

D6.5 - Report on installation activities



Renewable and Waste Heat Recovery for Competitive District Heating and
Cooling Networks

REWARDHeat



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1 Introduction

The REWARDHeat project aims to enhance urban district heating and cooling (DHC) networks by integrating renewable energy sources and waste heat recovery technologies. This effort focuses on developing competitive, low-temperature DHC networks across various European cities, transforming how these networks manage energy to meet both environmental and operational objectives. The project involves construction, retrofitting, and testing of advanced heating and cooling solutions across multiple demonstration sites, each presenting unique applications and innovations.

This document summarizes the outcomes achieved across these sites, detailing construction activities, objectives, and technical approaches adopted in cities including Albertslund (Denmark), Gardanne (France), Helsingborg (Sweden), Milan (Italy), Mölndal (Sweden), Szczecin (Poland), and Topusko (Croatia). Each demonstration showcases diverse methods to harness renewable energy and waste heat.

This report documents challenges encountered as well as achievements, and showcases DHC networks' substations P&I diagrams, together with relevant pictures testifying the construction works at the demonstration sites.

2 Albertslund, Denmark

2.1 Description of the demonstration site

The case study of Albertslund is located about fifteen kilometres west of central Copenhagen. Currently, the existing DHN supplies heat to a major portion of the municipality. The DHN was initially built in 1964 and covers around 90% of the municipality's thermal demand.

This network is connected to the Greater Copenhagen DH transmission network, which integrates heat produced by waste incineration, CHP plants and peak-load boilers, and provides most of the heat uses throughout the year, i.e., 100 MW of heat capacity from the transmission company *VEKS*, supplied at 100-110°C.

Additionally to withdrawing energy from the backbone, natural gas and oil boilers are also set up as local reserve sources, accounting for 145 MW of capacity installed, while waste heat from a data centre (0.35 MW approximately, recovered at ~20°C) is also supplied nearly constantly to the DHN by means of a heat pump.

Around 270 GWh are distributed along the DHN and 220 GWh are finally supplied to end users yearly.

