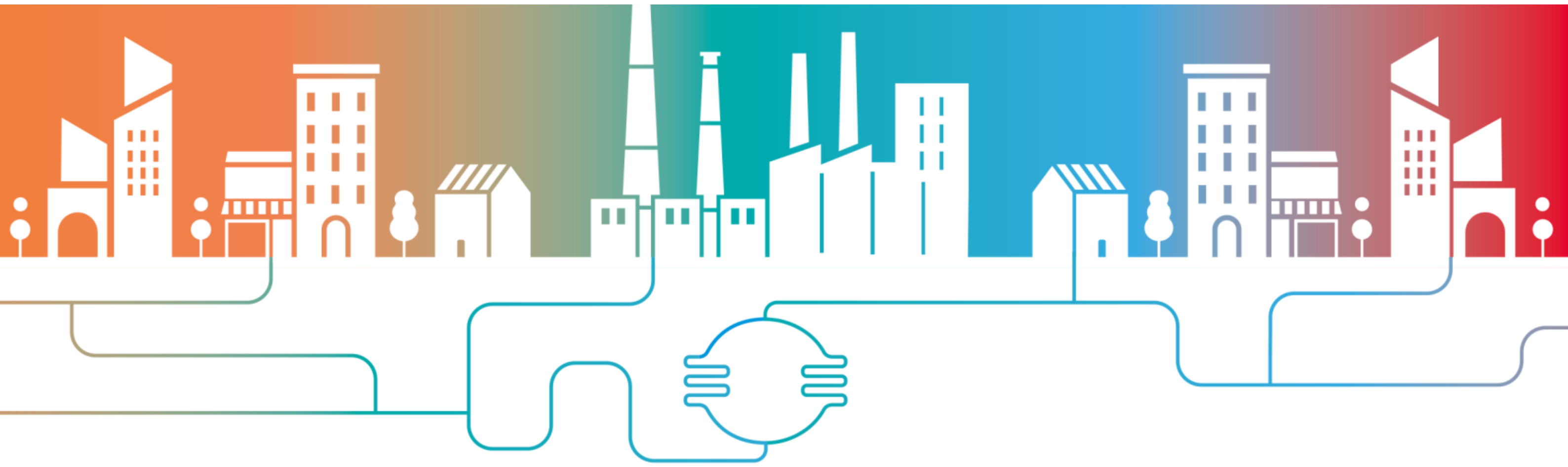
LIFE 4 HEAT
RECOVERY

Guidebook for planners –
Action E.2



Low temperature, urban waste heat into district heating and cooling networks
as a clean source of thermal energy
LIFE4HeatRecovery

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1 Introduction

This Guidebook reports on the waste heat recovery solutions developed within LIFE4HeatRecovery, starting with specific reference to the considered demonstration cases and then presenting more general recommendations.

LIFE4HeatRecovery demonstrated the recovery of urban waste heat (WH) available at low temperature (< 40 °C) in highly efficient district heating and cooling (DHC) networks operated at conventional or low temperature.

This is done by means of heat pumps (HPs) used either at heat recovery or heat utilization sites, with a focus on skid-mounted prefabricated substations.

Starting from a generic cooling load, the aim of these substations is to recover waste heat into district heating (DH) networks.

The project included 3 demonstration cases:

- **Ospitaletto**, Italy: heat recovery from the cooling system of a **foundry** into a **cold network**, operated by Cogeme. The waste heat temperature is about 25 °C, while the network temperature is the same or lower (as it can be supplied also by aquifer wells at 15 °C). The installed substation can also deliver heat to the local heating system of the foundry (for space heating and sanitary hot water production), up to 60 °C.
- **Aalborg**, Denmark: heat recovery from a **data centre** of Aalborg University into a **medium-high temperature network**, operated by Aalborg Forsyning. The waste heat temperature can be in the range 40-60 °C (depending on the server operating conditions), thanks to a two-phase passive liquid cooling system developed by Heatflow. The network supply temperature is about 80 °C in winter and about 60 °C in summer. A heat-pump-based substation (with a configuration proposed by Eurac and a control implemented by Enisyst) is used to inject the recovered heat into the network, enabling direct heat exchange when the waste heat and the network temperatures match each other. The recovered heat is also used to heat the local building.
- **Heerlen**, the Netherlands: heat recovery from the cooling system of a **foundry** into a **cold network**. The network is a full neutral-temperature district heating and cooling network – often also defined as 5th generation DHC – managed by Mijnwater, with supply temperatures of the order of 30 °C. The waste heat can be recovered up to a temperature of 42 °C, through a simple heat exchanger. The heat is then mainly reused at a nearby swimming pool, where a heat pump substation is installed.

Each of these cases involves the design and installation of the substation in order to satisfy both the heat recovery from the cooling process and the local thermal demand. Although each specific case is characterised by different temperature levels of the loads and the network, a common feature can be identified. Indeed, the considered configurations provide interfaces between 3 possible heat circuits/processes:

- A pure heating process (heat consumer).
- A pure cooling process (heat producer).
- A balancing process (the network), used either to supply or absorb heat.

When both a producer and a consumer are present (yielding a prosumer) the net heat transfer to the network can be either positive or negative. This requires a bidirectional connection.

Concerning the satisfaction of heating and cooling needs, the skid can be designed to operate either in an alternating or in a simultaneous way. The latter option has been prioritized in LIFE4HeatRecovery, thanks to proper hydraulic configurations.

Similarly, valve-aided hydraulics has been used to invert the energy flow direction when necessary (alternatively, reversible heat pumps might be used in certain cases).

The report is organized as follows: in chapter 2 the details of each demonstration case are presented, providing an overview of the corresponding schemes, while in chapter 3 common aspects are identified and a few general recommendations are summarized. In chapter 2, the schemes of the demo cases have been slightly simplified and adapted with respect to the actual pipe and instrumentation diagrams (P&IDs). This was done in order to better highlight the connection configurations and the operating schemes while getting rid of some implementation details (like using multiple heat pumps in parallel instead of a single large modulating heat pump). The presented experience can be used by designers to obtain general configurations which can be adapted to all heat producer/consumer/prosumer cases which can be encountered in thermal networks.

2 Demo case analysis

2.1 Heerlen demo case

The operator of the district heating and cooling network in Heerlen is Mijnwater. The network consists of a 2-pipe system with a hot and cold pipe for distribution, exchange, and storage of energy. The network includes a main “backbone” connected to local “clusters”, through properly designed compact stations which also allow the hydraulic separation.

The temperature level in the hot and cold pipes lies between 28 ˚C and 16 ˚C. With decentralised heat pumps in the connected buildings, the source temperature is lifted or reduced to the required levels.

