RELaTED

D2.3 – Interconnection schemes for producer installations

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PROJECT SUMMARY

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Project Coordinator	Roberto Garay. TECNALIA roberto.garay@tecnalia.com
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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 55-75 ºC are prescribed.

OVERALL RELATED CONCEPT

RELaTED pursues the development of DH networks with service temperature levels as low as 40-50 ºC. In many alternatives, traditional DHW preparation methods are substituted by "innovative methods". In these concepts, mains water is primarily heated by the DH, and then complemented by electric heaters/boosters up to the required temperature levels. In more advanced alternatives, heat pumps are used for such purposes.

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

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

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 a top 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.

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

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

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Acronyms

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

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1. Executive summary

In RELaTED Task 2.3 the use of distributed energy sources and the possibilities for integration and control in district heating systems are presented along with legal and practical barriers and solutions as well as pricing options for energy sales.

Different distributed energy sources are described and discussed in relation to integration along with other heat sources and how these supplementary heat sources can be controlled and utilised in a DH system.

Description of legal and practical barriers along with pricing models for local DH production are presented to clarify the challenges these barriers represent. A few cases from some of the participating countries are used to show how these barriers can be handled in practice. Seasonal storage can be a possible solution for some of these challenges but are not discussed in this report

A set of sketches showing possible connections of distributed energy sources to district heating networks are compiled to help understanding the necessary technological solutions described in this report.

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 2.3. It will elucidate specific barriers and solutions for the use of distributed energy sources (DER) in ULT DH networks. Moreover, it will sketch solutions for producer connections to the network. The report is a continuation of the report "Low temperature concepts" carried out in task 2.1. Further it is a parallel to the task 2.2 report "Interconnection schemes for consumers". 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 2.3 is to investigate possible interconnection schemes for producer installations and to explore the control opportunities and strategies including local storage when relevant and with respect to the overall boundary conditions, pricing and taxes as well as regulation.

2.2. Methodology

To carry out task 2.3 the following methodology was used:

1. A questionnaire, see annex A, was sent to the partners for getting country specific information about prices, taxes, legal and practical barriers for connecting DER to DH networks and how pricing and metering of local production is handled in practice as well as case examples and interconnections schemes for country/supplier specific solutions.

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2. Energy sources, connections technologies and control systems are described based on the questionnaire, general expertise in DH, database searches and manufacturer specific information.
3. Based on the answers in the questionnaire and research from WP 3 concerning connections a wider picture of the challenges of integration of DER's are presented.
4. Solutions for connection of DER's to the DH networks in the three demo sites on public networks are sketched in relation to both producer and combined producer/consumer connections.

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. ULT DH heat sources, storages and control. Description of relevant distributed energy sources: Solar heating, heat pumps, surplus heat and geothermal heat. Description of technologies for storage, connection and exchange of DER's.
4. Barriers for local ULT DH producers. Description of legislation of heat delivery, pricing models and practical barriers.
5. Solutions for ULT DH producers in practice based on cases from some of the participating countries.
6. Interconnection schemes for producer installations. Examples of interconnections schemes for producer only installations and for combined producer and consumer installation with the use of triple function substations (3FS). Various connections for delivery of heat to both supply and return line is sketched.

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3. ULT DH heat sources, storage and control

3.1. Relevant heat sources

A ULT DH system can consist of many different heat sources in combination. In the following sections some of the relevant heat sources for ULT DH systems are described along with the possibility for storage and control of the different heat sources. Figure 1 shows a principle for combination of different heat sources in an ULT DH system.

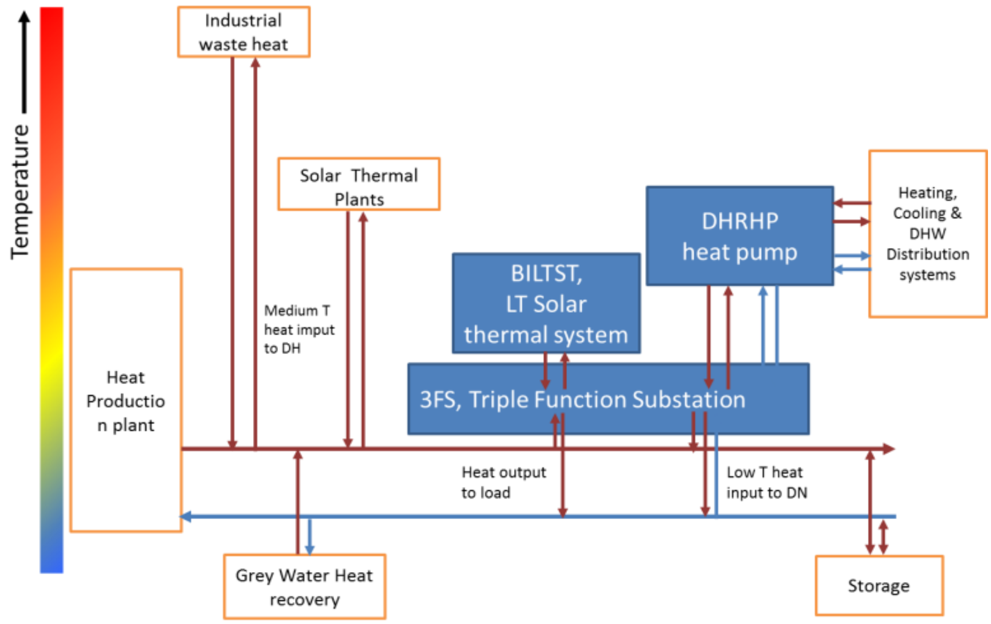

Figure 1 example of a DH system with a combination of sources and storage

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3.2. Solar thermal heating

The use of solar thermal heating as an energy source in DH networks can lower or even supply the use of the primary energy source in the summer months because of the low heat demand mainly consisting of DHW production and distribution losses in the network. There are examples in Denmark and Sweden where the combination of Thermal solar plants and seasonal storage can cover up to 50% of the total system demand [1].

The use of lower distribution temperature in ULT DH makes it even more interesting to use solar thermal heating as a energy source as it is possible to cover an even longer period of the year with solar energy. Figure 2 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.

