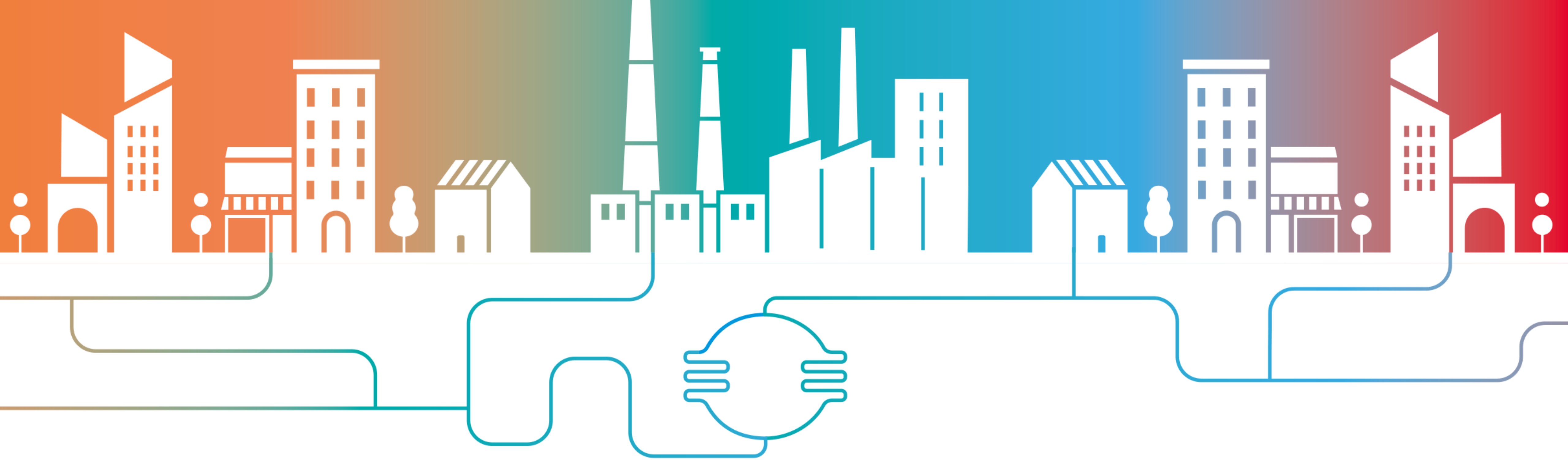

Database of waste heat recovery solutions – Action C.6.1

Daniele Anania, Marco Cozzini – EURAC

Due date: 14 September 2023

LIFE 4 HEAT RECOVERY

LIFE4HeatRecovery

This document has been produced in the context of the LIFE4HeatRecovery Project:
Low temperature, urban waste heat into district heating and cooling networks as a clean source of thermal energy LIFE4HeatRecovery

The project has received funding from the LIFE programme of the European Union under contract number LIFE17 CCM/IT/000085

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Nomenclature and concepts

LIFE 4 HEAT RECOVERY

Nomenclature

DH – District Heating
DHN – District Heating Network
HP – Heat Pump
WH – Waste Heat
LT – Low Temperature
HT – High Temperature
HEX – Heat Exchanger
TES – Thermal Energy Storage
EV – Evaporator side of heat pump
CO – Condenser side of the heat pump
TSP – Temperature Set Point
HL – Heating Load
SH – Space Heating
SHW – Sanitary Hot Water

Concepts

Passive sharing: heat transferred without operating the heat pump.

Theoretical passive sharing: the maximum amount of heat which can be transferred passively according to the thermal level conditions.

The LIFE4HeatRecovery project

LIFE4HeatRecovery demonstrates the recovery of **urban waste heat** available **at low temperature** (< 40 °C) in highly efficient **district heating and cooling networks** operated at conventional or low temperature.
This is done by means of **heat pumps** used either at heat recovery or heat utilization sites, with a focus on **prefabricated** solutions

The project includes 3 demonstration cases:

- Ospitaletto: heat recovery from the cooling system of a foundry into a cold network
- Aalborg: heat recovery from a data centre into a medium-high temperature network
- Heerlen: heat recovery from the cooling system of a foundry into a cold network

More information can be found at the project website: https://www.life4heatrecovery.eu/

Waste Heat recovery substations

LIFE 4 HEAT RECOVERY

Starting from a generic cooling load, the aim of these systems is to recover waste heat into district heating networks. In case of low-temperature waste heat, a HP-based substation is required.

This database shows examples of different configurations of HP-based substations for low-temperature waste heat recovery into district heating systems.
The considered configurations provide interfaces between 3 possible heat circuits/processes:

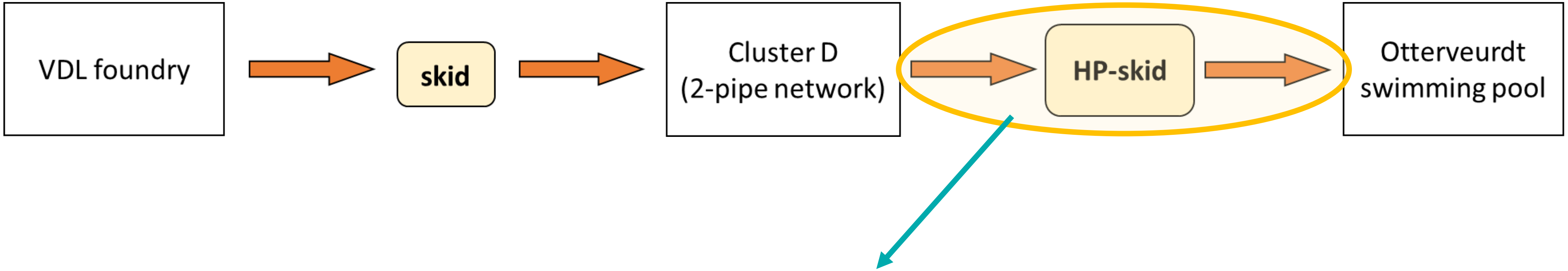
- A pure heating process (heat consumer).
- A pure cooling process (heat producer).
- A balancing process (the district heating network), used either to supply or absorb heat.

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 obtain energy flow direction inversion when necessary (alternatively, reversible heat pumps might be used in certain cases).

Heerlen (Mijnwater) – first development stage

System description

Waste heat recovery from VDL foundry (***producer***) and heat supply to Otterveurdt swimming pool (***consumer***)