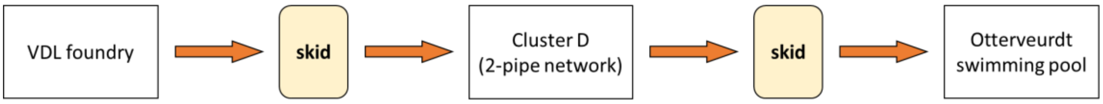
A total of 3.5 GWh/y of thermal energy are distributed to final users, 3.2 of which is waste heat from datacentres, supermarkets, and space cooling in general. The primary energy factor of this network is about 0.52.

The waste heat source considered here is the VDL foundry, located along the track of Cluster D. To support high-temperature melting processes, the factory includes low-temperature cooling processes, based on cooling towers. The main user of the recovered heat will be the Otterveurdt swimming pool, located along the same cluster. The swimming pool requires about 650 kW of heating power, which will be basically matched by VDL supply.

The recovery measure at VDL involves low-temperature waste heat from cooling processes. Recovered heat is delivered to Cluster D through a proper exchange substation. The network of Cluster D provides some natural buffer volume. On the other hand, heat is mostly reused at the site of the Otterveurdt swimming pool (a few hundred meters away from VDL), where a substation based on heat pumps transfers the heat to a “warm” buffer, in turn connected to the heating system (with a low-temperature circuit at 35-55 °C and a mid-temperature circuit at 45-65 °C, with an overall power of about 650 kW). While for this initial connection it is not planned to provide cooling to the swimming pool, the substation circuits were prepared to easily add this feature, expected to be likely in the future.

All the needed equipment (heat pump, heat exchangers, etc.) are arranged in two compact skid solutions (one at the VDL foundry, one at the swimming pool), with a thermal capacity of about 650 kW each, Figure 1.

a) First stage: waste heat recovery from VDL foundry (producer) and heat supply to Otterveurdt swimming pool (consumer)



b) Second stage: waste heat recovery from VDL foundry (producer) and heat or cold supply to Otterveurdt swimming pool (prosumer)

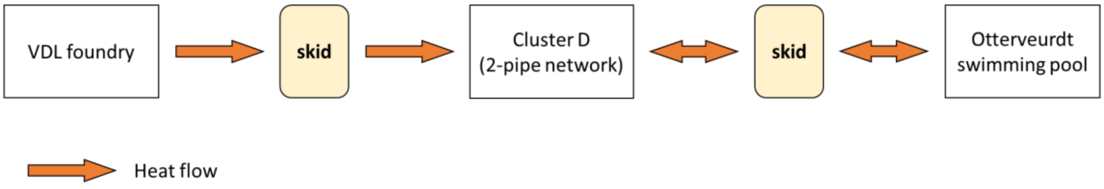


Figure 1 – Schematisation of Heerlen demo case.

A **simplified diagram**[1] of the P&ID of the skid at the swimming pool for the first stage is reported in Figure 2.

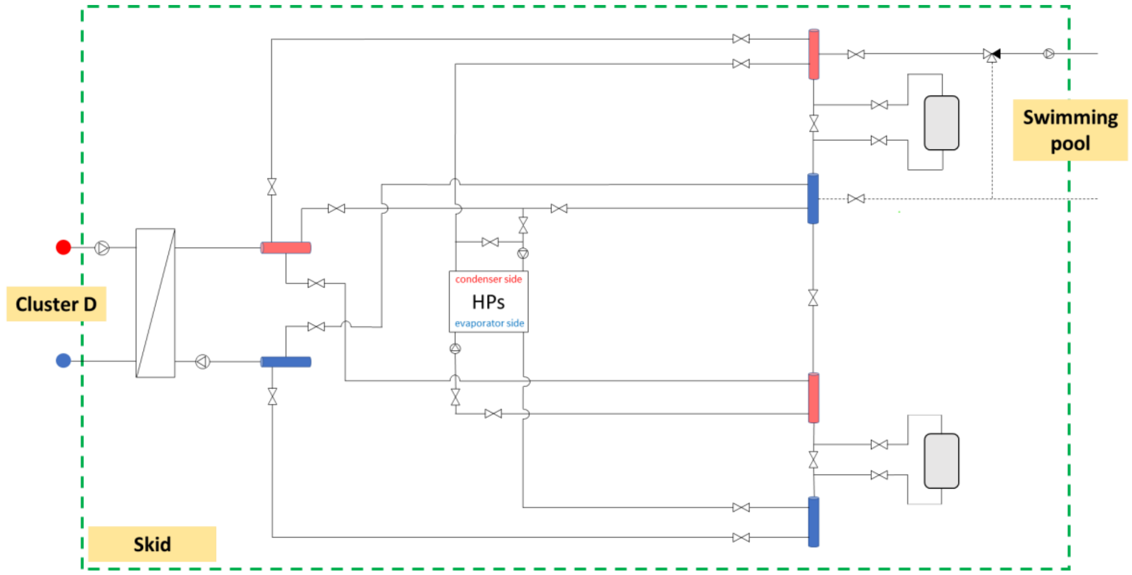


Figure 2 – Simplified diagram of the swimming pool skid at Heerlen demo case.

The current configuration consists of a monodirectional HP-skid in terms of heat direction: the skid absorbs heat from Cluster D and supplies it to the swimming pool heating circuits. The skid is equipped with four pairs of heat pumps (represented in the figure as a single HP block) which have both evaporators and condensers connected in series to ensure the desired temperature difference. The pairs of heat pumps, on the other hand, are connected in parallel to guarantee modulation of the heating capacity supplied to the user.

The interface with the Cluster D network consists of two heat exchangers connected in series (represented as a single unit in the figure). This allows the amount of heat drawn to be modulated. The current hydraulic connection is monodirectional, i.e. it only allows heat to be transferred from the network to the skid.

On the user's side, in the figure only one "warm" tank is shown but in the real scheme there are two separate tanks at different temperatures, each serving a specific heating circuit (space heating and sanitary hot water production).

In the bottom-right corner of the figure, another storage tank is represented. In the current configuration, its function is only to be a hydraulic buffer for heat pump evaporators. When the second stage will be activated, it will also serve the cooling process of the swimming pool. Therefore, in the second stage the skid will be able to recover heat from the cold process and reuse it to cover the local heat demand. If the cold demand is higher than the heat demand, the excess of waste heat will be recovered in the Cluster D network. For this reason, when the second stage will be activated, the connection

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[1] The schemes shown in this report do not exactly correspond to the P&IDs of Mijnwater plant. For example, as mentioned in the text, the real system typically uses multiple modules for certain components (heat pumps, heat exchangers, tanks, pumps) which are here represented as single elements. The purpose is to focus on the conceptual scheme and on its possible uses, beyond the details of the specific application. For the same reason, only the swimming pool substation is discussed, as it is the most flexible system including heat pumps (while the foundry substation basically consists in a simple heat exchanger).

between the Cluster D network and the skid must become bi-directional. Examples of bidirectional connections are discussed next.

2.1.1 Operating schemes

The substation's hydraulic configuration allows for different operating schemes to optimise skid performance according to network and user thermal levels.