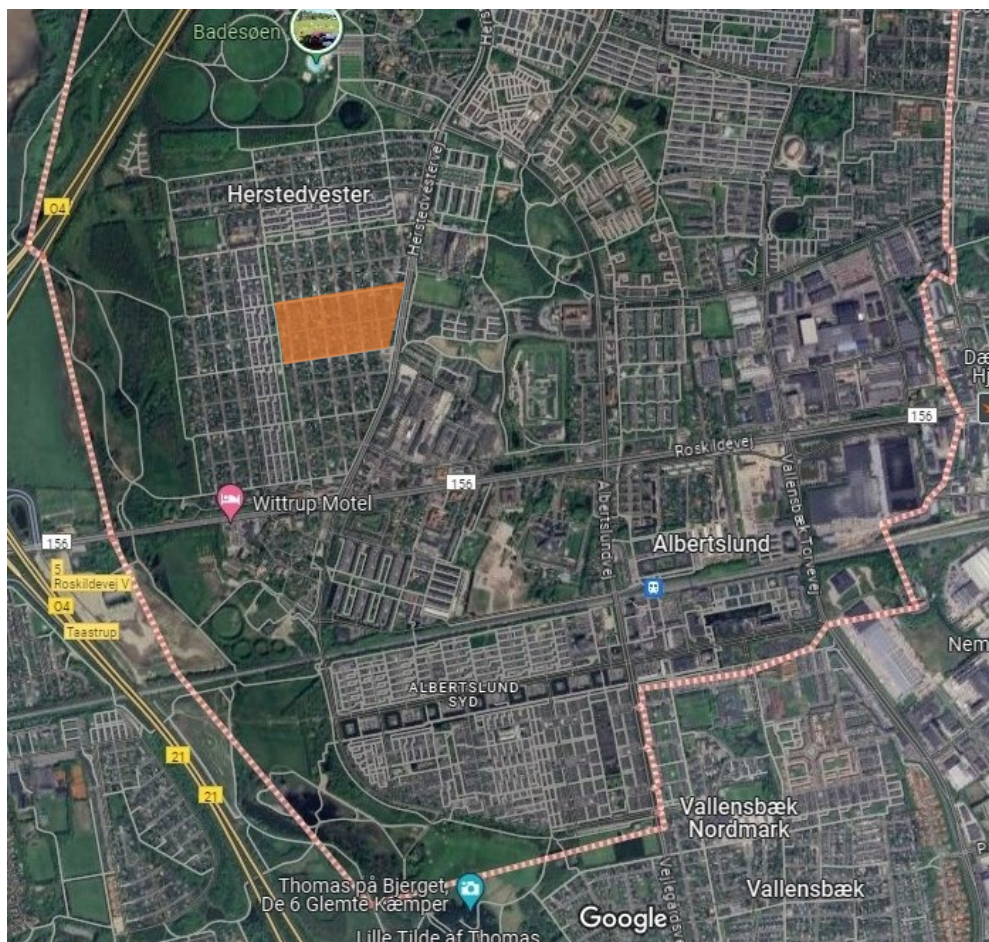


Figure 2-1 – Albertslund municipality; Porsager district in orange

2.2 Objectives of the demonstration activity

The project involves two partners: Albertslund Forsyning's, the municipal utility company who manages the DHN and Artelys who have developed the datamining and optimisation tool.

Albertslund Forsyning's overall energy efficiency strategy focuses on moving from a 3rd generation, high-temperature (i.e. 85°C) and centralised DHN, to a 4th generation system with lower supply temperature (i.e. 60°C) and a more distributed heat generation. To implement their strategy, a range of activities is foreseen addressing both heat distribution and distributed generation.

In the framework of the REWARDHeat project, effort has been placed on lowering the supply temperature to a subnetwork, consisting of around 110 residential houses in Porsager, an area in the South-East of Albertslund. This has been pursued by:

- Installing a shunt valve to lower the district heating supply temperature from 85°C to 60°C across the entire area. This measure follows an extensive retrofit of most of the district's homes, completed in recent years in collaboration with Albertslund Forsyning. The change occurred on the fourth of January 2021.
- Developing a datamining software to gather and structure monitoring data from two separated SCADA solutions in place and enable implementing performance optimisation through continuous supply temperature modulation (led by Artelys within WP5 scope).
- Exploration of a data-based approach to minimize DHN operation costs. In particular, it aims at adapting the operation of the shunt in order to control the return temperature under a certain threshold to prevent maluses and foster bonuses. (Incidentally reducing heat losses too) (led by Artelys within WP5 scope)

2.3 Description of the Results Achieved

Grundfos, with its iGrid system, was selected as the supplier of shunt valves and associated control systems. Under current legislation, no tendering process was required, and all necessary construction permits, specifically for the excavation work related to the shunt installation, were obtained. As the land is municipally owned, no additional permits were needed.

The shunt valve combines hot supply water from the main pipe with cooler return water to supply the 105 houses in Porsager with water at 60°C. Initially, it was thought that some properties might not be compatible with low-temperature district heating, potentially requiring booster heat pumps. However, after installing the shunt valves, no issues emerged, so booster substations to further heat the water were unnecessary.

The shunt was installed in late 2020, and while the temperature reduction caused minor initial problems for a few consumers in the area, the shunt operated with a higher supply temperature initially, allowing for a comparison of grid loss before and after the temperature adjustment. Albertslund Forsyning first ensured that the shunt was functioning optimally before gradually lowering the supply temperature while monitoring each home's performance. The reduction to 60°C presented minimal issues; technical interventions and substation adjustments were required for only four homes, with one substation needing a complete replacement. Since February 2021 the entire Porsager quarter—comprising homes built in the 1960s—is supplied with low-temperature DH. Building on this experience, 400 additional homes have since been converted from gas to LTDH.

Following the shunt valve installation and the commencement of LTDH operations, emphasis has shifted towards refining data flow and applying insights gained throughout the project. Consequently, the shunt system has been integrated into the central SCADA system, with ongoing discussions around cybersecurity, data accessibility, and data flexibility. The shunt is controlled through an online platform, which requires SCADA system communication with a hosted platform. Communication occurs via GSM, which presents some limitations in connection stability. However, the shunt can operate independently, so daily operations are unaffected.

