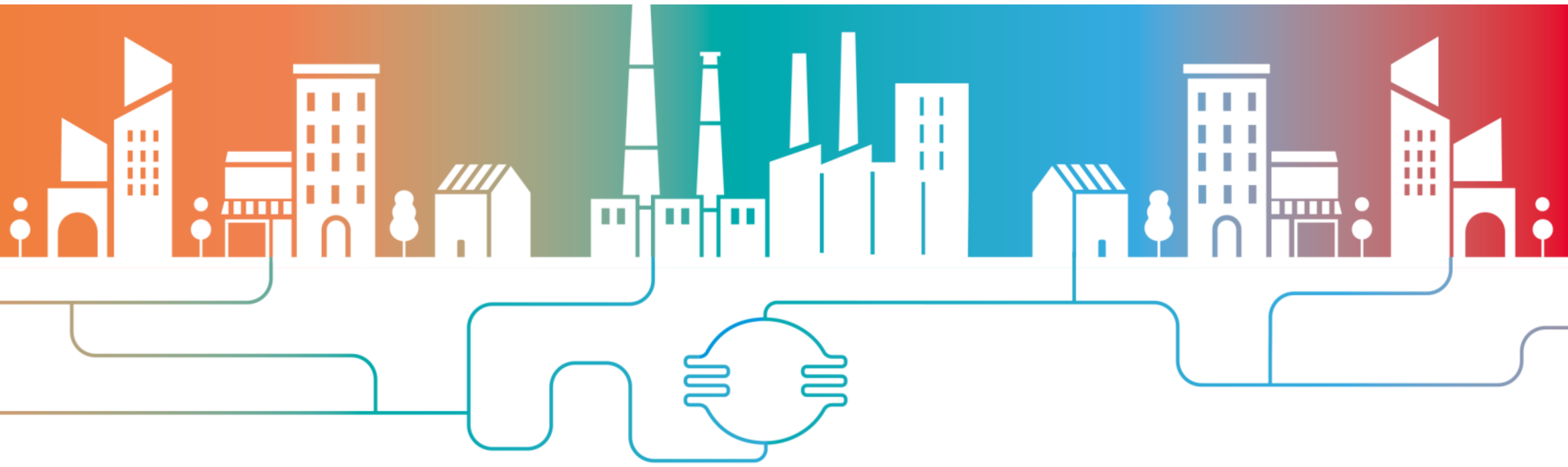
Implementation of the waste heat recovery measures at Heerlen – Action C3



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

LIFE4HeatRecovery

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

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1 Introduction

Mijnwater has an agreement with VDL Castings Heerlen for the extraction of residual heat from the cooling process of the melting and warming furnaces. Mijnwater has already realised the heat recovery plant, including the heat exchanger. The recovered heat is discharged directly to the transport network (Cluster D of the Mijnwater district heating & cooling network). The recovered heat is used as source heat for both MFA Hoensbroek and Zwembad Hoensbroek (formerly known as Swimming Paradise Hoensbroek) (see Figure 1). If excess heat is recovered it is distributed to the backbone where it can be used in other clusters within the network or to regenerate the underground.

Figure 1 – Cluster D of the district heating network in of Mijnwater.

The Mijnwater heat recovery plant contains a heat exchanger and a standard Mijnwater grid connection which includes the circulation pumps. The heat is recovered with the use of a heat exchanger on top of which a funnel is built to capture the cooling water from 5 different stream pipes. Of these stream pipes, 4 are used to cool the melting furnace and 1 is used to cool the warming furnace. After the heat is extracted, the cooling water is returned to the cooling water basin.

Currently, the cooling water from this basin is continuously passed through cooling towers to be cooled with air. Therefore, its temperature fluctuates with the seasons.

A simplified diagram of the system is provided in Figure 2. At the moment, waste heat is recovered only towards cluster D. This was considered a first project phase by Mijnwater, with a possible second phase implementing an additional system to supply heat to VDL offices, transforming the factory into a thermal prosumer. This would have required also a contractual change. The resulting system would have been conceptually identical to the system initially planned for the Dalli de Klok factory, in the same cluster. At the moment, however, the second phase is not expected to take place, due to operational difficulties at VDL.