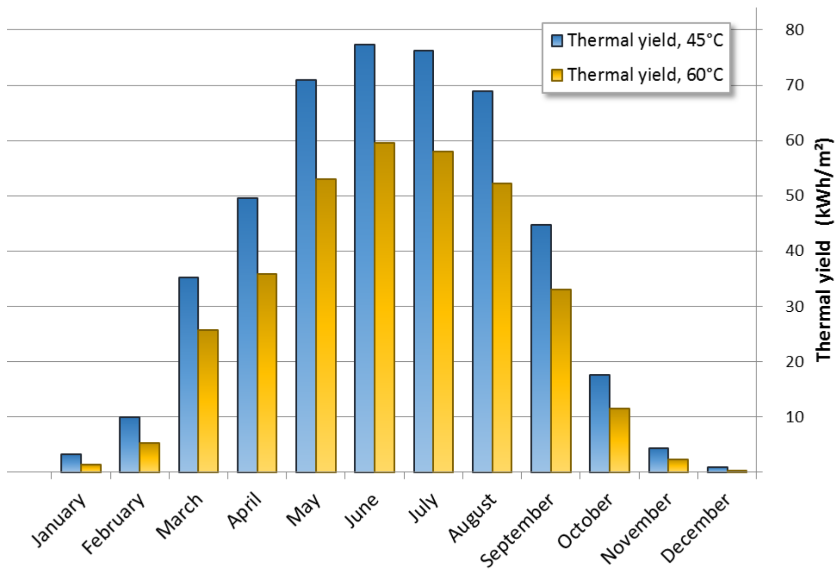

Figure 2 thermal yield for solar collector in Stockholm at 60°C and 45°C respectively. Source: ScenoCalc v5.01 [2]

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Solar thermal heating systems can be divided into three groups:

a) Small systems for single family houses with the purpose of producing DHW. Those systems are sized in relation to the estimated usage of DHW and storage capacity. Usually not used with connection to DH systems.

b) Larger systems on buildings in combination with DH networks. Those systems are sized in relation to cover the heat consumption of the building in the summer month and eventual surplus can be delivered to the DH network thus elimination the use of a storage system. Those systems can be established by building owners to become a heat producer. The systems can be built with conventional solar thermal panels or with building integrated solar thermal panels (BILST). The use of lightweight BILST systems makes it possible to use the panels as facade systems and thereby using areas not normally used for solar heating. For more information about some of the possible connections see section 6.1.

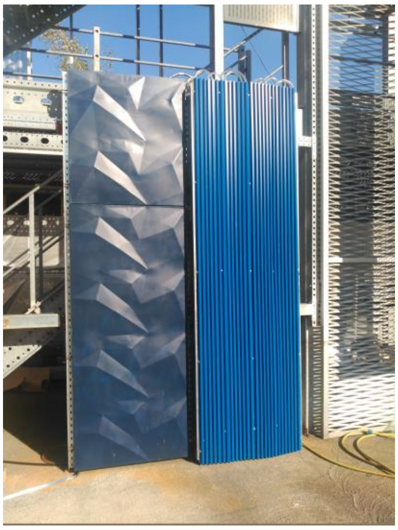

Figure 3 example of BILST facade system. Source: IMAR singular metal solution

c) Very large systems placed in open fields are usually established by DH suppliers as an integrated source in the production facility and with some form of day-to-day or seasonal storage facility for the produced heat.

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3.3. Heat pumps

Heat pumps are used for upgrading energy with a low temperature level to a higher temperature level for example for use in a DH system. The principle is that a working fluid (refrigerant) extract the energy at the low temperature level via a heat exchanger called the evaporator. A compressor is used to compress the fluid from low to high pressure thus elevating the temperature level. The heat from the fluid is delivered to the DH system via another heat exchanger called the condenser and the fluid is returned to the evaporator via an expansion device. The compressor use electricity for the process and the ratio of heat produced vs the electricity used for the compressor is the efficiency of the heat pump and is denoted COP (coefficient of performance). With a COP of 1 the amount of energy produced is the same as the electrical energy used for the compressor. The nomenclature of a heat pump is:

- First: energy source
- Second: useful effect

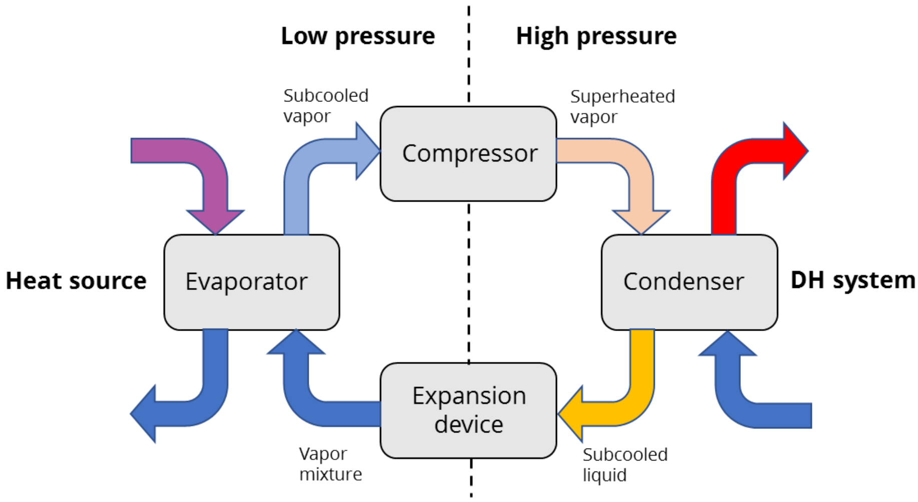

Figure 4 principle of a heat pump in a DH system

The energy sources for a heat pump can be very widespread but can be divided into two main groups; ambient and surplus heat. The ambient sources can be air or ground sources. In air-to-water heat pumps fans are used to pull large amounts of ambient air through the evaporator. In Ground-source solutions water can be circulated in a grid near the surface (2 m depth) or pumped into wells in the ground (see more in section 3.5) Surplus heat sources can be everything from waste water to heat from industrial process. See section 3.4 for more information.

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The heat sources have very wide spread temperature levels where the air-to-water heat pump have fluctuating temperature levels over the year from low negative temperatures to high positive temperatures whereas geothermal heat sources have a higher and more stable temperature over the year. The COP of the heat pump is reliant on the energy source temperature and the temperature needed to deliver. The higher source temperature and the lower delivered temperature the better efficiency. The use of ULT in a DH system makes it easier to integrate heat pumps as the efficiency gets better with the lower temperature demand.