For example, if the temperature required by the user TSP_HL is lower than the temperature T1 of the hot water from the heat exchanger with the Cluster D network, it is possible to completely bypass the heat pumps, Figure 3.

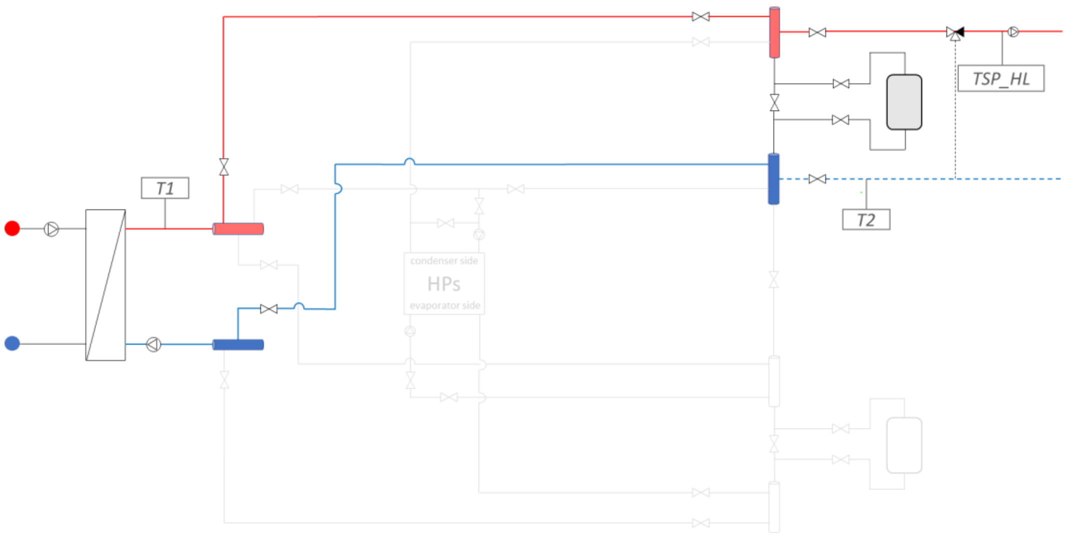

Figure 3 - Operating scheme: heat pump bypass. Heerlen demo case.

In this situation the passive sharing rate is 100 % (i.e., all the heat is transferred from the cluster to the swimming pool without operating the heat pumps). Due to the temperature levels foreseen at the moment, this operation mode is not expected to be activated on the short term, but it might be useful if the cluster temperature would be increased in the future (e.g., due to higher heat recovery temperatures at VDL).

On the other hand, if thermal levels require the heat pump to be switched on to provide an adequate supply temperature to the user (i.e., T1 is lower than TSP_HL), the hydraulic configuration allows hot water from the heat exchanger to be directed to the inlet of both the evaporators and condensers. The specific operating scheme (defined by the position of the valves) will be decided according to the temperatures of the different water flows, as follows.

If the return temperature of the heating process T2 is higher than the temperature T1 of the water from the heat exchanger, the operating scheme which maximizes the skid performance is the one represented in Figure 4.

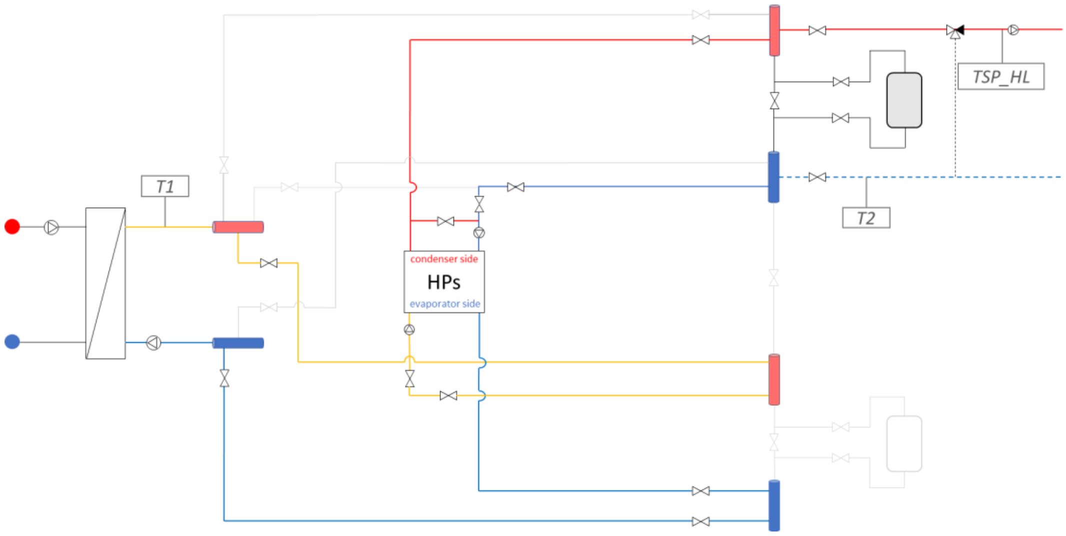

Figure 4 - Operating scheme: district heating at evaporator inlet. Heerlen demo case.

In this configuration the heat pumps allow for a hydraulic separation of water flows between the heat exchanger with the cluster and the end-user's heating circuits. All the heat is transferred operating the heat pump, hence no passive sharing is present.

If instead T2 is lower than T1, the skid performance is maximised with the operating scheme in Figure 5.

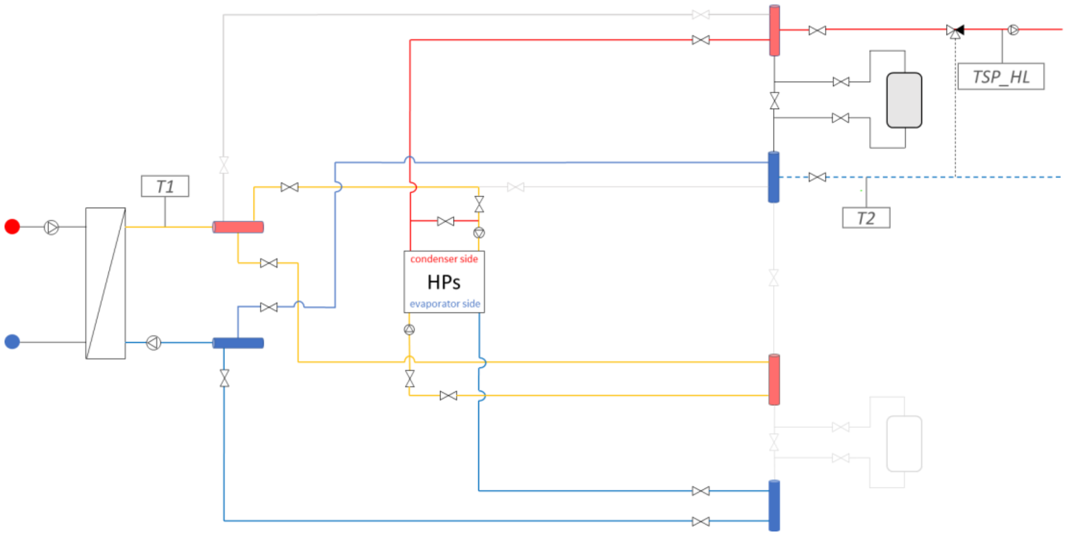

Figure 5 - Operating scheme: district heating at both evaporator and condenser inlet (split flow). Heerlen demo case.