Waste Heat Recovery Substation

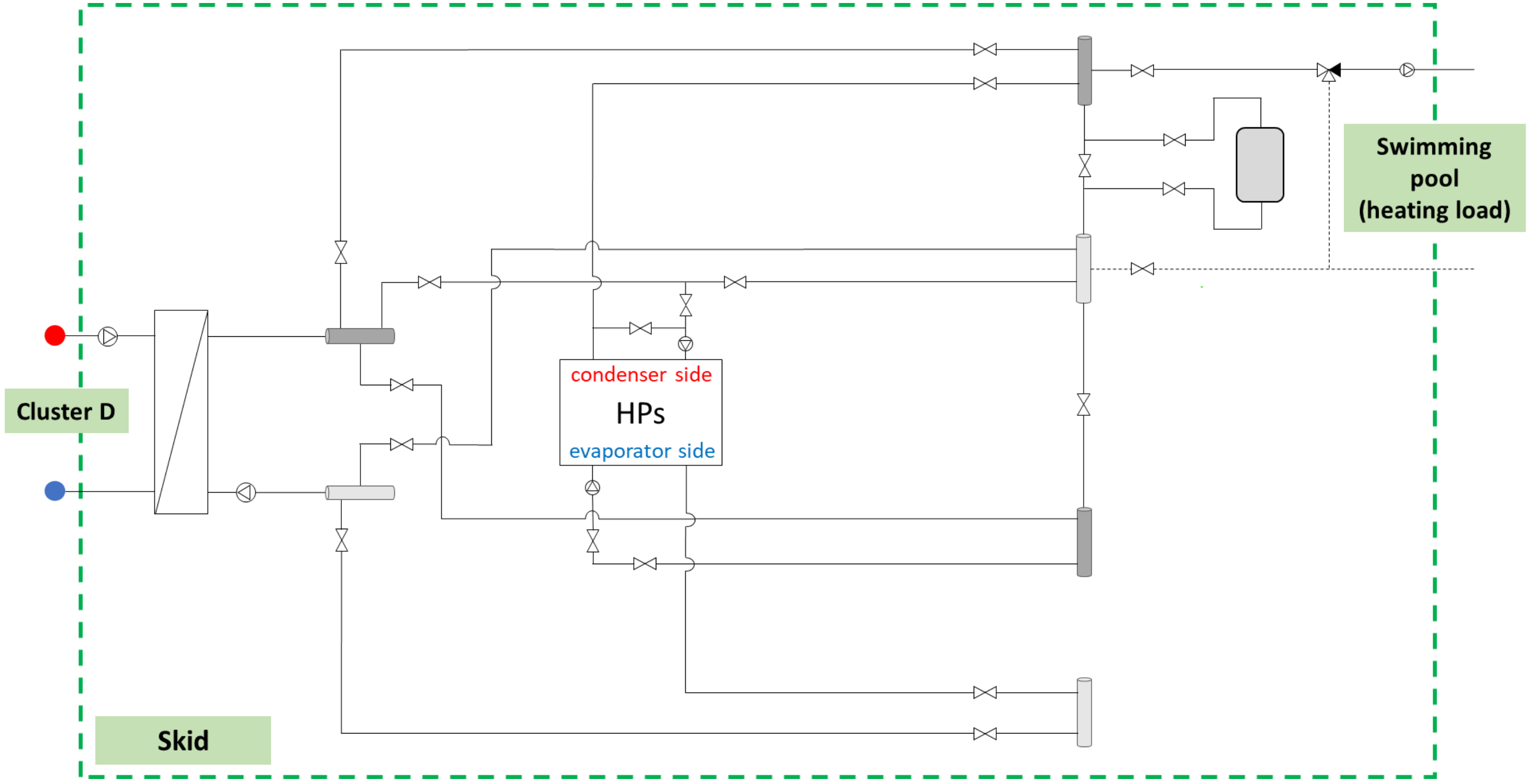
- monodirectional HP-skid providing **only heat** to the user.
- monodirectional connection with the network.

Heat flow

LIFE 4 HEAT RECOVERY

Heerlen (Mijnwater) – first stage

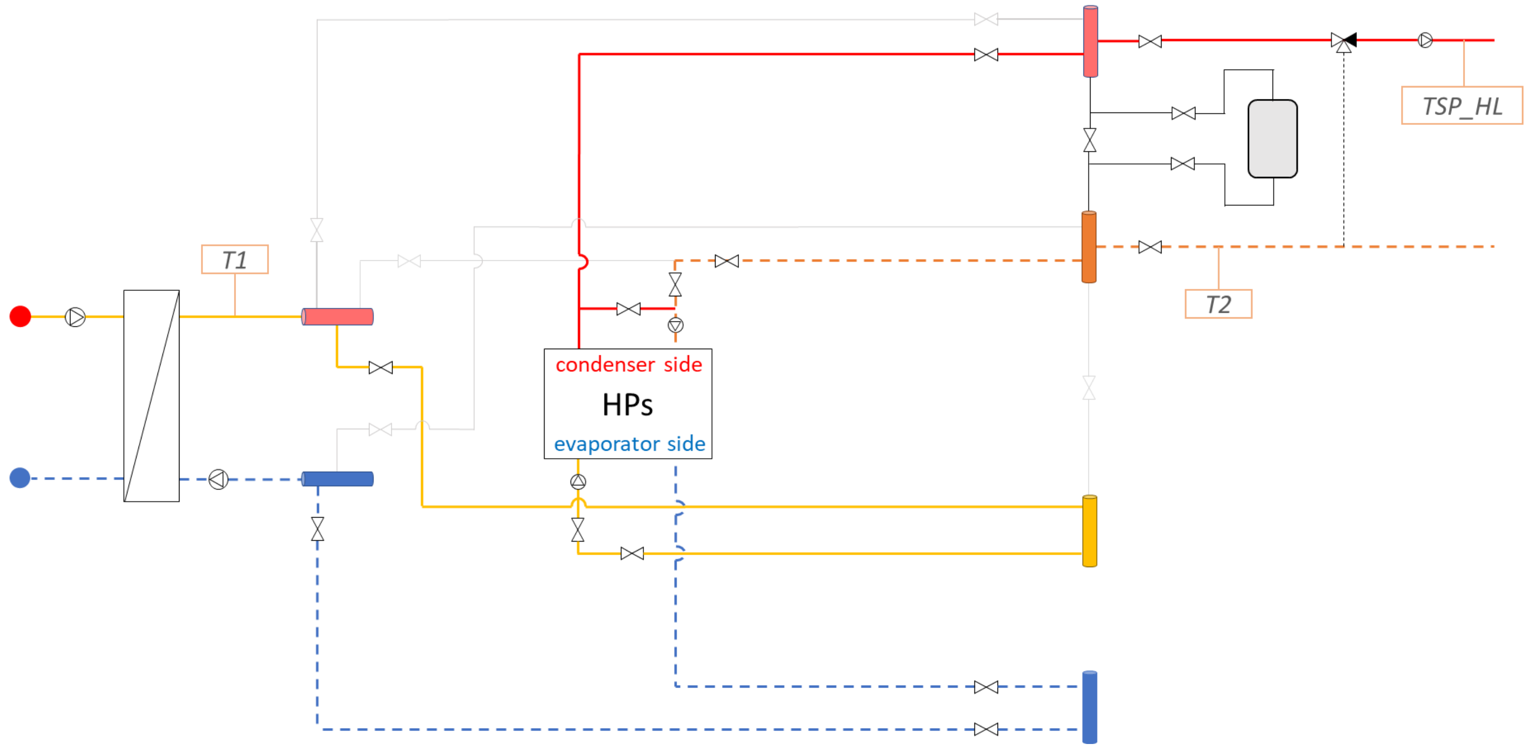
Substation configuration: general scheme



- The skid draws heat from the network and supplies it to the user at the desired temperature level.
- Monodirectional connection between the skid and the network.
- One or more heat pumps connected in series or parallel can be installed depending on requirements.
- The heat exchanger enables hydraulic separation between the skid and the network.
- This configuration allows for different operating schemes to optimise skid performance according to network and user thermal levels (see next).

