# RELaTED

# D2.2 – Interconnection schemes for consumer installations

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# PROJECT SUMMARY

| Project Acronym | RELaTED |
|---|---|
| Project Title | REnewable Low TEmperature District |
| Project Coordinator | Roberto Garay. TECNALIA<br>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 |



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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.

## 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 55-75ºC 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.).

## 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 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

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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 2.2 the design and control challenges for connections for ULT DH consumers are presented along with a discussion about the barriers regarding legionella and billing and metering of ULT DH consumption. A set of sketches of interconnections schemes for consumer installations are included.

Design and control challenges for different types of ULT DH consumer connections for space heating and DHW production respectively are presented and, when available, with possible solutions.

The barriers regarding legionella in domestic hot water installations are discussed and different studies about legionella and national requirements are presented. Some of the methods for prevention of legionella and general recommendations concerning legionella are covered.

The challenges regarding billing and metering in a ULT DH system with a combination of DH and electricity for DHW production is discussed and some methods for billing options are proposed.

A set of interconnections schemes for consumer installations in ULT DH networks are presented for different buildings types and installations. The different operation modes of a microbooster HP (Heat pump) for DHW production is explained.

The information gathered in this report 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 activities carried out under RELaTED task 2.2. It will elucidate specific problems and solutions for consumer connections in relation to legionella bacteria prevention and treatment, metering and billing options and control opportunities. Moreover, sketches that could be used as specific solutions for consumer interconnection schemes for three of the demonstration sites on public networks in the project are presented.

The report is a continuation of the report “Low temperature concepts” carried out in task 2.1. Further it is parallel to the task 2.3 report “Interconnection schemes for producer installations”. 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 2.2 is to sketch possible interconnection schemes for consumers and exploring the control opportunities and strategies, including local storage when relevant, and metering and billing options with respect to the overall boundary conditions as well as regulation.

## 2.2. Methodology

To carry out task 2.2 the following methodology was used:

1. A questionnaire, see annex A, was sent to the partners for getting country specific information about country specific legal requirements and other guidelines for prevention of legionella.
2. A questionnaire, see annex B, was sent to the partners for getting country specific information about prices and billing options for consumers as well as case examples and interconnections schemes for country/supplier specific solutions.

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3. Challenges for control opportunities at consumer connections are explored based on the questionnaire (annex B), general expertise in DH, database searches and manufacturer specific information.
4. Based on the answers in the questionnaire (annex A), and research from other projects, legionella prevention and treatment options are identified and investigated.
5. Billing and metering options for consumer interconnection schemes are explored based on the questionnaire (annex B).
6. Based on the above solutions for interconnection schemes for consumers in the three demo sites on public networks are sketched.

## 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. Challenges for connections for ULT DH regarding heating and domestic hot water production.
4. Legionella barriers and actions concerning domestic hot water. Bacterial challenges including legionella, legislation and guidelines concerning legionella, occurrence and prevention of legionella, recommendations concerning legionella.
5. Billing and metering of consumption. Specific ULT billing challenges, metering by smart meters and specific ULT metering challenges.
6. Interconnection schemes for consumer installations. General consumer installations for conventional and nearly zero energy buildings, consumer installations for heat and domestic hot water in conventional buildings,. Challenges in the consumer connections for ULT DH

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# 3. challenges for ULTDH consumer connections

## 3.1. General Challenges

| Challenge | Description | Possible solution |
|---|---|---|
| Pump consumption | Risk of increased pumping power consumption due to:<br>• Lower temperature difference between DH flow and return-line.<br>• Consequential higher flow rates, hence increased pressure drops. | DHW can be stored in a local water storage tank. This allows for a reduction of the maximum required DH flows which reduces pumping power. |
| Heat exchangers | Heat exchangers require additional surface area and occupied space. | - |
| Piping | An increase of water flows may negatively affect pressure drops in the distribution network and through local substation. In some cases, it might be needed to adapt and increase piping dimensions according to the new DH flow conditions. | DHW can be stored in a local water storage tank. This allows for a reduction of the maximum required DH flows which reduces pumping power. |
| Legionella | Higher attention should be dedicated to Legionella prevention and disinfection. | Prevention by boosting DHW temperature to 55 °C.<br>Prevention by reducing DHW volumes.<br>Disinfection by periodically boosting DHW temperature to 60-70 °C. |

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| | | |
|---|---|---|
| Flow control | On one hand LTDH flow control valves risk to be under dimensioned for ULT DH systems. | Larger orifices. |

## 3.2. Challenges of connections for heating

| System | General challenges and considerations | General Benefits |
|---|---|---|
| Low temperature radiator | Larger heat transfer area required to high temperature radiators<br><br>Flow control regulation. | Lower dimensioning temperature. |
| Underfloor heating | - | DH supply can be directed to floor heating system. No or reduced mixing with cold water.<br><br>Good comfort.<br><br>Large surface area. |
| Air heating through ventilation system | Heating capacity limitations due to limitations on ventilation air flow.<br><br>Regulation of indoor humidity and air supply temperature. | If balanced ventilation with heat recovery, pre-heating of air supply offers better comfort. |

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## 3.3. Challenges of connections for domestic hot water

| System | General challenges | General Benefits |
|---|---|---|
| **Apartment level** | | |
| Instantaneous production + flow water electric heater<br><br>(See paragraph 6.4.1). | For a 16 A connection, limited DHW temperature boost at high flows.<br><br>400 V might be needed in order to supply sufficient DHW temperature. In some countries this might not be available in dwellings.<br><br>Require higher electricity consumption.<br><br>Keep DHW volume in piping system low.<br><br>Additional pressure drops on secondary side.<br><br>Risk of scaling. | Low investment cost.<br><br>Easy implementation.<br><br>Existing systems require minor adjustments. |
| Electric booster with storage on DHW secondary side<br><br>(See paragraph 6.4.2). | Require higher electricity consumption.<br><br>Maintaining a low return temperature during the all heat up-period with DH. | Low-Medium investment cost.<br><br>Low DH flows. |
| HP booster with storage on DH primary side.<br><br>(See paragraph 6.4.3) | High investment costs per dwelling.<br><br>High condensing temperatures.<br><br>Compressor sound emissions in the dwelling. | Low DH flows.<br><br>Low electricity consumption. |

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| | | |
|---|---|---|
| HP booster with DHW storage on secondary side<br><br>(See paragraph 6.4.4) | Compressor sound emissions in the dwelling. | Low electricity consumption.<br><br>Low DH flows.<br><br>Medium-Low investment cost per dwelling. |
| Air HP booster with DHW storage on secondary side<br><br>(See paragraph 6.4.4). | Maintaining a low return temperature.<br><br>Air ducts are required.<br><br>In general, the units today are rather silent. However, when replacing a standard district heating unit, for example, a new noise emission pattern can affect some people. | Free heat source for heat pump operation.<br><br>Low electricity consumption.<br><br>Low DH flows. |
| | **Building level** | |
| Central HP booster with DH storage on primary side | DHW recirculation heat losses.<br><br>High condensing temperatures. | Medium investment cost per apartment. |
| Central HP booster with DHW storage on secondary side | DHW recirculation heat losses | Medium investment cost per apartment.<br><br>The central HP can be configured for cooling in the summer applying active hydronic cooling. |

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# 4. Legionella barriers and directed actions concerning domestic hot water

## 4.1. Bacterial challenges including Legionella

### 4.1.1. Legionella challenges from water at 30 to 50 °C

The Legionella pneumophila disease was original related to ventilation/air-condition systems, and much focus was also on cooling towers and spa pools. Another important Legionella risk is however due to low temperature water that is sprayed from the water installations, e.g. via showers. Therefore, when using low flow temperatures in DH water, you must be aware of the additional low temperatures of Domestic Hot Water (DHW) and the resulting risk of health.

The figure below, which is typical for Legionella, shows considerable risk of Legionella at domestic hot water temperature from 30 to 50 °C and high risk from 34 to 45 °C. This means that Legionella can exist at temperatures over 50 °C, but the Legionella growth is confined.

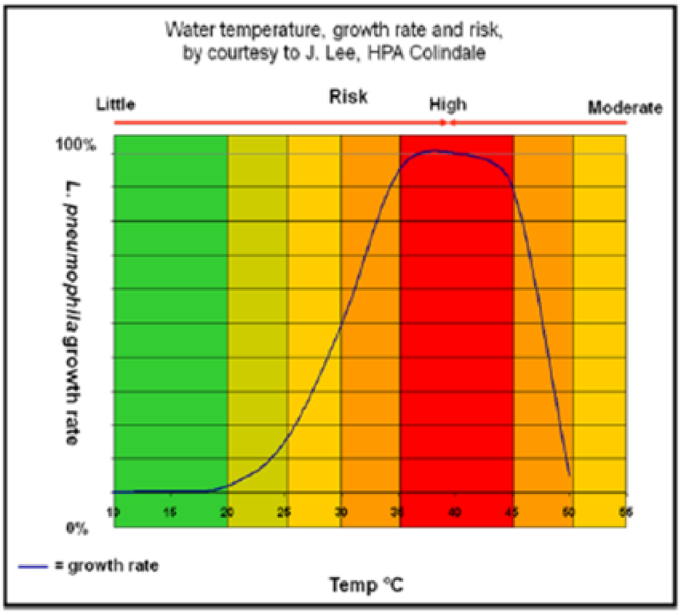


Figure 1: Water temperature and Legionella growth. Source: IEA Guidebook [5]

Also, for the drinking water supply there is a risk when the normally cold-water temperatures rise to over 20 °C, e.g. caused by building water installation with low flow.

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## 4.1.2. International focus on the risk of Legionella

There has been, and there is, considerable international attention on the risk of Legionella from water installations. At an NSF (National Sanitation Foundation) workshop from 2018 an up-to-date of the international knowledge about the disease, the challenges and the design of water installations for buildings was presented and covering input from several countries [1]. In the article "Overview and comparison of Legionella regulations worldwide" from 2018 [2] is given a survey focussing on Legionella regulations and control worldwide, and concluding the need of more unified international guidelines, standards and regulations, but without losing important country-specific nuances.

In the European surveillance report from 2018 concerning Legionnaires' disease [3] is further concluded, that the number of people having the illness were increasing from 2011 to 2016, but without conclusions concerning the reasons. Finally, the EU in 2018 published a revision of the Drinking Water Directive [4], which after advice from e.g. WHO (World Health Organization) also comprises requirements concerning Legionella in cold and hot water.