In this configuration, the inlet temperature at the condenser side is the same as the one at the evaporator side (split flow). This allows for greater COP of the heat pumps; but the hydraulic separation described above is no longer present: water from the heat exchanger is also sent to the end-user's heating circuits. The theoretical passive sharing (i.e., the maximum amount of heat which can be transferred passively according to the thermal level conditions) is equal to:

$$\frac{\mathrm{T_1 - T_2}}{\mathrm{TSP_{HL} - T_2}}$$

The described operating schemes with their respective control logics aim to maximise passive sharing between the Cluster D network and the end-user (i.e., aim to minimize the amount of heat exchanged through the heat pumps). It is worth pointing out that, beside the optimisation of the skid performance, the control logic must also respect the operable temperature ranges of the heat pumps. Using multiple HP modules, a larger flexibility is anyway introduced.

2.2 Ospitaletto demo case

The demonstration network in Ospitaletto is a cold network that, thanks to the low temperature, can in principle deliver both heating and cooling services on the same pipelines. It is however currently used for heating only. The network is a 2-pipe system that develops over a length of 2.3 km. Customers are both public buildings (schools and gyms) and private owned multifamily houses with a total heat demand of approx. 1.9 GWh/year.

The heat sources are represented by low-temperature waste heat taken from the cooling circuit of the ASO factory steel mill (immediately before its connection with cooling towers) and by groundwater wells. Groundwater wells have a temperature of around 15 °C with a negligible temporal variability over the year. Also the waste heat temperature is rather stable, though not as constant as the ground temperature. It is indeed related to the cooling towers, where temperature is affected by the wet bulb temperature of the ambient air. The cooling system of the ASO steel mill is anyway operated to have a temperature of at least 25 °C, even in winter.

Space heating and domestic hot water production for the changing rooms and the canteen of ASO steel mill were originally covered by a gas boiler. Within LIFE4HeatRecovery, Cogeme (the network operator) and ASO agreed to develop a new waste heat recovery system to cover the local heating demand based on a heat pump station. The heat pump is supplied on the source side by the waste heat (recovered from the ASO cooling circuit through an additional heat exchanger) when it is available, otherwise it exploits the connection to the district heating network to draw heat from groundwater wells. Finally, in the case of excess waste heat with respect to the local need, the surplus is injected into the network. To this purpose, a bidirectional connection was implemented. An independent installation was made with respect to the previous heat recovery system in order to fully demonstrate the stable operation of a bidirectional system in practice.

The new layout of the whole system is shown in Figure 6. Beside the new prosumer substation p1, the figure also shows the recovery heat exchanger installed in June 2018 (source s1) and the groundwater wells (source s2), as well as the centralized pumping station and the users (u1, u2, u3 and u4, each with a heat pump substation).

Before the installation of the prosumer substation p1, the centralized pumping station imposed a monodirectional flow between the ASO steel mill and the connected users: the water heated in the recovery heat exchanger s1 up to about 25 °C was supplied to the consumer's heat pump substations. When waste heat from source s1 was not available, the centralized pumping station supplied the connected users (u1, u2, u3 and u4) with water extracted from the groundwater wells at approx. 15 °C.

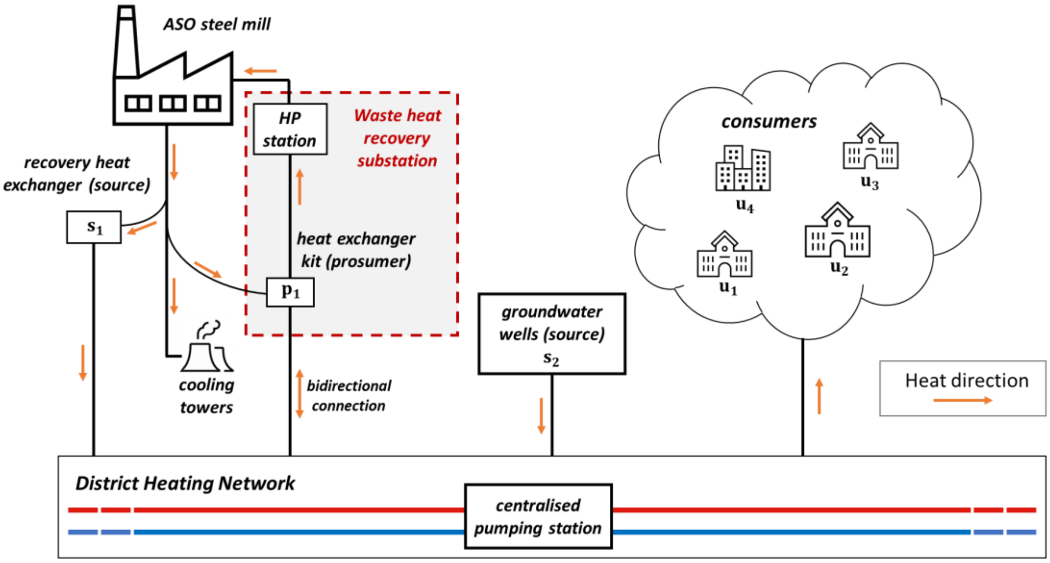

Figure 6 – Ospitaletto district heating: schematisation of the new layout. A decentralized pump (see text for details) is included in the new WH recovery substation within the red dashed rectangle.

A schematisation of the original centralized pumping station is shown in Figure 7.

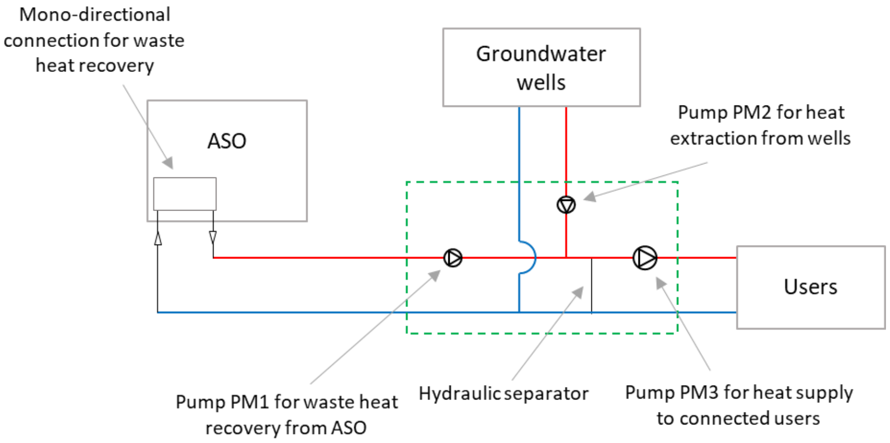

Figure 7 – Schematisation of original centralized pumping station at Ospitaletto demo case.