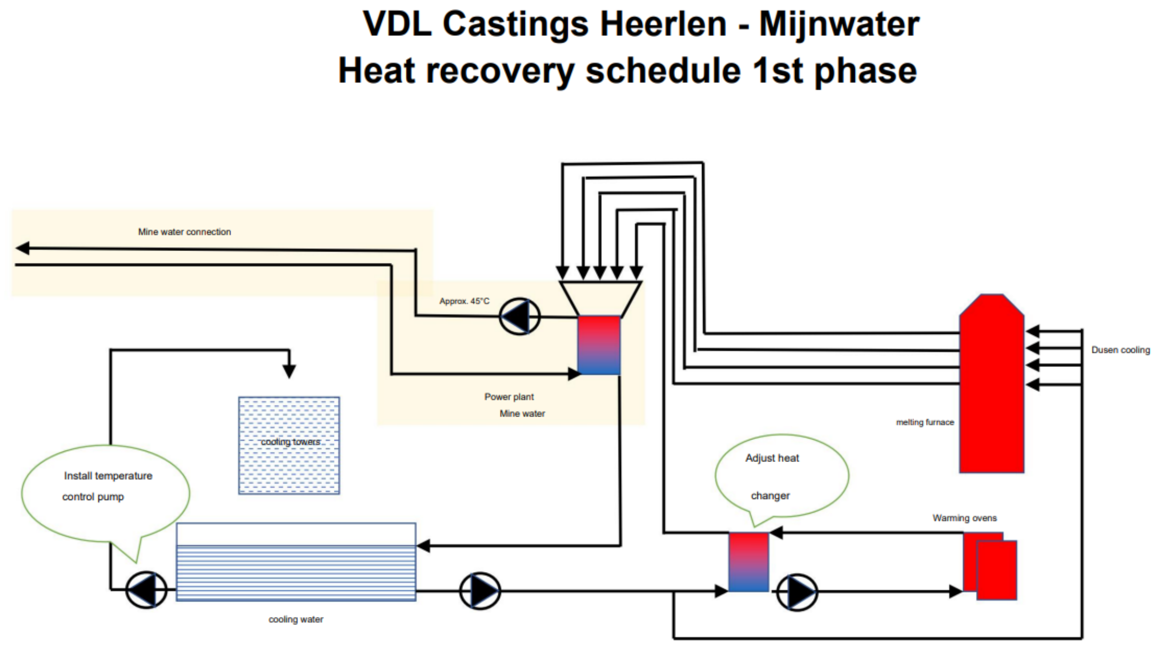

Figure 2 – Waste heat recovery system at Mijnwater case study: a simplified diagram for the first operation phase, without heat recovery towards VDL offices. A second phase was expected by Mijnwater, where internal heat recovery to VDL offices would be implemented. At the moment, the plan for this second phase could however not be implemented.

Mijnwater benefits from the highest possible temperature of the cooling water till a maximum of 42 °C (maximum operating temperature of the transport network is 40°C).

The cooling process of the ovens takes place with a minimum required temperature difference of 12-15 °C.

The temperature of the return flow of the heated cooling water from the ovens might in principle rise to approx. 55 to 60 °C in the summer months. During current operation, however, the maximum observed temperature has been about 35°C.

Currently VDL has 2 flow setpoints and can turn off their cooling towers one by one. While Mijnwater is recovering the heat, the cooling towers should hardly need to be used. Therefore, it was decided that the pumps of the cooling towers will be equipped with a temperature control that will make sure the maximum cooling temperature is not exceeded. Currently the cooling towers have been actively used and the temperature of the recovered heat is about 25-30 °C, which is in line with the maximum source temperature of the heat pumps at MFA Hoensbroek and Zwembad Hoensbroek.

Additionally, the heat exchangers between the primary and secondary cooling circuits of the warming furnaces have been designed to achieve an LMTD (logarithmic mean temperature difference) of 1° K and therefore minimise the temperature drop over the heat exchanger.

The heat from the warming ovens is continuously present (approx. 102 kW), even when there is no production (approx. 84 kW). However, the heat from the cooling process of the melting furnace is only available during the melting process. The expected peak power can reach approx. 400 kW (though higher peaks have been observed; see section 2.1) with an average power during production of approximately 227 kW.

In total, approximately 4133 GJ could be harvested on an annual basis, the majority of which is available intermittently (See Table 1).

Table 1. Table summarizing the expected main data of the WH sources at VDL. Operation hours for the furnace are estimated assuming the conservative operation of 1 shift per day (i.e., 8 h/day; maximum production would be 3 shifts per day, i.e., 24 /day) for 5 days per week, with 48 weeks per year. This conservative assumption reflects the current situation observed at VDL. The warming oven is instead assumed always active for 48 weeks per year.

