heat from the cooling system in a food market and excess heat from industry.

Excess heat from cooling from a supermarket will typically be able to supply the same amount of heat to the district heating network as its yearly district heating consumption, if no recovery of waste heat has been implemented. This means, that on average, the district heating net consumption will be zero - the supermarket will be net producer during summer and net consumer during winter. Further, assuming an average yearly condenser temperature of 30 °C with R404 (not just the gas temperature of 60 °C), a heat pump is used to raise the supply temperature to the required level.

The following cases have been calculated for distributed heat sources in the Tarkon subnetwork in Tartu.

Case 1.1 Heat source is CHP with various fuel sources at temperature set 75-45°C. This case is like the existing Tarkon subnetwork.

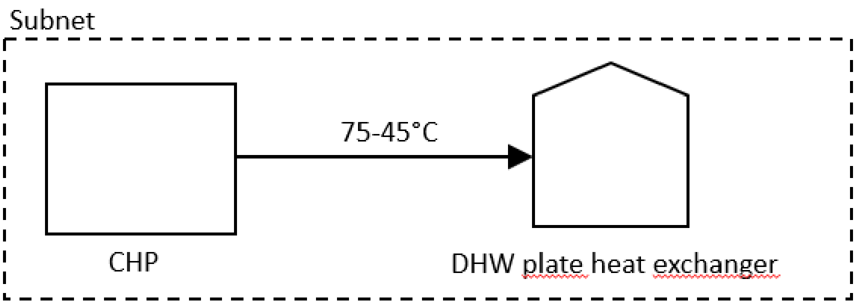

Figure 15. Tartu Case 1.1

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Case 1.2 Heat source is CHP with various fuel sources. Temperature set is lowered 10 °C. CHP is supplemented with 365 MWh excess heat from food market cooling system boosted from 30 °C to 65 °C with a heat pump. COP is 4.1.

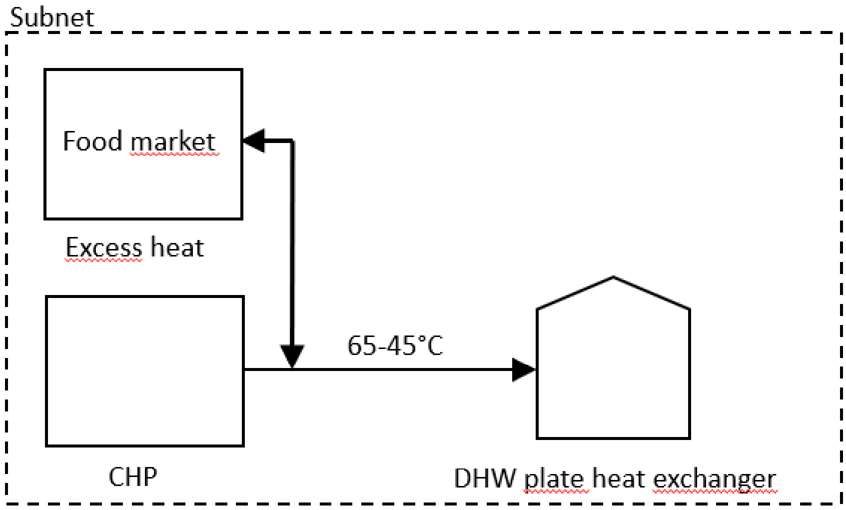

Figure 16. Tartu Case 1.2

Case 1.3 Heat source is CHP with various fuel sources. Temperature set is lowered 10 °C. CHP is supplemented with 1.6 GWh excess heat from food factory boosted from 30 °C to 65 °C with a heat pump. COP is 4.1.

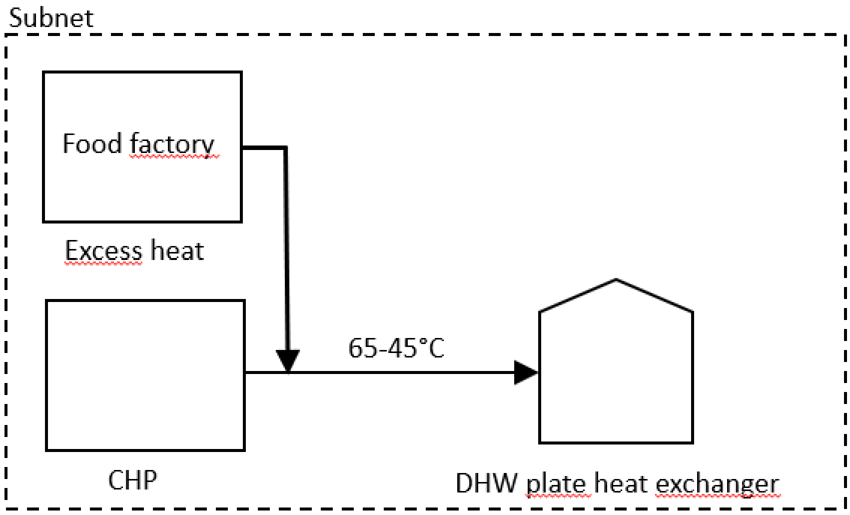

Figure 17. Tartu Case 1.3

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Building level

The use of a small distributed heat source like the food market is not significant in a subnetwork like the one in the Tarkon area. Therefore, a comparison is also made on building level where the energy consumption for heating the building is covered with the excess heat from the food market cooling, boosted with a heat pump to 75 °C and 65 °C respectively.

Case 2.1 Food market with the existing installation with DH from the existing network at temperature set 75-45 °C.

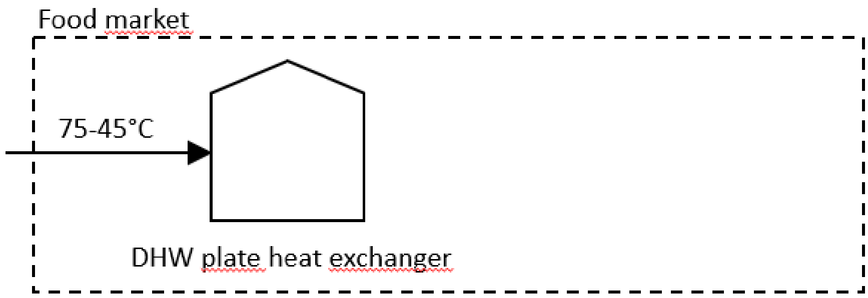

Figure 18. Tartu Case 2.1

Case 2.2 Food market with the existing installation with DH from the existing network at temperature set 75-45 °C substituted with excess heat from the food market cooling system boosted from 30 °C to 75 °C with a heat pump. COP is 3.2.

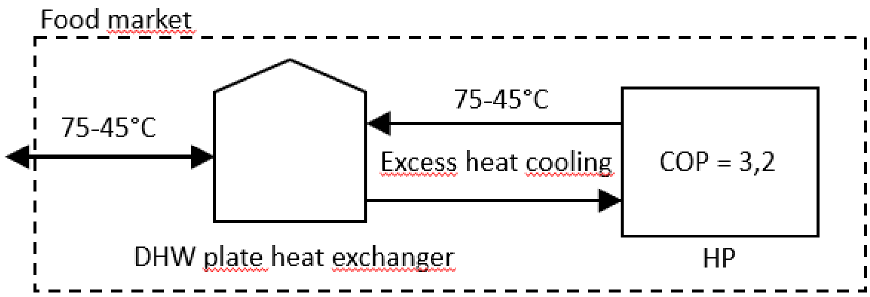

Figure 19. Tartu Case 2.2

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Case 2.3 Food market with the existing installation with DH from the existing network with lowered temperature set to 75-45 °C substituted with excess heat from the food market cooling system boosted from 30 °C to 65 °C with a heat pump. COP is 4.1.

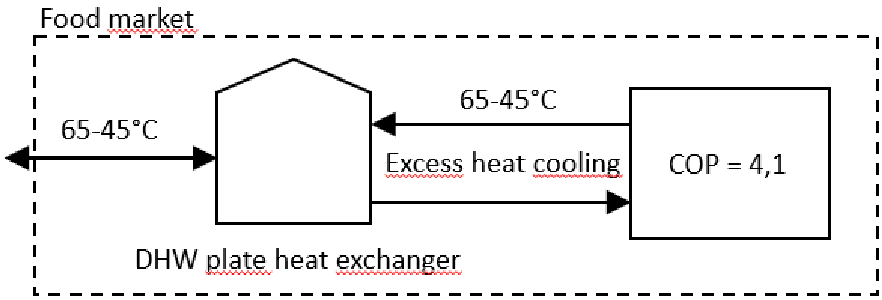

Figure 20. Tartu Case 2.3

6.6.2. Potential large-scale heat sources

The following cases for large scale heat sources outside the Tarkon subnetwork in Tartu has been calculated for the temperature sets 75-45 °C and 65-45 °C.

Case 3.1 Heat source is CHP with various fuel sources at temperature set 75-45 °C. This case is like the existing Tarkon subnetwork.

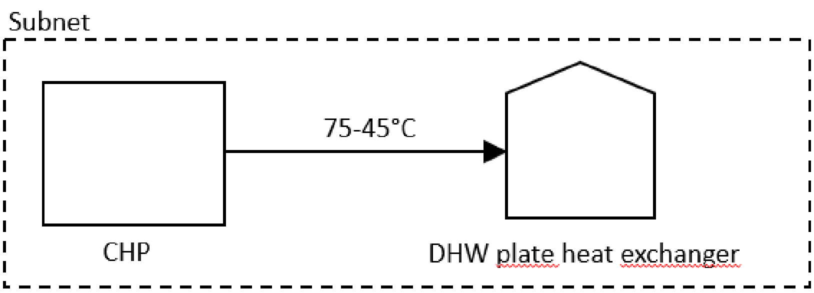

Figure 21. Tartu Case 3.1

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Case 3.2 Heat source is CHP with various fuel sources. Supply temperature lowered 10 °C to 65-40 °C. CHP is supplemented with 1.6 GWh waste heat from industry and 3 GWh waste heat from other heat sources outside the subnetwork.