The SCADA web interface requires rigorous verification of cybersecurity measures but also opens new possibilities. In Denmark, Open Data spaces are being explored for district heating to support sector integration, optimise flexibility services, and enhance innovation by leveraging production and consumption data on a broader scale.

Throughout the project, data mining has been explored in partnership with Artelys (see Deliverable 5.9), focusing on data collection from the SCADA system and consumer billing meters. This enables direct comparison between produced and consumed heat, facilitating more accurate grid loss assessments. While grid loss measurements were possible before, automating data collection now enables advanced modelling and optimisation techniques.

Key takeaways from Porsager indicate that the existing housing stock in Albertslund and across Denmark is more compatible with low-temperature DH than previously assumed. Shunt valves increase flexibility in the use of existing DH networks, and collaboration with Artelys has proven valuable for forecasting and KPI monitoring. These methodologies are planned for integration into routine operations.

Starting in January 2026, Albertslund will begin lowering the temperature in the entire DH network, which will be divided into 30 zones, each managed by shunt valves to ensure flexibility.

2.4 Technical Drawings

Figure 2-2 and shows Albertslund's district heating network with a focus on the Porsager area and the location of the shunt valve in blue.

Figure 2-3 and Figure 2-4 show the shunt valve simplified P&I diagram and 3D construction plan.

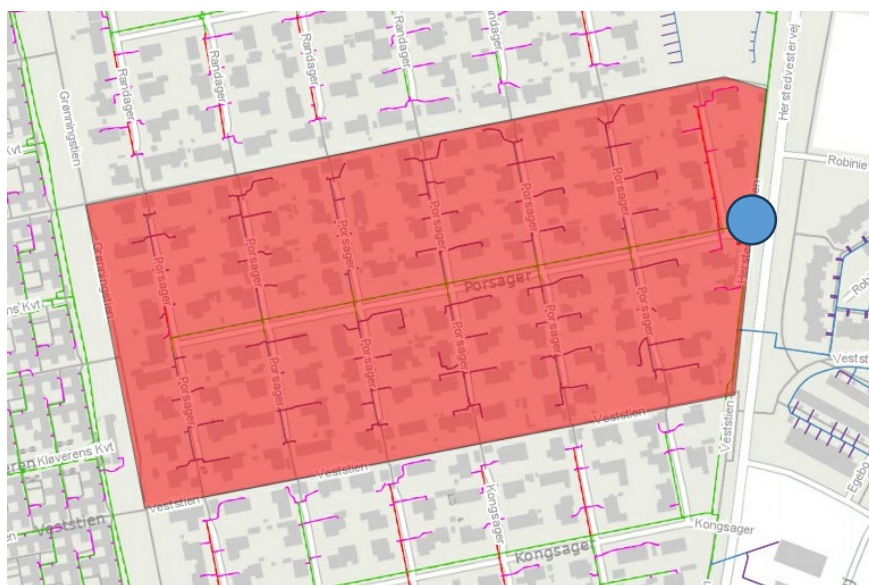


Figure 2-2: Focus on the Porsager district and position of the shunt valve.