Heerlen (Mijnwater) – first stage

Operating scheme: hydraulic separation



Thermal level combination

$\mathbf{TSP_{HL} > T_2 > T_1}$

Passive sharing: 0 %

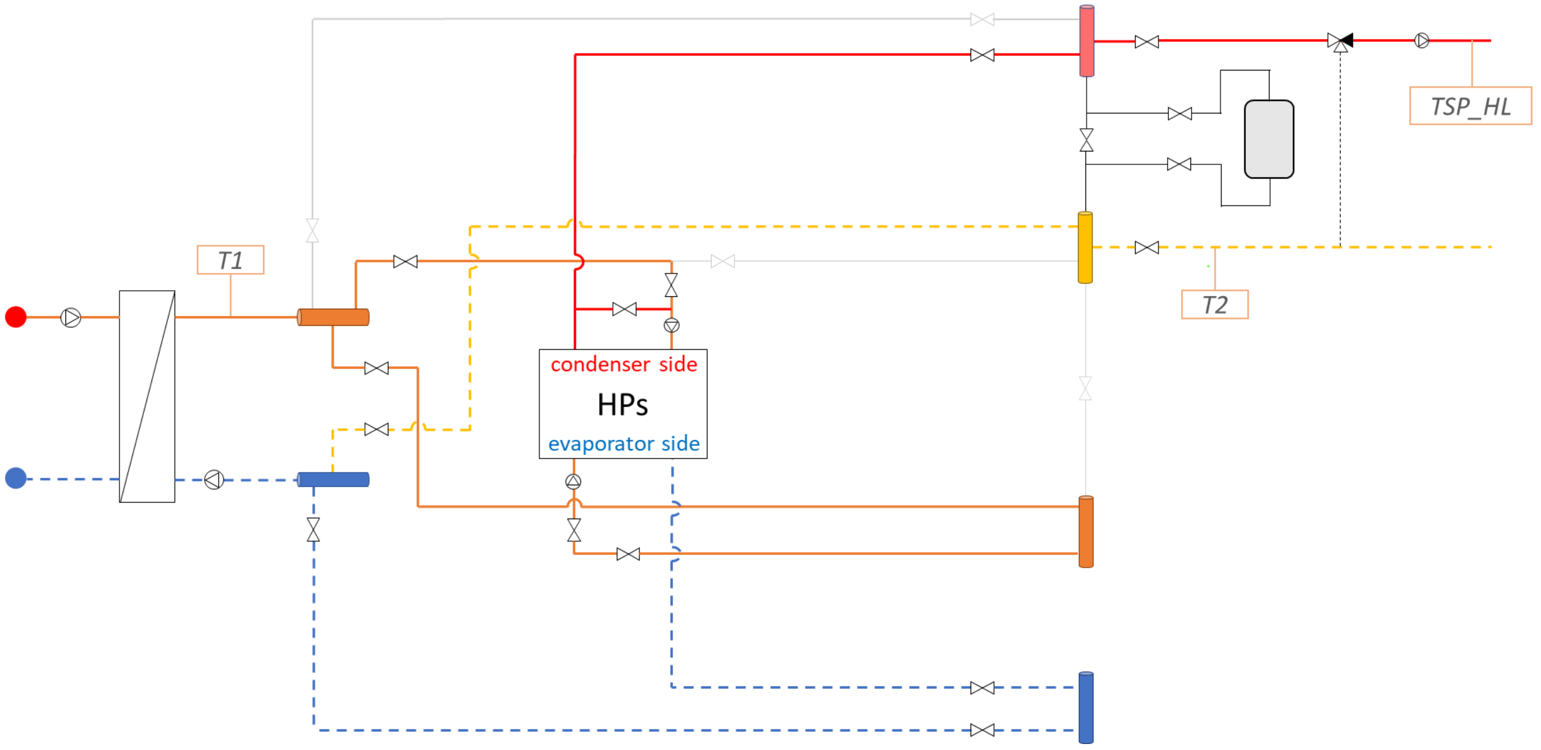
Heat pumps operation is required since T_1 does not meet the level required by the user TSP_{HL}.

The flow coming from the HEX is sent to the evaporator side of the heat pumps while the return water from the user goes to the condenser side.

HPs allow for hydraulic separation between HEX and user.

Heerlen (Mijnwater) – first stage

Operating scheme: split flow



Thermal level combination

$$\mathbf{TSP_{HL} > T_1 > T_2}$$

Theoretical passive sharing: $\frac{\mathbf{T_1 - T_2}}{\mathbf{TSP_{HL} - T_2}}$

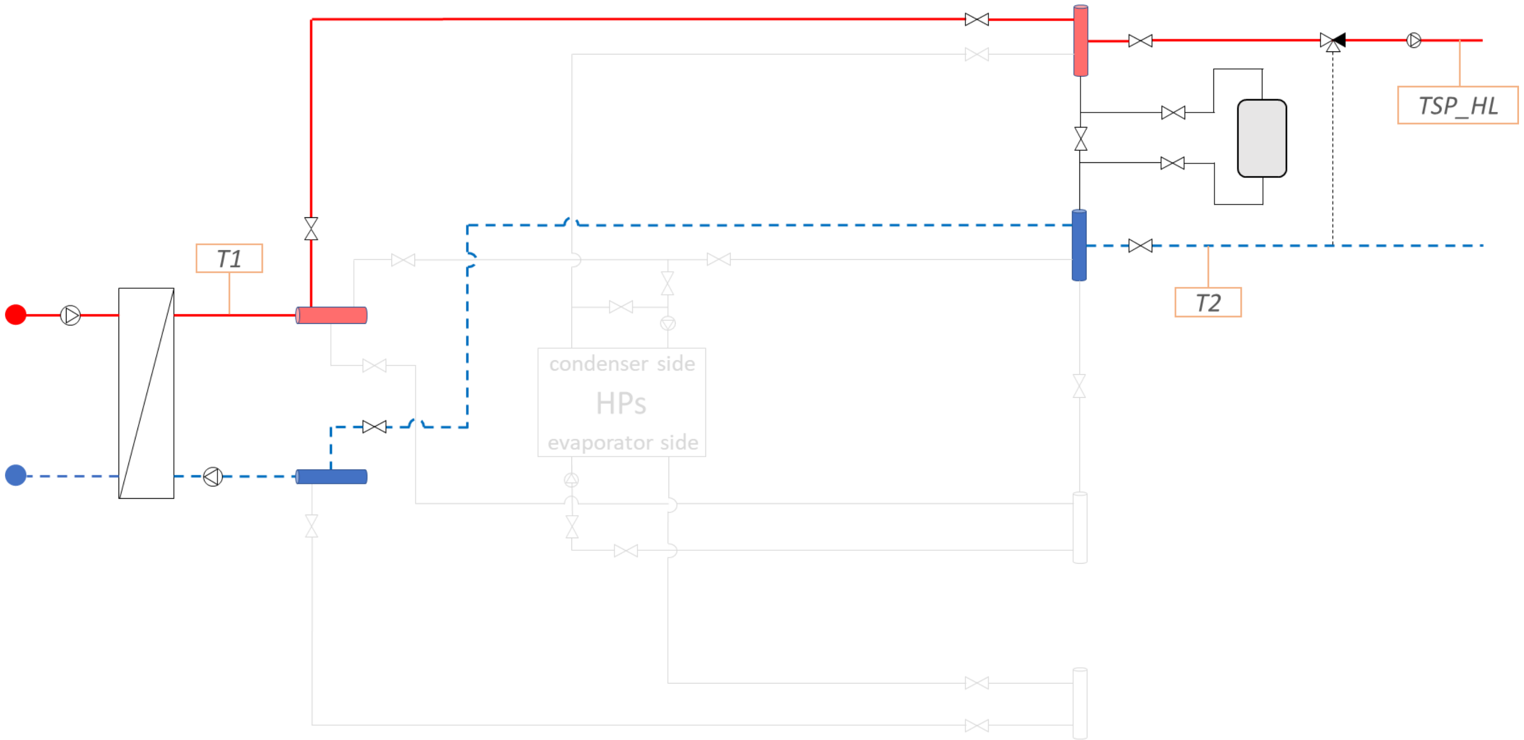
Heat pumps operation is required since T_1 does not meet the level required by the user TSP_{HL}.

The flow coming from the HEX is sent to both the evaporator and condenser side of the heat pumps. The return water from the user directly goes to the HEX.

Multiple HP modules manage temperature differences.

Heerlen (Mijnwater) – first stage

Operating scheme: heat pump bypass



Thermal level combination

$$\mathbf{T_1 > TSP_{HL}}$$

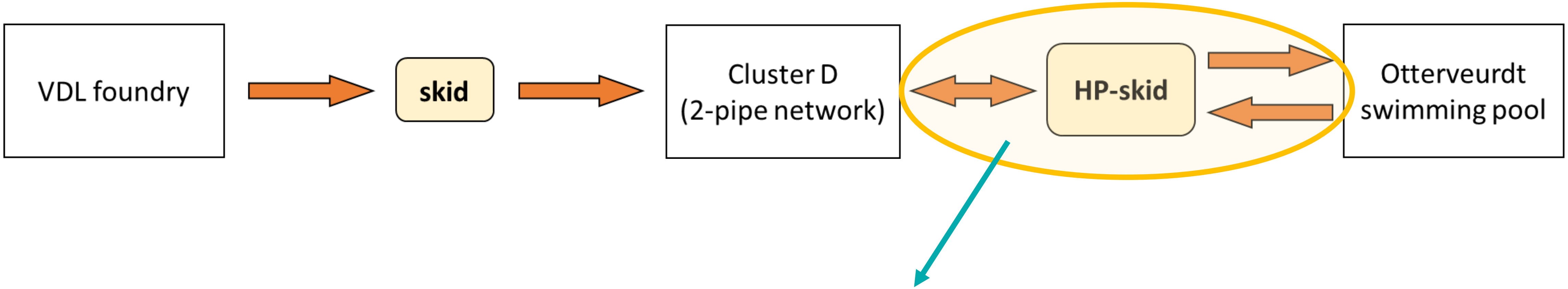
Passive sharing: 100 %

Since the temperature T_1 of the hot water leaving the heat exchanger is higher than the temperature TSP_{HL} required by the user, the heat pumps can be bypassed. The flow coming from the HEX is directly supplied to the user.