For combined consumers and producers, a District heating reversible heat pump (DHRHP) in combination with a 3FS substation can be used for both cooling and heating purposes. The DHRHP can boost ULT DH to a higher temperature level for existing buildings with high temperature heating systems and for DHW production, or it can be used for cooling and heating of DHW at the same time, or cooling and injection of surplus heat to either the supply or return line of the DH network. For more information about some of the possible connections see section 6.1.

3.4. Surplus heat

Surplus heat can come from very different types of applications. It can range from heat recovery from sewage water at very low temperature levels, cooling applications for air condition and food market cooling at medium temperature levels to process related surplus heat at high temperature levels.

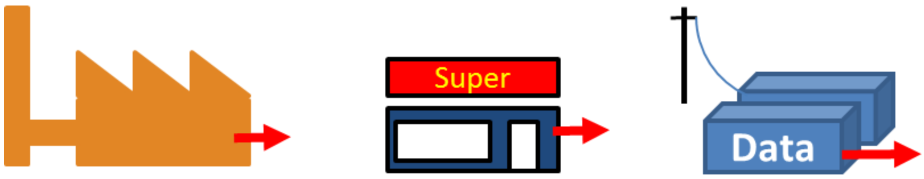

Figure 5 Different surplus heat sources

Depending on the surplus heat media it will often be necessary to use a heat exchanger for collecting the surplus heat in a water-based system. Depending on temperature levels of the surplus heat and the DH system and whether the surplus heat is injected into the return or the flow line of a DH system it can be necessary to boost the temperature level with a heat pump to match the actual system temperature. In table 1 is examples of surplus heat temperature levels from different applications.

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Application	Temperature level
Sewage water	10-20 °C
Datacenter	25-35 °C [3]
Supermarket cooling	30 °C
Flue gas condensate	40-60 °C
High temperature process	>70 °C

Table 1 examples of surplus heat temperature levels

Applications with a constant surplus heat output will be easier integrate into a DH system than for example surplus heat from air-conditioning systems that primarily generates surplus heat in the summer months when the demand in the DH system is low. The feasibility of these solutions is therefore dependent on the variation in production from other heat sources in the DH system.

Applications with a fluctuating temperature output can go, via combined connections (see more in section 3.7.2) from delivering to the flow line at high temperature levels to the return line when the temperature level of the surplus heat is low. This all depends on the possibility for injecting heat into the return line in the actual DH system.

For smaller applications like air-conditioning plants in office buildings or cooling systems in food markets where there is a need for heating of the buildings in the winther and for DHW production. A strategy for surplus heat in these types of applications can be a 3FS substation an a DHRHP so the DH network can be used as a buffer and the surplus heat can be sold/injected during the summer when it is not needed, and the necessary supplemental heat can be bought/obtained from the DH network.

For larger amounts of surplus heat from for example industrial processes where the need for heating and DHW is minimal the strategy for surplus heat is more obvious a sales strategy the whole year.

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3.5. Geothermal heat

The working principle for geothermal energy is injection of cold water into layers where it is heated by underground deep drilled well (1.000-3.000m). From here the water flows through the cracks in the underground heat. Another well placed for example 1,5km away is used to pump up the heated water. Depending on the size of the plant it can consist of more drilled wells.

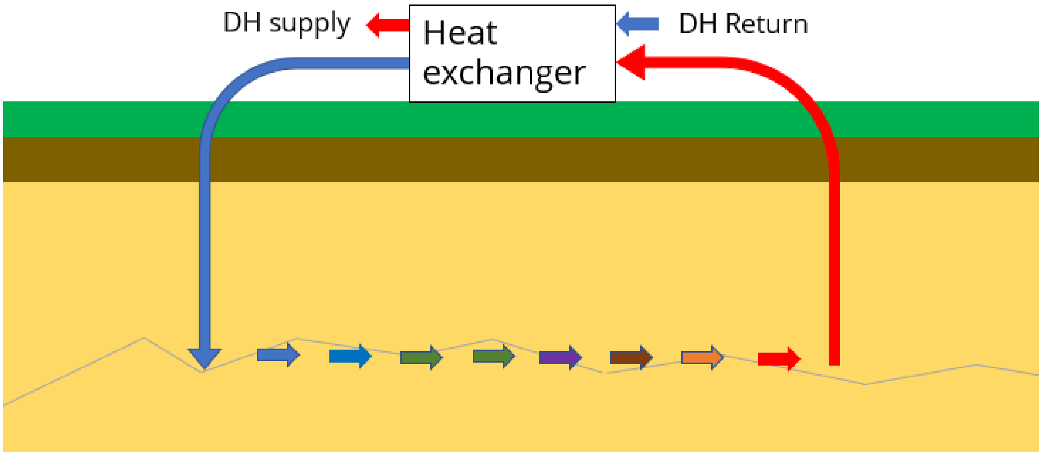

Figure 6 principle of geothermal heat in a DH system

The temperature level of the geothermal heat is dependent of dept and the geology of the underground. In Denmark the temperature in the underground rise around 25-30°C per. km depth. There are examples of geothermal drillings with temperature levels around 75 °C. If the temperature of the geothermal heat is high enough it can be exchanged directly with a DH system. If the temperature of the water is lower than the temperature needed in the DH system, it can be boosted to a higher level with a ground source heat pump. The use of ULT DH is beneficial in this matter as the need for temperature boosting is lower than for conventional DH systems and the use of electricity for the heat pump will be lower.

Deep drillings will almost always require a permit because of the risk and the consequences for the environment and nature. In Denmark it is the state that gives exploration and recovery permits of geothermal energy from geothermal drillings deeper than 250m.

Another ground source technology is Aquifer thermal energy storage (ATES) where groundwater is used as a source for either heating in the winter and cooling in the summer. The cold or warm water is injected

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back into the ground water and the system will therefore act as a kind of buffer for seasonal variations in heating and cooling demand.

3.6. Heat storages

Heat storages can be used as a kind of buffer for local heat production. For producer only, installations it can be used to store heat for a period when there is no demand from the network and utilize it when there is a demand. For combined consumer and producer installations it can be used to save the produced heat for the demand in the building when the buying price is high, and deliver surplus to the DH network when the selling price is high.