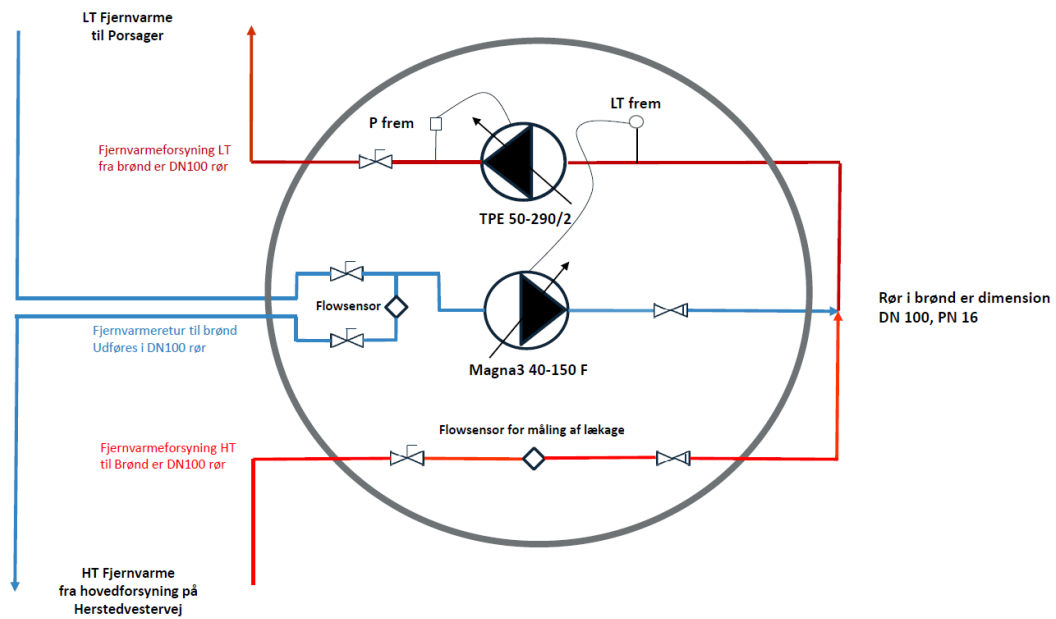


Figure 2-3: Shunt valve simplified P&I diagram

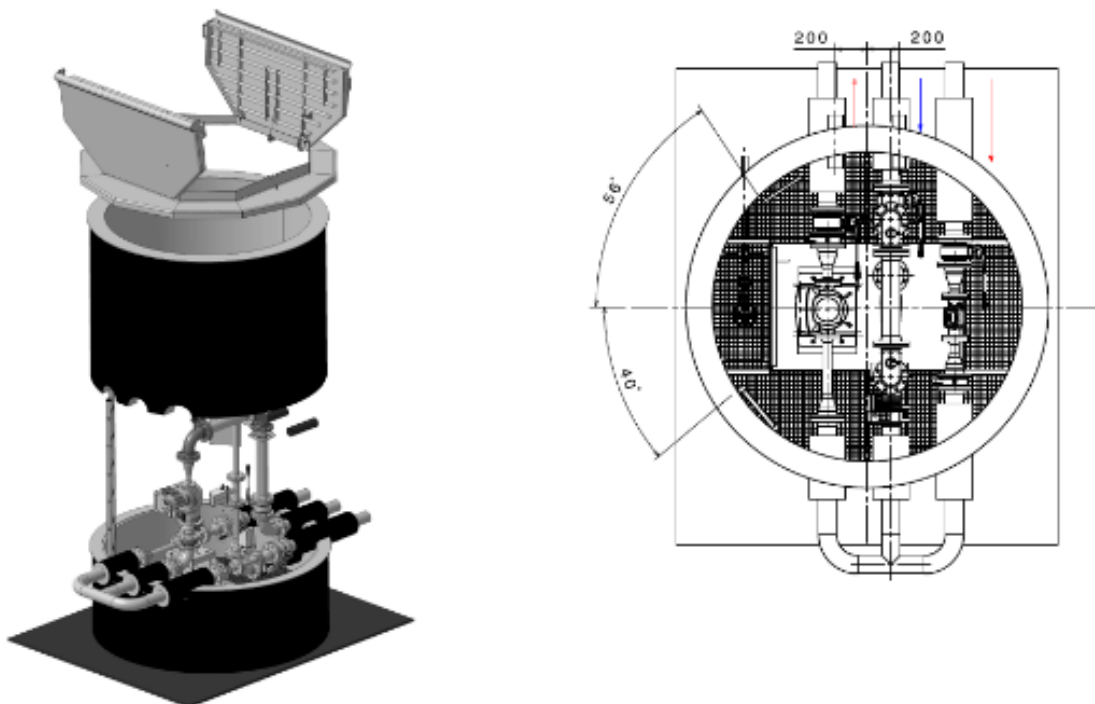


Figure 2-4: Shunt valve assembling drawing provided by Grundfos

2.5 Pictures of the Construction Works

The following pictures show the works for the installation of the shunt valves in the Porsager area.