Heerlen (Mijnwater) – second development stage

System description

Waste heat recovery from VDL foundry (***producer***) and heat and cold supply to Otterveurdt swimming pool (***prosumer***)

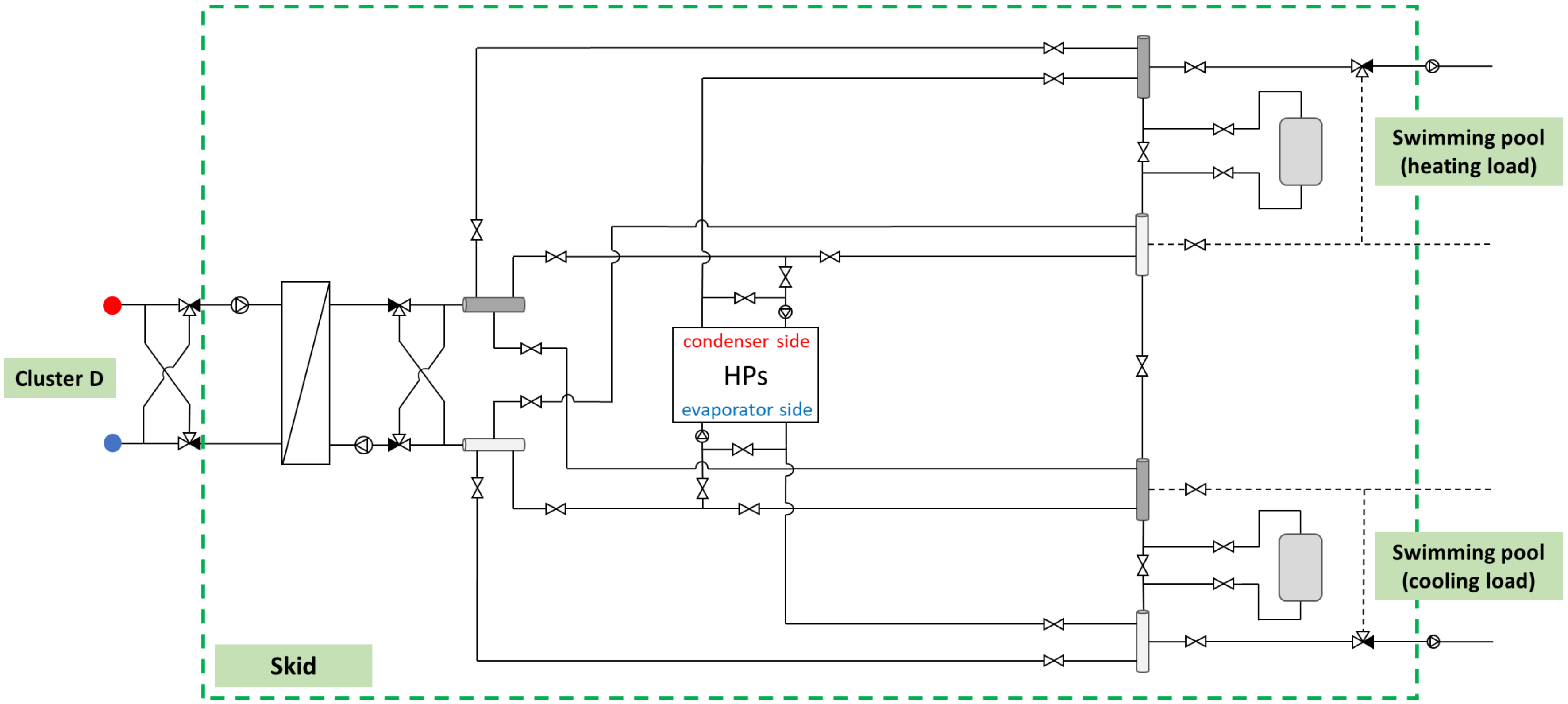


Waste Heat Recovery Substation

- bidirectional HP-skid providing **both heat and cold** at the same time to the user.
- bidirectional connection with the network.

Heerlen (Mijnwater) – second stage

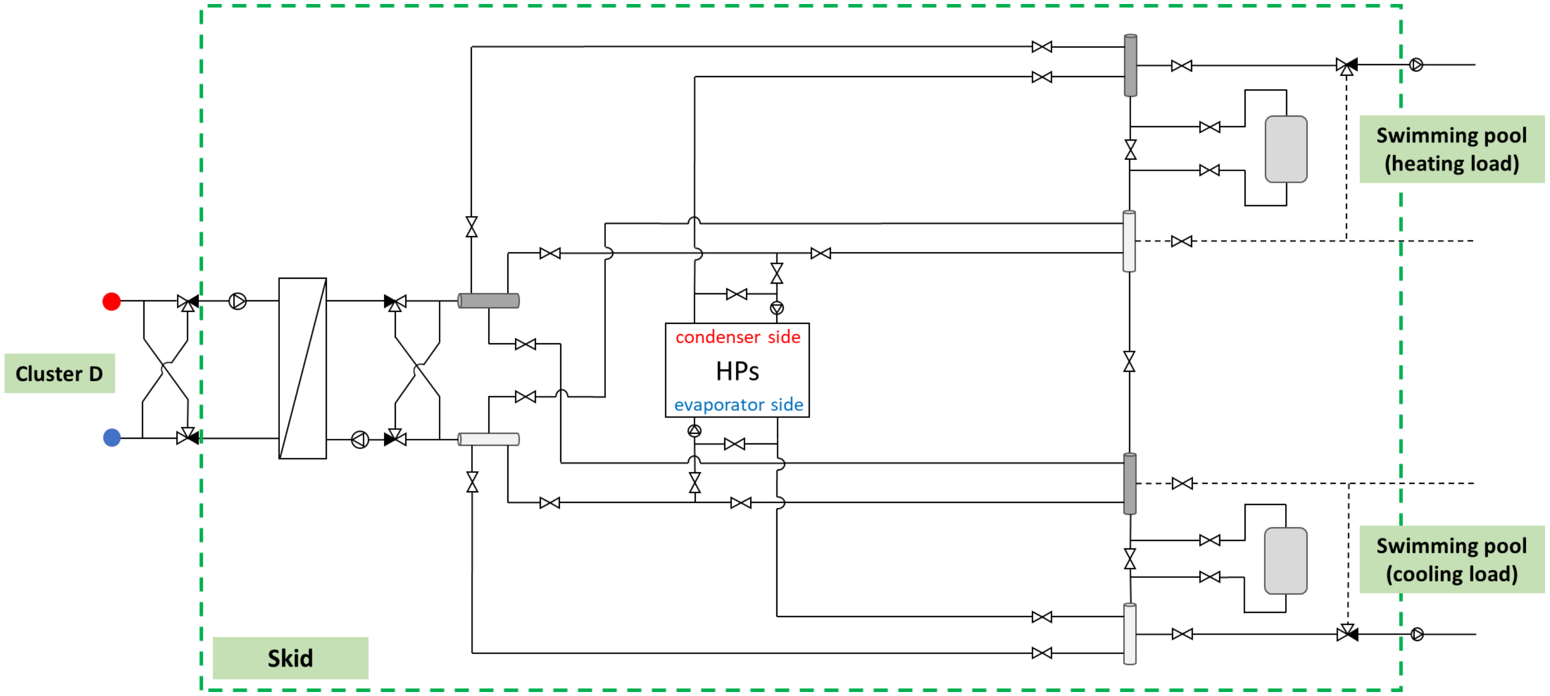
Substation configuration



- Now the skid can supply both heat and cold to the user at the same time.
- The shortage of heat/cold is drawn from the network thanks to a bidirectional connection made by two pairs of 3-way valves.
- One or more heat pumps connected in series or parallel can be installed depending on requirements.
- The heat exchanger enables hydraulic separation between the skid and the network.
- To optimize the performance, different operating schemes, decided according thermal levels of the user and the network, are enabled by the complex hydraulic configuration.