Storage systems can vary from storage tanks in DHW systems inside the building to larger storage facilities placed outside. The size of the storage depends on whether it is only used as a day-to-day buffer or more like a seasonal storage system.

3.7. Connections for exchange of heat

3.7.1. Producer only installations

Connection of producer only heat sources to the DH system will in most cases be relatively simple and consist of a pump which extracts the heat from the return line and inject it into the supply line and a shut-off valve to prevent extraction and-/or backflow from the DH network at times with no heat production or when it is not beneficial to sell heat to the DH network. For solutions with fluctuation heat sources where it is necessary to change between delivery of heat to the supply or the return line respectively a three-way valve will be necessary to make this changeover. Depending on the heat source and the requirements from the DH network supplier an optional heat exchanger may be necessary.

For configurations see connections examples in section 6.1.

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3.7.2. Combined consumer and producer (3FS)

For combined consumer and producer installations a solution for connection is a new type of substation developed within the RELaTED project which will allow bi directional heat flow.

The Triple Function Substation (3FS) is proposed as a fundamental technology within the RELaTED project. The 3FS has the goal of interconnecting the Ultra-Low Temperature District Heating (ULTDH) with the Building Integrated Low-Temperature Solar System (BILTST) and with the building District Heating Reversible Heat Pumps (DHRHP) and HVAC systems.

The 3FS should be able to adapt its operation to different systems conditions and operations. In each moment of the year, the intent of the 3FS is to minimize the energy consumption, its costs and the related CO_2 emissions.

The 3FS should assure robust and continuous heat supply to the connected buildings. Heating demand should be always satisfied and comfort temperatures for DHW should always be reached.

The name Triple Function Substations comes from the main three functionalities that the system should provide:

- Extraction of heat from the district heating network
- Injection of high-grade heat in the supply line
- Injection of low-grade heat in the return line

Figure 7 shows a principle for use of 3FS. This way it is possible to heat a building with ULTDH, boost the DHW in the building (either centrally in existing buildings or distributed in NZEB buildings) while at the same time supply with building integrated heat sources like BILST when available, or deliver the produced heat to either the supply, or return line of the DH system depending on temperature level.

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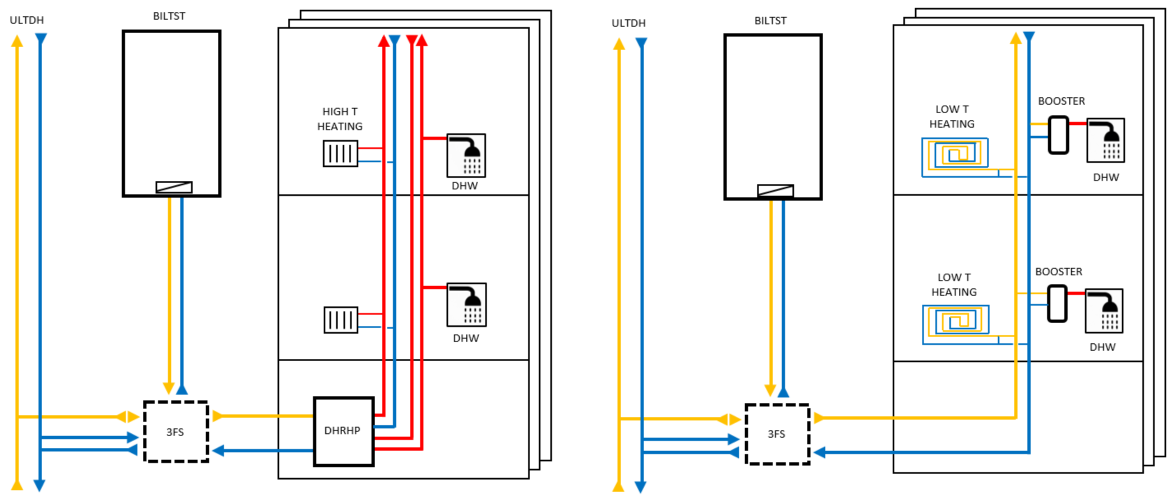

Figure 7 principle of 3FS substation usage in existing and NZEB buildings

For configurations and possible operation modes see connections examples in section 6.2.

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4. Barriers for local ULT DH production

4.1. Legislation concerning energy supply to DH

In some countries, it is possible to get reduced taxes for fuels when used for industrial process and not for heating of buildings. In Denmark those reduced taxes are generally supplied with taxes on the excess heat from the industrial process when this is recovered with the use of electricity. This is to ensure that there is no incitement to have inefficient production equipment with reduced fuel taxes to get cheaper heating of buildings. There are some exceptions to those rules like the use of excess heat from an industrial process that can be used for another industrial process without taxation.

There can be legal requirements for meters used for production of heat. If a private consumer becomes a local heat producer, the rules for metering of consumption and production respectively can be different and with different taxation. Therefore, it might not be possible to use just one meter for both consumption and production. Also, different connection schemes will require the use of more than one meter.

4.2. Pricing models for purchase of heat

Pricing models must be based on several factors among others investment in heat recovery, connection, meters, quality of the delivered heat, time of production in relation to the demand and so on.

In Denmark, purchase agreements are generally made individually with each producer and will reflect the size of investment, risk of investment, existing district heating tariffs, and security of supply. For a district heating company, long payback times will typically not be a problem. It is not unusual to see payback times exceeding 10 years for projects utilizing excess heat.

Investments in the necessary heat recovery equipment connection and meters can be taken by the heat purchaser alone and become part of the heat purchasers' productions facilities. In other cases, all the investments can be taken by the producer and the investment can also be shared so the producer invests in heat recovery and the purchaser in connections. In some cases, the existing connections for consumption can also be used for production, depending on the installation type.

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The "quality" (temperature) of heat supplied to the district heating can be reflected in the pricing model. For example, the supplied heat might have to be a higher temperature level than the actual network temperature, or the heat might have to be injected into the return line at a lower price if technique is possible.

The pricing model might also be dependent on the demand in the DH network. This implies that peak load capacity costs much more than base load capacity. If electricity is used for heat production, e.g. heat pumps, the fluctuation of electricity prices might also be deciding for the price of the heat purchase, compared to other heat sources with a steadier production price.