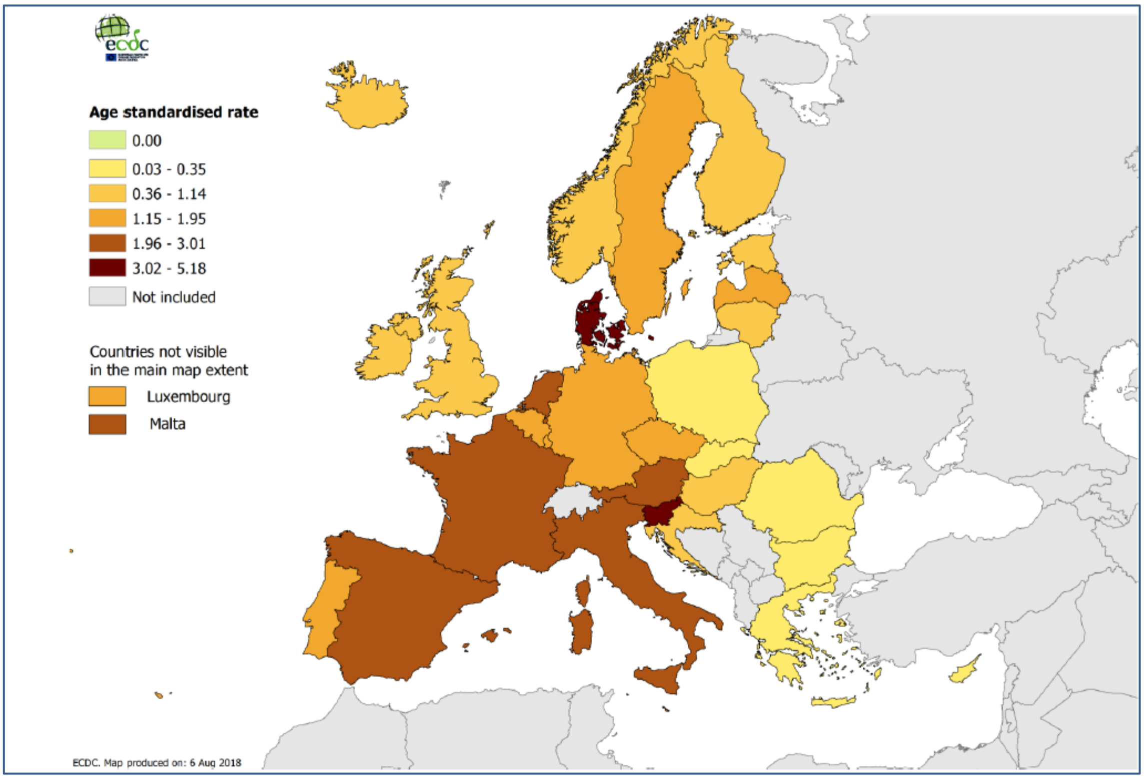


Figure 2: Distribution of Legionnaries' disease cases per 100.000 population in the EU/EEA countries, 2016. Source: Surveillance report Legionnaires' disease [3]

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## 4.2. Actions to find safe DHW solutions in relation to DH

Use of low and ultra-low DH temperatures in general results in an increase of the energy efficiency of the heating system. However, the low temperatures in general also increase the risk of Legionella. This emphasizes the need of finding safe Legionella solutions for the DHW production from DH.

Focus has been on both large installations in multi-family houses and commercial buildings often using a storage tank for hot water, and for smaller installations in one-family houses or in each flat in newer multi-storey houses with instantaneous heating by a heat exchanger. A survey of various challenges and solutions can be found in the IEA Guidebook “Future Low Temperature District Heating Design Guidebook” from 2017 [5].

### 4.2.1. Prevention of Legionella by safe DHW installation principles

Especially in Germany and in the Scandinavian countries, where energy efficiency reasons have caused considerable attention on reducing the DH flow and return temperatures, focus have been put on initiatives for preventing or reducing the risk of Legionella from DHW at low DH temperatures. Some of the measures have gone towards designing the water installations and DH connections, so Legionella does not develop so easily.

Discussions and preliminary investigations at German branch institutes for water and district heating supplies (DVGW and AGFW) resulted in a preliminary conclusion that small DH installations heated by small water volumes (up to 3 l) and with small length installations pipes apparently result in less likelihood for Legionella. German universities were also involved, and further research activities were started up [6a], as well the conclusion became a part of the CEN/TR 16355 recommendation [7].

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### 4.2.2. Current activities and challenges for safe DHW installations

The preliminary German investigations have been followed up, see e.g. [6a-c] but at the moment still without clear conclusions and documentations concerning small water storages of up to 3 l.

The German indications that the use of small drinking water exchangers could be the solution, when reducing DH temperatures, have further resulted in various related research in Denmark and Sweden.

The Danish activities have mainly had focus on practice tests for finding out what happens with DH units when installed like in practice and when tested at various DH and water temperatures. Tests were made on 5 different installations/test rigs at various Danish DH supplies. Tests were made over 2 separate periods/phases and included frequent temperature tests and Legionella analysis.

The results were not quite as expected. Overall, there was no significant correlation between operating temperatures and levels of cultured Legionella or Legionella detected by PCR (Polymerase Chain Reaction). There were two installations where L. pneumophila was not detected at all, and there were two installations where there was no constant detectable difference in the levels of L. pneumophila between water at 45 degrees C and 55 degrees C. That is, there are other ratios (unknowns) than the temperature level that has occurred for Legionella to / could not establish.

Further some of the results points to that existence of Legionella might be affected from the incoming drinking water coming in. Often water installations are being laid out for greater consumption than in fact exists, which is a problem for the drinking water quality as well as for the heated water. The full effect of this challenge is not yet cleared up.

The Danish tests and the results were together with Swedish tests presented at a thematic day at DTI 24 September 2018 [8a-b]. The Swedish tests have until now comprised various laboratory tests including Legionella analysis for finding out how units and installations can be designed and optimised for preventing Legionella. In continuation of the thematic day, discussions have been started up for further knowledge exchange as well for in the future coordinated research efforts.

In context with the above the Danish Agency for Health, SSI, had a presentation [8c] showing that according to [3] Legionella is still in high focus and in some countries in fact is increasing, e.g. Denmark and Slovenia. Both real increasing Legionella problems and more insight into being able to detect Legionella were pointed out as possible reasons.

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It was from the presentations concluded, that Legionella disease is still a serious problem as well as considerable challenges still exists in relation to finding safe solutions with handling of DHW at low DH temperatures. The conclusions call for use of supplying heating possibilities for in shorter periods (thermal treatment) to increase the water temperature up over 60 °C.

The microbooster solution, which is in focus in the RELaTED project, might thus be an important step in finding Legionella safe solution for ULT DH.

Another possibility is to combine with actual cleaning methods, in combination with control of the content of Legionella in the installations. Especially, control is in focus in relation to larger DHW solutions.

Both thermal treatment and other cleaning methods are shortly described in the next section (4.2.3).

### 4.2.3. Prevention of Legionella by cleaning methods

Various methods for cleaning of water installations are presented below:

| Method | Functioning | Assessment of the effectiveness of the methods and the risk of use |
|---|---|---|
| Thermal disinfection, Temperature shock (temperature gymnastics up to 60 °C - 70 °C) | Increased temperature in the hot water tank with subsequent rinsing of the wiring harness | Effective and proven method. Provides increased risk of scalding. Provides increased calcium precipitation, and increased energy and water consumption.<br>Can be difficult to carry out in circulating systems where there are thermostatic balancing valves especially of the older type. |
| Chlorination | Disinfects and inactivates bacteria | The formation of toxic by-products is possible. |
| Chlorine Dioxide | Has a devastating effect on the transport of nutrients across the cell membrane of the bacteria | There can be formation of toxic by-products such as chlorite and chlorate. The method has an effect on the formation of biofilm. |
| Ozone | Destroys bacteria and removes bad smell and taste and color | Ozone is corrosive and is also rapidly degraded. |

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| | | |
|---|---|---|
| Hypochlorous Acid | The system for the system produces on-site disinfectant hypochlorous acid by electrolysis of saline. | Hypochloric acid which is a biocide kills all the bacteria and removes the biofilm coatings in hot water containers and piping systems.<br>There are different makes and types of plants based on this principle on the Danish market. |
| Copper-silver ionization | Works toxic for bacteria | The method is pH dependent, therefore a pretreatment may be necessary. |
| Membrane technology. Ultrafiltration. Reverse osmosis | Filtering water through small pore size filters | Has no effect on biofilm formation in the pipeline network and should therefore be combined with other methods. |
| Ultraviolet radiation (UV) increases the effect of UV treatment | Has a devastating effect on the DNA of bacteria, thereby stopping growth | Has no effect on biofilm formation in the wiring network, and should therefore be combined with other methods.<br>Ultrasound can be used as a pretreatment. |

Treatment of the water against various bacteria including Legionella has for long been carried out when serious problems with the water and are being used as well for more ordinary treatment of water for various bacteria including Legionella, see e.g. [5].

Thermal treatment is based on that Legionella bacteria will be killed at temperatures higher than 60 °C. The best effect is obtained by rapid changing the temperature ("Temperature gymnastics") e.g. by use of an electric heater element. Various temperature shock effects are being prescribed according to use and traditions and the method is being used both for regular and controlled cleaning as well as for cleaning bacteria disinfected water installations. In EN 806 [9] and in CEN/TR 16355 is described the importance of a facility for enabling the temperature to be raised to at least 70 °C at any point in the water installation, why ETG [11] prescribe a shock treatment to be at 70 °C to 80 °C.

For checking the thermal, a monitoring of temperature is sometimes installed in larger circulation systems. The system monitors the temperatures in ascending and circulating circuits and provides an alarm at too low temperatures. The plant can connect directly to the property's CTS facility, or send a SMS to the selected person.

Chemical treatment cleans the installation with use of chemical biocides like chlorine, chlorine dioxide, ozone, monochloramine and hydrogen peroxide and is often used for cleaning bacteria disinfected water installations. Use of copper-silver ionization is another treatment. Effective chemical treatment requires precise control of dosage concentration and of residuals and odor, which is one

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of the weak points of these methods. It further means that they in general are being used at larger water installations were the effect can regularly be surveyed.

Physical treatment of water includes membrane filtration and UV sterilization. Membrane filtration is based on membranes with a large number of microscopic pores which retains the bacteria. They are very efficient and are often used for physical treatment in installations with high health risk. Because of the regularly need of cleaning or renewing of the membranes, they are however in general expensive. UV methods, which cleans the water by ultraviolet light, which damage the bacteria DNA replication, has become rather popular due to a rather uncomplicated installation and low price.

Chemical and physical treatments might, in various kind, be combined for covering short-term and long-term treatments.

Treatment of the water is an extra cost, as well as it requires regularly surveillance and control of the water installations. Further it is a challenge that the treatment in general cleans at the spot where they are installed. When the water flows to other parts of the water installation it might already be affected, resulting in starting up new Legionella in the incoming, cleaned water. This calls for a risk analysis of the water installation, which documents the spread of the Legionella and local treatment efficiency, as well as a monitoring system can be a part of it.

## 4.3. DH awareness of Legionella in relation to DHW

Most countries have legal requirements and/or guidelines for the drinking water installations and temperatures as well as for the DH connections. The legal requirements may be based on European Standards (EN) and guidelines, or on national specifications. In [2] it is found that, although different, the requirements have multiple similarities in their set-up, contents and specific requirements, as well as they include temperature requirements for both cold water and for hot water in heaters (DHW).