Heerlen (Mijnwater) – second stage

Strengths and weaknesses of the substation

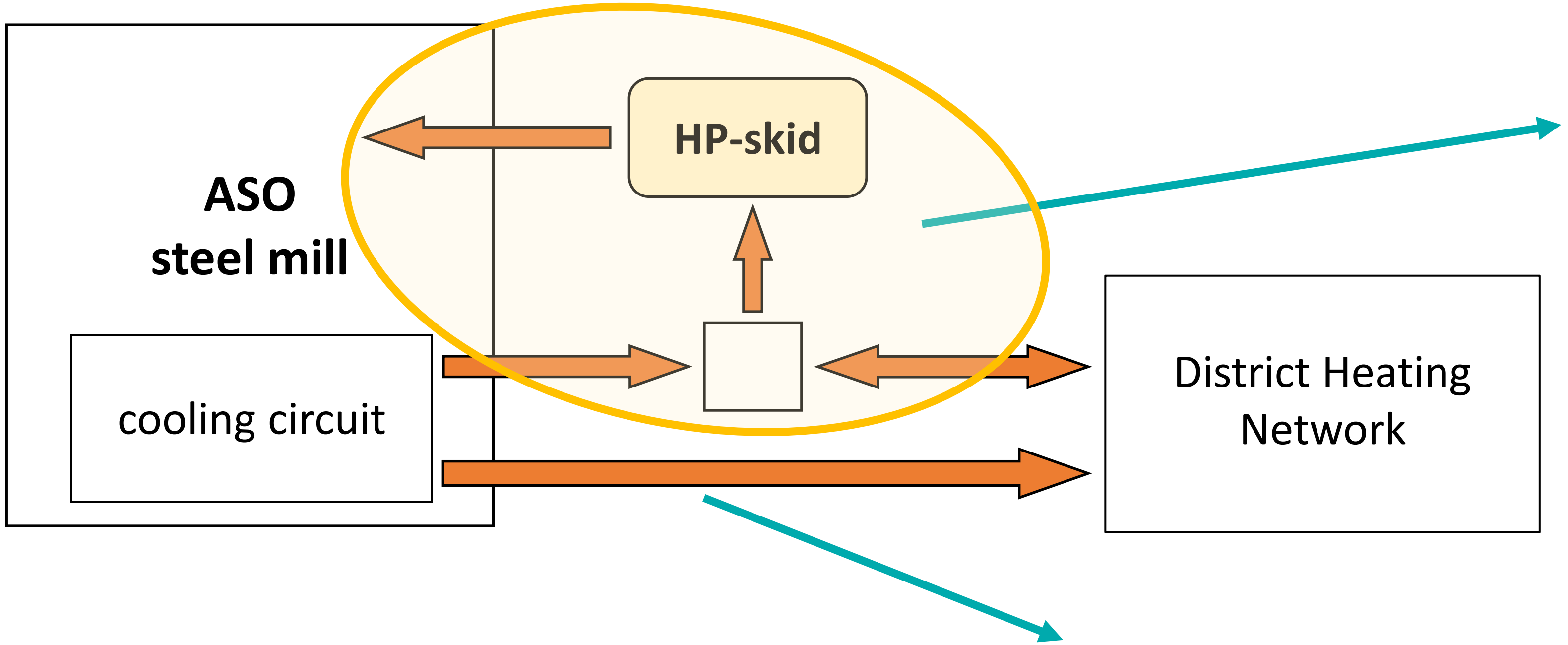


- Strengths
  - ✓ **Modularity.** Using multiple HP modules, a larger flexibility in the sizing is introduced.
  - ✓ **Replicability.** Well adaptation to different combination of thermal levels.
  - ✓ **Bivalent.** Avoiding the installation of two dedicated heat pump modules for heating and cooling load, respectively.
- Weaknesses
  - ✓ **Complex hydraulics.** Many hydraulic components (valves, actuators, piping) are present. (∗)
  - ✓ **Complex control.** Switching between the different operating schemes requires a smart control unit with transition hysteresis to avoid instabilities.

(∗) In less complex situations, it is possible not to install all the hydraulic components, deriving simpler configurations by installing only the necessary parts.

Ospitaletto (Cogeme)

System description



Waste Heat Recovery Substation

- monodirectional HP-skid providing **only heat** to the user.
- hydraulic kit comprising a bidirectional connection with the network.
- partially contribute to the cooling effect.

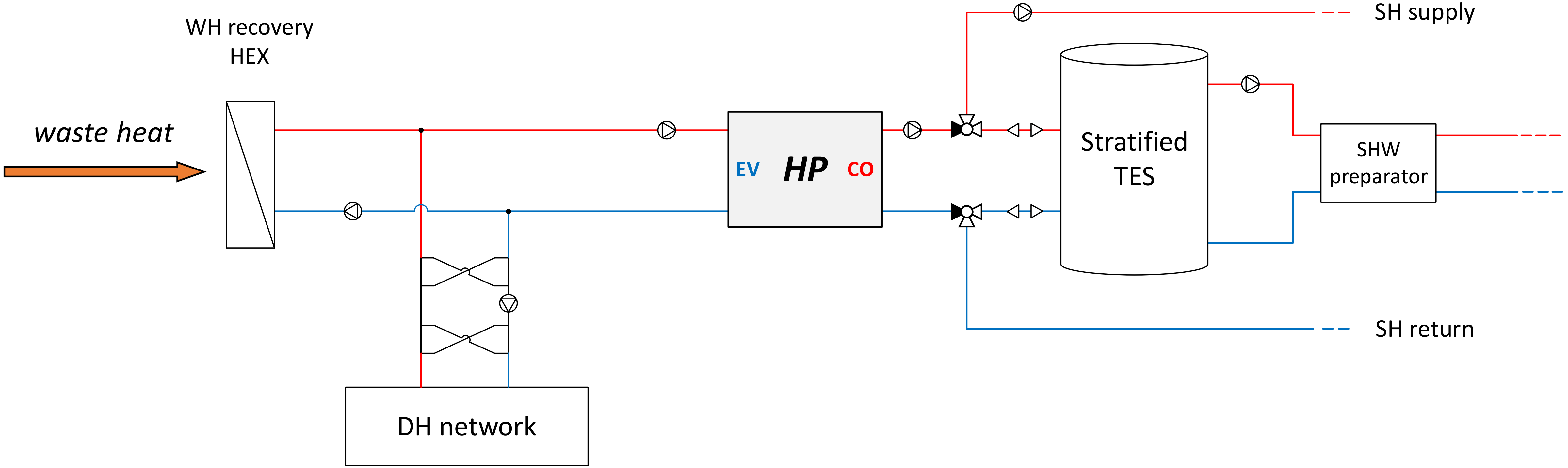
Already existing recovery heat exchanger.

Hydraulic kit

Heat flow

Ospitaletto (Cogeme)