Quantity	Unit	Furnace	Warming oven	Total
Peak power	kW	400	102	502
Average power	kW	227	102 when furnace on, 84 in weekend	About 300
Operation hours	h/y	1920	8064	8064
Yearly energy	GJ	1570	2563	4133

2 Installation Description

2.1 VDL Heat Exchange Station

2.1.1 Technical Description

As mentioned in section 1, the heat exchange plant consists of a heat exchanger with a funnel built on top to collect the cooling water from both the warming and melting furnace. In figure 3 a 3D model of the installation is included. The Mijnwater installation also includes a pump group to circulate the required water over the cluster installation to discharge the extracted heat to the grid. A high resolution P&ID scheme is made available as a separate attachment to this document.

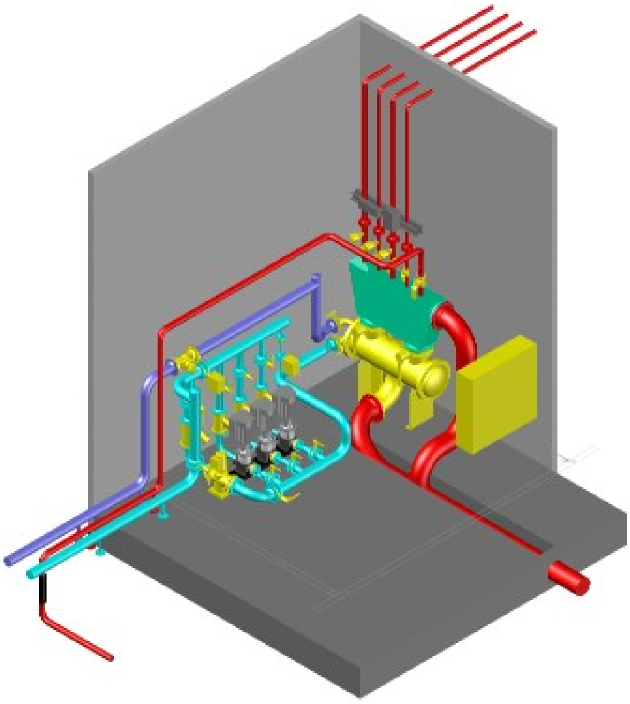

Figure 3: 3D-model of the heat exchange station at VDL.

2.1.2 Tie-in to production process

VDL makes uses of a centralised cooling reservoir which collects all the cooling water and is kept in control by the cooling towers. The heat exchanger with Mijnwater is implemented in the return flow towards this cooling reservoir. Therefore, if the installation is turned off, the warm cooling water is returned to the reservoir and cooled down by the cooling towers instead.

The flow through the cooling system should be temperature controlled in order to maintain nominal operational parameters. At the funnel, one temperature sensor in one stream pipe is implemented. There is no flow sensor present on the VDL side that Mijnwater can use, but there are sensors on Mijnwater side (see below for details).

Mijnwater therefore maintains a minimum discharge temperature of 25°C for the recovered heat to the grid. If the temperature decreases, the flow will be decreased until the temperature reaches this minimum temperate again. If the temperature increases the flow rate will be increased to a maximum of about 50 m^3/h (the control has a tolerance of +/- 5 m^3/h depending on pressure gradients within the grid).

The source temperature for the process from Mijnwater is on average 18°C, but can fluctuate by a couple of degrees depending on network conditions. The maximum discharge temperature allowed in the network is 45°C. Therefore, the maximum theoretical power that can be discharged is about 1700 kW.

2.1.3 Monitoring

Mijnwater makes use of Priva Blue ID building automation hardware and software. Measurements of all sensors are collected with the use of the automation software. Measurement resolutions vary depending on measurement.

For VDL the following data is recorded with their corresponding measurement interval:

Measurement Point	Unit	Measurement Interval	Remarks
Supply Temperature Mijnwater	°C	1 minutes	
Return Temperature Mijnwater	°C	1 minutes	
Flow Mijnwater	m^3/h	1 minutes	
Power	kW	1 minutes	
Energy usage circulation pump 1	kWh	1 hour	Indirect measurement from pump
Energy usage circulation pump 2	kWh	1 hour	Indirect measurement from pump
Energy usage circulation pump 3	kWh	1 hour	Indirect measurement from pump

There is no useful data available for the VDL side of the heat exchanger, other data is recorded, like network pressure, for operational or maintenance purposes.

2.1.4 Initial results

While heat recovery started earlier, in terms of monitoring the installation has become fully operational in early January 2024. Operational data from the monitoring is available since the 26th of January.