In Tartu, Estonia, the pricing is at monthly bases and it is equal to the weighted average price of production of the "last MW". During winter it is weighted average for gas and peat boilers, during summer it is equal to the condensing price in the CHP plants. The pricing is agreed with customers beforehand at budgetary bases. Heat and production curves from the previous year can be used for calculation. As a result, the highest purchasing price is during winter period and the lowest at summer period.

4.3. Practical barriers

Injection of heat to the supply line might require a higher temperature than actual flow temperature to meet the requirements of heat quality (temperature). If the energy source is a lower temperature than the network requirement it may be necessary with a heat pump thus making a more complicated installation.

Delivery to the return line is problematic in networks where part of the energy sources is flue gas condensation, as this requires a low return temperature in order to be effective.

If the heat source is not near the DH network, investments in new pipelines to make the necessary connections can make the solution less cost-effective and be the reason not to use the surplus heat in the DH system. In Denmark there are examples of large datacenters (Apple and Google) which will not be connected to the DH network among other reasons because of the distance to the existing DH networks.

Delivery of heat to the supply line will require local pump capacity to overcome the pressure in the DH network, whereas delivery to the return line can be done using the network pressure. For combined producer

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and consumer installations, the 3FS substation mentioned in section 3.7 can be used for this purpose.

If the base load in the DH network is covered by other more efficient heat sources, local heat producers might only be able to supply heat when there is a high demand. Also, the base load can be fully covered by surplus heat from waste incineration and/or electricity production. In those cases, solar thermal heating might not be the best supplemental heat source.

With many local heat producers in a DH network it might be necessary to have a central control system based on smart metering to control the priority of the different heat sources in relation to demand, pricing, etc.

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5. Solutions based on cases

In the following, a few cases from some of the participating countries are presented in order to show how some of the barriers presented in section 5 are handled in practice.

5.1. Surplus heat from supermarket cooling DK

In Aarhus, Denmark, one of the largest supermarket franchises have made an agreement with the local DH supplier, AVA about delivering surplus heat from the cooling systems in one of the biggest supermarkets in the city to the LT DH system. Because of the complicated tax systems regarding the sales of heat in Denmark, the supermarket franchise has chosen to deliver the heat for free to the DH supplier and only benefit from the solution by gaining a greener profile. The supermarket franchise has made the necessary investments in heat recovery systems and connections.

Under normal circumstances, AVA pays heat deliveries from local producers based on variable prices depending on capacity and time of the day. As the amount of heat deliveries from local producers often are small compared to the total production AVA has no requirements to the delivery temperature. The local produced heat must be delivered to the supply line, because the temperature of the return line must be kept low for the flue gas condensation in the CHP, in order to work under optimal conditions.

5.2. Open DH Stockholm SE

In Stockholm, Sweden, Stockholm Exergi is offering a business model called Open DH with three different models for heat delivery to the DH network. The three models have different demands for temperature, but common for all three is that the supplier receives payment for the energy based on the outdoor temperature level. The lower outdoor temperature the higher price.

The first is called Spot Prima and requires the supplier to deliver heat that follow the network temperature between 68 °C and 103 °C throughout the year.

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The second is called Spot Mix, and it requires the heat delivers to be at least 68 ºC all the time.

And the last model is called Spot Return where heat which is delivered to the return line has a temperature requirement, at least, 3 °C higher than the actual return temperature.

Stockholm Exergi invests in the necessary pipe system and connections and the suppliers make the investments in heat exchangers or heat pumps.

Some of the suppliers in the Open DH systems are data centers that are selling their excess heat from their cooling systems to the DH network typically when the outdoor temperature is below 7 °C which is around half of the year in Stockholm.

5.3. Estonian national Museum Tartu EE

The Estonian National Museum was built in 2015. The public tender for heating and cooling solutions was arranged. According to the tender conditions, there were strict architectural rules. Auxiliary equipment (like chimney, dry cooler etc.) outside of building were forbidden. The need for heating was 2.260 kW and the cooling demand for ventilation device was 1.070 kW.
Fortum Tartu provided a solution based on DH for heating and DHW production and a heat pump for cooling. The surplus heat at 62 °C from the heat pump is used for DHW preparation and/-or delivered to the DH net, depending on the demand for DHW in the museum.

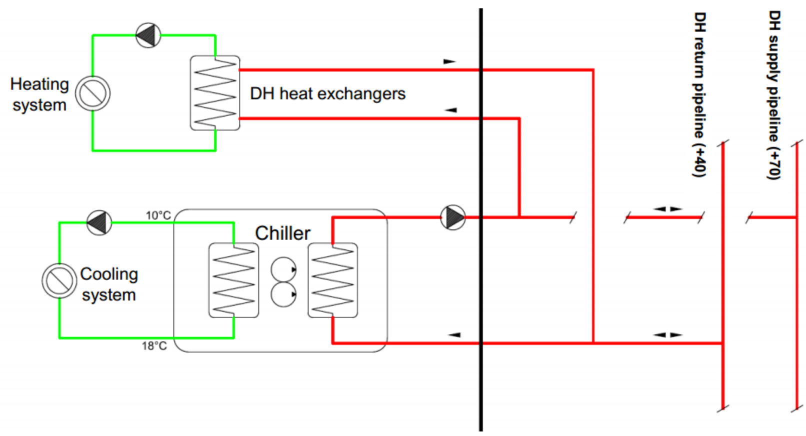

Figure 8 principle of the solution used in the Estonian national Museum

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In this solution there is no direct sale of surplus heating. Fortum Tartu owns and operates the heat pump in the museum and pays for the electricity to run the heat pump. The Estonian National Museum pays the normal DH tariff for heating and an agreed tariff for cooling.

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6. Interconnection schemes for producer installations and storages

In this section some of the possible connection options for producer and combined producer/consumers installations are presented. Some of the thoughts about combined producer/consumer installations have been studied in, and earlier DTI project, LAREF [4] and others have come through the work on the 3FS substation in work package 3 in RELaTED.

6.1. Producer connections

In the following, some of the possible configurations for producer only connections are presented.
The number of components vary among the different configurations. The main components to ensure correct operation of these solutions are:

- Shut-off valves to prevent extraction and/or backflow from the DH network when there is no production.
- Pumps for injection to supply line and/or extraction from return line.
- Optional heat exchanger depending on the heat source and/or the DH suppliers' requirements.
- Three-way valve (combined connection to supply and return only) to change between delivery to supply or return line.