The network section between the ASO steel mill and the centralized pumping station was mono-directional, as the circulation pumps are installed **in-line**. With the introduction of the waste heat recovery substation at ASO steel mill, this network section had to become bi-directional, since also the heat pump at the ASO steel mill uses water extracted from the wells as a heat source when there is no waste heat available.

To achieve this, a bypass of the circulation pump PM1 in the centralized pumping station was implemented and a pump was installed at the steel mill to ensure reverse circulation. The adaptation of the centralized pumping station is shown in Figure 8.

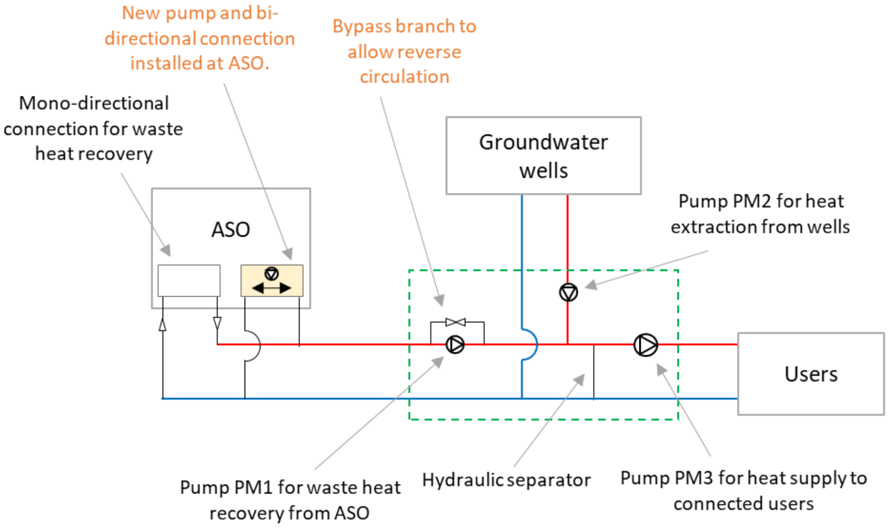

Figure 8 – Adaptation of centralized pumping station at Ospitaletto demo case.

Regarding the new waste heat recovery skid installed at the ASO steel mill, it consists of the following main components:

- **Heat pump station**. It is equipped with a water-to-water heat pump to reach the thermal level desired by the user and a thermal energy storage. The main function of the tank is to store heat for the domestic hot water production. The tank is also connected to the space heating circuit, thus acting as a buffer when the power supplied by the heat pump is different from that required for heating.
- **Heat exchange kit**. It is composed by the new waste heat recovery heat exchanger, the circulation pumps, and the bidirectional connection between the skid and the network. Thanks to this component, ASO steel mill can both supply heat to the network (producer behaviour) and draw heat from the network (consumer behaviour), i.e., it is a prosumer.

A schematisation of the waste heat recovery skid is represented[2] in Figure 9.

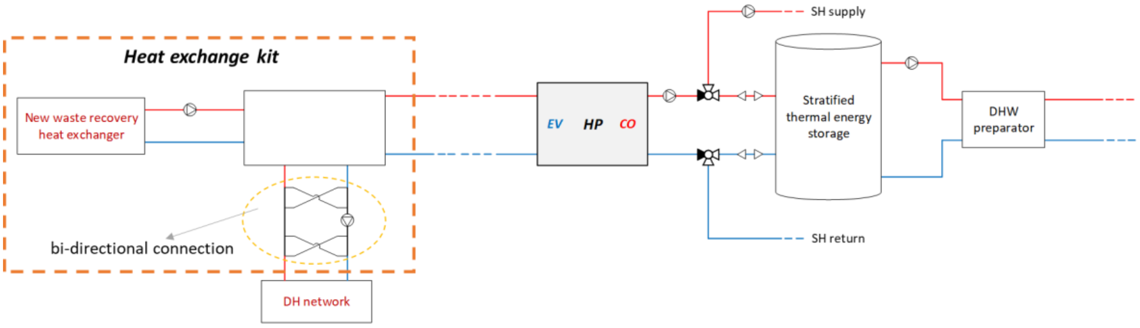

Figure 9 – Schematization of the waste heat recovery skid at Ospitaletto demo case.

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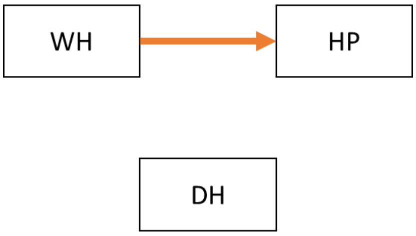
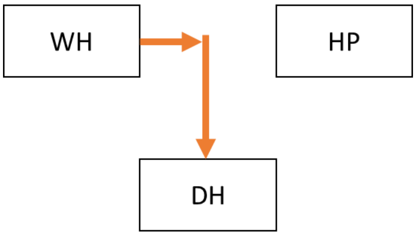
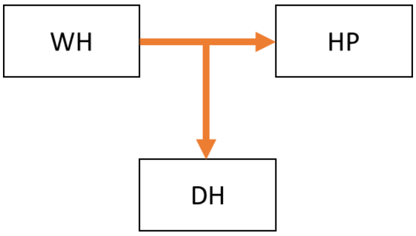
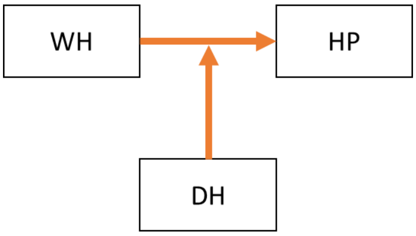
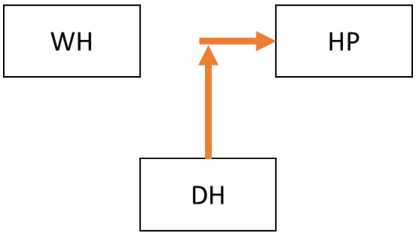
[2] As for the case of Mijnwater, the scheme represented in the figure does not exactly correspond to the P&ID of the real Cogeme plant. This simplified representation is meant to capture the main concepts.

2.2.1 Operating schemes

Thanks to the skid configuration, based on the comparison between the thermal power required by the heat pump HP on the evaporator-side and the available waste heat WH thermal power, the operating schemes summarised in Table 1 are possible. If the above-mentioned powers are not perfectly balanced with each other, the district heating DH network is used to close the energy balance (it is assumed that the DH network can always supply/receive the amount of heat to close the balance).

Table 1 – Operating schemes at Ospitaletto demo case.