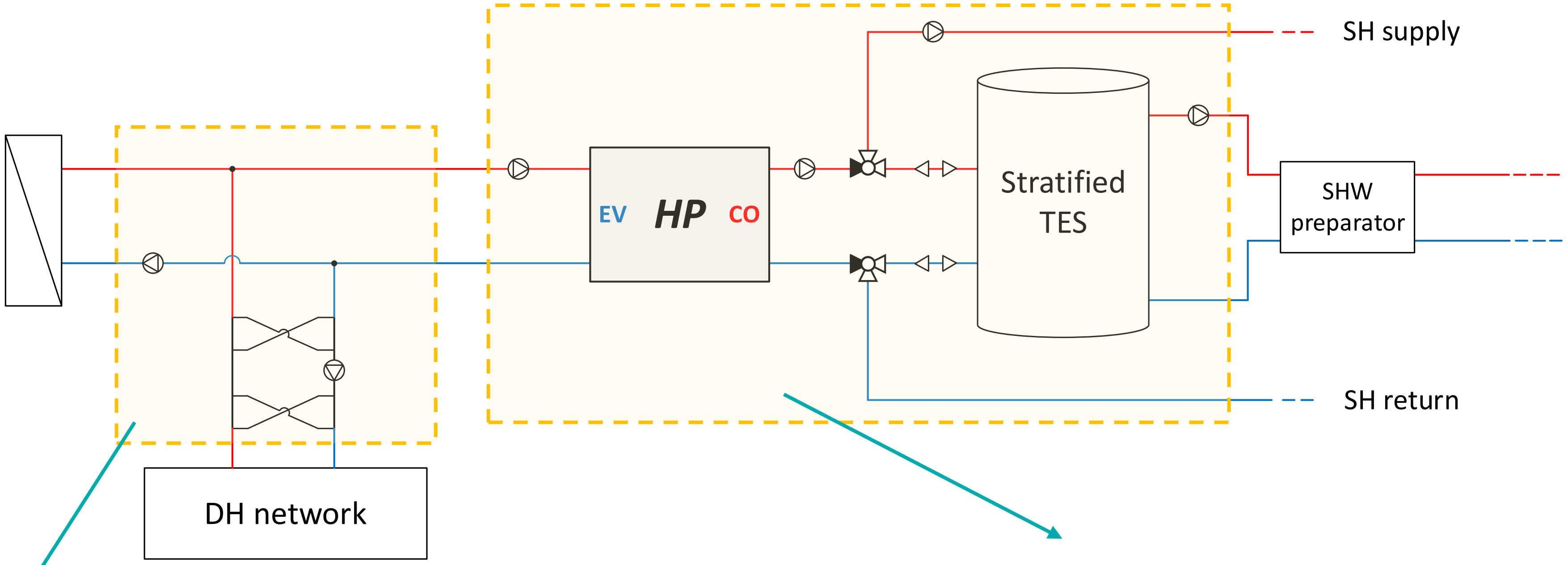
Substation configuration



Passive sharing: 0 %

Ospitaletto (Cogeme)

Substation configuration



WH recovery HEX.
It allows waste heat to be recovered from the cooling circuit, also ensuring hydraulic separation.

Hydraulic kit.
It represents the connection point between the WH heat exchanger, the HP station and the district heating network. The connection with the latter is bi-directional.

Heat Pump skid.
It consists of a water-to-water heat pump to ensure the thermal level desired by the user and a stratified thermal energy storage.

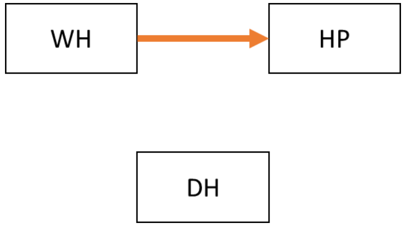
Passive sharing: 0 %

Ospitaletto (Cogeme)

Operating schemes

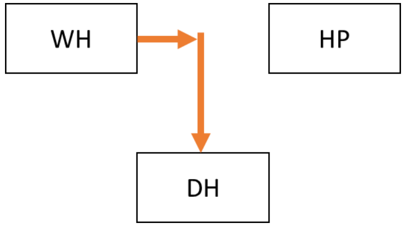
Stand-alone / Disconnected

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.



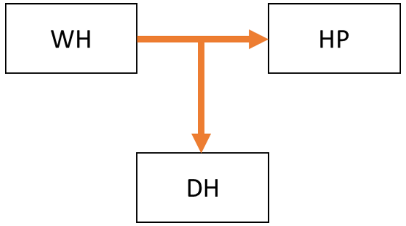
Producer

If waste heat is available and the heat pump is not in operation, all the heat is recovered within the district heating network.



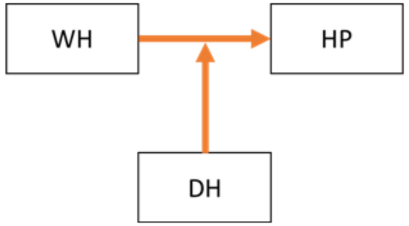
Hybrid: self-consumption and producer

When the available waste heat exceeds local demand, all excess is supplied to the district heating network. Therefore, priority is given to self-consumption.



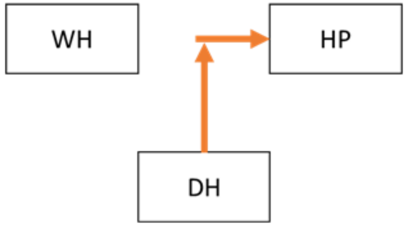
Hybrid: self-consumption and consumer

When the available waste heat is not sufficient to cover all the local heat demand, the residual is withdrawn from the network.



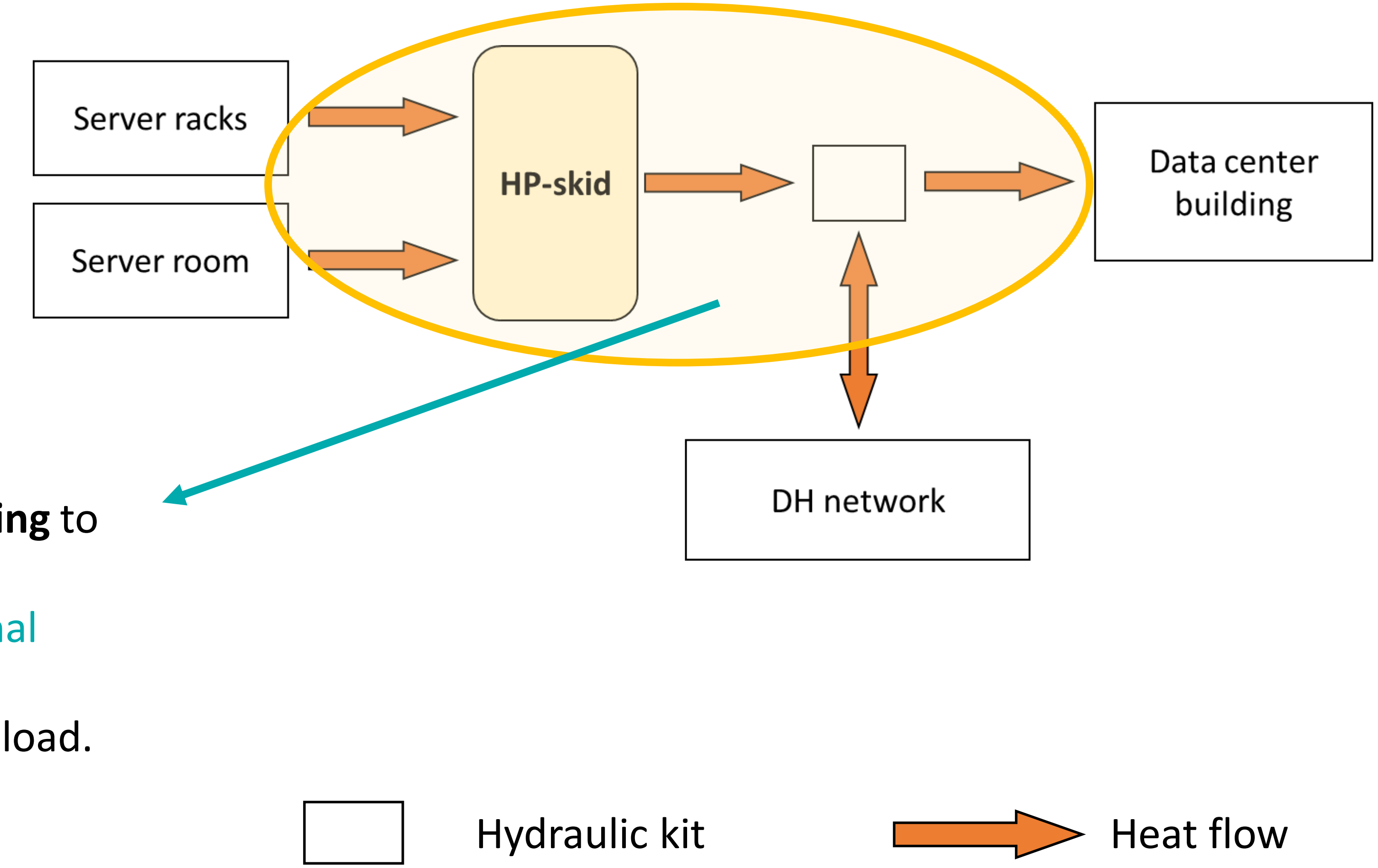
Consumer

If there is no waste heat and the heat pump is operating, all the required heat is supplied by the district heating.