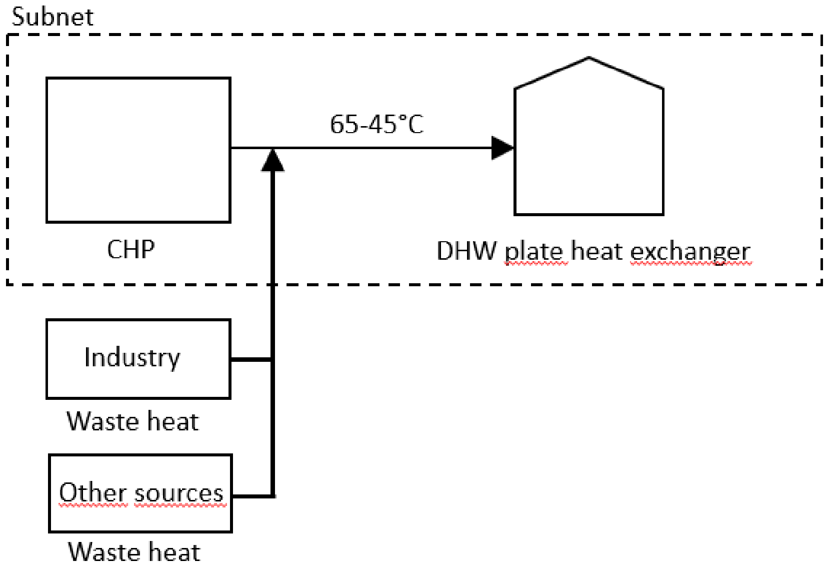

Figure 22. Tartu Case 3.2

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6.7. Overall concept evaluation

Evaluation of the cases are based on primary energy factors (PEF), CO_2 emission factors and renewable energy ratio according to EN 15316-4-5.

In the evaluation tables the part concerning distributed heat sources is defined to show the effect of these in each case.

6.7.1. Building-integrated + distributed heat sources

In this scenario, the supply temperature is lowered 10 °C in the existing Tarkon DH network with mixed heat sources and supplied with 356 MWh waste heat from supermarket cooling in case 1.2 and 1.6 GWh waste heat from industry in the subnetwork in case 1.3

	Case 1.1 Existing heat sources	Case 1.2 Existing heat sources + 10°C lower temperature + waste heat supermarket	Case 1.3 Existing heat sources + 10°C lower temperature + 1,6 GWh waste heat subnetwork
Total Consumption (MWh)	6.837	6.837	6.837
Heat delivered an net (MWh)	8.218	8.090	8.090
Distribution heat loss (%)	16,8%	15,5%	15,5%
Distributed electricity consumption (MWh)	0	89,6	394
Total electricity consumption (MWh)	82	170,5	475
Solar thermal energy (MWh)	0	0	0
Waste heat (MWh)	16	379	1616
Primary energy factor	0,90	0,89	0,50
CO2 emission factor (g/kWh)	260,00	252,97	142,57
Renewable energy ratio	0,00	0,00	0,00

Table 8. Distributed heat sources case 1.1-1.3

In case 1.2 and 1.3 the distribution heat loss is reduced around 1.3% units. The total use of electricity and distributed electricity is higher because of the need for a heat pump to boost the waste heat temperature. The share of waste heat is higher in both cases. The primary energy factor and CO_2 emission factor is reduced a little in case 1.2 and significantly in case 1.3. The renewable energy factor is almost unchanged in both cases as the renewable energy ratio factor for waste heat from process related component is 0. The change in numbers is on 3rd and 4th decimal and is therefore not noticeable in this case.

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Building level

In this scenario, a comparison is made on building level to show the impact of the use of waste heat from supermarket cooling for the building itself. The case is with the shopping centre's existing DH consumption in case 2.1 and supplied with the waste heat from supermarket cooling boosted with a heat pump to 75 °C in case 2.2. Case 2.3 is the same as case 2.2 but with the temperature boost to only 65 °C.

	Case 2.1 Shopping center existing heat sources	Case 2.2 Shopping center existing heat sources + waste heat supermarket	Case 2.3 Shopping center existing heat sources + 10°C lower temperature + waste heat supermarket
Total Consumption (MWh)	363	363	363
Heat delivered an net (MWh)	363	395	363
Distribution heat loss (%)	0,0%	0,0%	0,0%
Distributed electricity consumption (MWh)	0	0	0
Total electricity consumption (MWh)	3,6	125,4	93,2
Solar thermal energy (MWh)	0	0	0
Waste heat (MWh)	0	395	363
Primary energy factor	0,90	0,84	0,62
CO2 emission factor (g/kWh)	260,00	140,77	103,55
Renewable energy ratio	0,00	0,03	0,02

Table 9. Building level heat sources 2.1-2.3

In case 2.2 and 2.3 the electricity consumption is higher because of the use of a heat pump to boost the waste heat temperature to DH levels. The primary energy factor and the CO_2 emission factor is lowered in case 2.2 and 2.3. The renewable energy ratio is higher in case 2.2 than 2.3 because the waste heat produced in case 2.2 is higher than in 2.3.

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6.7.1. Potential large-scale heat sources

In this scenario, the existing heat supply with mixed sources is supplied with 1.6 GWh waste heat from industry outside the subnetwork and 3 GWh other heat sources outside the subnetwork.

	Case 3.1 Existing heat sources	Case 3.2 Existing heat sources + waste heat outside subnetwork + 10°C lower temperature
Total Consumption (MWh)	6.837	6.837
Heat delivered an net (MWh)	8.218	8.090
Distribution heat loss (%)	16,8%	15,5%
Distributed electricity consumption (MWh)	0	0
Total electricity consumption (MWh)	82	81
Solar thermal energy (MWh)	0	0
Waste heat (MWh)	16	4.616
Primary energy factor	0,90	0,54
CO2 emission factor (g/kWh)	260,00	145,54
Renewable energy ratio	0,00	0,00

Table 10. Large scale sources 3.1-3.3

In case 3.2 the primary energy factor and the CO_2 emission factor is reduced remarkably compared to case 3.1 because of the use of waste heat. The renewable energy ratio is unchanged.

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7. Operational large DH network with heat production based on a mix of different heat sources (Belgrade)

7.1. Overall description of DH system

Belgrade is the capital and largest city of Serbia. It is located at the confluence of the Sava and Danube rivers. The urban area of the City of Belgrade has a population of 1.34 million, while over 1.65 million people live within its administrative limits. The city of Belgrade is served by the DH operated by BEOELEKTRANE, with an installed capacity of CA 3GW from 60 heat sources over a DH network comprising 750 km, which delivers 3500GWh to approximately 50% of the city of Belgrade. Each year several dozens of kms are added to the network.

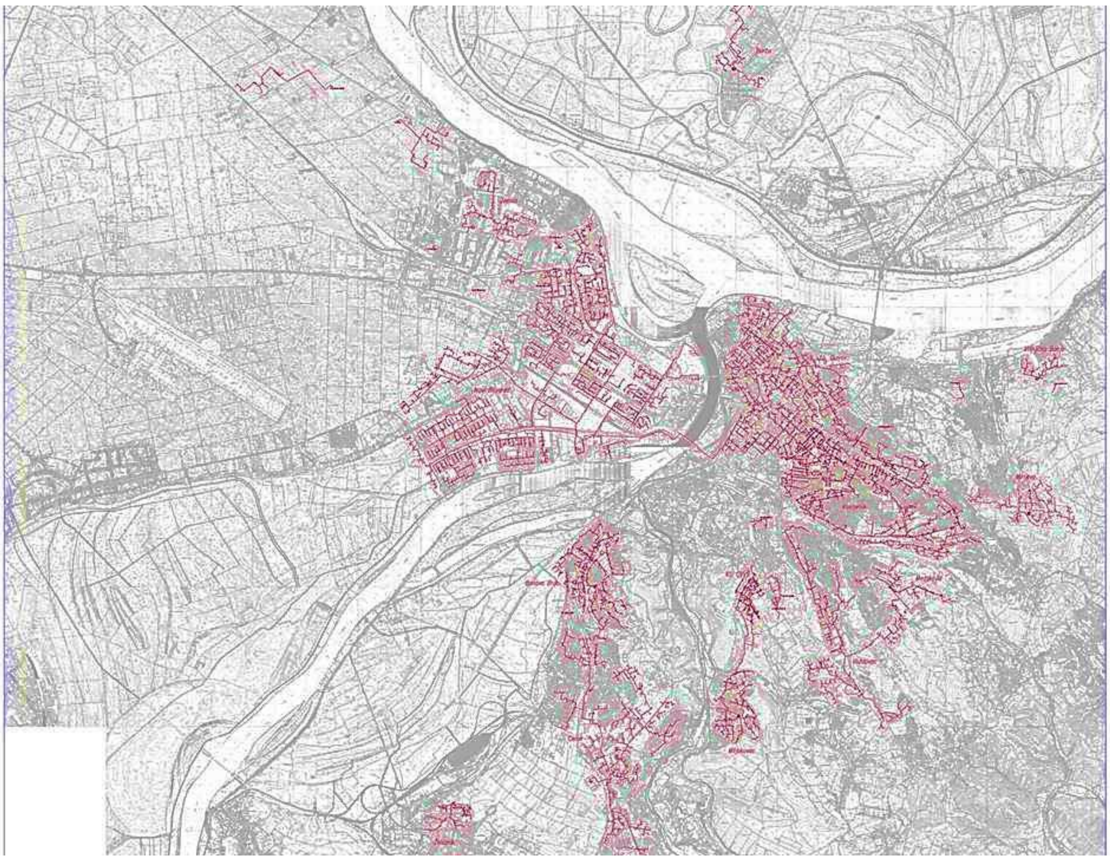

Figure 23. Overview Beoelektrane DH network Belgrade

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7.2. Long term implementation of ULT concept

Energy efficiency measures and retrofitting of multifamily buildings in Belgrade will be conducted with the increased pace in the following years. This presents a great opportunity for decreasing temperatures in district heating system and internal heating installations of buildings. In order to utilize this potential for ULT, the conversion concept should be developed for both existing and new networks that will be developed. This concept should be adapted by a district heating operator and City government.

