

## 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<sub>2</sub>-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:

- 3<sup>rd</sup> Generation District Heating (3GDH): Temperature level < 100 °C
- 4<sup>th</sup> 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 4<sup>th</sup> generation district heating.



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

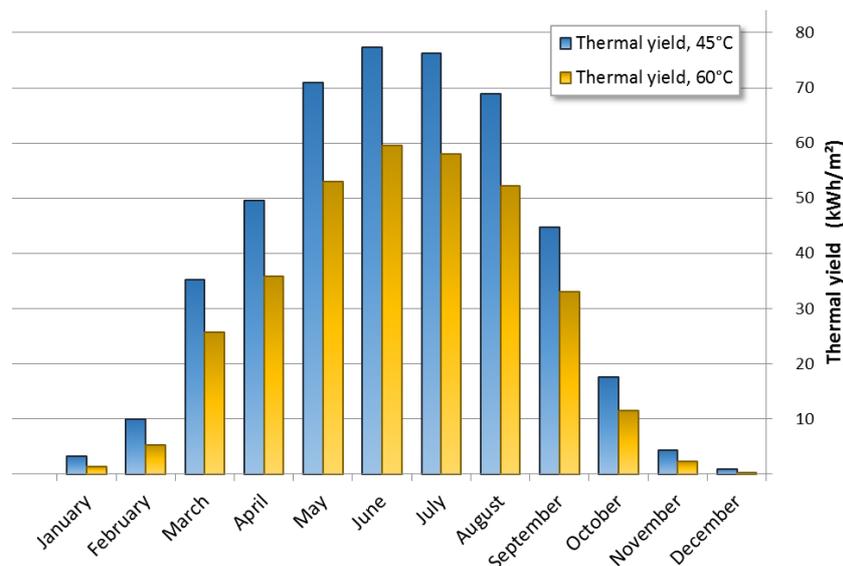
*District heating systems that supply district heating to the customers at a temperature level where production of domestic hot water requires a supplementary heat source to deliver satisfactory domestic hot water temperatures. The supply temperature limit will depend on national requirements set to 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).*

### **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.

### 3.3. Space heating

Outdoor design temperatures for space heating varies across Europe. Within the RELaTED project, they range from (~0°C) 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 °C (return) -> Heating system 55-90 °C (flow)/30-50 °C (return) -> System type: Radiators.
- DH 45 °C (flow)/30 °C (return) -> Heating system 35 °C (flow)/30 °C (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.

### 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 °C (flow)/30 °C (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 °C (flow)/30 °C (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.



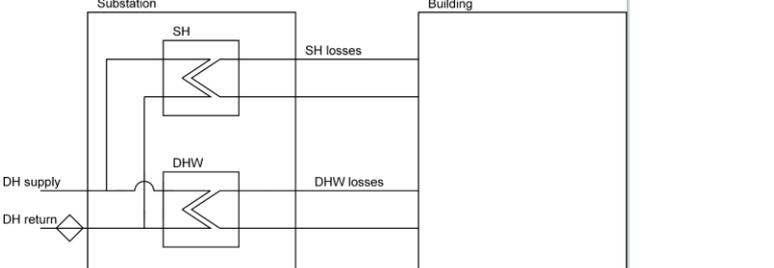
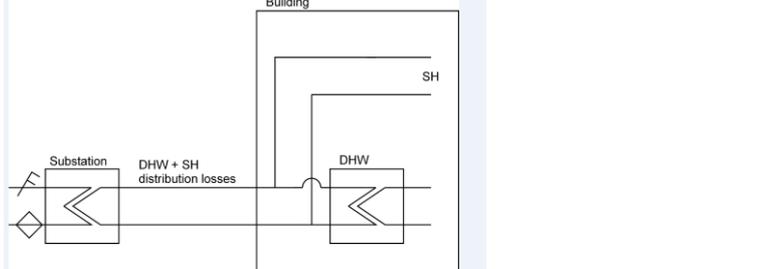
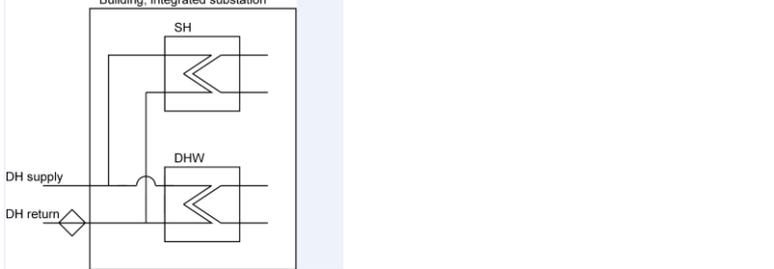
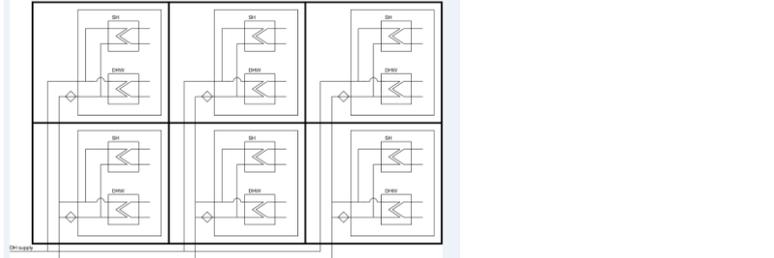
DHW Type identification	Installation type
DHW-0	
DHW-1	
DHW-2	
DHW-3	
DHW-4	

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.



### 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.

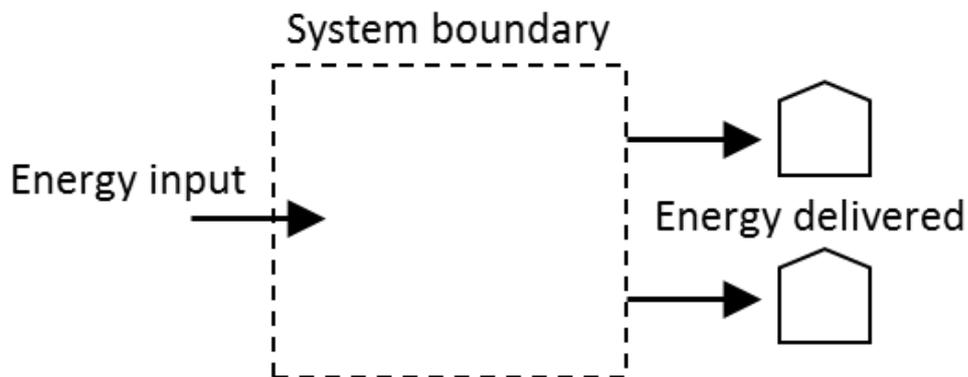
### 3.7. Primary energy factors, CO<sub>2</sub>-factors and renewable energy ratios

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<sub>2</sub>-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.



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

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

The standard further specifies methods to allocate primary energy, CO<sub>2</sub>-emissions 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.

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 CO<sub>2</sub>-emissions are used in the present report. The reference is found in Annex 1 and 2. In general, the default values of Annex 1 are conservative. 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 of 2.1 [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.

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 heat 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	200.440	216.842
Distribution heat loss (KWh)	82.222	65.220	65.220
Distribution heat loss (%)	34,6%	32,5%	30,1%
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 2. Example of presentation of calculation results**



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