6.1.1. Connection to supply line

This connection scheme covers connection of distributed heat sources to the supply line of a DH network. One energy meter (m1) with temperature sensors (T1.1, T1.2) is used for the metering of the produced heat.

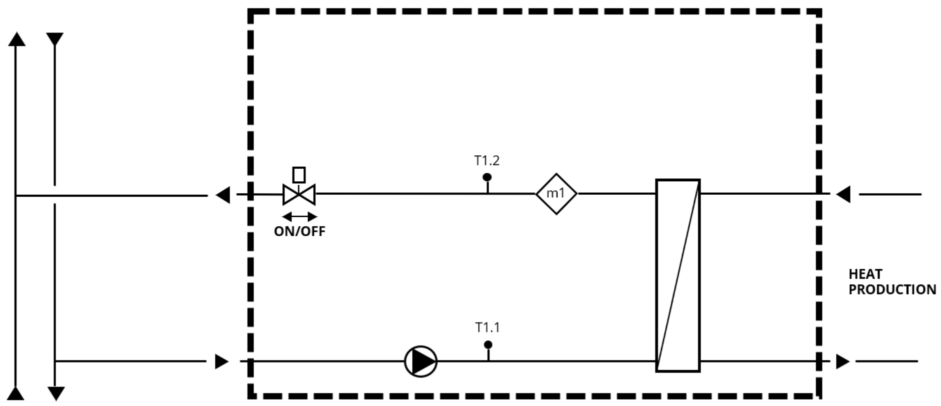

Figure 9 connection of heat source to DH supply line

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6.1.2. Connection to return line

This connection scheme covers connection of distributed heat sources to the return line of a DH network. One energy meter (m1) with temperature sensors (T1.1, T1.2) is used for metering of the produced heat.

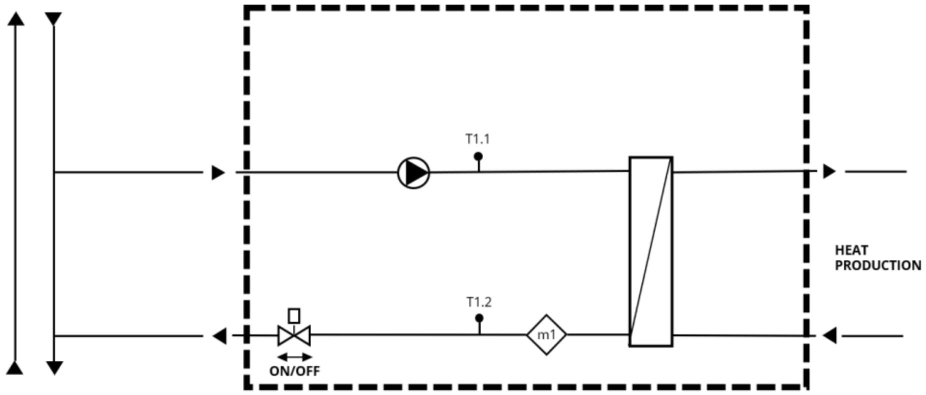

Figure 10 connection of heat source to DH return line

6.1.3. Combined connection to supply and return line

This connection scheme covers combined connection of distributed heat sources to the supply (A) and the return (B) line of a DH network respectively. The three-way valve is used to change between delivery to the supply and return line. One energy meter (m1) with temperature sensors (T1.1, T1.2) is used for metering of the produced heat.

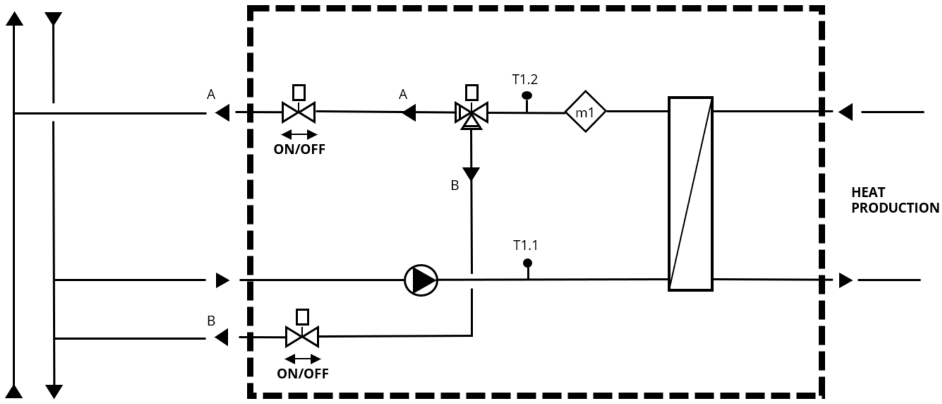

Figure 11 combined Connection of heat source to DH supply and return line

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6.2. Combined producer and consumer (3FS)

In the following, some of the possible configurations for use of 3FS substations and the different operations modes are presented for:

- Existing buildings with high temperature heating systems and-/ or cooling in ULT DH networks with supply temperatures of 45 °C or below. These examples can be relevant for installations in the demo sites in Tartu and Belgrade

- NZEB buildings with low temperature heating systems in ULT DH networks with supply temperatures of 45 °C or below. These examples can be relevant for the demo site in Vinge.

In both cases, the need for boosting temperature levels for DHW production is essential to secure proper DHW temperature and bacterial disinfection.

The 3FS substations consist of a number of components to ensure correct operation. The number of components vary among the different configurations of the 3FS substation for each application. The main functional components of the 3FS are:

- Shut-off valves to prevent extraction or backflow from supply when local production is sufficient to cover the heating demand.
- Three-way valves to change flow direction and choose heat source.
- Pumps for injection to supply line or extraction from return line.
- Optional heat exchanger for indirect DH installations.

6.2.1. Existing buildings DHRHP and BILST

This connection scheme covers the use of ULT DH and integration of BILST in existing buildings with high temperature heating systems and cooling demand. DHRHP is used for boosting temperature levels for both heating system and DHW production. This connection scheme will work in all operation modes in section 6.2.3. The configuration can also be used without BILST.

Metering is a bit more complicated with this connections scheme because of the possibility for producing heat with both the BILST and the DHRHP and deliver heat to both the return and supply line.

In figure 12 an example on how to meter this situation, when the BILST and the DHRHP is owned by the building owner, is presented.