In Annex 1 the results from a questionnaire raised to the participating partners about Legionella is presented. The answers give an impression of how Legionella challenges are known and handled in the participating countries in the RELaTED project.

As a follow, up on the questions about legal requirements can be seen that all the respondents are aware of minimum operation temperatures of 50 – 55 °C, however the attention on other requirements is in general low. This also includes know-how about use of various recommendations and guidelines.

It is general understandable that European countries with a tradition for high DH temperatures are not very upset on Legionella problems, as well as the survey of

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Legionella disease in Europe indicates fewer problems. It is however important that this not becomes a sleeping pillow when decreasing the DH temperatures.

## 4.4. Recommendation for avoiding Legionella

### 4.4.1. Minimum water temperatures and insulation

When designing DHW systems and installations, it is very important to be aware of the risks for legionella, especially when having low or ultra-low DH temperatures. According to the newest research [2] and the experiences [3], the following is recommended:

- The hot water temperatures in the total system must not be lower than 55 °C at normal operation, and 45 °C in peak loads (absolute minimum temperature).
- Operating water temperature for the outlet from the DHW cylinder/tank must not be lower than 60 °C. For smaller systems (up to 3 l) lower temperatures have been considered, however at the moment no complete documentation for this exists.
- Return water temperature to the DHW cylinder/tank not lower than 50 °C.
- In order to ensure the hot water temperatures in the installation, the installation must be insulated according to a recognized national or international standard.

### 4.4.2. Risks and risk assessment

The risk of Legionella is, according to [11], present when there exist e.g.:

- temperature conditions suitable for Legionella growth (20 °C – 50 °C)
- poor or no flow
- cross connections and dead legs from where bacteria can penetrate
- inadequate backflow protection
- the use of inappropriate materials, providing a source for biofilm
- components resulting in inhalable droplets
- potential for contamination from poor source water.

Risk assessment has become an important new element in prevention of Legionella growth by been taken up by EU [4] and various organizations, as well as work on detailing the risk assessments has started up in general [11] and in various countries.

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A risk assessment must be carried out to provide the user enough information about the risks in the system, and to provide the necessary measures to ensure that the water systems are safe and without health risks.

The risk assessment is a critical element and should be regularly reviewed and updated. Risk of DHW systems should include the following:

- Identification of the water system and associated equipment and components.
- A current and valid schematic diagram that gives an overview of the total installation and its components.
- Consideration of the temperature of the incoming cold water (at the warmest time of the year) and the temperatures in all parts of the system, including an assessment of the potential for thermal transfer (cold water heating and cooling of the hot water, e.g. in installations shafts).
- Consideration of the potential for aerosol generation at the individual taps.

The main principles in setting up a risk assessment are described in [11] and with primary focus on larger building water systems. However, the general principles, including recommendations for suppliers of products and services as well installers, are of relevance also in relation to e.g. small DH connections of single houses.

At present, there are no clear thresholds for the risk assessment, except that it is probable that the temperature thresholds in section 4.4.1 are not exceeded.

For a DH supply the risk analysis might include e.g. a temperature control and measuring system showing that the connected substations will reach DH flow temperatures which will allow locally produced hot water with sufficient safety against legionella. If specified in the DH supply rules, it could also be requirements forwarded to the suppliers of the substations, meaning that they must make a risk analysis for the unit and, with general considerations, concerning its use in the installations.

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### 4.4.3. Other standards and guidelines

If legal requirements for the temperatures and for the design of DHW systems exist in the country, these must of course be fulfilled. For further recommendation/guidance shall be referred to the following documents:

- EN 806, part 2: Specifications for installations inside buildings conveying water for human consumption, 2005 [9]
  This is the main European standard covering DHW and gives various requirements and instructions concerning designing domestic water installations, including for preventing Legionella problems.

- EN 1717: Protection against pollution of potable water installations and general requirements of devices to prevent pollution by backflow, 2011 [10]
  This standard is primary focusing on backflow prevention, however inefficient back flow prevention might be a germ to Legionella problems.

- CEN/TR 16355: Recommendations for prevention of Legionella growth in installations inside buildings conveying water for human consumption, 2012 [7]
  This document has been carried out as a technical report from CEN and drawn up by the Technical Committee CEN/TC 184 Water supply. It comprises the following main sections:
  - General recommendations
  - Types of hot water installations
  - Blended water system within the temperature ranges of 37 to 45 °C.

  The Recommendation discloses the distinguish between small and large volumes (3 l), but recommends in general the volume of water to be as small as possible

- European Technical Guidelines for the Prevention, Control and Investigation of Infections caused by Legionella species, June 2017 [11].
  This document has been carried out by number of European experts in Legionella infections and comprise 4 main parts:
  1) Procedure for the risk assessment, environmental investigation and the control and prevention of Legionella in water systems
  2) Methods for the investigation and control of an outbreak of Legionnaires' disease in a hotel, other accommodation sites and other public buildings.
  3) Technical guidelines for the control and prevention of Legionella in water systems
  4) Treatment methods for various water system

  The Guideline is the general basis for carrying out risk analysis. Further shall be noted that the Guideline distinguishes between systems with small volumes (up to 15 l) and large volumes (from 15 l), which is different from the definition in CEN/TR 16355.

And to the IA Guidebook [4] which as former mentioned also cover Legionella.

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# 5. Metering and billing of consumption

In general, metering of district heating consumption in ULT DH systems is not different from traditional district heating. However, when electricity is used to boost DHW temperature, this share of the DHW production is no longer metered by the district heating company, or must be metered separately by an additional electricity meter.

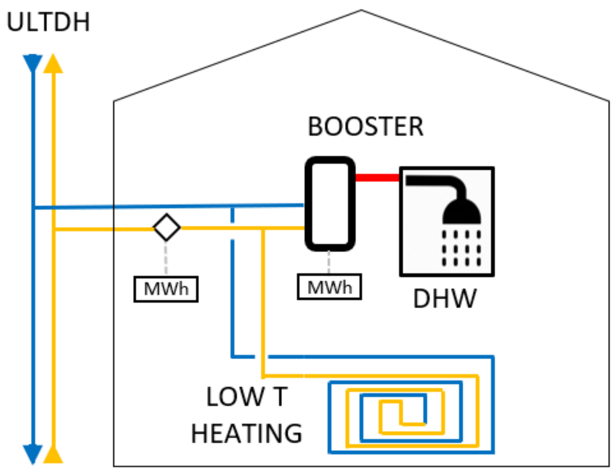


Figure 3: principle of metering in ULT DH systems with electric booster

In this case, there might be different ways to bill the consumer. One option is that the consumer is just billed the district heating consumption with usual tariffs, and then pays the additional electricity consumption over the general electricity bill. Though, this typically results in higher costs for the consumer as electricity is typical priced higher than district heating. Another option is that the district heating company is compensating the consumer the costs of the electricity consumption used for boosting. A third option is that the tariffs of ultralow district heating can be adjusted to reflect the system advantages of using ultralow temperature and thus compensate the electricity consumption for boosting.

In this section, we will first take a look at general metering and billing practices and then finally discuss specific ultra-low temperature challenges and options.

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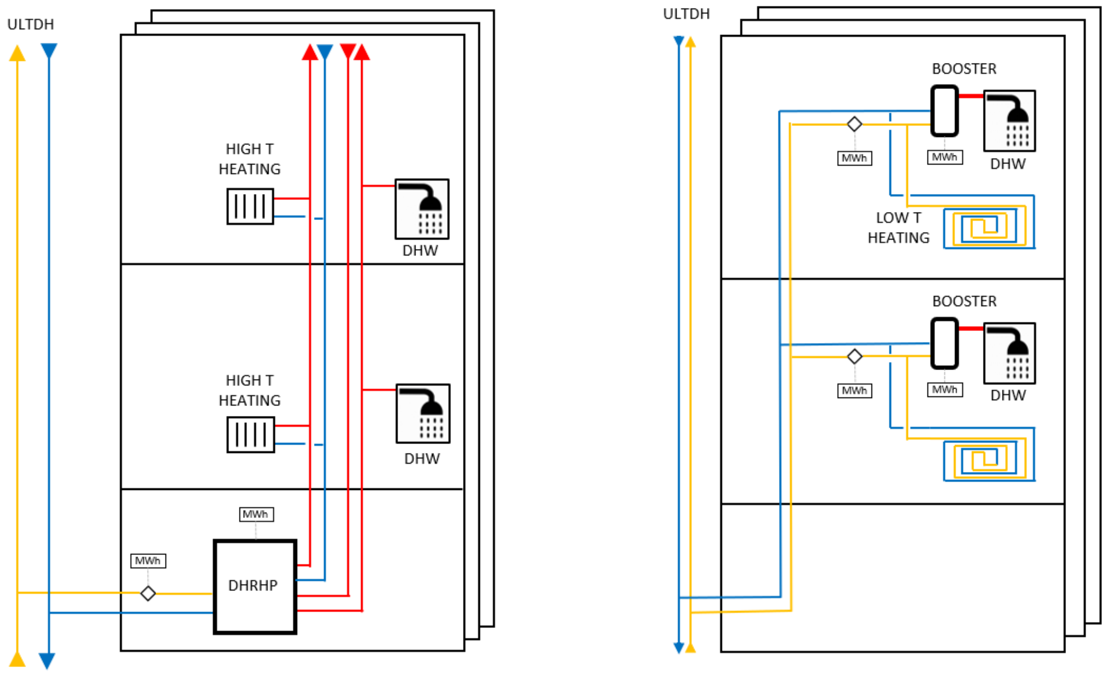
## 5.1. Metering

### 5.1.1. Meter per dwelling or per building

In multi-dwelling buildings with collective heating systems, the district heating meter can be placed at the interconnection with the district heating systems and the collective substation that provides space heating and DHW. Alternatively, meters can be placed in the individual dwelling in combination with an individual substation (flat station). In the first case (A), electricity for boosting may be included in the general metering of the building's shared electricity consumption or can be measured separately typically at relatively low costs. In the individual dwellings (B), the electricity for boosting may be included in the general metering of electricity, or can be measured separately by an additional electricity meter.




(A) (B)

Figure 4: Central metering (left) and metering per dwelling (right) in multi dwelling building

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### 5.1.2. Meter parameters

Modern district heating meters have various properties:

- **Measured standard parameters:** Flow, supply and return temperature.
- **Calculated standard parameters:** Temperature difference, heat power, accumulated energy, accumulated volume and time.
- **Additional calculated parameters:** 'Supply energy' and 'Return energy'. These parameters are the integration of the temperature over the volume ($\Sigma$ temperature x volume). The parameters can be very useful as they make it possible to calculate the average supply or return temperature by dividing by the accumulated volume.
- **Additional input parameters:** Some meters have the option of including additional temperatures or pulse signals from e.g. water meters or electricity meters.
- **Data storage:** The different registers may be stored such as hourly values, daily values, monthly values, yearly values
- **Display:** Showing the standard measures and calculated parameters.
- **Power supply:** battery and/or AC/DC supply. AC/DC power supply is typically required when the sample frequency of the meter data is high (also dependent on communication and battery technology as well as amount of data).
- **Communication:** Multiple options including M-Bus (wired/wireless), buses used in Building Automation and Control Systems (BACS), radio frequency networks, analogic output, etc. Some meters have the option of providing more communication channels within the same meter, e.g. one communication channel for billing and another communication channel for BACS.