During the month of February an average power during operation of 278 kW has been recorded and a peak power of 768 kW. It is expected that during warmer months this average and peak power will increase. However, when the melting furnace is not in use, the cooling water temperature of VDL decreases to below 25°C. It is expected that the flow of the cooling water is not reduced, which results in a significant decrease in temperature. Due to this lower temperature Mijnwater is currently unable to capture the residual heat from the warming oven outside of working hours.

2.2 Swimming pool Hoensbroek

2.2.1 Technical Description

The swimming pool at Hoensbroek uses 2 different temperature ranges, 65-45 °C and 55-35 °C. These temperatures are created by the use of 8 SWP561H heat pumps. The warm water from the grid is used as the heat source for these heat pumps. The 3D substation image is reported in Figure 4. A high resolution P&ID scheme is made available as a separate attachment to this document.

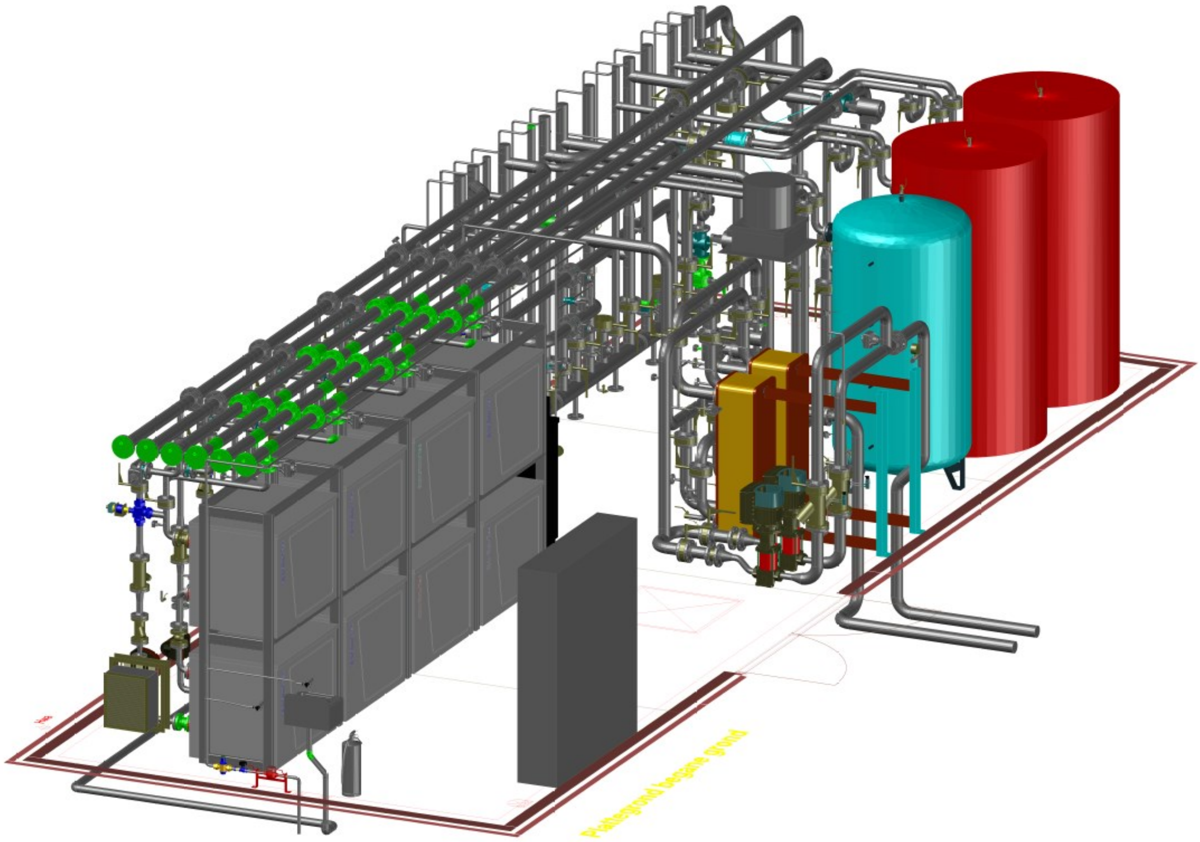

Figure 4 – 3D drawing of the swimming pool substation. One can recognize the 4 pairs of skid-mounted heat pump modules of the left.

A small buffer is present for each heating temperature and for the cooling side. These buffers are used to bridge the period of time it takes to turn a heat pump on or off.