Aalborg (Heatflow)

System description

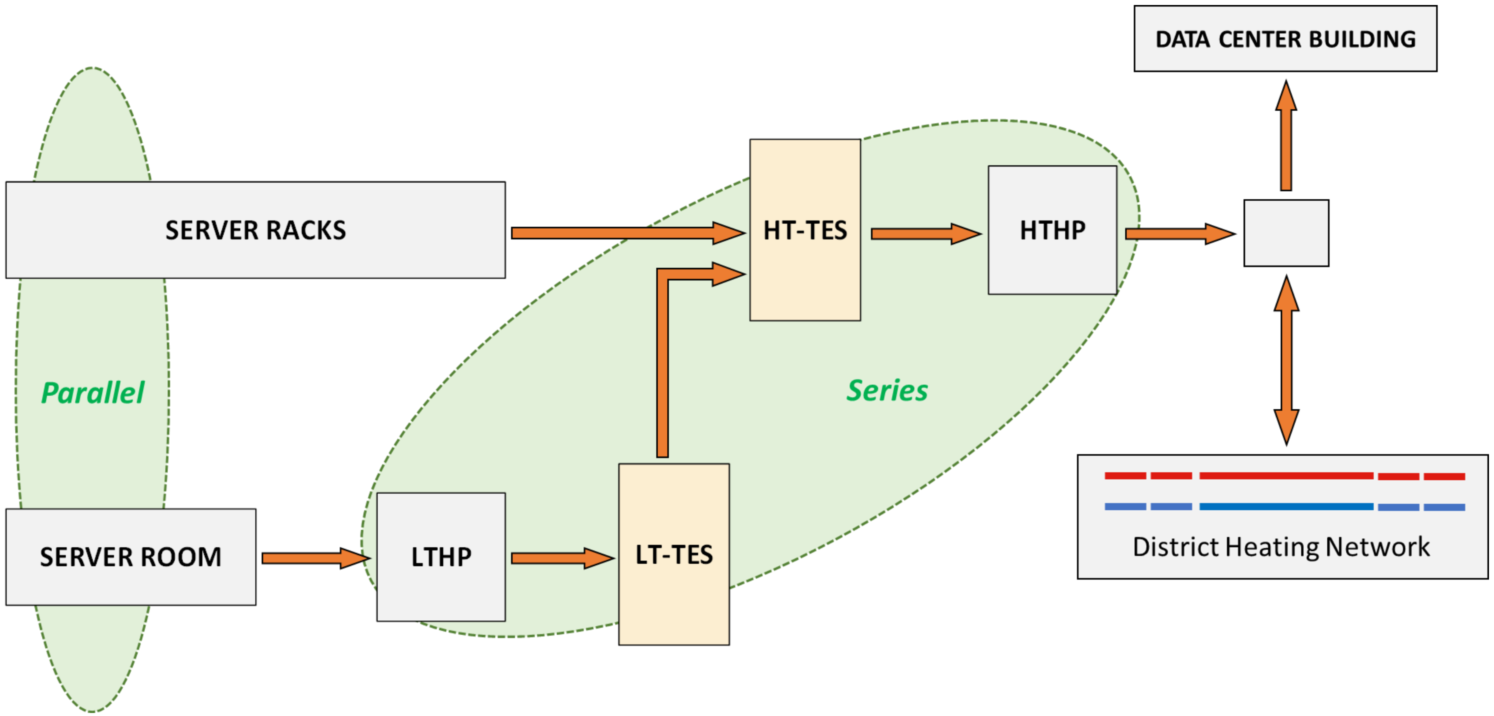


Waste Heat Recovery Substation

- monodirectional HP-skid providing **cooling** to the servers.
- hydraulic kit comprising a bidirectional connection with the network.
- partially contribute to the local heating load.

Aalborg (Heatflow)

Substation configuration

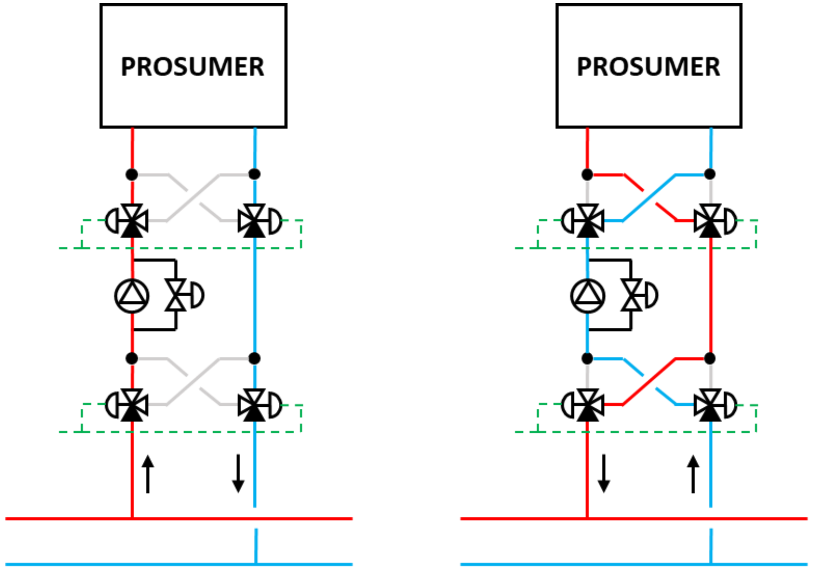


- The aims are to cool the server racks by keeping them at a temperature of around 60°C and to keep the server room at a temperature of around 20-25°C.
- The WH recovery substation recovers heat both from the cooling system of the server racks and the air-cooling system of the server room *(**parallel system**)*. Since the heat from the server rooms is at a significantly lower thermal level than that from the server racks, the skid is implemented with a cascade system, implementing two dedicated heat pumps and storage tanks *(**series system**)*.
- The two storage units decouple the WH recovery process from the cooling process of the user, which also makes it possible to compensate for possible mismatches between the required cooling power and the cooling power provided by the heat pumps.

General recommendations

Bidirectional connection with the network

Bidirectional connection between the user and the network realised by using two pairs of three-way valves. As an alternative, each three-way valve can be replaced by a pair of two-way valves.



a) Consumer mode b) Producer mode

The prosumer is connected to both pipes of the district heating network:

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

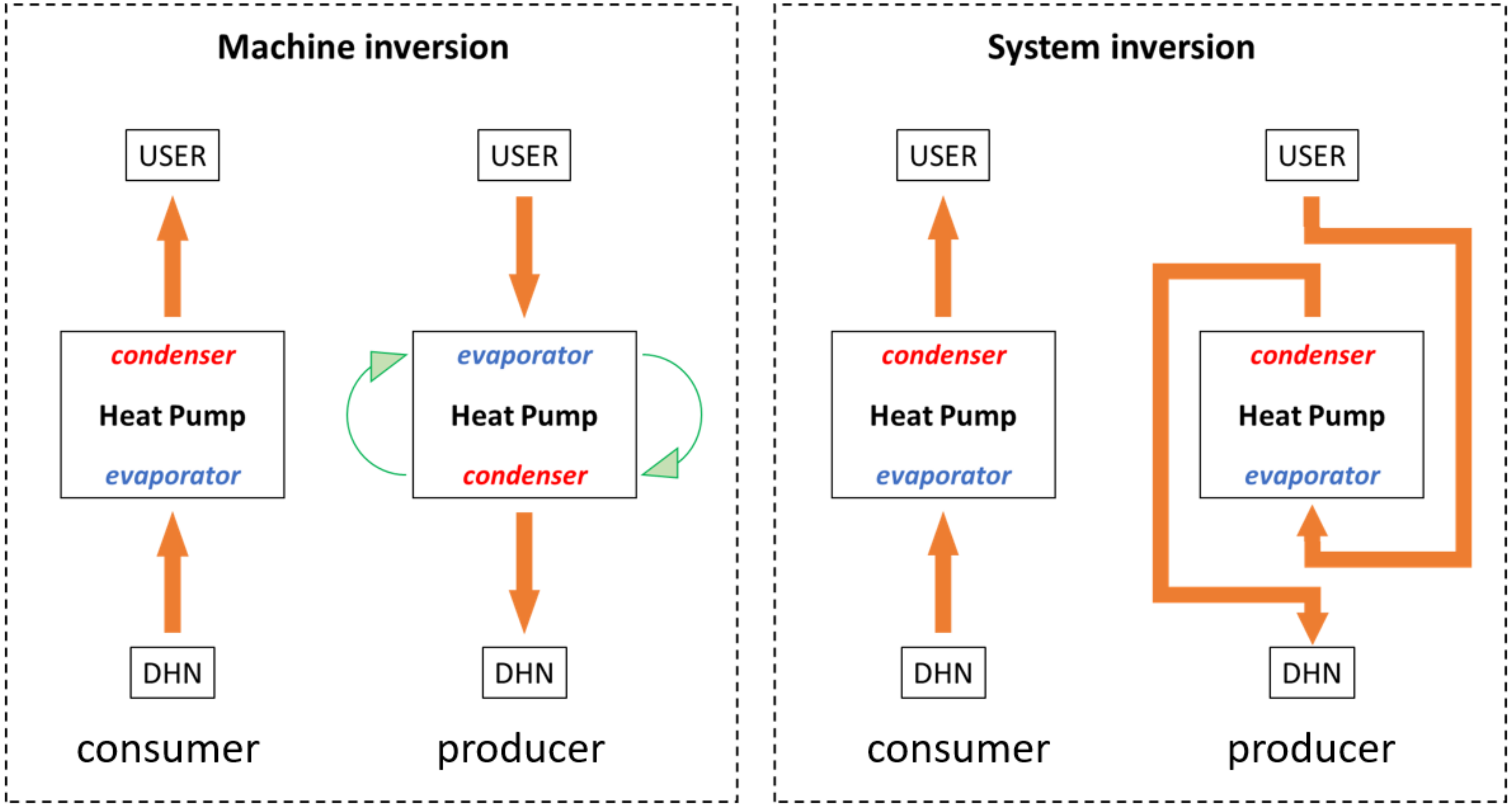
b) Producer mode: return-to-supply connection. The user withdraws water from the return line and returns it into the supply line at a higher temperature.