Stand-alone / Disconnected If the power required by the heat pump on the source side is equal to the power available on the waste heat side, the skid has no interaction with the district heating network.	
Producer If waste heat is available and the heat pump is not in operation, all the heat is recovered within the district heating network.	
Hybrid: self-consumption and producer When the available waste heat exceeds local demand, all excess is supplied to the district heating network. Therefore, priority is given to self-consumption.	
Hybrid: self-consumption and consumer When the available waste heat is not sufficient to cover all the local heat demand, the residual is withdrawn from the network.	
Consumer If there is no waste heat and the heat pump is operating, all the required heat is supplied by the district heating.	

Waste heat from the foundry is available during the furnace operation period, which runs from Tuesday morning to Saturday afternoon. On the other hand, local heat demand is present from Monday morning to Saturday afternoon. Therefore, during Mondays, the skid operates in consumer mode, as waste heat is not available.

During the periods when waste heat is present, the available power is such that it exceeds the local demand, so the skid operates in self-consumption and producer hybrid mode (or possibly in stand-alone mode). In case the local heat demand is not present (i.e., the heat pump is switched off) the operation mode of the skid will be producer.

Finally, if for some reason the available waste heat is in short supply compared to local demand (e.g., in the transition period of the furnace start-up), the skid can operate in self-consumption and consumer hybrid mode.

Despite the excess of available waste heat compared to the local demand, a thermal storage system was not installed. In principle, such a system could store the excess heat during periods of availability and later use it to increase self-consumption. In this case, this role is played directly by the network.

2.3 Aalborg demo case

The district heating network in Aalborg is operated by Aalborg Forsyning. It is a 2-pipe system with a length of approximately 1250 km. The network temperature is regulated according to season, outdoor temperature, and wind strength. For instance, with low outdoor temperatures in winter the supply temperature is approx. 80 °C, while in summer it can drop to about 60 °C.

In LIFE4HeatRecovery, a demonstration site was installed at the Aalborg University data center located at the university campus in Aalborg East. The data center building is connected to the Aalborg DH supply. The demonstration plant recovers waste heat from the data center. A general design – recovering heat both from an innovative passive liquid-cooling system of the server racks (provided by Heatflow) and from the air-cooling system of the server room – was developed, though as a first phase only heat recovery from the liquid cooling system was installed. The recycled heat can be used to heat the building. The remaining surplus heat is supplied to the DH network.

Below, a simplified description of the most general scheme is provided. In this case, waste heat can be recovered from two separate cooling processes with two different temperature levels and possibly developed in two separate moments.

- WH recovery from server racks (actually installed at Aalborg demo site).

  The temperature is related to the control of the racks' cooling system, which can reach about 60 °C. Servers are indeed cooled by an innovative two-phase passive liquid cooling system (Heatflow proprietary design), exploiting dedicated thermosyphon circuits. Thanks to this solution, a high recovery temperature can be achieved while preserving the normal server operation. This high temperature increases the recovery efficiency, giving rise to high heat pump COPs or even allowing for direct recovery in periods of low network temperature.

- WH recovery from server room (being considered for a possible second phase of the Aalborg demo site).

  The room is also equipped with an air heat exchanger supplied with cooling water at a temperature of approx. 15-20 °C (to keep the room temperature below 25 °C). This is expected to be generally required even in the presence of a liquid cooling solution, as not 100 % of the heat can be captured by the latter.

Since both waste heat sources have a temperature level usually lower than the one of the district heating network, heat pumps are required to adapt the temperature level.

A schematization of the demo case in this full configuration is shown in Figure 10.

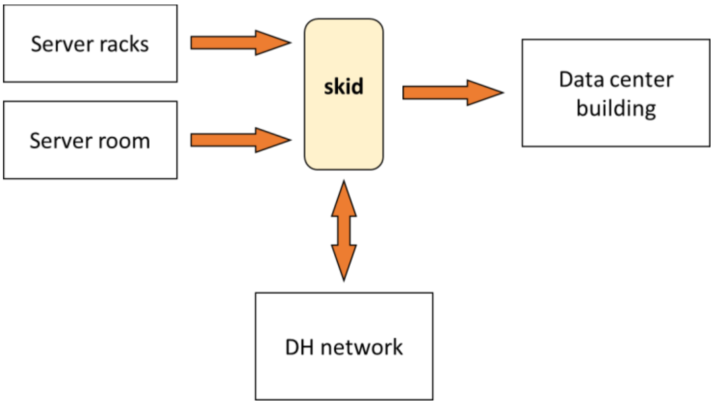


Figure 10 -Schematisation of Aalborg demo case.

As mentioned, within LIFE4HeatRecovery only the first development phase, focused on passive liquid cooling, was completed and tested. Figure 11 represents the installed waste heat recovery skid.

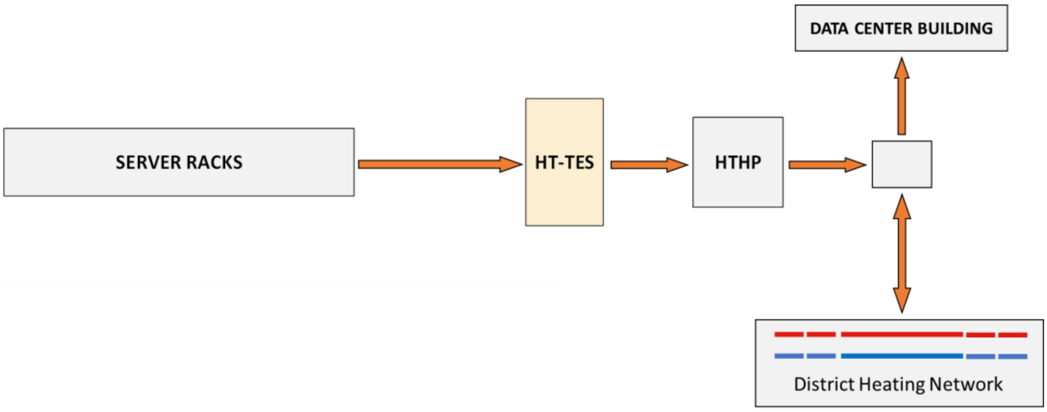


Figure 11 – Schematisation of the waste heat recovery skid at Aalborg demo case. The acronym HT refers to high temperature (to distinguish from a possible low-temperature system based on air cooling), TES refers to thermal energy storages, HP to heat pumps.

The thermal storage unit ("HT-TES" in the figure) decouples the waste heat recovery process from the cooling process of the servers, which allows compensating for possible mismatches between the required cooling power and the cooling power provided by the heat pump. This was a practical need in the demonstration prototype, as the small size of the system limited the choice of available components. It can be useful in general – with a properly sized TES volume – to simplify control.

The details of the hydraulic connections are not shown for brevity. They are anyway similar to the ones explained for the other two demonstrations sites, except for some proprietary details related to the Heatflow solution.

3 Construction recommendations

In this section, some recommendations regarding the construction of waste heat recovery skids are collected. They are based on the experiences from the different demo cases.