### 5.1.3. Smart metering

Smart meters are mostly referred to as meters giving the option to register energy consumption on hourly basis which allows for billing based on hourly prices. Further, there must be a communication of these data to the trader of energy which relief the reading and reporting of the meter stand. In other words, the smart meter must be remotely read.

Other intelligent meter applications include e.g. leak surveillance detection or sensor fault detection.

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## 5.2. Billing

### 5.2.1. Billing information and frequency

The information on the energy bill should explain and reflect the tariffs which are applicable for the district heating system. Some tariffs are a fixed contribution per year, others are variable tariffs where the final bill will depend on the actual use of energy or other measurable entities. The fixed tariffs may reflect the fixed costs of the district heating scheme, including the appreciation on the assets, and the variable part the variable costs. But it is not necessarily so. Billing based on just variable tariffs exists as well. The questionnaire sent to the project partners have confirmed that.

The frequency of billing is typically based on the amount of consumption. Customers with smaller consumptions will typically be billed interim 3-4 times per year with a yearly calculation of the actual consumption, and the large consumers more often e.g. on monthly base. The introduction of smart meters, also for customers with smaller consumptions, makes it applicable to provide bills more often. The district heating company may provide the consumer with a web-interface or an app to lookup own consumption. Monthly bills may be sent by the means of electronic communication. In principle, future billing can be done down to the hour in case the meter resolution and communication/remote reading allow.

### 5.2.2. Variable district heating tariffs

Variable district heating tariffs may be related to the energy and the transport costs of supplying the district heating to the consumer. Transport costs are in some sense equivalent to the costs the electric distribution system operator (DSO) charges for distributing electricity:

- **Energy:** The energy consumption as metered is multiplied by the district heating tariff. This tariff is typically set for one year and will remain unchanged throughout this year. However, also seasonal tariffs are used by a few of the Danish DH suppliers today, and perhaps in the future hourly tariffs may be applicable.

- **Transport:** The transport tariff can take many shapes but would, in most cases, be based on the actual volume of district heating used. When the actual volume used is related to the actual energy used, the cooling-off of the district heating water can be calculated. The better the cooling-off is, the less the consumers are drawing on the capacity of the district heating system. The transport tariff can also be based on a return temperature limit that must be met ie 40 °C. Thus, the transport tariff is expressing both capacity issues and temperature issues which are relevant e.g. in relation

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to flue gas condensation at production plants or utilisation of renewable distributed energy resources. The transport tariff may also be seasonal or even hourly.

In case the district heating tariff is based on volume only, this is to some extent a combined energy and transport tariff. In case of the transport tariffs, these can take advantage of some of the additional calculated meter parameters available in modern heat meters such as the ‘Supply energy’ and ‘Return energy’.

### 5.2.3. Fixed district heating tariffs

Compared with the transport tariff mentioned in the previous section, district heating tariffs can also include a fixed part attributed the capacity provided. This can be a fixed tariff based on the living area of the building or it can be a tariff based on the heating power capacity provided. Other capacity tariff exists as well. In addition, a fixed tariff is sometimes also put on the heat meter related to the lifetime cost of metering. This fixed meter tariff is sometimes denoted as a subscription of the meter. Other administrative costs can be included in the fixed tariffs as well.

### 5.2.4. Electricity tariffs

When boosting the temperature with electricity, the electricity consumption as metered is multiplied by the electricity tariff to get the number to be billed. The electricity tariff can, as for district heating, typically consists of variable parts taking into account the traded electricity and the transport on distribution (DSO) and transmission (TSO) level. Fixed parts may include subscription of the meter as well as other administrative costs. In addition, different taxes may be part of the electricity tariff.

The rollout of electricity smart meters in Europe will facilitate the use of hourly tariffs which are expected to be variable in a wider range in the future due to the massive introduction of renewable fluctuating electricity production plants such as wind turbines and PVs.

### 5.2.5. Connection fees

When connecting a building to the district heating system, the new customer would typically have to pay for the connection/branch pipe based on the actual enterprise costs. Different incentive schemes may apply when introducing new district heating network to an area. The connection fee may also include a lump sum e.g. taking into account the administrative costs associated with getting a new customer.

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## 5.3. Discussion of specific ULT metering and billing challenges and options

When applying ULT DH to an area, the district heating tariffs should optimally reflect the benefits of ULT for the district heating system. This may imply that the district heating company is operating with two different tariff structures – one for traditional district heating and one for ultra-low temperature.

A non-exhaustive list of general benefits is:

- When ULT DH is supplied to a new area from the return pipe of an existing system, the capacity of the whole system is expanded.
- When ULT DH is supplied to a new area at the end of an existing network, no additional increase of the supply temperature is required at the plant(s) in the existing network to cope with the temperature loss in the new area.
- When ULT DH is supplied to a new area, the distribution losses will be lower than if supplied with traditional temperatures.
- When DH (not only ULT) is supplied to a new area with low energy buildings, the required capacity for each building is less than for traditional buildings.
- When ULT DH is supplied to a new area, local distributed energy resources based on renewables or low exergy waste heat are applied easier.
- When ULT DH is supplied to a new area, because of the low temperature, pipe materials with less demanding properties can be used which can result in lower connection costs.
- When ULT DH is supplying micro-booster units to boost the temperature at the consumer, the build-in storage tank can take advantage of the variation in hourly electricity tariffs to minimise the cost of boosting.

Thus, optimally these benefits should be divided into variable and fixed ULT DH tariffs as well as the connection fees. A threshold between when to apply the traditional and the ULT-tariffs can be based on the ULT-definition used in the RELaTED-project:

*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,*

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*all district heating systems supplying district heating at temperatures below 50 °C will be considered ultra-low temperature district heating systems (ULT DH).*

Supplying district heating for low energy buildings and applying ULT also introduces challenges that can be handled in the tariff structure and billing practice:

- In low-energy buildings, the consumption of DHW can be relatively high compared to the consumption for space heating. For the most efficient buildings, the DHW consumption equals the space heating consumption. In case, an exhaust air ventilation heat pump is used to produce the DHW. In worst case, half the expected heat sale may disappear.

- ULT DH tariffs should preferable reflect the real cost reductions due to ULT DH to motivate its use. For calculation of private economy for the consumer, the electricity consumption of boosting the temperature cannot be neglected.

- Separate electricity meters may be required and remote-read over the district heating meter (possible with extra inputs). Alternatively, a fixed reduction can be applied. In any case, this will require some additional posts on the bill.

- In some countries, the tariffs of district heating schemes must be approved by a legal body. Adapting and getting new tariffs approved can be a time-consuming process which must be taken into consideration, when addressing specific ULT-tariffs.

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# 6. Interconnection schemes for consumer installations

In this paragraph, different ULT DH interconnection schemes at the consumer level are presented. The goal of this study is to both explore possible installation possibilities as well as indicate possible solutions for three of the four Demonstration sites of the RELaTED project.

Moreover, in this part of the report, some examples of existing solutions and available solutions are introduced

Some examples of installation schemes are introduced. Some of these solutions are already existing and well proven in the market today. Others are entering the market, and others are under demonstration phase.

## 6.1. General consumer installations for existing and nearly zero energy buildings

### 6.1.1. ULT DH in Existing buildings

In those cases in which ULT DH is supplied to existing buildings equipped with high temperature radiators, ULT DH requires an increase of the supply temperature in order to match space heating comfort temperatures. The RELaTED project proposes a DHRHP with storage tank for DHW at building level. The HP (heat pump) supplies both SH (Space heating) for high temperature radiators and DHW. DHW recirculation can be required in this type of installations. A Figure representing a possible configuration is shown below (Figure 5):

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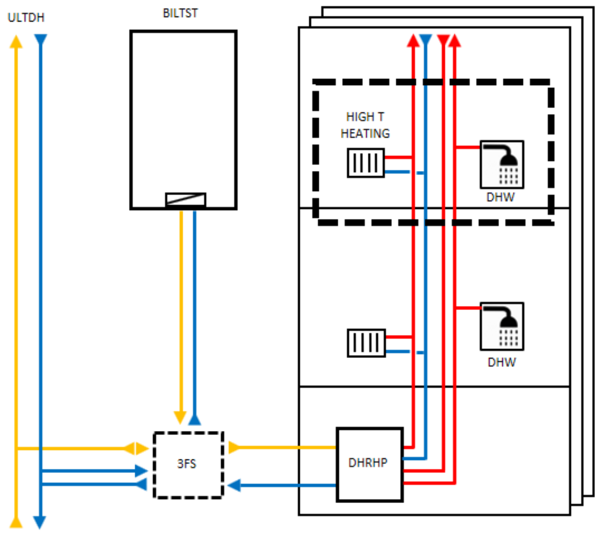


Figure 5: possible configuration for ULT DH installation in existing buildings

This report focuses on the interconnection schemes located within the building.

It should be considered that the interconnections schemes for consumers in this type of applications will often be unchanged or similar to those needed by DH systems with conventional supply temperatures.

However, if distribution temperatures at building levels are modified compared to existing ones, the replacement or modification of some of the system components might be needed. An example could be the need of replacing existing radiators and thermostatic control valves in those buildings that reduce distribution temperatures from 80 down to 55-60 °C.

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### 6.1.2. ULT DH in nearly Zero Energy Buildings

In case of ULT in nZEB, district heating can be supplied directly to the low temperature heating systems. ULT DH supply temperatures below 50 °C are not sufficient to supply DHW at comfort level and without risk of Legionella contamination. Electric boosters in these cases are used to further increase DHW temperatures. The configuration proposed in RELaTED can be found in the Figure below (Fifure 6).