New networks could be developed as an expansion of the DH network to new areas in the outer edge of the existing network, thereby making use of lower temperature without expanding the existing network.

To achieve this goal, the following actions should be gradually implemented at the demonstration site.

- Conversion of the DH network of Vinogradski Venac 36 without interventions or replacements of the existing radiators.
- Application of BILTST system in the Primary school “United nations”.
- Improvement of the measurement and regulation system in Vinogradski venac 36 and the “United nations” school, to ensure the optimization of the system functioning. Adaptation of control strategies to ensure the maximum use of BILTST.
- Installation of thermostatic valves in the “United nations” school in order to facilitate energy efficiency measures (replacement of windows and doors) in the school.

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7.3. Developing activities within RELaTED

Within RELaTED, BEOELEK will deploy the following conversion activities to the DH network in Belgrade:

- LT conversion of subnetwork Vinogradski Venac 36.
- Connection of heat recovery from waste incineration plant. Estimated power: 56,5 MW
- Connection of large solar heat production plant. Estimated heat production of 60GWh/year.
- Connection of several reject heat producers from cooling applications.
- Planning and tendering for the conversion for heat recovery and connection of a 1500MW electric power plant with an estimated heat output of 600MWt.

Promotion of adoption of 3FS, BILTST and DHRHP technologies by customers and partners connected to the Belgrade DH network.

7.4. Analysing buildings and installations

7.4.1. Building energy performance

The five apartment buildings in the Vinogradski subnetwork are built in 1986. The building envelope including the roof is protected and might not be changed. Therefore, energy optimization of the building envelope is not possible. Pictures of the internal pipe systems show missing insulation in some of the channels, so this might be a place to focus on energy optimization to lower the supply temperature as intended.

The United Nations Primary School are built in 1984 and has been renovated in 2006. Windows are renovated, and the heat load has been reduced. Thermostatic valves on heat emitters are to be installed and the school is Interested in BILST.

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7.4.2. Heating systems

Radiator heating are used in the five apartment buildings in Vinogradski Venac 28, 29, 31, 36 and 40 and the United Nations Primary School. The radiator systems are designed for a temperature set of 90-70°C but are in practice used at a temperature set of 80-60°C.

Lowering the supply temperature in the DH network in the winter from around 100 °C to around 90 °C should not cause problems as the temperature is mixed down to a lower system temperature in the buildings.

Lowering the network temperature in spring and autumn months must be with a little more consideration to ensure high enough service temperature on cold days.

7.4.3. Domestic hot water systems

A central DHW plate heater is used for DHW production in the five apartment buildings in Vinogradski Venac 28, 29, 31, 36 and 40. DHW is distributed from no. 36 through an internal DHW circulation pipe system to the 5 buildings. The minimum hot water circulation temperature is set to 50 °C.

In the United Nations Primary School the DHW production is also based on a plate heater with a heating capacity of 80 kW. The hot water is distributed through an internal circulation network. The minimum hot water circulation temperature is set to 50 °C.

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7.5. Analysing distribution network

7.5.1. Hydraulics and pump power

In the calculations pump power is set to 1% of the total heat consumption.

7.5.2. Distribution heat losses

The main distribution lines M1 and M2 in the Cerak area consist of a combination of channel pipelines and pre-insulated pipelines. Around 70% of the main pipelines are in channels. Estimated heat loss in the whole network is around 13%.

According to Beoelek the supply temperature already is as low as 55 °C in the summer. Therefore, the focus is on lowering the temperature in spring, autumn and winter periods.

Lowering the network supply temperature 10 °C in November to February and 5 °C in March, April and October will lower the estimated heat loss to around 1%.

Since the network supply temperature is not lowered under 55 °C there will be no need for distributed energy sources to boost the DHW temperature at the consumers and therefore this will not affect the primary energy and CO_2 emission factor and the renewable energy ratio.

The distribution network between the 5 buildings in Vinogradski Venac 28, 29, 31, 36 and 40 is single pipes in channels. In these buildings, there is both a network for SH and a network for DHW.

The heat loss in this building network might be relative high considering the double pipe network and that all the pipes are placed in channels.

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7.6. Analysing energy resources

7.6.1. Building-integrated + distributed heat sources

Within the Cerak subnetwork some of the possible distributed heat sources are BILST on the United Nations Primary School and a large 20.000m² solar plant within the subnetwork [12].

The following cases have been calculated for the Cerak DH network

Case 1.1 Heat source is a gas boiler with 90% efficiency. This case is like the existing Cerak subnetwork.

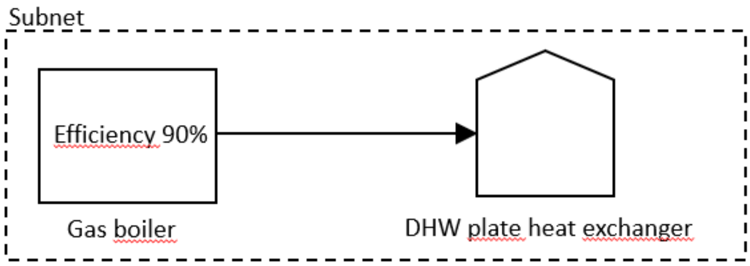

Figure 24. Belgrade Case 1.1

Case 1.2 Heat source is a gas boiler with 90% efficiency supplemented with 250m² BILST at the United Nations Primary School

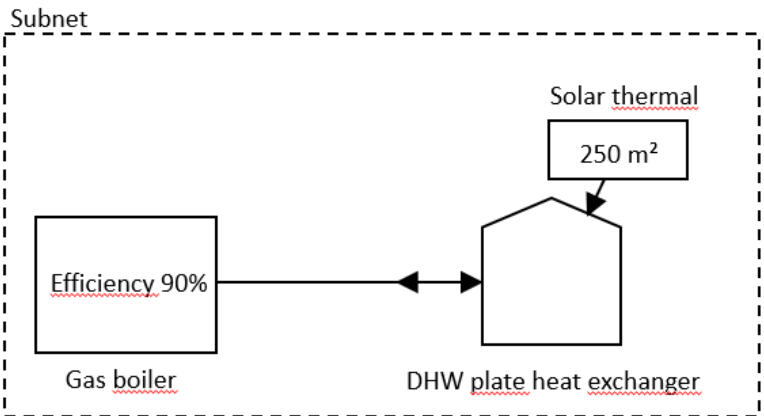

Figure 25. Belgrade Case 1.2

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Case 1.3 Heat source is a gas boiler with 90% efficiency supplemented with a 20.000m² thermal solar plant within the subnetwork

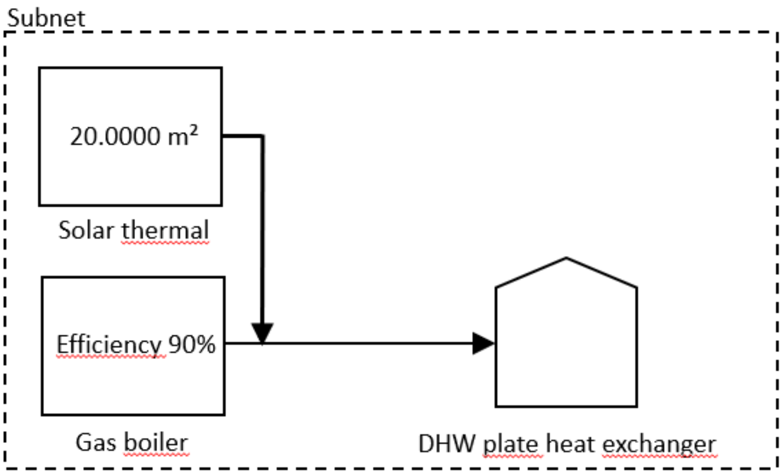

Figure 26 Belgrade Case 1.3

Building level

The use of a small distributed heat source like BILST on the United Nations Primary School is not significant in a subnetwork like the one in the Cerak area. Therefore, a comparison is also made on building level where the energy consumption is covered 100% in July.

The two cases show the United Nations Primary School before and after integration of BILST.

Case 2.1 United Nations Primary School with DH from the gas boiler in the Cerak DH network

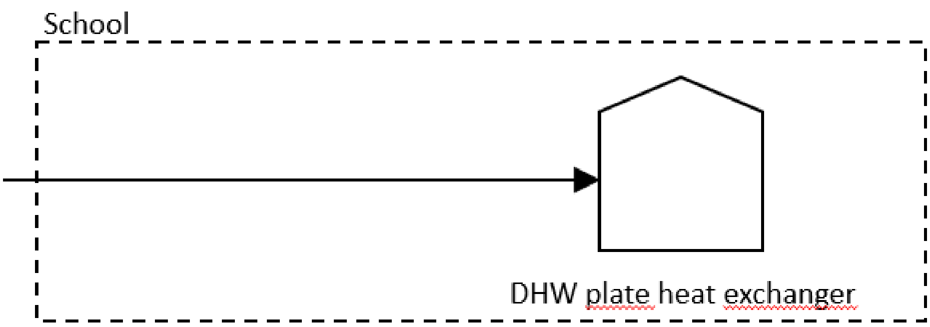

Figure 27. Belgrade Case 2.1

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Case 2.2 United Nations Primary School with DH from the gas boiler in the Cerak DH network supplemented with 250m² BILST covering 100% of the heat consumption in July.