3.1 Bi-directional connection for prosumer

The *integration of waste heat sources* into district heating networks can occur through various methods:

- **Integration of a new producer**: a new user, with no local heat demand but having waste heat availability (or, equivalently, with a cooling demand), is connected to the network.
- **Integration of a new prosumer**: a new user with available waste heat and a local heat demand is integrated into the network.
- **Conversion of a consumer into a prosumer**: a user already connected to the network as a consumer installs an on-site waste heat recovery skid. The latter is primarily used to meet local demand (self-consumption), with any excess being fed back into the network.

In all situations except for the first, the hydraulic connection between the district heating network and the user must be bi-directional. The **bi-directional connection** can be realised by using two pairs of three-way valves as shown in Figure 12. Each three-way valve can be replaced equivalently by a pair of two-way valves.

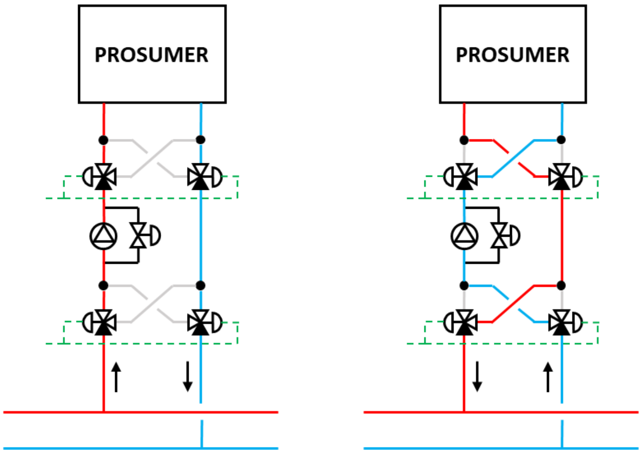


Figure 12 – Bi-directional connection between the district heating network and a prosumer. Left panel: consumer mode. Right panel: producer mode.

In the example in figure, the prosumer is connected to both pipes of the district heating network (supply and return pipe). Therefore, the withdrawal and return of the water flow occur in different pipes:

a) Consumer mode: it is a *supply-to-return* connection. The user withdraws water from the supply/warmer line and returns it into the return/colder line at a lower temperature.

b) Producer mode: it is a *return-to-supply* connection. The user withdraws water from the return/colder line and returns it into the supply/warmer line at a higher temperature.

Other solutions involving connections to a single pipe (i.e., *supply to supply* or *return to return* connection) are also possible. A bypass of the circulation pump is also shown in the figure. This branch makes it possible to keep the pump switched off if the pressure difference between the withdrawal pipe and the returning pipe is such that the required flow rate is ensured. Such pressure difference might be determined either by a centralized pumping station or by decentralized pumps at other prosumers (see also below the discussion about Figure 14).

With respect to the case where the process from which heat is to be recovered can be active at the same time as the local heat demand, the skid implemented in the Heerlen demo case enables the conversion of a consumer into a prosumer to be achieved easily as all the necessary hydraulic components (pipes, valves, storage tanks, and bi-directional connection) are already in place.

Instead, in the case of a user characterised by a single process that can alternately be a hot process (i.e., consumer mode) or a cold process (i.e., producer mode), the conversion of a consumer into a prosumer can be achieved by either installing a reversible heat pump (**machine inversion**) or by designing a hydraulic configuration capable of reversing the heat source and load of the heat pump (**system inversion**), see Figure 13. Of course, in both cases the bi-directional connection between the user and the district heating network (DHN in the figure) is needed.

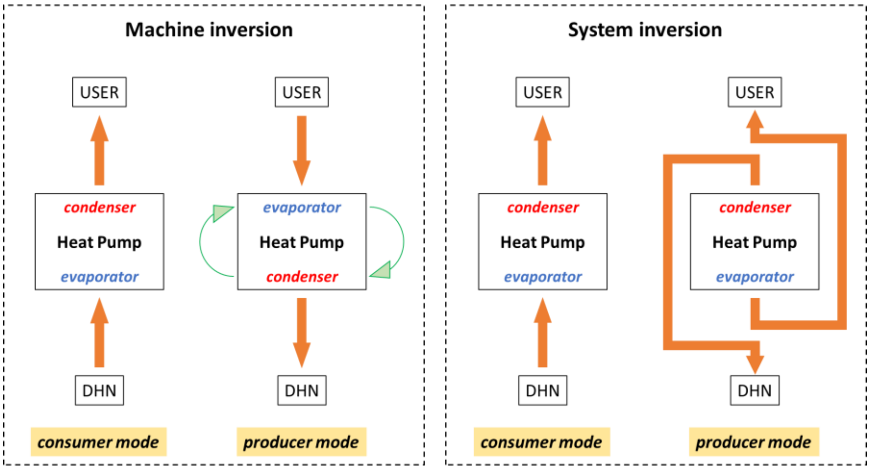


Figure 13 – Machine and system inversion for a prosumer.

The introduction of a prosumer connected to the supply and return pipes requires these network sections to be bi-directional. If the network is characterized by decentralized pumping (i.e., each user has its own circulation pump), then this aspect is not critical (for example, see Figure 14 showing the case of conversion of a consumer into a prosumer). Each user has a circulation pump, possibly in parallel with a valve to bypass the latter whenever the rest of the network ensures enough pressure difference. In the example in the figure, in the network section between the consumer and the prosumer (bottom figure panel), the flow can be reversed thanks to the introduction of a bi-directional connection between the network and the prosumer.

As learnt from the experience of the Ospitaletto demo case, when dealing with networks featuring a centralized in-line pumping system, the introduction of a prosumer can instead be more critical, since it can require hydraulic adaptations of the system.

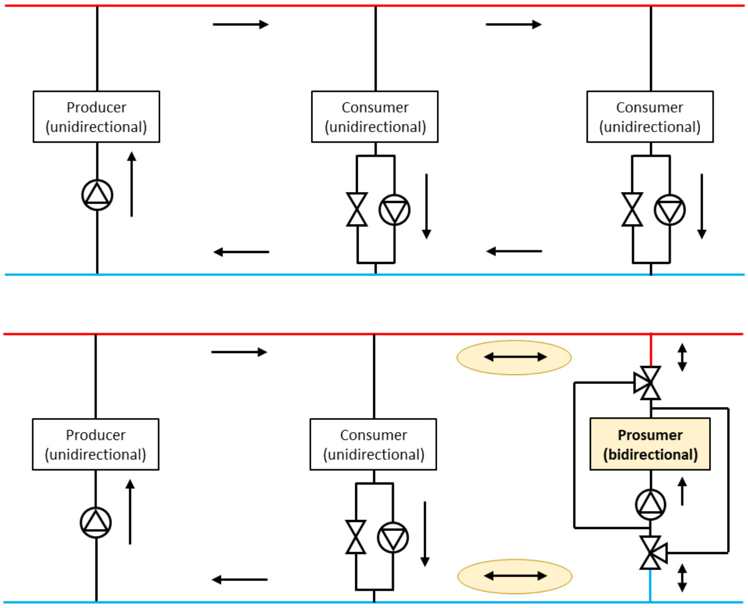


Figure 14 – Integration of a prosumer into a network with decentralised pumping. Top panel: example with a single producer and multiple consumers, every pipe has a single flow direction. Bottom panel: example where a consumer is turned into a prosumer, some pipe can have flow in different directions depending on the time (as it can happen in the case of multiple producers with different schedules). In the prosumer case, the valve in parallel with the pump is omitted for simplicity.