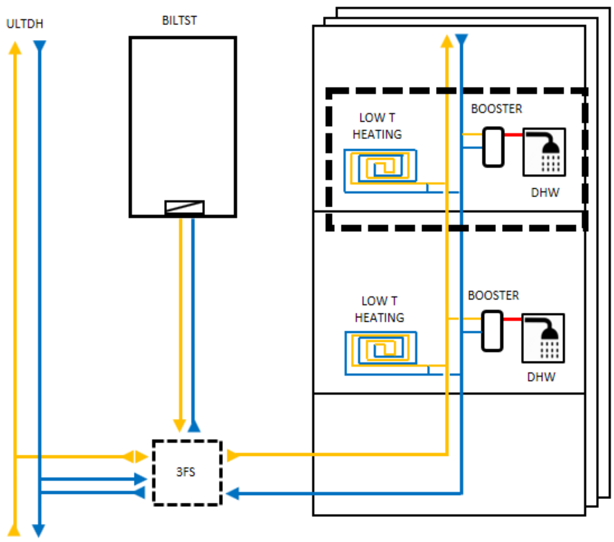
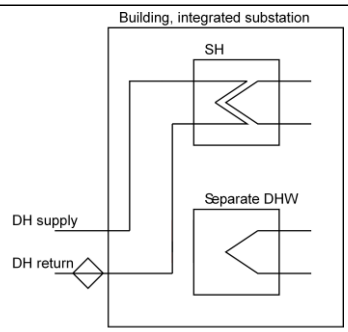



Figure 6: possible configuration for ULT DH installation in nZEB buildings

## 6.2. Consumer installations for heat (SH) and domestic hot water (DHW)

Typical DHW and SH installations of existing systems are described in Table 1. An overview on the general possible configurations for DHW combined to SH are illustrated.

| DHW Type identification | Installation type |
|---|---|
| DHW-0 |  |

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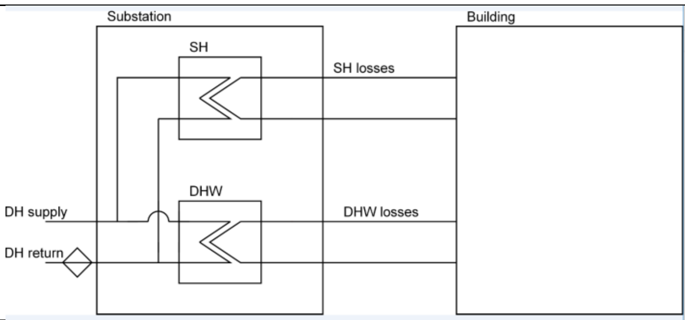
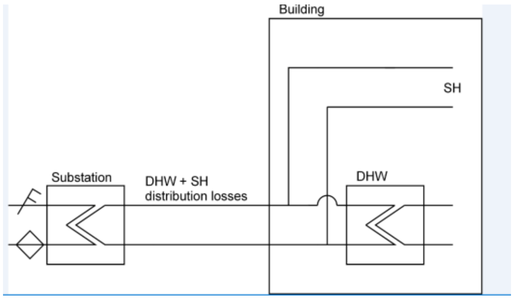
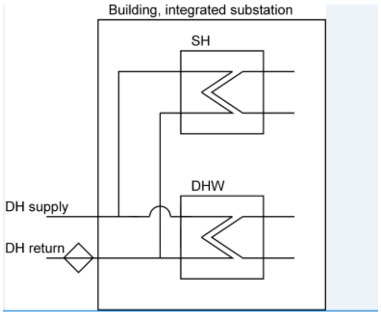
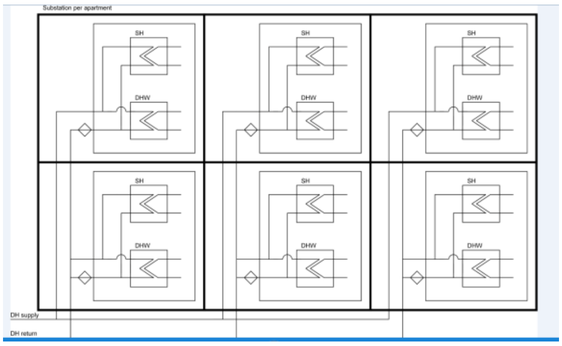
| | |
|---|---|
| **DHW-1** |  |
| **DHW-2** |  |
| **DHW-3** |  |
| **DHW-4** |  |

Table 1: Overview of Domestic Hot Water System configurations

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| | |
|---|---|
| DHW-0 | Building integrated substation with DH only for SH. DHW is produced with 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 where a separated substation for DHW production is installed. |
| DHW-3 | Building integrated substation. Both SH and DHW productions are placed in the building. |
| DHW-4 | Substation per apartment. Both SH and DHW productions are placed in the apartments. DH is distributed to each apartment. |

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## 6.3. Existing buildings

### 6.3.1. Instantaneous DHW production – Direct DH connection to SH system

In the configuration presented in Figure 7, DH is supplied directly to the space heating system, with no heat exchanger between primary and secondary side. In some cases, a mixing loop can be available in order to control space heating supply temperature.

DHW is instantaneously supplied through a flat plate heat exchanger which divides primary and secondary side. A thermostatic flow control valve assures a constant DHW supply temperature.

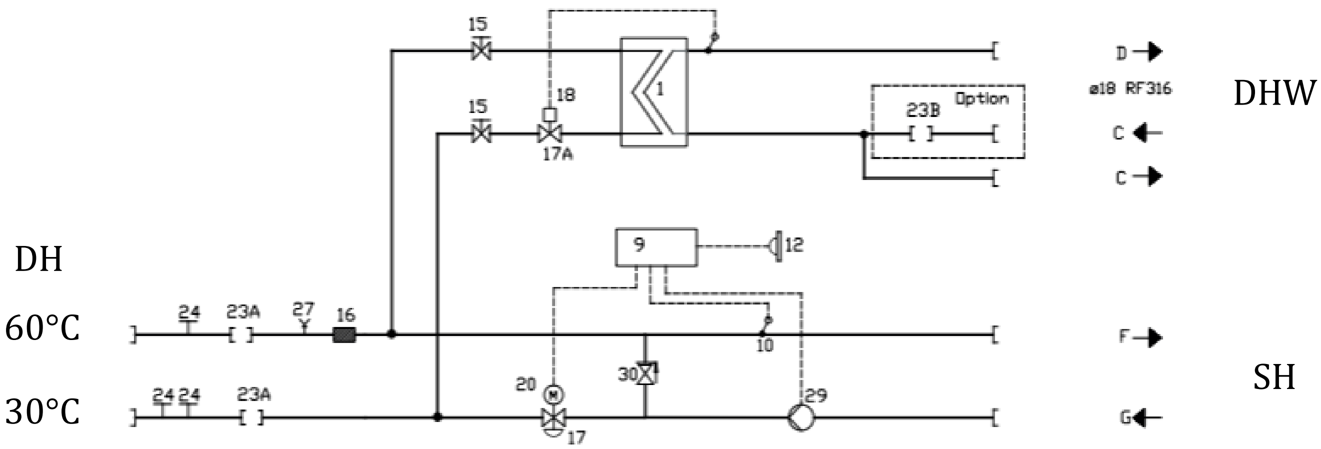


Figure 7: Consumer substation with instantaneous DHW production. Unit commercially available Source: Metro Therm A/S [12]

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### 6.3.2. Instantaneous DHW production – Indirect SH

This example is similar to a DHW-4 consumer substation, but with no interface between DH and SH system.

DH is supplied to the space heating system through a flat plate heat exchanger between primary and the heating system. These types of installations are normally equipped with a motorized flow control valve, electronically controlled and based on space heating supply and DH return temperatures.

DHW is instantaneously supplied through a flat plate heat exchanger which divides primary and secondary side. A thermostatic flow control valve assures a constant DHW supply temperature.

An example of a DHW-4 substation at apartment level for existing buildings is shown in the following Figure (8):

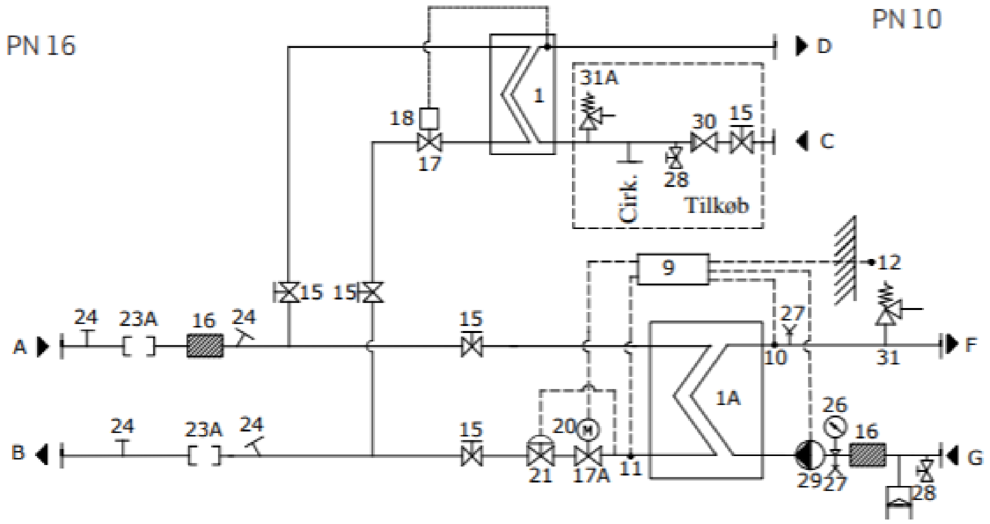


Figure 8: Consumer substation with heat exchanger for space heating and for instantaneous DHW production Source: Metro Therm A/S [12]

This type of installation is a possible solution for the demonstration site in Tartu.

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### 6.3.3. DH Storage on primary side - Direct SH

In this configuration, DH is stored in a storage tank on the primary side. A circulation pump and a control valve are used to refill the tank with hot DHW. A pump and an additional control valve are used to produce DHW. This type of configuration can be found today in the market.

DH is directed to the SH system. (Figure 9)

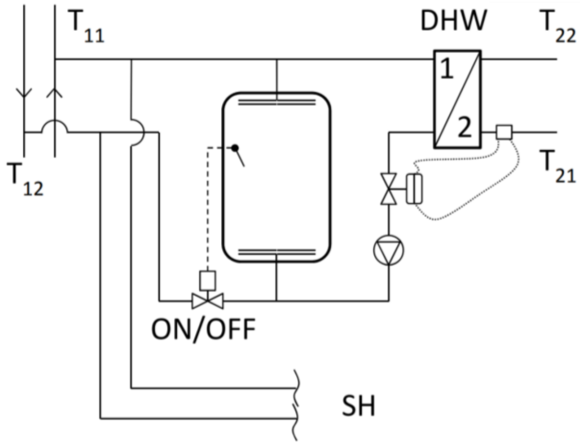


Figure 9: DH storage on the primary side Source: Heating and Domestic Hot Water Systems in Buildings Supplied by Low-Temperature [13]

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### 6.3.4. DHW storage on secondary side – Direct or Indirect SH

An alternative to the previous system is an installation with DHW storage tank on the secondary side. In the following Figure (10) a system in which DHW is heated only by DH is shown.

The installation described is equipped with indirect heat exchange from DH to SH systems, but different alternatives with direct connection can be also found in the market.