Figure 2-5: Installation of the Shunt valve - 1



Figure 2-6: Installation of the Shunt valve - 2

3 Gardanne, France

3.1 Description of the demonstration site

Located in the town of Gardanne, the site is an historic coal-mine, operated between 1989 and 2003 and is the largest mining well in Europe, with 1100 m depth, 10 m diameter, currently filled with water as the rest of the mining complex ensuring the geological stability of the terrain. Through the launched district sized real-estate development project the site aims at becoming the economic hub of the territory with very stringent energy, environmental and social requirements offering 80000 m² of offices, companies, or hotel, aiming thus at becoming the driver for employment and social integration in Gardanne. Additionally, it aims at hosting cultural activities with a sciences museum for improving education, science and innovation. The complex is fed by a thermal and electric smart grid, cooling and heating the «Yvon Morandat Well» district.

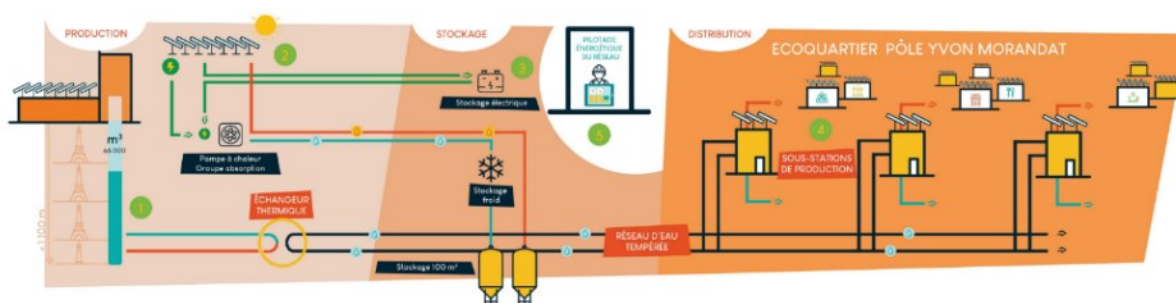


Figure 3-1 : Schematisation of the site's working principle, integrating the thermal and electric smart grids.

Source: DALKIA.

The network is partially delivered: the network already connects 3 tertiary and commercial customers and 3 more are under construction, with a foreseen total heating demand of about 2,198 MWh/year and a cooling demand of about 1,425 MWh/year.

The main neutral-temperature network is used for both DH/DC and operates at a temperature between 7-29°C. The extraction depth is at -950 m and injection happens at -264 m, whilst the whole shaft is equipped with a 1 km long optic fibre for temperature data acquisition. Moreover, the system was initially equipped with a 230 kWp PV plant, which produced energy is self-consumed by the network, thanks to a cascade of installed storage means (2x 50m³ water tanks, a 200 kW Li-Ion BESS and 40 kW second-life BESS as well as an ice-storage).

Once completed, the DHCN should account for a 1,3 km long neutral-temperature network and produce 2.1 GWh/y of heating energy and 1.4 GWh/y of cooling energy.

3.2 Objectives of the demonstration activity

The demonstrator leans on the currently developed neutral-temperature DHC network. The project partners involved are ENERGIE SOLIDAIRE, DALKIA and EDF that collaborate to achieve the following goals:

- Set up of PV fields combined with different storage solutions (thermal, electric) to reduce electricity consumption from the grid

- Optimization of RES utilisation and energy balancing across the DHC network, to foster “energy solidarity”, by integrating production/load forecasts and new optimized operation modes in the automation system
- Utilization of the water well as a seasonal storage aimed to balance injection/extraction of energy in the mineshaft
- Design and set up of a permanent exposition on DHC ,i.e., the “House of Energy”, with dedicated guided tours to explain through visual media, renewable based DHC networks.

3.3 Description of the Results Achieved

In terms of asset deployment, the main energy storage and heating/cooling generation systems have been delivered and are operational. The project’s work on these assets focused on integrating them efficiently, with particular attention to control and hydraulic systems.

Set up of PV fields and electricity sharing: As shown in Figure 3-2, Substation 1 has been upgraded to integrate with Substation 4 for shared heating, cooling, and PV energy delivery. Copper wiring has been laid to allow PV energy generated at Substation 4 to be conveyed directly to Substation 1’s switchboard, helping increase the renewable energy ratio within the network. A total of 90 kWp is planned for Substation 4, with phased installation of 30 kWp per building. Discussions are ongoing with building owners at Substation 2 to explore integrating further PV capacity into the DHCN.