Two energy meters are used:

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- For metering of heat consumption m1 with 2 temperature sensors (T1.1, T1.2) is used. An ultrasound meter is used as it will not register the backflow coming when delivering to the supply line.

- For metering of produced heat m2 with two flow sensors, and 3 temperature sensors (T2.1, T2.2 and T2.3) are used. When delivering to the supply line the temperature sensors T2.1 and T2.2 are used and when delivering to the return line the temperature sensors T2.1 and T2.3 are used.

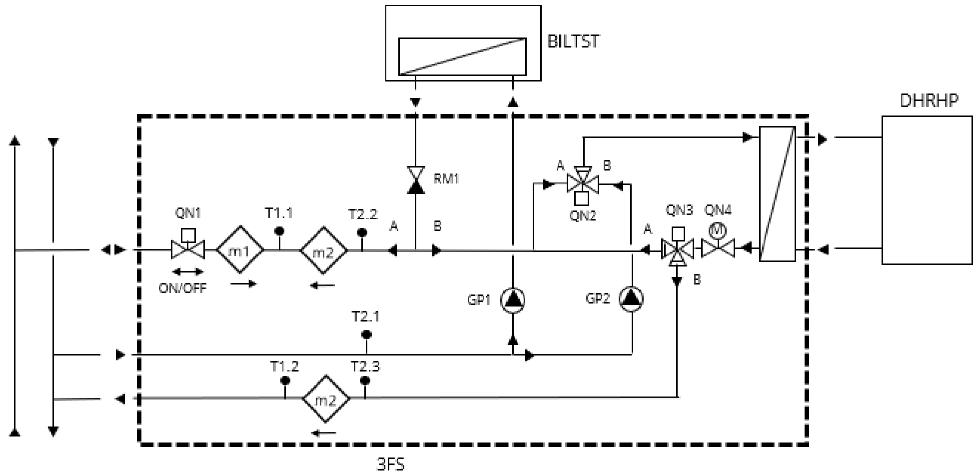

Figure 12. 3FS with DHRHP and BILST owned by the building owner

A simple configuration for metering can be used if the BILST is owned by the heating supplier and the DHRHP belongs to the building owner. In figure 13 an example on how to meter this situation is presented.

Two energy meters are used:

- For metering of heat consumption m1 with 2 temperature sensors (T1.1, T1.2), is used. An ultrasound meter is used as it will not register the backflow coming when delivering to the supply line.

- For metering of produced heat m2 and 2 temperature sensors (T2.1, T2.2), is used for metering of the delivered heat from the DHRHP to either the supply or the return line. The heat produced from the BILST is not metered and is just a part of the supplier's production system.

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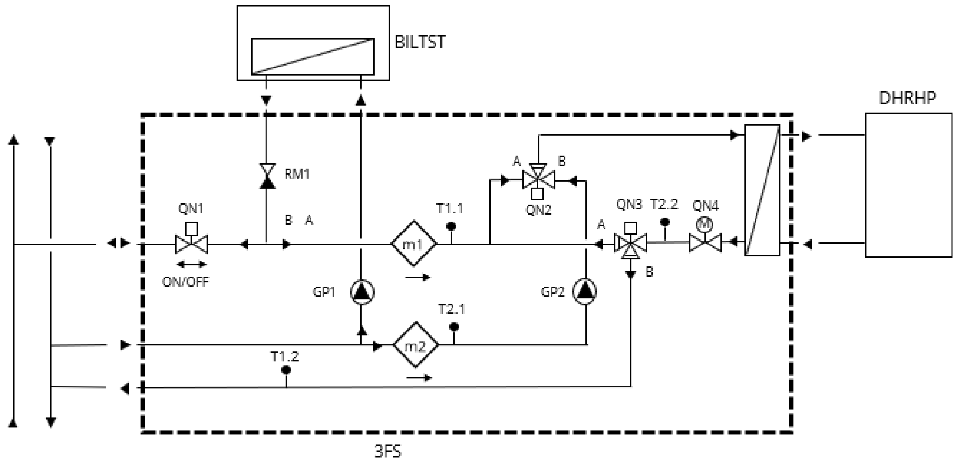

Figure 133. 3FS with DHRHP owned by the building owner and BILST by the supplier

6.2.2. NZEB buildings BILST and DHW booster

This connections scheme covers the use of ULT DH in NZEB buildings with BILST. The use of DHW boosters is for boosting temperature levels for DHW production. This connections scheme will work in operation modes 1-6 and 9 in section 6.2.3.
The configuration can also be used without BILST. Two energy meters are used:

- m1 with temperature sensors (T1.1, T1.2) is used for metering of heat consumption.
- m2 with temperature sensors (T2.1, T2.2.) is used for metering the produced heat.

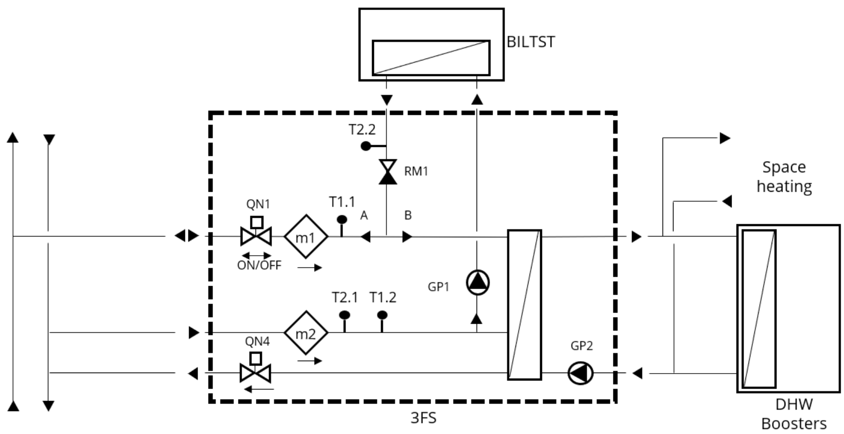

Figure 14: 3FS connected to NZEB building with BILTST and DHW boosters.

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6.2.3. Operational modes of 3FS substations

The 3FS work in different operational modes. In this paragraph several operational mode possibilities are presented. Some of these modes may not be optimal for the operation of the DH network.