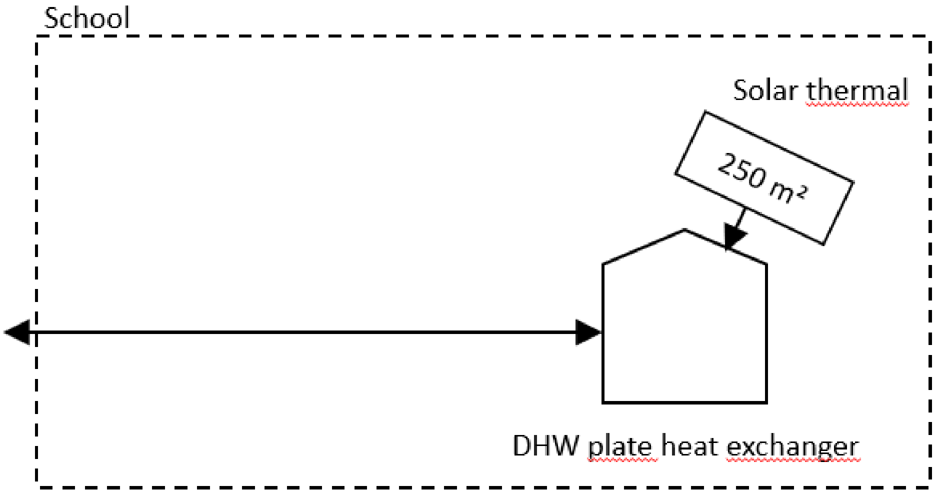

Figure 28. Belgrade Case 2.2

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7.6.2. Potential large-scale heat sources

A potential large-scale heat source is the conversion of an existing electric power plant outside Tartu to CHP supplying Tartu with DH via a new 28 km transmission line.

The following cases for large scale heat sources outside the Cerak subnetwork has been calculated.

Case 3.1 Heat source is a gas boiler with 90% efficiency, supplemented with a 20.000m² thermal solar plant within the subnetwork.

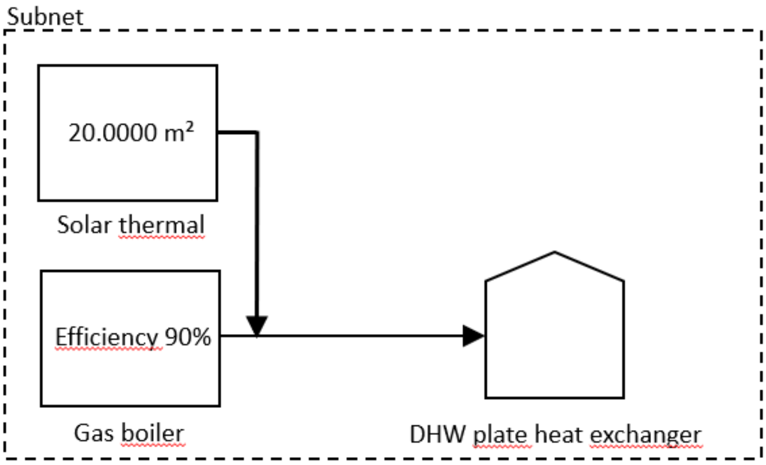

Figure 29. Belgrade Case 3.1

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Case 3.2 Heat source the new CHP plant outside the subnetwork covering 80% of consumption in the subnetwork. Heat losses in new transmission line considered. CHP is supplemented with 20.000m² thermal solar plant and existing gas boiler with 90% efficiency for peak load inside the subnetwork.

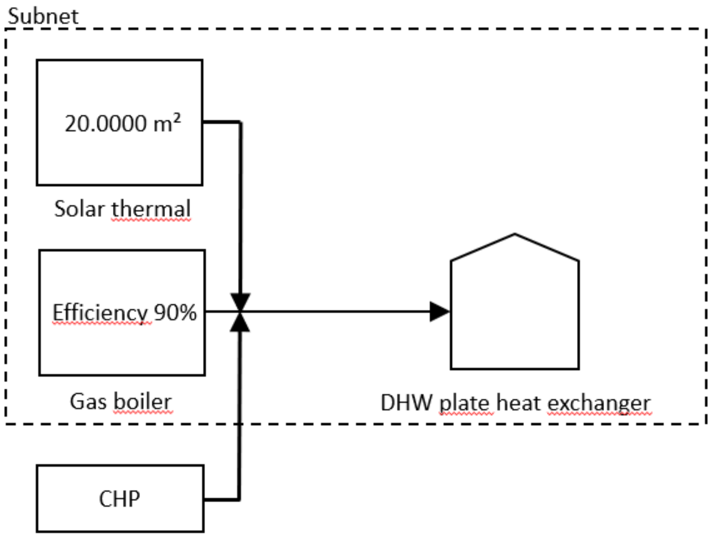

Figure 30. Belgrade Case 3.2

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7.7. Overall concept evaluation

Evaluation of the cases are based on primary energy factors (PEF), CO_2 emission factors and renewable energy ratio according to EN 15316-4-5.

In the evaluation tables the part of distributed heat sources is defined to show the effect of these in each case.

7.7.1. Building-integrated + distributed heat sources

In this scenario the existing Cerak DH network with a gas boiler is used in case 1.1. In case 1.2 the network is supplied with solar thermal energy from a 250m² solar thermal array on the United Nations Primary School. The solar thermal array is set to this size to cover the school's consumption in July. In case 1.3 the gas boiler is supplied with a 20.000m² solar thermal array.

	Case 1.1 Gas boiler	Case 1.2 Gas boiler + 250m² solar thermal School	Case 1.3 Gas boiler + 20.000m² solar thermal
Total Consumption (MWh)	240.000	240.000	240.000
Heat delivered an net (MWh)	318.671	318.671	318.671
Distribution heat loss (%)	24,7%	24,7%	24,7%
Distributed electricity consumption (MWh)	0	0	0
Total electricity consumption (MWh)	3.187	3.187	3.187
Solar thermal energy (MWh)	0	181	14.424
Waste heat (MWh)	0	0	0
Primary energy factor	1,25	1,25	1,19
CO2 emission factor (g/kWh)	248,6	248,5	237,6
Renewable energy ratio	0,00	0,00	0,05

Table 11. Gas boiler and solar thermal case 1.1-1.3

In all three cases the distribution heat loss in the network and the use of electricity is the same. The part of solar thermal energy in case 1.2 is 181 MWh and rises to 14.424 in case 1.3. The primary factor, the CO_2 emission factor and the renewable energy ratio are nearly unchanged from case 1.1 to case 1.2. In case 1.3 the primary energy factor and the CO_2 emission factor is lowered because of the higher share of solar energy and the renewable energy ratio is risen a little because of the thermal solar energy.

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Building level

In this scenario, a comparison is made on building level to show the impact of the use of BILST for the building itself. The case is with the United Nations Primary School's existing DH consumption in case 2.1 and supplied with the 250m² solar array covering the consumption in July in case 2.2.

	Case 2.1 Gas boiler	Case 2.2 Gas boiler + 250m² solar thermal
Total Consumption (MWh)	867	867
Heat delivered an net (MWh)	867	867
Distribution heat loss (%)		
Distributed electricity consumption (MWh)	0	0
Total electricity consumption (MWh)	8,7	8,7
Solar thermal energy (MWh)	0	181
Waste heat (MWh)	0	0
Primary energy factor	1,25	0,99
CO2 emission factor (g/kWh)	248,6	197,5
Renewable energy ratio	0,00	0,21

Table 12. Building level gas boiler + solar thermal case 2.1-2.2

Because of the use of solar thermal energy, the primary energy factor and the CO_2 emission factor is lowered from case 2.1 to case 2.2. In case 2.2 the renewable energy ratio is higher than case 2.1 because of the use of solar thermal.

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7.7.2. Potential large-scale heat sources

In this scenario, the existing heat supply with gas is substituted with heat from CHP from the converted power plant (80%) and solar thermal from the 20.000m² solar array. The Gas boilers are used for Peak loads.

	Case 3.1 Gas boiler + 20.000m² solar thermal	Case 3.2 CHP + Gas boiler + 20.000m² solar thermal
Total Consumption (MWh)	240.000	240.000
Heat delivered an net (MWh)	318.671	318.671
Distribution heat loss (%)	24,7%	24,7%
Distributed electricity consumption (MWh)	0	
Total electricity consumption (MWh)	3.187	3.187
Solar thermal energy (MWh)	14.424	14.424
Waste heat (MWh)	0	0
Primary energy factor	1,19	0,85
CO2 emission factor (g/kWh)	237,58	441,87
Renewable energy ratio	0,05	0,05

Table 13. Large scale sources case 3.1-3.2

In case 3.2 the primary energy factor is lower than in case 3.1 because of the use of CHP. The CO2 emission factor is higher due to the solid fossil fuel used in the CHP plant. The renewable energy ratio is unchanged since no other VE sources are included.