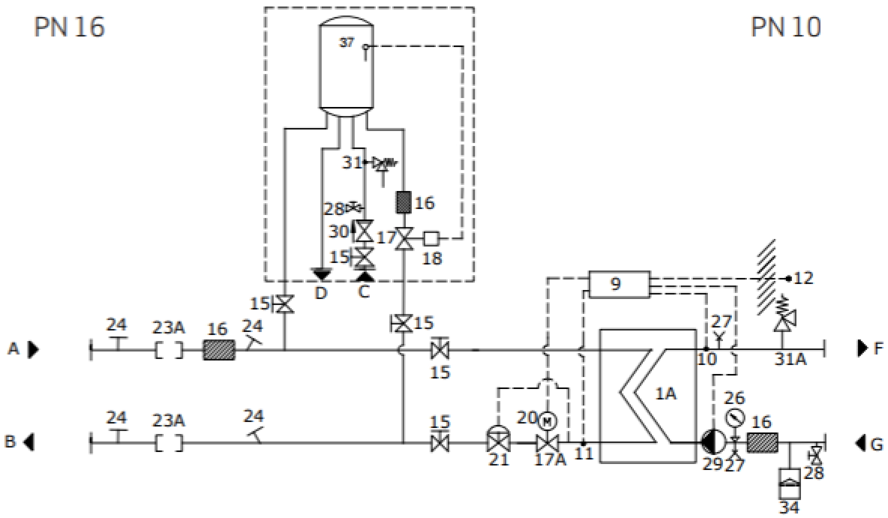


Figure 10: Existing substation with DHW storage tank on the secondary side and indirect SH connection
Source: Metro Therm A/S [12]

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## 6.4. ULT DH in nZEB

In nZEB buildings connected to ULT DH it is possible to use district heating to supply the floor heating system directly. In case the supply temperature is too high for the floor heating system, it should be possible to reduce the supply temperature from the central substation, for instance even down to 35 °C. As alternative, a mixing loop can be introduced before the floor heating system.

### 6.4.1. Instantaneous DHW with flow electric booster

ULT DH can directly produce DHW at 35-40 °C out of the flat plate heat exchanger. This supply temperature can be further increased by instantaneous flow electric heaters in order to reach 50 – 55 °C. (Figure 11)

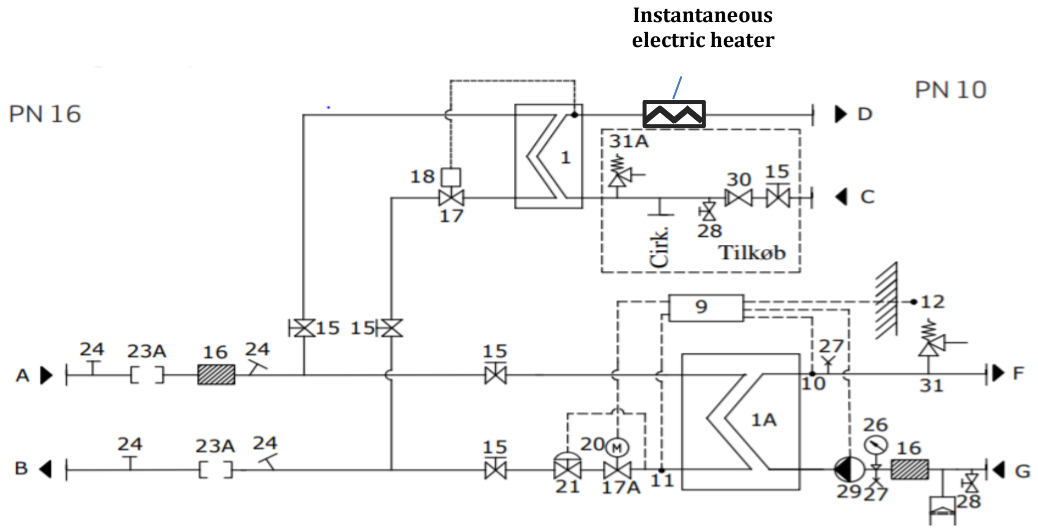


Figure 11: Example of consumer substation with flow electric booster for DHW preparation

Both instantaneous flow heater and instantaneous DHW substations are available on the market, however the integration of the two systems may require some design modifications.

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### 6.4.2. DHW storage tank with electric booster

In the solution presented below (Figure 12), ULT DH is used to pre-heat DHW in the DHW storage tank to 35-40 °C and sequentially DHW temperature is increased to 55 °C by the electric heater placed inside the tank.

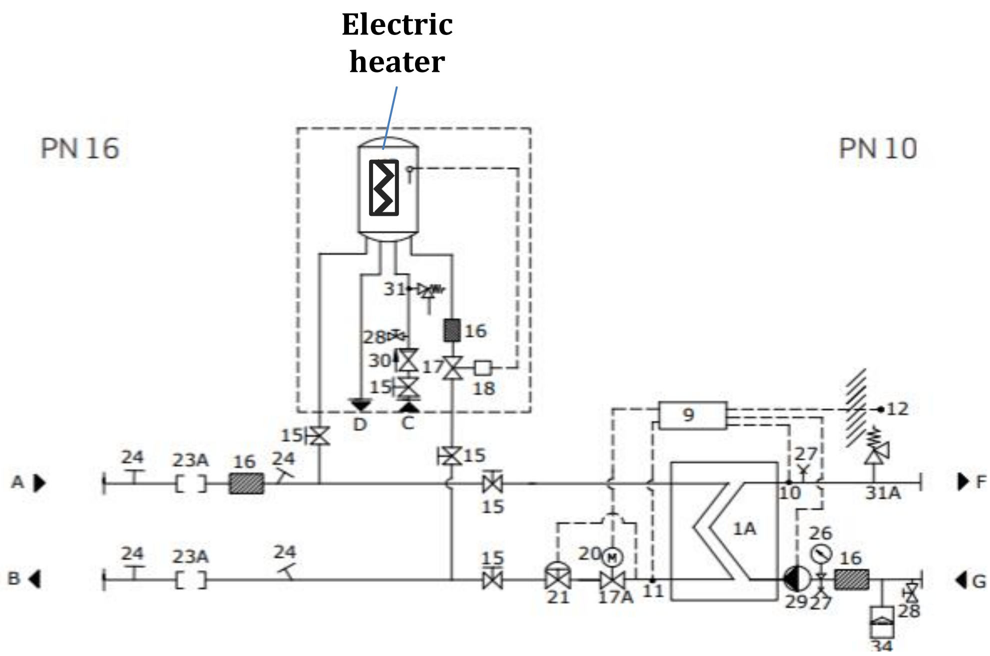


Figure 12: Example of consumer substation with electric heating element in storage tank for DHW preparation

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### 6.4.3. Booster HP with DH storage on primary side

In this configuration (Figure 13), DH is stored in a storage tank on the primary side. A circulation pump and a control valve are used to refill the tank with hot DH water. A pump and an additional control valve are used to produce DHW.

DH temperatures are increased by a heat pump on the primary side.

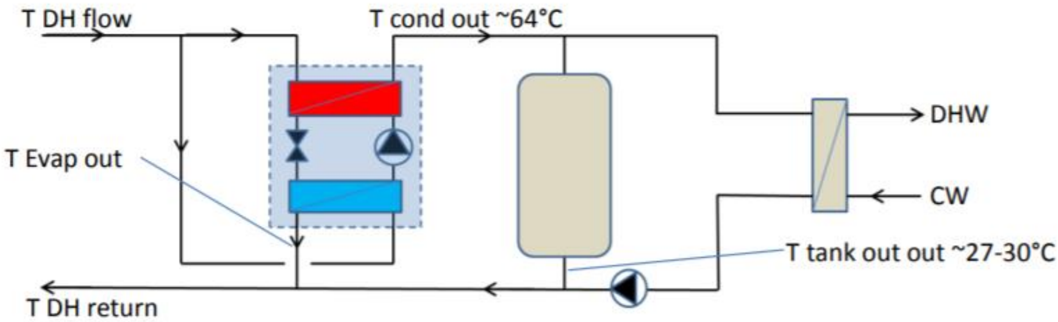


Figure 133: Booster HP with DH storage on the primary side. Source Danfoss, 2018 [14]

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### 6.4.4. Booster HP with DHW storage on secondary side

**a) Parallel connection to SH system**

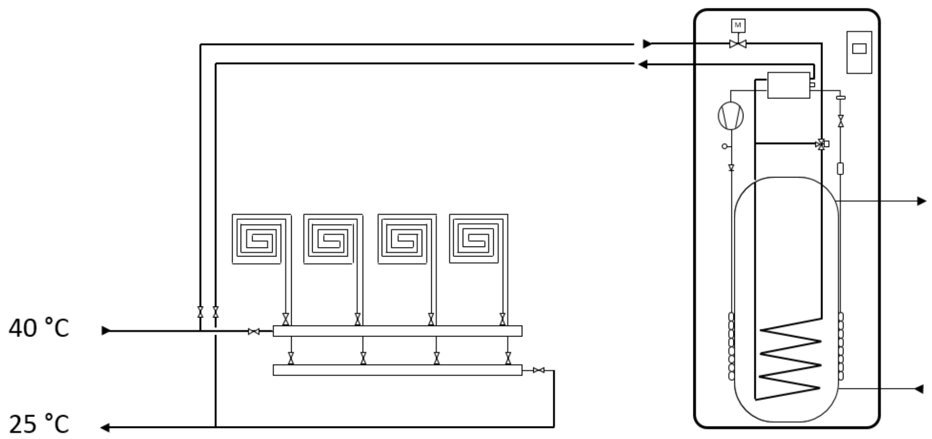


Figure 14: Booster HP with DHW storage on the secondary – Parallel connection to floor heating system

DHW is produced by a Microbooster HP with water storage on the secondary side. The Microbooster HP is connected in parallel to the floor heating system so that the flow control made by the unit is independent from the SH system.

**b) Serial connection to SH system**

An alternative possibility is to connect the Microbooster HP in serial connection to the floor heating system, using the return line as heat source for the HP operation. This type of installation is currently present on the market.

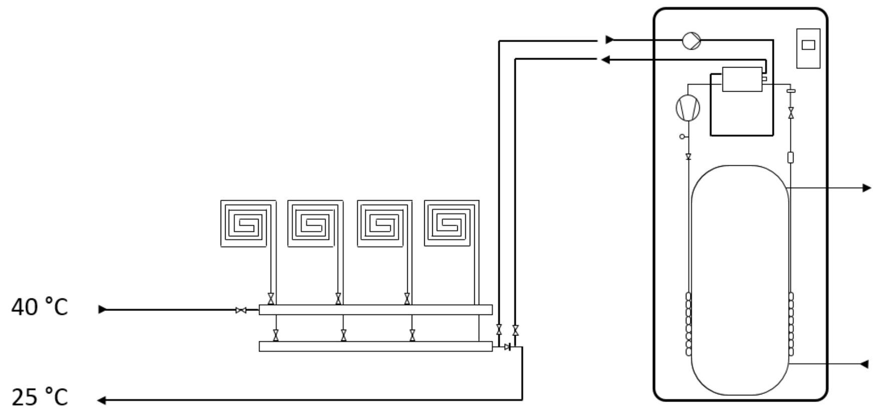


Figure 15: Booster HP with DHW storage on the secondary – Serial connection to floor heating return line.