The installation is connected via the grid in the same way as VDL, with the use of a circulation pump group and a heat exchanger.

Table 2: Table summarizing the main data of the Swimming Pool (average power and energy is estimated based on observational data)

Quantity	**Unit**	**Low Temperature (LT)**	**Medium Temperature (MT)**	**Total**
Peak power	kW	555	740	Max. 740 combined
Average power	kW	263	131	394
Operation hours	h/y	8760	8760	8760
Yearly energy	GJ	5400	3000	8400

Circulation pumps are used to provide both LT and MT to the client, these pumps are controlled based on pressure difference between supply and return flow. Therefore the system is entirely demand based.

The heat pumps are installed in 4 skids, each skid contains 2 heat pumps in series, circulation pumps for the condenser and evaporator side, temperature control valves and additional sensors. These skids can be switched between LT or MT, but can only be used for a single temperature regime at a time. The use of heat pumps is also entirely demand driven.

2.2.2 Monitoring

Mijnwater makes use of Priva Blue ID building automation hardware and software. Measurements of all sensors are collected with the use of the automation software. Measurement resolutions vary depending on measurement.

For the Swimming Pool the following data is recorded for the study with their corresponding measurement interval:

Measurement Point	Unit	Measurement Interval	Asset tag P&ID
Supply Temperature Mijnwater	°C	1 minute	00TT05
Supply Temperature LT	°C	1 minute	40TT01
Supply Temperature MT	°C	1 minute	60TT01
Number of heat pumps in use for LT	-	1 minute	n.a.
Number of heat pumps in use for MT	-	1 minute	n.a.
Flow LT	m^3/h	1 minute	40FqL01
Flow MT	m^3/h	1 minute	60FqL01
Flow Mijnwater	m^3/h	1 minute	00FqL01
Supply Temperature Condensor MT	°C	1 minute	09TT04
Supply Temperature Condensor LT	°C	1 minute	09TT03
Supply Temperature Evaporator	°C	1 minute	19TT01
Return Temperature Mijnwater	°C	1 minute	00TT03
Return Temperature LT	°C	1 minute	41TT02
Return Temperature MT	°C	1 minute	60TT02
Return Temperature Condensor LT	°C	1 minute	09TT01
Return Temperature Condensor MT	°C	1 minute	09TT02
Return Temperature Evaporator	°C	1 minute	19TT03
Electricity Consumption Installation	kWh	Daily	n.a.

2.2.3 Initial Results

The installation for the swimming pool has started production on August 1st. Over the past several months an average power of 400 kW has been recorded. Initial problems with very high return temperatures causing low COP have been solved. Based on the average recorded power a yearly energy consumption of 8400 GJ is expected.

Weather effects like outdoor temperature appear to be minimal. It has been observed that different attributes like waterjets in the recreational bath and increasing water temperature for specific groups of people have a much larger effect on energy usage than outdoor temperature.

Currently an average COP of about 3.8 since production started has been measured. This COP includes all electrical components of the installation, although an average energy usage of 90% by the heat pumps is estimated.

3 Installation Construction

3.1 VDL waste heat recovery substation

Most of the equipment was already in place before the realization of the LIFE4HeatRecovery demo, as contacts between Mijnwater and VDL already occurred. However, heat recovery was not active and the system needed to be refurbished. A full maintenance of the pump station was needed (pumps were sent back to supplied for a check) and a new monitoring system had to be installed (with full operation started in January 2024). Below, some pictures of the refurbished pipes and of the monitoring modules are shown.

Figure 5 – Pictures of the refurbished pipes and of the pump station at VDL.

3.2 Swimming pool Hoensbroek

For completeness, we report here the main swimming pool operational data:

Swimming pool accommodation	GFA = 7200 m^2
Low Temperature circuit	55-35 ˚C, 555 kW
Mid Temperature circuit	65-45 ˚C, 185-740 kW
Power connection	400 kVA

The installation of the swimming pool substation was completed in 2023. Below, some installation pictures are reported.