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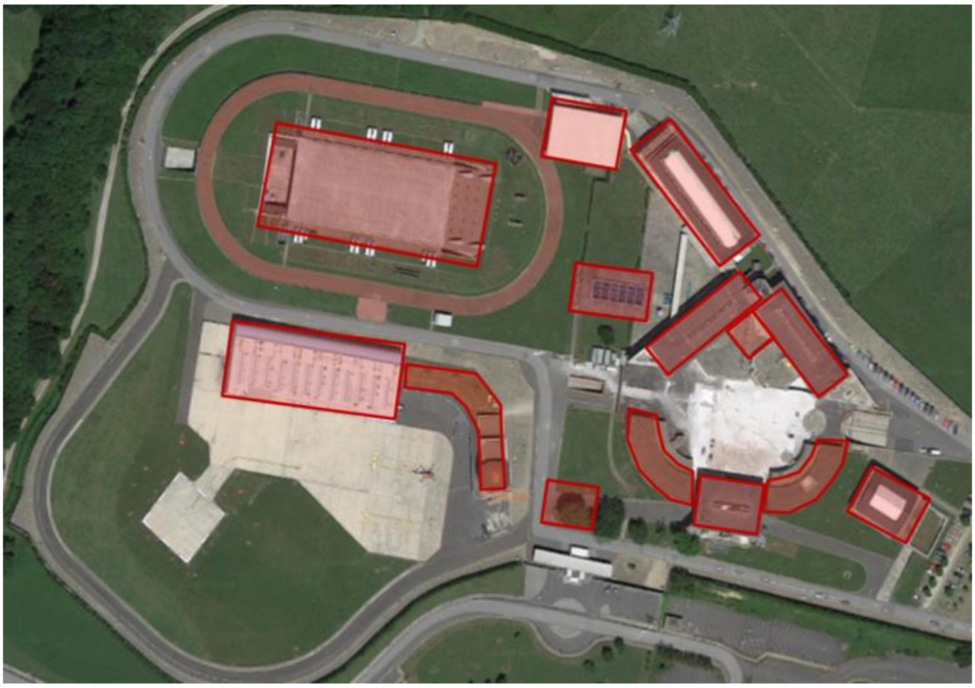
8. Operational small corporate DH network (Iurreta)

8.1. Overall description of DH system

Iurreta is located in the northern coast of Spain. The demonstration site consists on a set of buildings owned by the Basque Government. The building complex hosts part of the emergency, rescue and fast intervention groups of the Ertzaintza (regional police of the Basque Country).

The campus is composed by a total of 14 multi-rise buildings with different characteristics and uses including offices, accommodations, training rooms, sport facilities (including swimming pool) and heliport. Main constructions were erected between 1990 and 1993, in three different construction phases. Since then, some renovation activities were carried out including the extension of the HVAC systems.



Complex's energy demands include heating, cooling and domestic hot water needs. Originally, only heating and DHW demands were covered by means of the centralized heating plant designed to provide hot water for the complex.

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After different isolated interventions, additional generation units were installed to satisfy increasing energy demands, including cooling needs.

Therefore, currently, HVAC system which serves to the whole complex includes, in addition to the District Heating plant, locally deployed heat pumps feeding fan-coil systems, and several small and independent heat pumps used to serve a small subset of buildings.

District heating plant delivers energy for space heating and domestic hot water for most of the buildings in the complex.

8.2. Long term implementation of ULT concept

Total implementation of ULT concept in Iurreta would imply its transformation into a district heating where all distributed heat production plants and heat loads placed along Iurreta built area are connected, and work at lower temperature ranges than present time, increasing energy performance of the whole system.

To achieve this ambitious aim, following actions should be gradually implemented.

- ULT conversion of the DH network. Reduction of the operation temperatures of the distribution network in the range of 40-45ºC. Existing radiators should be gradually replaced by low temperature terminal units. With the aim of including cold water distribution in the district system, fan-coils should be fostered. In the future, fan-coils will provide heating as well as cooling using energy coming from the district generation system.
- Integration of reversible heat pumps (DHRHPs) replacing existing heat pumps.
- Densification of the DH network with the connection of presently isolated HVAC plants and new integrated DHRHPs. The connection with the network will be held by means of triple function substations.
- Integration of different distributed energy resources (DER), including BILTST system in South exposed walls, and available roofs.
- Adjustment of the centralized control system to allow the optimization of the system functioning. Adaptation of control strategies to ensure maximum use of BILTST and heat pumps capacity.
- Long-term heat density reduction by means of building envelope and ventilation system retrofits, to meet modern energy requirements for retrofitted buildings. Considering that buildings are relatively new, this is expected to occur in a 20-30 year timespan.

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8.3. Activities to be carried out within RELaTED

Activities to be performed within RELATED project aim to set out the way forwards the total implementation of ULT concept in Iurreta complex.

Expected activities include:

- Reducing DH network temperatures. The reduction will be addressed from two different perspectives:
  - Reduction of centralized heating services covered by hot water radiators. Operation temperatures will be adapted for working at 50-55ºC. Distribution network and terminal units will be tested evaluating their capacity for working under lower temperatures.
  - Modification of heat production scheme, with a dedicated boiler for DHW production, allowing for lowering heat production temperatures in off-peak periods. This is particularly relevant for summer periods where the only heat load is the swimming pool, allowing for flow temperatures as low as 35-40ºC
- Renovation of some of the existing heat pumps, replacing them by reversible heat pump to be connected to DH (DHRHPs). The system will enable to add recovered heat to the DH network. To perform this integration, triple function network substations will be installed.
- Installation of BILTST system developed within RELATED project in South exposed façades. In this case, triple function network substation will be also required to enable the coupling of DER to the DH network.

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8.4. Analysing buildings and installations

8.4.1. Building energy performance

Iurreta site includes 14 buildings with different uses including offices, accommodations, training rooms, sport facilities, swimming pool and heliport. Main buildings were built between 1990 and 1993, in three construction phases.

Complying with the requirement established by the Spanish law regarding energy performance certificates for public buildings, recently energy certificates have been obtained for each building.

Following table summarizes main characteristics of Iurreta's buildings regarding use, floor area and energy performance.

Building	Main use	Floor area [m2]	Energy rating
Building A	Security check	N/A	N/A
Building B	Sport facilities	845	D
Building C	Administrative facilities	1637	D
Building D	Sport facilities & classrooms	1221	D
Building E	Administrative facilities	487	D
Building F	Parking	N/A	N/A
Building G	Dormitories	4501	D
Building H	Dormitories	7442	C
Building I	Laboratories & meeting rooms	2699	C
Building J	Swimming pool & locker rooms	1799	F
Building L	Shooting gallery & sport facilities	N/A	N/A
Building M	Helicopter Hangar	N/A	N/A
Building N	Heliport (control tower, etc)	N/A	N/A

In general, energy performance of the buildings envelope is acceptable, therefore it is not planned a short-term intervention with the aim of increasing energy efficiency of the constructions. However, the integration of BILTST is included as a possible action within RELATED project.

B, C and D buildings comprise the best conditions to include BILTST system a priori. They are faced to south with no other nearby buildings generating shadows. However, C and D buildings have curved shape, thus it is not possible to integrate BILTST on them.

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8.4.2. Heating systems

Currently there are three different heating systems providing service to Iurreta Buildings.

Heating system based on hot water radiators fed by the DH plant.

- Heating system based on fan coil units fed by locally placed heat pumps in particular buildings
- Heating system based on autonomous direct expansion units for some small offices.

Following table shows the distribution of heating systems types and their contribution.

Building	Heating/cooling supply	%Floor area covered
Building A	Locally deployed heat pump (heating and cooling)	100%
Building B	District heating plant (heating and DHW)	50%
	Locally deployed heat pump (heating/cooling)	50%
Building C	District heating plant (heating and DHW)	0% (not in use)
	Locally deployed heat pump (heating/cooling)	100%
Building D	District heating plant (heating and DHW)	50%
	Locally deployed heat pump (heating/cooling)	50%
Building E	Locally deployed heat pump (heating/cooling)	100%
Building F	No heating/cooling (only exhaust ventilation)	-
Building G	District heating plant (heating and DHW)	67%
	Locally deployed heat pump (heating/cooling)	33%
Building H	District heating plant (heating and DHW)	100%
Building I	District heating plant (heating and DHW)	33%
	Locally deployed heat pump (heating/cooling)	67%
Building J	District heating plant (heating and DHW)	100%

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Building L	No heating/cooling (only ventilation)	-
Building M	No heating/cooling (only ventilation)	-
Building N	Locally deployed heat pump (heating/cooling)	100%

Hot water radiators are designed for working at 80/60ºC, but it is observed that they in fact they are working at 70/65ºC.

Within RELATED project, reduction of supply temperature from DH is expected in such a way that radiators will be working at 60-55ºC. The exact temperature range will be defined at a later stage. Depending on each case, low temperature distribution & diffusion systems will be deployed of DHRHP systems will be used to match temperature levels.

8.4.3. Domestic hot water systems

Most of the DHW used in Iurreta complex is produced by the DH production plant. There is an exception in building N where DHW is produced locally by electric heaters.

Spanish regulation regarding DHW systems constrains water temperature in DHW loops for safety reasons. To avoid legionella risk, temperature must be higher than 50ºC. Therefore, reduction of working temperatures in DHW loops is limited.

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8.5. Analysing distribution network

The central heating plant of the district is located in the basement of the B Building within a dedicated heating plant room. It is formed by 2 natural gas condensing boilers connected in parallel to 2 energy delivery manifolds.

The following table summarizes the thermal loads covered by each of the distribution circuits of the heating plant of the district.