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## c) Microbooster heat pump – Possible modes of operation

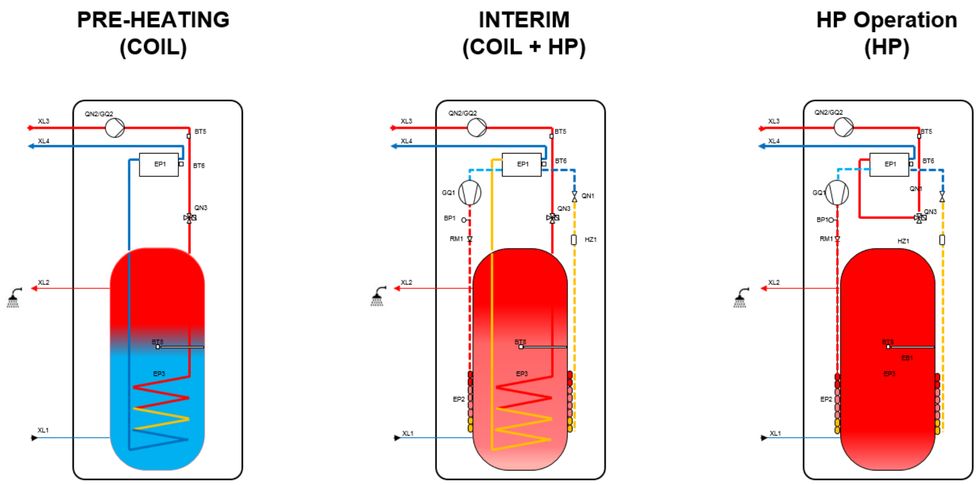


Figure 16: Possible operation modes of a Microbooster HP with DHW storage. This type of unit is currently entering the market.

The Microbooster HP produces DHW by three consequential operational modes:

1) A pre-heating mode in which the ULT DH is used to directly pre-heat DHW through a coil.

2) When the return temperature starts to increase, the water-to-water heat pump circuit is activated. In this mode of operation heat is transferred to the DHW simultaneously from the coil and from the HP.

3) When no more heat can be extracted by the preheating coil, the coil is by passed and only the heat pump boosts DHW to the required temperature which satisfies comfort levels and avoid Legionella.

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#### d) Air booster HP with DHW storage on secondary side

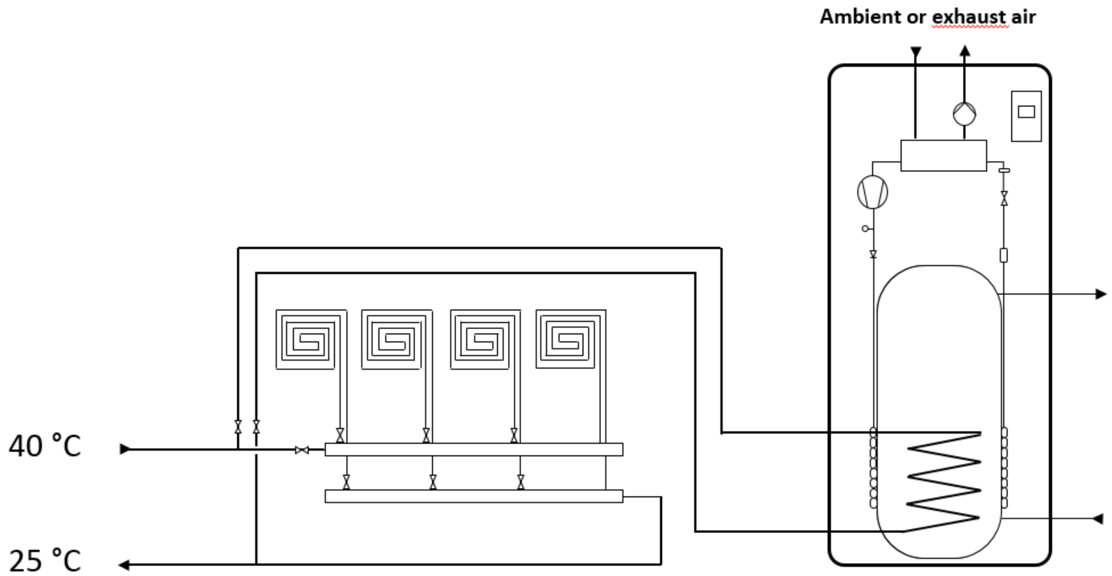


Figure 17: Air booster HP with DHW storage on secondary side.

An alternative solution to the Microbooster HP is an air to DHW HP which uses a coil to preheat DHW inside a tank and then boosts DHW temperature through a HP using ambient, outdoor or exhaust air as heat source.

The air DHW HP can also extract air from a ventilation system with heat recovery.

#### e) Demand Flexibility

Thanks to a 190 l storage tank and an electronic controller, the Microbooster HP and the Air booster HP can adapt the heat production to the needs of the network and to the users by the following control functionalities:

- **Smart Grid Ready**: the heat pump booster can be externally controlled by two potential free relays. The unit can be forced to start, to stop or to operate at maximum heating capacity.
- **Low Tariff function**: the unit operates only in pre-set periods of time, for instance in those periods in which electricity has a lower price as during night periods.
- **External control**: The unit can be stopped by an external signal.
- **PV**: The unit can be coupled to a PV panel. The booster operation will depend on the PV electricity production level.

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[3] Surveillance report Legionnaires' disease, European Centre for Disease Prevention and Control, Stockholm, 2018

[4] EU 2017/0332 Proposal for Directive on the quality of water intended for human consumption, 1 February 2018

[5] IEA Guidebook "Future Low Temperature District Heating Design Guidebook", Final Report of IEA DHC Annex TS1, IEA DHC&CHP, 2017

[6] German Legionella research in relation to DH, e.g.:

a) Untersuchungen zur Verifizierung von Sicherheitsabständen zur Zone des Legionellenwachsturms in der Trinkwassererwärmung (English: Investigations for the verification of safety distances to the zone of the Legionella vigil in the drinking water heating), Forschungsreport, Karin Rühling, 2012

b) Verifizierung von Sicherheitsabständen zur Zone des Legionellen Wächstums in der Trikwassererwärmung (English: Verification of safety distances to the zone of Legionella growth in water heating); Karin Rühling, 2014

c) Energieeffizienz und Hygiene in der Trinkwasserinstallation, DIN NormeAusschuss Wasserwesen, Vortragende Karin Rühling, Sitzung NA 119-07-07 "Trinkwasserinstallation", Berlin, 13.11.2018, and several other articles and presentations

[7] CEN/TR 16355: Recommendations for prevention of Legionella growth in installations inside buildings conveying water for human consumption, 2012

[8] Legionella – udfordringer og løsninger (Eng.: Legionella in relation to water installations – Challenges and Solutions), DTI, Aarhus, Denmark, 24 September 2018; including e.g.:

a) The Danish background and basis concerning Legionella in water installations (in Danish); Leon S. Buhl, DTI

b) Control of legionella in Swedish hot water by using limited water volumes (in Swedish); Charlotta Löfström, RISE

c) The Legionella problem and the current situation (in Danish); Søren

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Uldum, SSI – Agency under the auspices of the Danish Ministry of Health

[9] EN 806, part 2: Specifications for installations inside buildings conveying water for human consumption, 2005

[10] EN 1717 Protection against water contamination in water installations and general requirements for backflow fuses, 2002

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[12] METRO THERM A/S, Denmark, www.metrotherm.dk.

[13] Heating and Domestic Hot Water Systems in Buildings Supplied by Low-Temperature District Heating, PhD Thesis Department of Civil Engineering, Brand Marek, 2014

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# ANNEX 1 Questionary concerning legionella

| Legislation and guidelines | DK | EE | ES | NO | PL | SB | SE |
|---|---|---|---|---|---|---|---|
| | Denmark | Estonia | Spain | Norway | Poland | Serbia | Sweden |
| **1 Legal requirement 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?<br>If "Yes": Which requirements and why?<br>… | YES<br>DK1) | YES<br>EE1) | | YES<br>NO1) | YES<br>PL1) | NO | YES<br>SE1) min 50 °C at the tap |
| 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?<br>If "Yes": Which requirements and why?……… | NO<br>DK2) | NO | | ? | ? | NO | NO |
| Question 1C: Do you in your district heating supply/plant have any temperature delivery terms set up for preventing legionella or other bacterial growth?<br>If "Yes": Which requirements? | NO<br>DK3) | YES<br>Minimum temperature 55 °C | | ? | YES<br>PL2) Temperature maintenance | NO<br>SB1) flow system | NO |
| **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? | NO<br>DK4) | YES<br>EE2) | | ? | ? | NO | NO |
| Question 2B: Do you have specific requirements for District Heating based on EN 806-part 2, section 9? | NO | NO | | ? | ? | NO | NO |
| **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?<br>If "Yes": Where are you using CEN/TR 16355? and Why | YES<br>DK5) | NO | | NO | ? | NO | NO |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **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?<br>If "Yes": Which guidelines do you use? | YES<br>DK6) | 55 °C | | ? | YES<br>PL3) | 50 °C | YES<br>Säkertvatten kap 4 |

Notes:

SB1) We use flow system without accumulators (small volume and short time of water passing through system) to prevent Legionela growth.

SE1) Min. 50°C at the tap, required by Swedish building regulations, BBR to prevent legionella

PL1) The hot tap water installation should allow obtaining at the points of the tap water at a temperature not lower than 55 °C and not higher than 60 °C.
The hot water mains installation should enable continuous or periodic disinfection by chemical or physical methods (including periodic use of the thermal disinfection method), without reducing the durability of the installation and the products used in it. For thermal disinfection, it is necessary to ensure that the water temperature is not lower than 70 °C and not higher than 80 °C at the drawing points.
Cold and hot water installations should be adequately insulated to ensure proper temperatures (cold water < 20 °C heat water ≥ 55 °C). The materials from which the water installation is made should not promote the growth of microorganisms. The water installation should be resistant to temperatures of 70-80 °C (thermal disinfection). The design of heaters and tanks should allow easy access to them (inspection holes should be wide enough). Water should not be formed in the network (it is necessary to circulate water). Spray heads are to be constructed in such a way that microareosols with a droplet diameter of 2-5 μm are not formed. All blind sections of the installation must be removed. Prevent corrosion processes and create deposits. The use of self-draining shower lines should be sought.

PL2) Temperature maintenance:
- in cold water installations below 20 °C;
- in hot water installations above 55 °C;
- water leaving the heater not lower than 60 °C.

PL3) Ensuring proper cold and hot water temperatures by adequate insulation of the installation. No water stagnation. Liquidation of the so-called blinds of the installation. Prevention of corrosion processes and formation of deposits in installations. Proper maintenance and keeping the water system clean, including by removing corrosion products and deposits. Striving to use self-draining shower lines; conducting periodic monitoring of the microbiological quality of hot water towards the legionella bacteria.

Which guidelines do you use?

- Regulation of the Minister of Infrastructure of 12/04/2002 regarding technical conditions which should be met by buildings and their location (Journal of Laws from 2002, No. 75, item 690 with later amendments).