3.2 Thermal energy storages

The presence of thermal energy storages in the skid allows for several advantages. First, they allow peak shaving and valley filling, giving greater flexibility in sizing the heat pump by avoiding the constraint of sizing on peak demand. This aspect becomes particularly crucial, especially when the sizes of heat pumps available in the market do not align with the user's specific load. In addition, storage tanks allow the temporally decoupling of generation and demand profiles and can perform load shifting, enabling the possibility of optimal demand-side management. Figure 15 shows an example of these advantages.

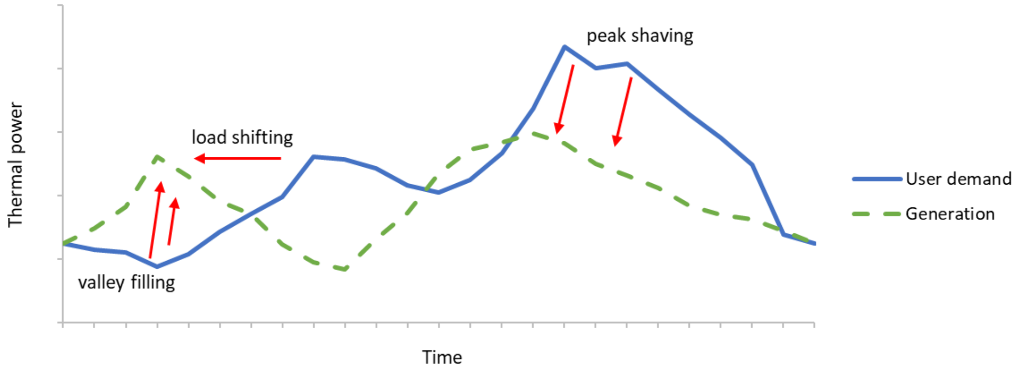


Figure 15 – Effects produced by thermal storage: peak shaving, valley filling, and load shifting.

Regarding the sole aspects of waste heat recovery, the presence of thermal storages in the case of a user characterised by both waste heat availability and local heat demand allows maximising the amount of waste heat reused on-site (i.e., minimising the amount of heat extracted from the district heating network). For instance, in the Ospitaletto demo case, it was feasible to install a thermal storage to store part of the excess waste on the condenser side of the heat pump, with benefits for sanitary hot water generation. In such decisions, beside technical aspects, also economic considerations play a significant role, given the significant cost of heat pumps and storage tanks.

3.3 Smart hydraulic design of the skid

The skid installed at the demo case in Heerlen implements a complex hydraulic configuration (in terms of valves and hydraulic connections present) that allows the **passive sharing**[3] rate to be maximised based on the thermal levels of the water flows.

A schematisation of a more complete hydraulic design is shown in Figure 16.

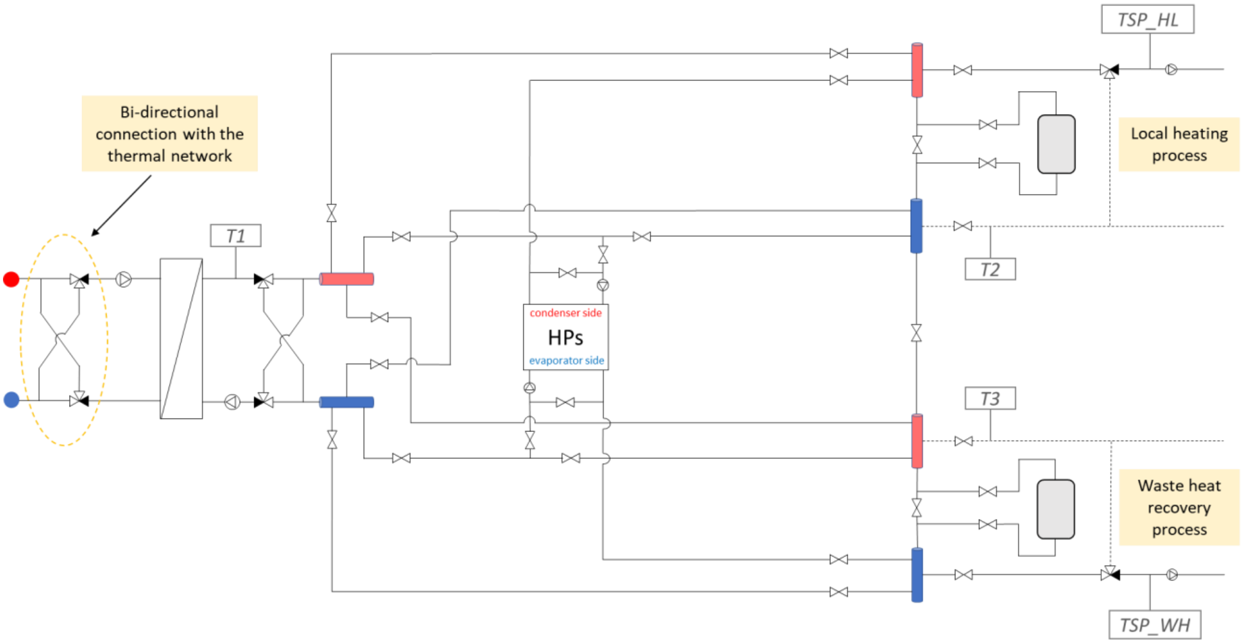


Figure 16 – Waste heat recovery skid with a smart hydraulic design.

This skid configuration was originally planned for the Heerlen demo case. Compared to the one actually installed, it has some more hydraulic connections that allow for a greater number of operating schemes.

The choice of the complexity of the skid must be made taking into account the variability of the thermal levels of the water flows. Where the **combination of the thermal levels**[4] of the flows remains constant, it is pointless to install all the hydraulic connections included here, as some of them would remain inactive since the skid would always work with the same operating scheme. This is for example the case in Ospitaletto: the hydraulic design of the skid does not foresee the possibility to change the HP

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[3] Passive sharing refers to the amount of heat transferred without being upgraded by the heat pump.

[4] Combination of thermal levels means the comparison of the temperatures of the water streams entering the skid (T1, T2, and T3) and of the set point temperatures for the local heating process and the waste heat recovery process (TSP_HL and TSP_WH).

operating scheme, as the thermal level of the heat source (be it waste heat or groundwater) is always lower than the thermal load.

It can be shown that all the skids discussed above can be obtained from the one shown in Figure 16 by removing one or more components and by setting a fixed position for the valves.