Hydraulic loop	Manifold	Building	Thermal load
1	1	B	Hot water radiators
		C	Hot water radiators
		D	Hot water radiators
2	2	I	Hot water radiators
3	1	G	First floor left block bedroom hot water radiators
4	2	G	Second floor right block bedroom hot water radiators
5	1	G	Second floor left block bedroom hot water radiators
6	2	G	First floor right block bedroom hot water radiators
7	1	H	Basement bedroom hot water radiators
8	2	H	Ground floor bedroom hot water radiators
9	1	H	First floor bedroom hot water radiators
10	2	H	Second/third floor bedroom hot water radiators
11	1	J	Swimming pool heating and AHU heating coils
12	2	B, C, D, E, F, G, H, I, J	DHW demand

Except for Building J, the connection of all the buildings to the different circuits that form the distribution thermal network of the district heating system is solved through a direct connection (without a building substation).

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Detailed analysis to determine heat losses and real capacity of the distribution network is being performed within work package 5.

8.6. Analysing energy resources

Building integrated heat sources in Iurreta site will consist on:

- Building-integrated solar system (BILTST)
- District heating reversible heat pump (DHRHP)

Analysis includes the study of existing situation without BILTST and DHRHP, and the effect of including energy provided by BILTST and heat recovery from DHRHP in the DH network.

Regarding the reduction of temperature of existing DH plant, different cases are calculating within work package 5 for temperature sets from 70ºC to 55ºC.

8.7. Overall concept evaluation

Evaluation of the different cases will be based on primary energy factors (PEF), CO_2 emission factors and renewable energy ratio according to EN 15316-4-5.

Due to the size and complexity of the system, evaluation has to be performed via detailed engineering analysis which are being performed within work package 5.

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9. Conclusions

The ultra-low temperature concept of RELaTED is defined by temperature levels below 50 °C where it is necessary to use supplemental heating for DHW production. The possibilities to improve performance of the network and to improve renewable share/CO_2-emission with a more diversified production with distributed heat sources are presented. The ability to expand existing district heating networks to new districts without changing the existing network and optimize the performance of the networks and thereby operate more feasibly.

Different options and barriers for or converting to ultra-low temperature are discussed. On building level, it is about the heat emitters and domestic hot water (DHW) systems. Radiators can be used in ultra-low district heating systems but have to be sized for optimal performance which ca be problematic in existing systems. Floor heating is optimal because of the low temperature set. For DHW systems the barrier is low temperature which must be boosted when used in ULT systems to prevent bacteria growth. An option for doing this can for example be a micro-booster at the consumer.

On network level, it is the importance of a pipe system with a high insulation level preferable in twin pipe system, optimized in dimension for the higher flow in the ultra-low temperature system, the shortest pipe length where possible and without too many thermostatic bypasses. Of course, some of these factors cannot be optimized in an existing system without a renovation of the pipe system.

Distributed energy sources like building integrated solar thermal (BILST), district heating reversible heat pump (DHRHP), micro-booster, industrial waste heat, solar thermal plants and air to water ground source heat pumps are presented as possibilities to integrate into a low temperature district heating network.

The four demo sites in the project, Vinge, Tartu, Belgrade and Iurreta are presented with a short description of the development activities within RELaTED ranging from lowering network temperatures in subnetworks 10 °C to conversion to ULT and with a wide range of distributed heat sources to integrate into the networks.

Thoughts about the long-term implementation of the RELaTED concept and how it may evolve for each of the four countries are shared.

Calculated heat losses for each of the demo sites are analysed. In Vinge, where the building density is low, the calculated heat loss is around 30-35%, whereas the heat loss for both Tartu and Belgrade with higher building density are only

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around 13% for the main networks but for the subnetworks the calculated heat losses are around 17% and 25% respectively.

For each of the four demo sites some of the development activities regarding heat sources are selected and analysed. The calculated cases for each site are compared on the parameters: share of distributed energy consumption, total energy consumption, share of solar energy and waste, performance indicator factors for primary energy, CO_2 and renewable energy ratio.

These results will be used in the succeeding work packages of RELaTED to investigate further the architecture of the ULT concept (WP2), design and adaption of subsystems to facilitate the use of distributed energy resources (WP3), analyse the economic feasibility and business case (WP4) and prepare and conduct demonstrations (WP5), of the RELaTED project.

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Annex 1 - Default values of EN 15316-4-5:2017

Table B.2 - Default weighting factors for heat

	Energy Carrier			f_{Pnren}	f_{Pren}	f_{Ptot}	f_{CO2} (g/kWh)
1	Heat from boilers[a]		Solid Fossil fuel	1,7	0	1,7	530
2			Liquid Fossil fuel	1,6	0	1,6	400
3			Gaseous fossil fuel	1,5	0	1,5	310
4			Solid bio fuel	0,4	1,4	1,8	70
5			Liquid Bio fuel	0,7	1,4	2,1	110
6			Gaseous Bio fuel	0,6	1,4	2	150
7	Heat from CHP[a]		Solid Fossil fuel	0,8	0	0,8	500
8			Liquid Fossil fuel	0,7	0	0,7	330
9			Gaseous fossil fuel	0,7	0	0,7	160
10			Solid bio fuel	0	2	1,8	0
11			Liquid Bio fuel	0	2,4	1,4	0
12			Gaseous Bio fuel	0	2,4	1,4	0
13			Nuclear power plant	0,6	0	0,6	120
14	Waste heat from[b]	Industrial process	Process-related component	0	0	0	0
15			District heating component + process-related component	0,4	0	0,4	90
16		Waste-to-energy	Incl. CHP	0,1	0	0,1	25
17			Without CHP	0,2	0	0,2	50
a	Values are "conservative" and calculated including losses of a distribution system						
b	Values are based on conventions						

Table B.3 - Default weighting factors for fuels

	Energy Carrier		f_{Pnren}	f_{Pren}	f_{Ptot}	f_{CO2} (g/kWh)
1	Fuels from multi-output systems	Waste	0	0	0	0
2		residual fuel	0,2	0	0,2	40
3		sewage sludge	0	0	0	0
4		land fill gas	0	0	0	0
5		Mine gas, coke oven gas	0	0	0	0

Table B.4 - Default weighting factors for electricity

	Energy Carrier	f_{Pnren}	f_{Pren}	f_{Ptot}	f_{CO2} (g/kWh)
1	Electricity exported from CHP to the grid	2,5	0	2,5	480

Table B.5 - Default values for RERmos and WHRmos

	Energy Carrier		RER_{mos}	WHR_{mos}
1	Industrial waste heat	Process related component	0	1
2		district heating component + process-related component	0	0,6
3	Waste-to-energy	waste as fuel	0,4	1
4		heat from waste-to-energy-plant	0,32	0,8
5	Fuels	residual fuel	0	0,8
6		sewage sludge	0,9	1
7		land fill gas	0,9	1
8		mine gas, coke oven gas	0	1

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Annex 2 - Default values of ISO 52000-1:2017

Table B.16 — Weighting factors (based on gross or net calorific value)
(See 7.3.5, 9.5.1, 9.6.2, 9.6.5 and 9.6.6.3)

	Energy carrier		f_{Pnren}	f_{Pren}	f_{Ptot}	K_{CO2e} (g/kWh)
	Delivered from distant					
1	Fossil fuels	Solid	1,1	0	1,1	360
2		Liquid	1,1	0	1,1	290
3		Gaseous	1,1	0	1,1	220
4	Bio fuels	Solid	0,2	1	1,2	40
5		Liquid	0,5	1	1,5	70
6		Gaseous	0,4	1	1,4	100
7	Electricity [c]		2,3	0,2	2,5	420
	Delivered from nearby					
8	District heating [a]		1,3	0	1,3	260
9	District cooling		1,3	0	1,3	260
	Delivered from on-site					
10	Solar	PV electricity	0	1	1	0
11		Thermal	0	1	1	0
12	Wind		0	1	1	0
13	Environment	Geo-, aero-, hydrothermal	0	1	1	0
	Exported					
14	Electricity [b] [c]	To the grid	2,3	0,2	2,5	420
15		To non EPB uses	2,3	0,2	2,5	420

[a] Default value based on a natural gas boiler. Specific values are calculated according to M3-8.5.

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Annex C - Sub-report template

RELaTED

DRAFT

RELaTED Task 2.1 Template

Subreport for demonstration site

....

Date: 2018/4/26

DTI Template – version 2018/04/26

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1 Introduction to the template

The overall objective of WP 2 is to explore and establish the system architecture of the RELaTED low temperature district heating concept including exemplification of it for new developing district heating areas, as well as at transition of district heating from high operational temperature to low temperature. Task 2.1 is defining the overall boundary conditions for the low temperature concepts of the four demo sites: Vinge, Taartu, Beograd and Irruetta.

Based on the available renewable energy sources and current operational temperatures and pressures of the participating district heating networks, different low temperature concepts are analyzed. This include three main components:

1. Analyzing the availability and efficiency of distributed energy resources
2. Analyzing low temperature distribution systems
3. Combining the two analysis above and proposing the most energy efficient and carbon-dioxide reducing low temperature concepts covering the variety of energy sources and the preconditions given by the demonstration areas of the project.

As a part of the work the following draft for **a template for characterizing the considered sub-networks** – inclusive the demo sites - has been worked out. The template comprises the following **contributions (A – E).**

A, B and C covering an analysis for each of the sub-networks considered:

A. Main characteristics overview based on filling out tables etc. for giving a similar and comparable overview of heating and cooling demand of buildings, heat density, available renewable energy sources and their potential operation temperatures and pressures
B. Analysis of system energy requirements and system efficiencies based on EN 15316-4-5
C. Analysis of system environmental benefits and economical costs based on the DHAP Tool from the Danish Energy Agency (DEA)

and D and E further information describing the demo sites:

D. Description, drawings and for the site for giving an overview of plans and main principles as well as analysis, drawings etc. for specific components
E. Questionnaire concerning bacterial barriers for hot water production.