Temperature in cold water installations below 20 °C; in hot water installations above 55 °C; water leaving the heater not lower than 60 °C.

NO1) Two larger outbreaks of legionella bacteria. happened (2001, 2005)

EE1) Only temperature requirement is 55 °C for hot water. Design shall be made according to EN 806 standard

EE2) Standard EN 806-part 2 has approved by Estonian legislation and standard EVS-EN 806 is used for design of DHW systems.

DK1) The Danish Building Regulation BR18 (Bygningsreglement BR18); see http://bygningsreglementet.dk/ inclusive a pdf-reference for a version in English. BR 18 refers to DS 439, the Danish code of practice for Domestic Water supply installations (Vandnormen) and DS 469 Heating and cooling systems in buildings (Varmenormen).

DS 439 requires a minimum temperature of 50 °C for domestic hot water in the whole supply system.

For avoiding legionella and other bacteria, which especially growth in water at temperatures between 30 – 40 °C.

DK2) The requirements described in question 1A also cover DH.

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DK3) The DH delivery terms normally refers to DS 439 and DS 469, see 1A.

DK4) No requirements, but EN 806-part2, section 9 is being used by some consultancies.

DK5) Yes, and the guideline is being used by some consultancies and equipment suppliers.

For designing water installations under special circumstances, e.g. in small installations with maximum 3 liter water and short pipe length.

For preventing legionella problems in small installations.

DK6) Rørcenteranvisning 017 Legionella - Installationsprincipper og bekæmpelsesmetoder, April 2012 (Legionella – Installation principles for preventing legionella problems), see http://docplayer.dk/2325975-Legionella-installationsprincipper-og-bekaempelsesmetoder-roercenter-anvisning-017-april-2012.html.

Various installation principles and different solutions for preventing legionella problems.

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……

| Occurrence and prevention of legionella | DK | EE | ES | NO | PL | SB | SE |
|---|---|---|---|---|---|---|---|
| | Denmark | Estonia | Spain | Norway | Poland | Serbia | Sweden |
| **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?<br>Answer:<br>If "Yes": Which methods? ……………… | YES<br>DK7) | ?<br>EE3) | | YES<br>Thermic disinfection | YES<br>PL4) | NO | YES<br>Thermic disinfection |
| **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?<br>Answer:<br>If "Yes": Which installations typically? | YES<br>DK8) | NO | | NO | YES | YES<br>SB2) | YES<br>SE2) |
| Question 6B: Which flow temperatures are in general used in your plant/supply? | 60-95 °C<br>DK9) | Min 65 °C<br>EE4) | | ? | 55-60 °<br>PL5) | 50–55 °C | 52-53 °C<br>SE3) |
| Question 6C: Do you have any knowledge about legionella problems in your plant/supply in relation to the operating temperature?<br>If "Yes": Which problems? | NO | NO | | ? | ? | NO | NO |
| **7 Other comments regarding legionella problems in DH** | | | | | | | |
| Question 7: Are you aware of the occurrence of legionella diseases that can be attributed to district heating plants and the hot water supply?<br>How many cases annually? | NO | NO | | NO | ? | Yes<br>SB3) No occurrence in past years | NO |

Notes:

SB2) With DHW tank / accumulator

SB3) In DHS in Belgrade – no legionella occurrence in past years

SE2) Sport facilities used periodically. To our knowledge, the growth of legionella rarely happens in the domestic hot water tank

SE3) The factory settings in our heat pumps are normally at a level of 52 – 53 °C in the hot water storage tank

PL4) Chemical disinfection can be carried out with: chlorine; sodium hypochlorite; calcium hypochlorite; chlorine dioxide; ozone; bromine chloride; copper and silver ions; potassium permanganate; hydrogen peroxide. Physical disinfection can be carried out by means of: elevated temperature; ultrasound; electromagnetic radiation including UV, RTG, gamma radiation.

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PL5) : Temperature in cold water installations below 20 °C; in hot water installations above 55 °C; water leaving the heater not lower than 60 °C.

EE3) I have seen UV light disinfection equipment's at food factory. No information about usage at DHW systems heated by DH.

EE4) Output flow temperature from heat production plant is from 72 °C to 110 °C. All DHW customer substations are designed with minimum DH supply temperature 65 °C.

DK7) Yes, the methods mentioned above are being used.

Depends on the installation. New research has recently been carried out in relation to disinfection with Chlorite dioxide, Hypro chlorite, ultraviolet light and filtering methods.

Some of the methods have been tested in relation to research projects, but no statistic about their general use exist.

DK8) Yes; SSI, a governmental institute called Statens Serum Institute collects knowledge about all legionella diseases in Denmark and make a yearly statistic.

The SSI statistics only mention the number of legionella disease cases and does not detailed analyze the reasons, which means that SSI do not have clear observances of the risk from domestic cold and hot water.

DK9) Today from 60 °C to 95 °C, but in the future ultralow temperatures from 20 °C to 40 °C are expected used in some cases.

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# ANNEX 2 Questionary

## Prices and billing options for consumers

How are the pricing and billing options for a typical DH consumer in your country?

1 tariffs system mainly for total network area
2 Varies from supplier to supplier

| Question | | DK | EE | ES | NO | PL | SB | SE |
|---|---|---|---|---|---|---|---|---|
| | | Denmark | Spain | Estonia | Norway | Poland | Serbia | Sweden |
| Fixed rate. Based on: | Building area | **YES** [2] | | **NO** | **?** | **?**[1] | | **NO** |
| | Building volume | **YES** [2] | | **NO** | **?** | **NO** | | **NO** |
| | Pipe dimension | **NO** | | **NO** | **?** | **NO** | | **NO** |
| | Other?....... | **NO** | | **NO** | **?** | | | |
| Unit price. Based on: | MWh/GJ | **YES** [2] | | **YES** | **YES** | **Yes** | | **YES** |
| | $m^3$ | **YES** [2] | | **NO** | **NO** | **Yes** | | **NO** |
| | Other?....... | **NO** | | **NO** | | | | **NO** |
| Reduced price for low temperature heat* | | **YES** [3] | | **NO** | **NO** | **NO** | | **NO** |
| Reduced price for using heat from return pipe* | | **YES** [3] | | **NO** | **NO** | **NO** | | **NO** |
| Extra charge for high return temperature | | **YES** | | **NO** | **NO** | **NO** | | **NO** |
| Bonus for return temperature below requirement* | | **YES** [4] | | **NO** | **NO** | **NO** | | **NO** |
| Compensation for electricity used for DHW boosting* | | **YES**[3] | | **NO** | **NO** | **NO** | | **NO** |
| Other?.................... | | **NO** | | **NO** | **NO** | **NO** | | **NO** |

3 Not very common only few suppliers
4 Few suppliers do this

## Typical interconnection schemes for consumers

How are the typical requirements for interconnections and metering for DH consumers in your country?

| **Question** | DK | EE | ES | NO | PL | SB | SE |
|---|---|---|---|---|---|---|---|

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| | Denmark | Spain | Estonia | Norway | Poland | Serbia | Sweden |
|---|---|---|---|---|---|---|---|
| Do the supplier's regulations have guidelines for connection and metering at consumers installations? * | **YES** | | **NO** | **YES** | **NO** | | **YES** |
| Are there other regulations or guidelines regarding connection and metering at consumers installations? * | **YES** | | **YES** | **NO** | **YES** | | **NO** |

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## Pricing options for local DH producers

How are the pricing options for local heat delivery in your country?

| Question | DK | EE | ES | NO | PL | SB | SE |
|---|---|---|---|---|---|---|---|
| | Denmark | Spain | Estonia | Norway | Poland | Serbia | Sweden |
| Variable hourly rate depending on demand in the network* | **YES**[2] | | **YES** | **?** | **NO** | | **YES** |
| Variable rate depending on delivery temperature to the network* | **NO** | | **NO** | **YES** | **NO** | | **NO** |
| Fixed rate with a requirement for higher temperature than actual network temperature* | **NO** | | **NO** | **?** | **NO** | | **?** |
| Reduced price for delivering low temperature heat to return line* | **NO** | | **NO** | **NO** | **NO** | | **NO** |
| Other?............... | | | **YES**[1] | | **NO** | | **?** |

1 Variable seasonal pricing. Delivered heat is paid according seasonality, higher price in winter. Pricing depends on heat production/fuel costs and demand. No demand during summer because of surplus heat from CHP

2 Are used by AVA in Aarhus

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## Barriers for local DH producers

What barriers do you see in your country or your network/supply for use of local energy sources?

| Question | DK | EE | ES | NO | PL | SB | SE |
|---|---|---|---|---|---|---|---|
| | Denmark | Spain | Estonia | Norway | Poland | Serbia | Sweden |
| Complicated tax systems regarding excess heat | **YES** | | **NO** | **NO** | **?** | | **YES** |
| Investments in heat recovery systems for excess heat | **YES** | | **NO** | **YES** | | | **NO** |
| Energy demanding temperature boost to follow network temperature | **YES** | | | **NO** | **?** | | **NO** |
| No demand in summer months because of surplus heat from electricity production | **YES** | | **YES** | **?** | **?** | | **YES** |
| It is complicated to balance too many different heat sources in the system | **NO** | | **NO** | **?** | **?** | | **YES** |
| Delivery to return line is not optimal because of flue gas condensation | **YES** | | **YES** | **?** | **?** | | **YES** |
| Other?............... * | | | | | | | **?** |

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## Solutions for local DH producers

What is done in practice for integrating distributed energy sources in the DH system in your network or country?

| Question | DK | EE | ES | NO | PL | SB | SE |
|---|---|---|---|---|---|---|---|
| | Denmark | Spain | Estonia | Norway | Poland | Serbia | Sweden |
| Some heat producers choose to give excess heat away for free because the tax system is too complicated* | **YES**[6] | | **NO** | **NO** | **?**[3] | | **?** |
| There are subsidy schemes as an incentive to utilize excess heat* | **YES** | | **NO** | **YES** | **?** | | **NO** |
| Conversion of subnets to a lower temperature level* | **NO** | | **NO** | **NO** | **NO** | | **NO** |
| Storage systems for balancing out the surplus heat* | **?** | | **NO** | **NO** | **YES**[4] | | **NO** |
| Smart metering for controlling and balancing heat input into the network* | **?** | | **NO** | **YES** | **YES**[5] | | **NO** |
| Heat is injected in flow line at lower temperature level than actual network temperature* | **YES**[7] | | **YES**[1] | **?** | **NO** | | **NO** |
| Other?............... * | | | **YES**[2] | | | | **?** |

1 Not case as usual. HP which producing comfort cooling inject heat with lower temp to DH supply line
2 HP which producing cooling inject heat into DH return due to better energy efficiency of HP
3 there are other reasons for not doing it
4 Storage systems occur, usually they are on customer side
5 Smart metering does not occur everywhere, but it is becoming more and more used
6 Supermarket franchises have chosen to do so in more cases to have a green profile
7 AVA in Aarhus accepts this as the produced heat is often a fraction of the total heat production in the net

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