Mode 1. (Figure 15) This is the conventional district heating operation in which heat is extracted from the network, in order to supply heat to the DHRHP and the HVAC systems.

Mode 2-5. (Figure 15) Heat produced by the BILTST system is directed to the DHRHP. **Mode 2** occurs if the heating demand of the DHRHP is lower than the BILTST heating capacity. Then additional heat produced by the BILTST can be injected back into the network at high temperature. **Mode 5** occurs when the heating demand of the DHRHP is higher than the BILTST heating capacity. Then additional heat is extracted from the DH network.

Mode 3. (Figure 15) The heat at high temperature produced by the BILTST matches the heating demand from the DHRHP. DH extraction is avoided and the BILTST production is prioritized.

Mode 4. (Figure 15) When the heating demand from the DHRHP is higher than the BILTST heating capacity at high temperature, the BILTST heat supply temperature could be reduced, by increasing pump speed, in order to increase BILTST heating capacity and keep matching DHRHP heating demand. This mode could be an alternative to **Mode 5.**

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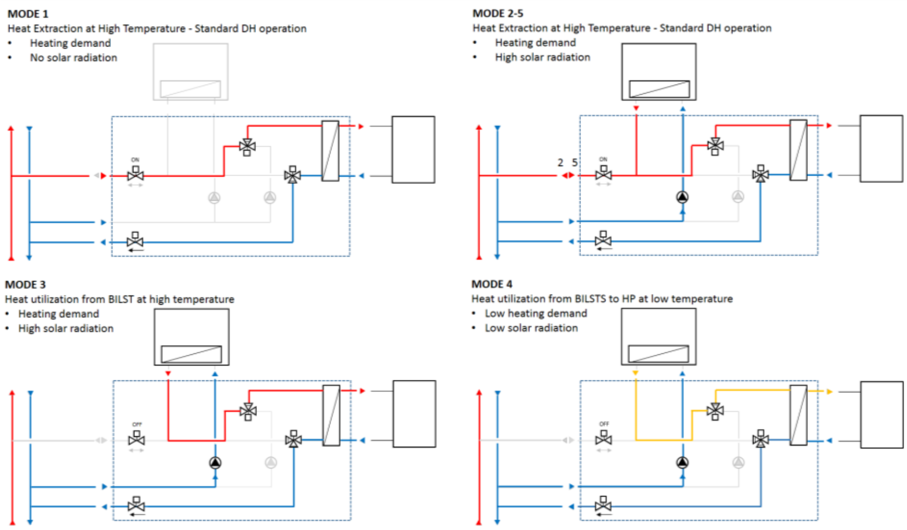

Figure 15: 3FS operational modes 1, 2-5, 3 and 4

Mode 6. (Figure 16) In non-heating periods and high heat production from the BILTST system, heat can be injected to the DH supply line. This mode would be normally used in summer periods.

Mode 7. (Figure 16) The DHRHP is operating in cooling mode, hence delivering heat to the 3FS. The heat from the heat pump can be injected back to the DH network supply line. This operational mode could, for instance, be used in warm summer nights in which building cooling is needed, but no solar radiation is available. Moreover, this mode could be selected in systems without BILTST.

Mode 8. (Figure 16) Heat is produced by BILTST at higher temperatures than the DH supply temperature and mixed with heat at low temperature coming from the DHRHP. This mode allows for the maximization of the DHRHP COP in cooling mode, by keeping its condensing temperature at minimum. This mode could, however present control challenges when applied in a real system.

Mode 9. (Figure 16) The 3FS offers the possibility to inject heat at low temperature back to the DH return line, in order to maximize the heat production from BILTST. In this mode, the DHRHP is deactivated since there is no heating demand. Heat extraction from the DH network is avoided and the BILTST pump is activated.

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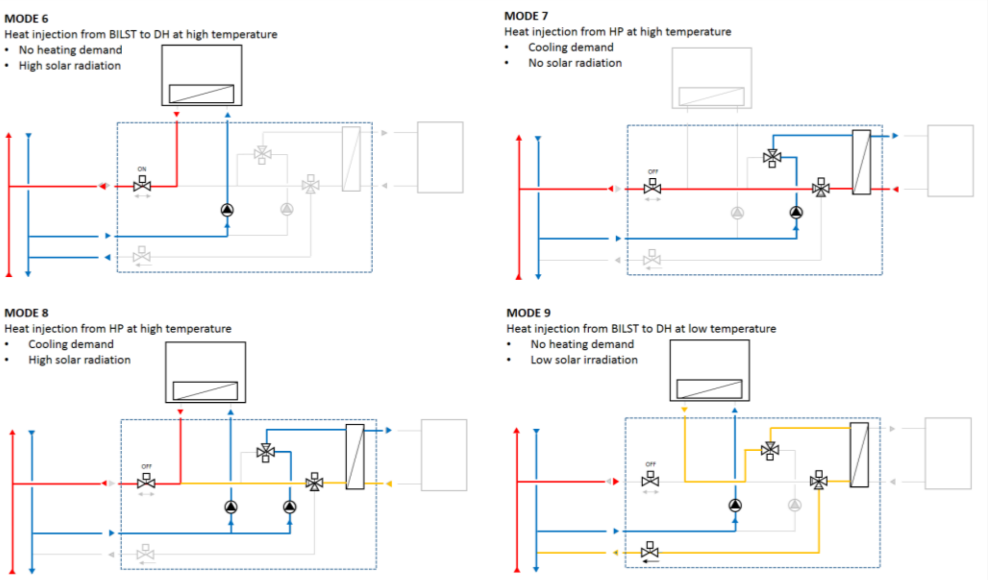

Figure 16: 3FS Operational modes 6, 7, 8 and 9.

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ANNEX 1 Questionary

Taxes for local DH Producers

How do the tax system influence on local heat delivers in your country?

Question	DK	EE	ES	NO	PL	SB	SE
	Denmark	Spain	Estonia	Norway	Poland	Serbia	Sweden
The taxes on fuels for heating of buildings are higher than the taxes on fuels for industrial process	**YES**		**NO**	**YES**	**NO**		**YES**
There are taxes for utilizing excess heat from industrial process for heating of buildings	**YES**		**NO**	**?**	**NO**		**NO**
There are taxes for utilizing excess heat from HVAC systems for heating of buildings	**NO**		**NO**	**NO**	**NO**		**NO**
Other?...............			**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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