For presenting the evolution from starting up from bare ground, or from a high temperature district heating system, to an efficient low temperature system, the contributions A – C should be repeated according to the time stages of the development. This as well as the contributions mentioned above are detailed in the following sections.

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2 Basis of analysis

All demonstrations of the RELaTED-project – as well as the considerations concerning **sub-networks** include evolution from starting up from bare ground, or from a high temperature district heating system, to an efficient low temperature system.

Further, the demonstrations will deploy the **three concepts**:

- Triple-function substation (3FS)
- Building-integrated low-temperature solar thermal systems (BILTST)
- Reversible heat pump concept for primary loop connection to DH (DHRHP).

This can be done inside the sub-network area or at another suitable place of the district heating system. In order to accommodate these differences it is proposed to include potential heat sources for the whole district heating system

The **boundary condition of the sub-network** compared to the whole district heating system is shown in the figure below.

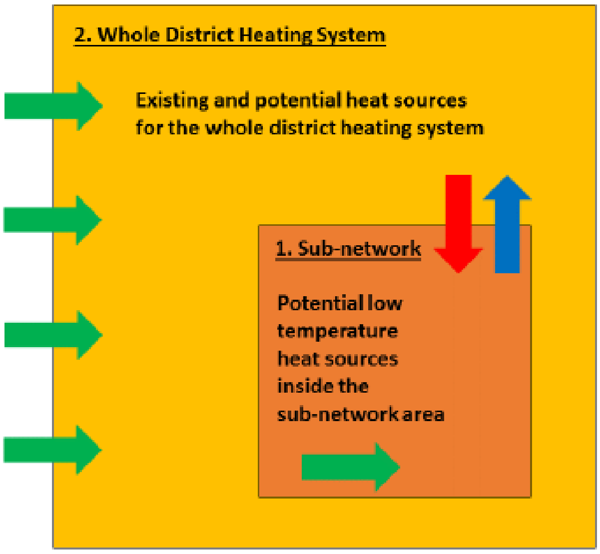

Figure "Boundary conditions":

The sub-network (1) is part of the whole district heating system and can exchange heat with this (red and blue arrow). Heat is supplied to the buildings and available renewable low temperature heat sources can be utilised inside the sub-network area (green arrow). Boundary condition 2: The whole district heating system with all heat sources, all network and all buildings (consumers).

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As the sub-network is a part of the whole district heating network, the mix of heat sources supplied to the whole district heating network will normally also be supplied to the sub-network. On the other hand if a surplus of heat is generated inside the sub-network this may also, dependent on temperature level, be supplied back into the whole district heating network.

Individual calculation tools may be used for specific calculations and analyses. However, we propose that for the overall analyses of resource efficiency, carbon dioxide emissions and economy (to be coordinated with WP 4), we use a consistent data format for all four sites and further considered sub-networks, as well as some known/standardized methodologies.

In large networks, differences in configurations, heat loads, etc. may be found among the sub-networks. For such district heating networks (here Belgrade) we suggest typically to designate 3-4 sub-networks as representing the entire network. That is the reason for the opportunity to carry out **sub-reports for each sub-network**

In relation to introduction of district heating in new or existing urban areas & new urban developments, we are talking about an "evolution" of the system configuration. This is suggested handled by the opportunity to define **various stages, typically 2 to 3 for each sub-network**, and fill in a template for each stage

A general report setup for the characterization of the different sub-networks is proposed in section 3 and further focusing on:

- **Heat demand**
  - Buildings
  - Heat consumption and supply conditions at consumer
  - Space heating system
  - Domestic hot water system
- **Distribution losses**
  - Pipe list
  - Measured distribution heat losses
  - Calculation of distribution heat losses
  - Electricity consumption of pump(s)
- **Heat production**
  - Production type, load and capacity
  - Technology and fuel.

For the analyses of resource efficiency and CO_2-emissions we propose to use the methodologies of EN 15316-4-5:2017, see section 4. This European Standard defines the determination of energy indicators of district energy systems. District energy systems may be district heating, district cooling or other district energy carriers.

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For a further analysis including for the economics of the sub-networks we propose to use the District Heating Assessment Tool (DHAT), see section 5.

PS! Based on the actual template, DTI plans for the final template to carry out a spread sheet version, where information from e.g. various stages analysis for a sub-network can easily be copied and compared.

Further we need a written description of the systems, analyses and scenarios as well as drawings and sketches, see section 6.

From the very beginning of the RELaTED project bacterial challenges in relation to domestic hot water production has been stated as a major problem in relation to the propagation of ultralow temperature district heating systems.
The discussions at the starting up meeting of the project in November 2017 underlined this problematic, as well as it was found of importance also for the in WP 3.
This is the main background for the questionnaire set up in section 7.

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3 Main characteristics for sub-networks (A)

Please describe the demo site district heating system and its main components by filling out the follow questions and identify and detail the main components on a drawing as described in section 6.

Identification of sub-network:

Identification of stage:	**Date of the stage:**

Heat demand

Buildings

Building Group Identification (ID)	Application 1)	Year of construction	Latest year of renovation	Energy efficiency measures	Useful (heated) area, m^2
BG-01					
....					
Total					

1) House, school, office, museum, industry etc.

Heat and cooling conditions promised (delivery conditions)

Parameter	Unit	Promised
Design pressure (e.g. 25 bar)	bar	
Minimum differential pressure guaranteed (e.g. 0.5 bar)	bar	
Minimum supply temperature guaranteed (e.g. 70 °C)	°C	
Maximum return temperature requested (e.g. 50 °C) - or alternatively minimum cooling-off of the district heating water (e.g. 35 K)	°C °C	

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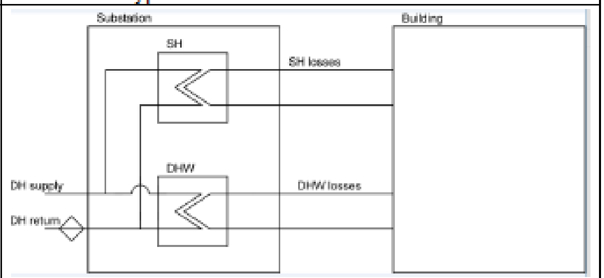
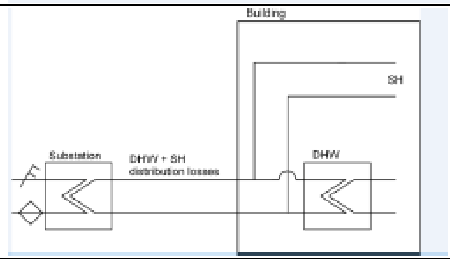
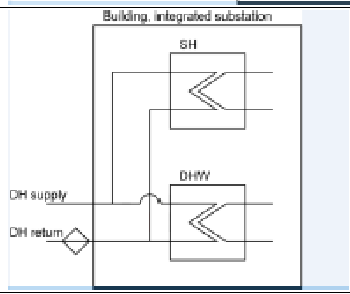
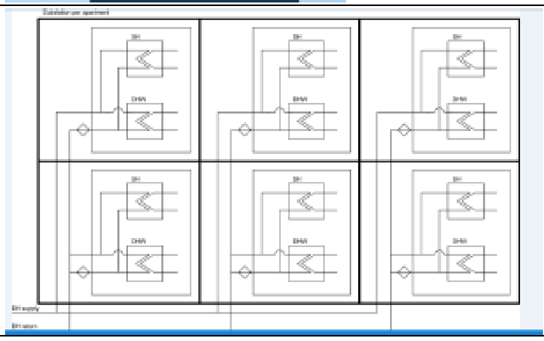
Specification of various Domestic Hot Water (DHW) installation types

Type identification	Installation type
DHW-1	
DHW-2	
DHW-3	
DHW-4	

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Heat consumption and supply conditions at consumer

Building Group Identification (ID)	District heating consumption, (MWh) 2)	Part for space heating (SH) excl. losses, (MWh)	Domestic Hot Water DHW-solution 1)	Part for domestic hot water (DHW) excl. losses, (MWh)	Part for losses related to SH and DHW, (MWh)	Part for losses related to DHW, (MWh)	DH connection Direct (D)/ Indirect (I)
BG-01			e.g. DHW1				
….							
Total							

1) See the various possibilities on the table above; If none of these types answer "Other"
2) Annual or 12 months summarized

Please, specify the cooling demand in case this is present!

Cooling consumption and supply conditions at consumer

Building group Identification (ID)	Cooling demand, (MWh)	From district heating consumption, (MWh)	From district cooling consumption, (MWh)	Comments
BG-01				
….				
Total				

Space heating operation

Parameter	For building group (ID)	Tempe-ratures °C	Comments
Outdoor design temperature (e.g. -12 C)			
	….		
Radiator design temperature set (e.g. 90 °C/70 °C)			
	…..		

Please note: The radiator design temperatures may have changed over time in history

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Domestic Hot Water operation

Parameter	For building group (ID)	Temperature/ Capacity °C/kW	Comments
Minimum temperature in hot water circulation (e.g. 50 C)			
	....		
Minimum hot water temperature in storage tank (e.g. 55 C)			
	....		
Design capacity requirement of water heater for one dwelling or building (e.g. 30 kW)			
	...		
Water heater type, (heat exchanger/storage tank/combined charging system related to)		%	
	....	%	

Distribution losses

The goal is among other things to determine the distribution loss. If the amount of produced and summarized sold energy is known by measurement from energy meters, the pipe list is not essential or required.
If the pipe list is used, information about the length, insulation class or channel, pipe type (single or twin) and temperature levels is needed.