Other solutions involving connection to a single pipe (i.e., supply-to-supply or return-to-return connection) are also possible.

The bypass branch on the circulation pump makes it possible to keep the pump switched off if the pressure difference between the withdrawal and the returning pipe is such that the required flow rate is ensured.

General recommendations

Reversibility of monodirectional HP-skid



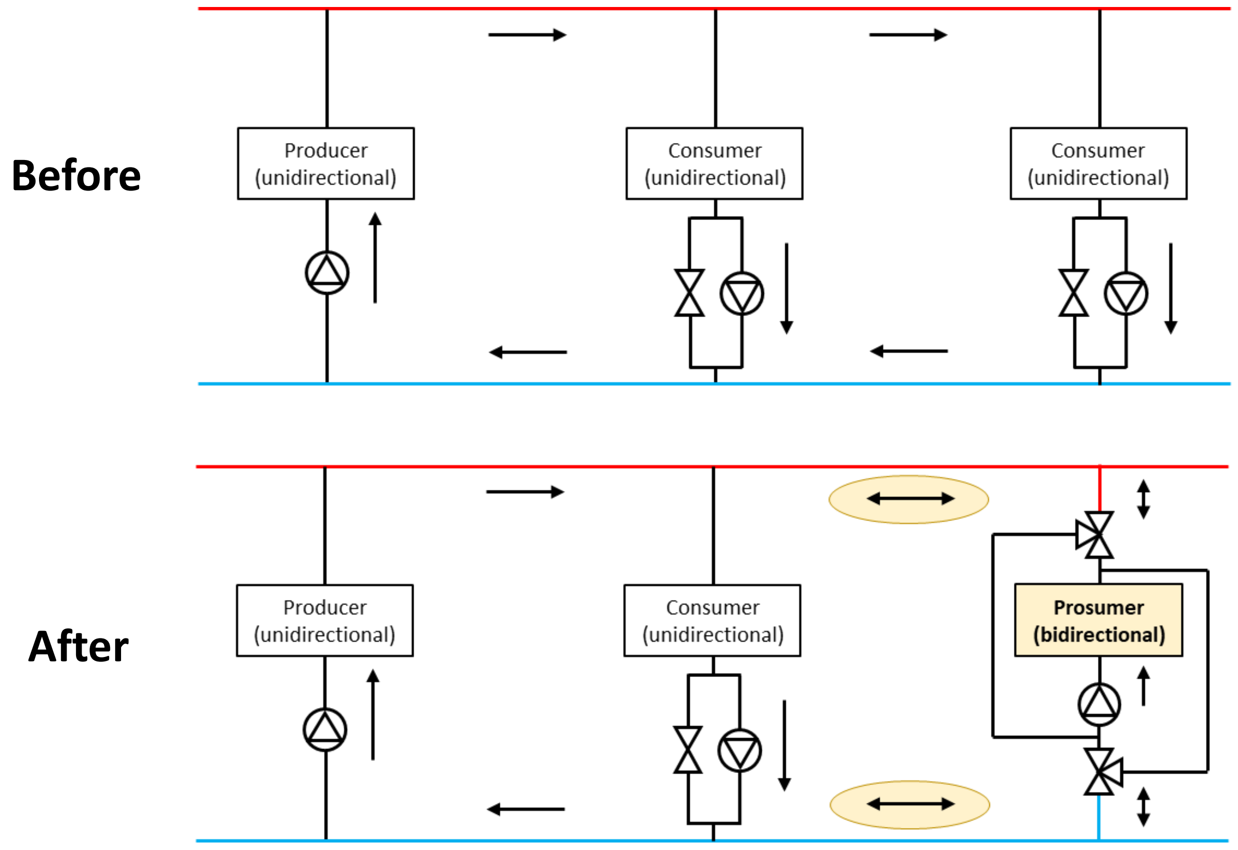
The reversibility of a HP-skid can be achieved in two different ways.

Machine inversion: reversible heat pumps are installed in the skid. Operation inversion typically requires some switching time.

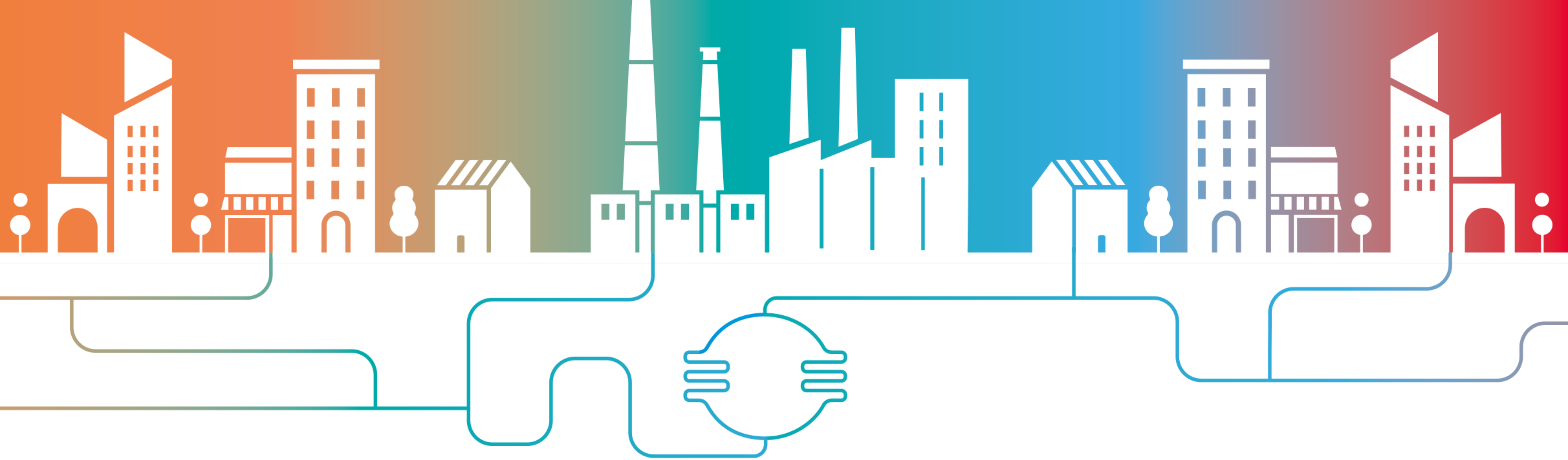
System inversion: a hydraulic configuration capable of reversing the heat source and load of the heat pumps is installed. This might allow smoother operation.

General recommendations

Integration of a prosumer into the network



The conversion of a consumer into a prosumer connected to the supply and the return pipe requires these network sections to be bidirectional.
If the network is characterized by decentralized pumping (i.e., each user has its own circulation pump), then this aspect is not critical, as shown in the figure.



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Thank you !

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