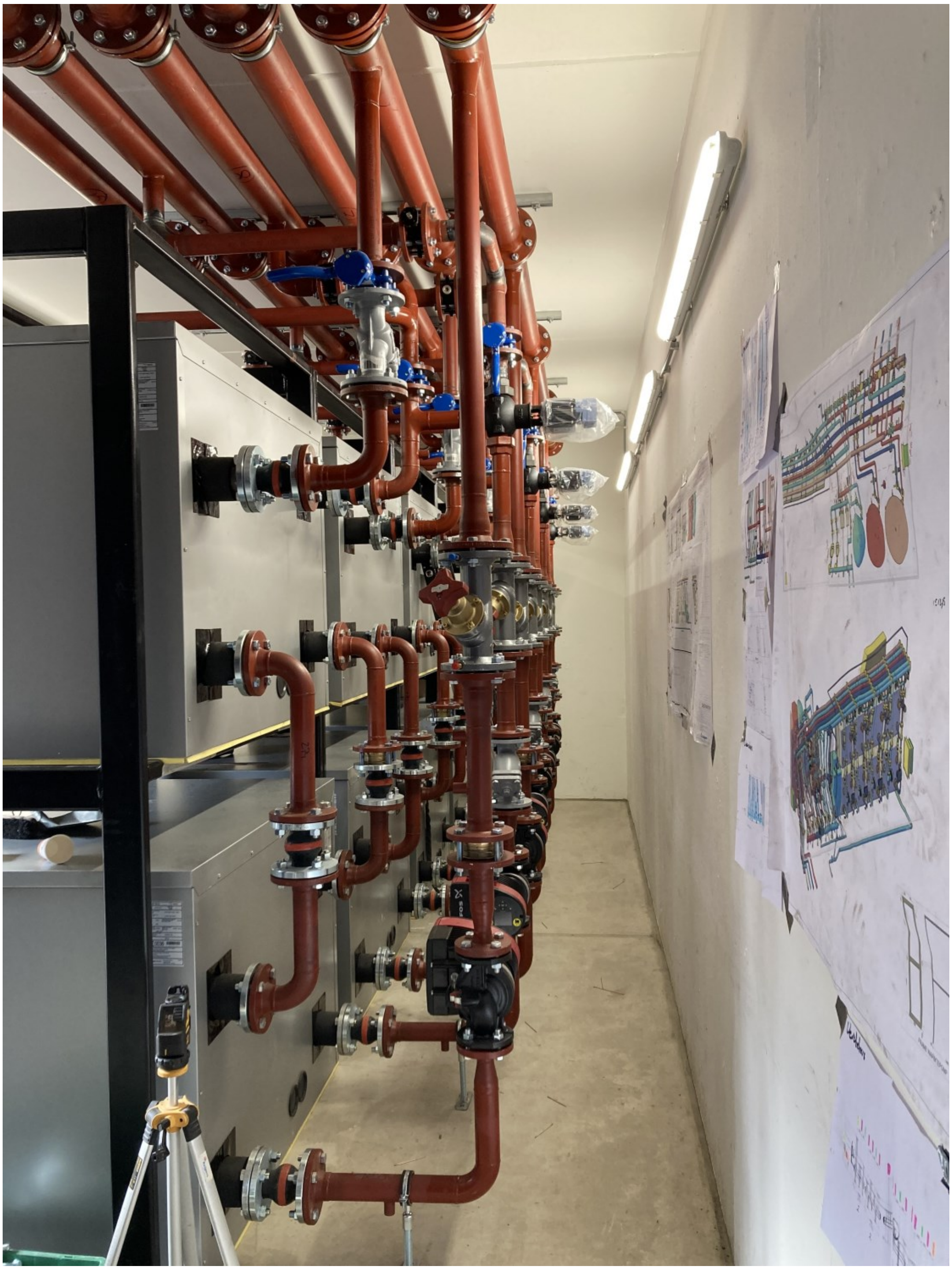

Figure 6 – The skid mounted heat pump modules at the swimming pool.

Figure 7 – Other pictures of the swimming pool substation.

Figure 8 – Details of heat pump nominal data and of the machine interface.

4 Conclusions

The overall timline of the project articulated on a significant time range:

- June 2021 start re-build and renovation swimming pool
- October 2021 start build Energy plant swimming pool
- 1 august 2023 opening swimming pool
- renovation system VDL July 2023
- new software VDL system October 2023

This timing was strongly affected by the building renovation process of the swimming pool. In the presence of an already operational user, a faster commitioning would be possible.

In terms of operation, more changes would need to be made in the control system on the VDL cooling side to increase the constant return temperature, so that it allows for waste heat recovery of the warming furnaces outside of office hours.

The average waste heat power appears to be in line with the expected design and might be even higher than anticipated. It is also worth noting that the peak power from the waste heat recovery is significantly higher than expected.

Power demand in swimming pools is highly dependent on indoor equipment in use and the effects of outdoor temperature are minimal.

Overall, all installations were successful and apart from possible further minor control optimizations the system is working properly.