Pipe list

If possible, divide the pipes into branch pipes (house connecting pipes) and the other parts of the DH network.

DH network						
Pipe dimension	Length of pipes	Insulation class (1, 2, 3 or channel)	Pipe type (single or twin)	Typical forward temp.	Typical return temp.	Comment
-	m	-	-	°C	°C	-
DN15						
DN20						
DN25						
DN32						
DN40						
DN65						
DN80						
DN100						

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DN125						
DN150						
DN200						
DN250						
DN300						
Totally						

* Comment if Individual pipe length or tracé-length has been used

DH network						
Pipe dimension	Length of pipes	Insulation class (1, 2, 3 or channel)	Pipe type (single or twin)	Typical forward temperature	Typical return temperature	Comment
-	m	-	-	°C	°C	-
DN15						
DN20						
DN25						
DN32						
DN40						
DN65						
DN80						
DN100						
DN125						
DN150						
DN200						
DN250						
DN300						
Totally						

* Comment if Individual pipe length or tracé-length has been used

Heat losses

Method for identifying heat losses from pipe system	Conditions	Heat loss MWh	Comments
By calculation			
By measurements			

Calculation of distribution heat losses

Calculation formulas and tools exist for calculation of distribution heat losses. This calculation must be done when establishing a new district heating area. In case of existing networks it might be more difficult, but calibration of models based on the measured distribution losses may be useful for analyses and for the evaluation of concepts

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Measured distribution heat losses

For a sub-network, the distribution heat losses are the difference between what heat is supplied to the sub-network and what heat is used by the consumers. If it is not measured what is supplied to the sub-network, it may be an idea to establish a heat meter as part of the RELaTED-project as soon as possible. It will be required for the final demonstration and evaluation of the concepts.

Electricity consumption of pump(s)

Overcoming the hydraulic losses in the network has a cost of pumping energy, which must be estimated as well.

Method for identifying energy losses from use of pumps(s)	Conditions	Power consumption MWh	Comments
By calculation (theoretical)			
By measurements			

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Heat production

Heat Production unit, P 1)	Production type 2)	Production technology and fuel 3)	Capacity (MW)	Heat Production per year (GWh)	Pct. of total	Comments 4)
Total					100	

1) PL = Local Production (at the demo site); PC = Central Production (at the central district heating plant); PO = From Other production sources associated to the site
2) Production type according to use and divided into Base, Intermediate (identify order) and Peak (identify order)
3) Production technology e.g. CHP, Solar, Geothermic, Surplus heat…,and fuel e.g. Wood chips, Wood pellets, Straw, Natural gas, Oil, Coal .. or surplus heat from e.g. Industry
4) Detail where relevant:
   - Triple-function substation (3FS)
   - Building-integrated low-temperature solar thermal systems (BILTST)
   - Reversible heat pump concept for primary loop connection to DH (DHRHP).

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4 Analysis of demo site based on EN 15316-4-5 (C)

The European standards EN 15316-4-5 for energy performance assessment of district energy systems have recently been released in a version covering energy performance assessment of district energy systems.

We thus find that the standards will be a good reference for a similar evaluation of various solutions both in relation to new systems and in connection to changing old high temperatures to low temperature.

The background, the purpose and use of the new standards are described in http://www.rehva.eu/fileadmin/REHVA_Journal/REHVA_Journal_2016/RJ_issue_3/p.28/28-29_RJ1603_WEB.pdf.

The standard is partially based on former work carried out in a EU project managed by EuroHeat and Power and with participation of district heating supplies, institutes etc., including DTI. The result of the project – including a labelling (which we will not use) is described on the EHP homepage included the guideline https://www.euroheat.org/wp-content/uploads/2016/04/Ecoheat4cities_3.1_Labelling_Guidelines.pdf.

The main result from using the standard is a weighting factor of the district energy system, which tells about the resource efficiency and the environmental friendliness of the district heating system.

Weighting factors for the demo site

	For optimistic parameter values 1)	For pessimistic parameter values 1)
Weighting factor of the district energy system		

1) Detail the chosen parameters for each situation

Calculation of the weighting factor of the actual district energy system will for complex systems normally need calculation by using a spread sheet.
PS! DTI will before finalizing the Template investigate if a common spread sheet can be set up. Input to this is very welcome.

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5 Analysis of demo site based on DHAT (D)

The District Heating Assessment Tool (DHAT) is a tool initiated and owned by the Danish Energy Agency, see https://ens.dk/en/our-responsibilities/global-cooperation/district-heating-assessment-tool-dhat. The programme has been carried out by the large consultancy company Ramboll, which has considerable experience from district heating plants in Denmark as well as abroad.

DHAT is performing economic feasibility studies for establishing district heating compared to individual heating, and can be adjusted to local conditions globally.

In the case of the RELaTED-project we will have both new development areas and existing areas among the demonstrations. For the latter, the analyses of individual heating is not relevant, but the tool can still be used to analyse different district heating options.

A very nice feature of the tool is that it can handle district heating solar thermal including different types of storages. The tool comes with a number of preset data of e.g. cost of network, cost of technologies etc. based on Danish experiences/cost levels. These may be updated for the national conditions if it show to be applicable to use the DHAT-tool in WP4.

The DHAT model is freely available to everyone interested and the MS Excel-based model and a guideline for each use be downloaded from the link just above.

We thus for each site suggest a calculation as described in section 4.1 and 4.2 of the guideline and as documentation and basis for discussing enclose a list of your used input parameters and the resulting graphic surveys (at a later stage further information can be exchanged).

DHAT calculation resulting in a list a list of used input parameters and the resulting graphic surveys in relation to DHAT guideline section 4.1 and 4.2

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6 Descriptions, drawings etc. for the demo site (B)

Map of the district heating supply system

Please describe the district heating system by identifying the main pipes (DN…), building groups (ID…), production facilities (P…) on a map of the district heating supply system to establish an overview.

Technical drawings of specific district heating solutions

For important technical solutions make a technical drawing identifying main components and principles, e.g. principle for specific building units/solutions; spread sheet analysis etc.

Relevant specific drawings, analysis, scenarios etc.

Enclose other relevant document information.

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7 Bacterial barriers for domestic hot water production (E)

Use of low water temperatures in domestic hot water, eg. down to 40 °C, will usually cause a greater risk of bacterial growth, including the dangerous legionella bacteria. Therefore, when using low flow temperatures in district heating water, which is used simultaneously for domestic hot water for use, it is necessary to exhibit special attention.

Through the following questions is being sought to clarify how the problems are handled within the countries and supplies involved in the RelaTED project.

1 Legal requirements concerning domestic hot water temperatures etc.

Question 1A: Do you in your country have any legal requirements concerning designing and operation of installations for domestic hot water?

Answer: Yes/No;

If "Yes": Which requirements? ....

What prescribes the requirements? ....

Why do you have the requirements? ....

Question 1B: Do you in your country have any legal requirements concerning specific designing and operation of installations for domestic hot water supplied by district heating?

Answer: Yes/No;

If "Yes": Which requirements? ....

What prescribes the requirements? ....

Why do you have the requirements? ....

Question 1C: Do you in your district heating supply/plant have any temperature delivery terms set up for preventing legionella or other bacterial growth?

Answer: Yes/No;

If "Yes": Which requirements? ....

Which minimum temperatures are being required? ....

Why do you have the requirements? ....

2 Requirements based on the EN 806 series

Question 2A: The EN 806-serie gives various requirements and instructions concerning designing domestic water installations, including for preventing legionella problems. Do you have any requirements describing general use of e.g. EN 806-part 2, section 9 about hot water systems and installations?

If "Yes": Which requirements describe use of EN 806-part 2? ....

Why do you have these requirements? ....

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Question 2B: Do you have specific requirements for District Heating based on EN 806-part 2, section 9?

If "Yes": Which requirements for district heating are based on EN 806-part 2? ....

Why do you have these requirements? ....

3 Guidelines based on the technical report CEN/TR 16355

Question 3: The technical report CEN/TR 16355 from 2012 gives various recommendations for preventing legionella growth in water installations. Do you have any knowledge of this report and its use?

If "Yes": Where are you using CEN/TR 16355? ....

Why do you use CEN/TR 16355? ....

4 Other guidelines for preventing of legionella in domestic hot water

Question 4: Do you use any other guidelines for preventing of legionella in domestic hot water; e.g. by required specific minimum temperatures?

If "Yes": Which guidelines do you use? ....

What does the guidelines require? ....

5 Use of legionella prevention methods

Question 5: Are specific methods for prevention of legionella being recommended or being used, e.g. use of ultraviolet light, thermic disinfection, chlorite disinfection, other methods?

Answer: Yes/No;

If "Yes": Which methods? ....

Which experiences do you have with the method(s)? ....

6 Experiences about operation temperatures and legionella problems

Question 6A: Do you have knowledge about legionella problems in your country caused by domestic hot water in general?

Answer: Yes/No;

If "Yes": Which installations typically? ....

Question 6B: Which flow temperatures are in general used in your plant/supply? From ......°C to ......°C.

Which minimum flow temperature is required? ....°C.
Which maximum flow temperature is required? ....°C.

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Question 6C: Do you have any knowledge about legionella problems in your plant/supply in relation to the operating temperature?

Answer: Yes/No;

If "Yes": Which problems? ....

How often problems, approximately per installation? ....

At which minimum water flow temperature? ....

7 Other comments regarding legionella problems in dh

Are you aware of the occurrence of legionella diseases that can be attributed to district heating plants and the hot water supply?
If "yes"

How many cases annually? ....

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