The overall network’s control system has been thoroughly revised to include smart integration of solar energy metering (one pyranometer), PV curtailment monitoring, PV forecasting via SolarGIS (providing hourly forecast, 24 hours ahead that accounts for shadowing from surrounding buildings and system efficiency), and improved management of the storage and generation cascade. The pyranometer measures solar radiation intensity and duration, providing real-time reference values for PV production and efficiency. This data is essential for evaluating curtailed energy, as the PV system is designed without grid injection, leading to curtailment of any excess energy.

The objective function of this initiative is to reduce PV curtailment, redirecting energy to storage assets to improve the network’s overall carbon footprint and increase the substation’s performance.

Thermal energy sharing among substations: The “energy solidarity” initiative focused on thermal energy exchanges among substations to balance network demands, particularly from Substations 5 and 6 to Substations 1 and 2.

Efforts have centred on enabling Substation 1 to manage the neutral-temperature DHCN temperature and, if necessary, serve as a backup source for the mineshaft. Hydraulic connections and control systems have been integrated between Substations 1 and 2, achieving secure energy sharing (Figure 3-5 and Figure 3-5). Key modifications in each substation include:

- Substation 1: A new variable speed pump was installed to decouple the thermal storage from the network, allowing it to function independently and absorb surplus PV energy via an air-to-water HP. Smart control valves were also installed to maintain network stability during mineshaft outages, ensuring energy delivery to customers.

- Substation 2: A new heat exchanger was added to ensure network reliability using the air-to-water HP during mineshaft malfunctions. Smart control valves were also introduced to maintain stable operations during outages. Existing pumps were upgraded to variable-speed models to better balance loads on the heat pump and overall network.

With the completion of Substation 1's upgrades in late 2022, it has been operational in balancing the network, injecting 695 MWh of heating and 458 MWh of cooling in 2023. This enhancement has provided resilience against mineshaft outages, and all related controls are now integrated into the site's smart control system.

Mineshaft as a seasonal storage: Regarding the mineshaft, the objective is to utilise data from a one-kilometre optic fibre that gathers temperatures at various depths, along with knowledge of the well's behaviour, to develop an optimised operational strategy for the DHCN, as this approach leverages seasonal energy variations and the well's storage capacity. Data extraction and analysis revealed unexpected complexities in the temperature profiles, leading to the decision to abandon this optimisation activity (see Deliverable 4.9).

Particularly, an initial assessment of the shaft's temperature data has revealed that external factors, independent of water and energy injection/extraction activities in the DHCN, are causing temperature variations and water movement within the shaft. This finding led to a larger study in collaboration with BRGM (France's national public institution for Earth Science applications, specialising in the management of surface and subsurface resources and associated risks). Results confirmed the preliminary assumptions: the well is directly influenced by the nearby Gerard well and its pumping activity. Additionally, significant water infiltration occurs due to a local aquifer (contributing one-third of the infiltration) and rainwater infiltration from neighbouring valleys (accounting for two-thirds).

House of Energy: The House of Energy (HoE) has been placed in the historic mining building, at the heart of Pôle Yvon Morandat - Gardanne. The centre, located in such dynamic economic area, has as objective to propose different activities to create a dialogue among stakeholders. It opened in 2023, with a special focus on schools and students, with an objective of 1000 visitors per year at the horizon 2028. With about 300 m², the HoE offers guided visits accompanying visitors through 2 main spaces:

- A pedagogic area to introduce general concepts of local innovative energy systems to the public, thanks to innovative scientific media (as augmented reality, collaborative games or physical manipulations, Figure 3-14 and Figure 3-15).
- The main building's substation revamped and set-up to this purpose. Visitors are able to see real-life application of REWARDHeat technologies. Here, the 2 existing HP (about 100 kW) are kept in place, and DANFOSS prefabricated substation and THERMAFLEX pipes added to the system (Figure 3-16, Figure 3-17 and Figure 3-18).

3.4 Technical Drawings

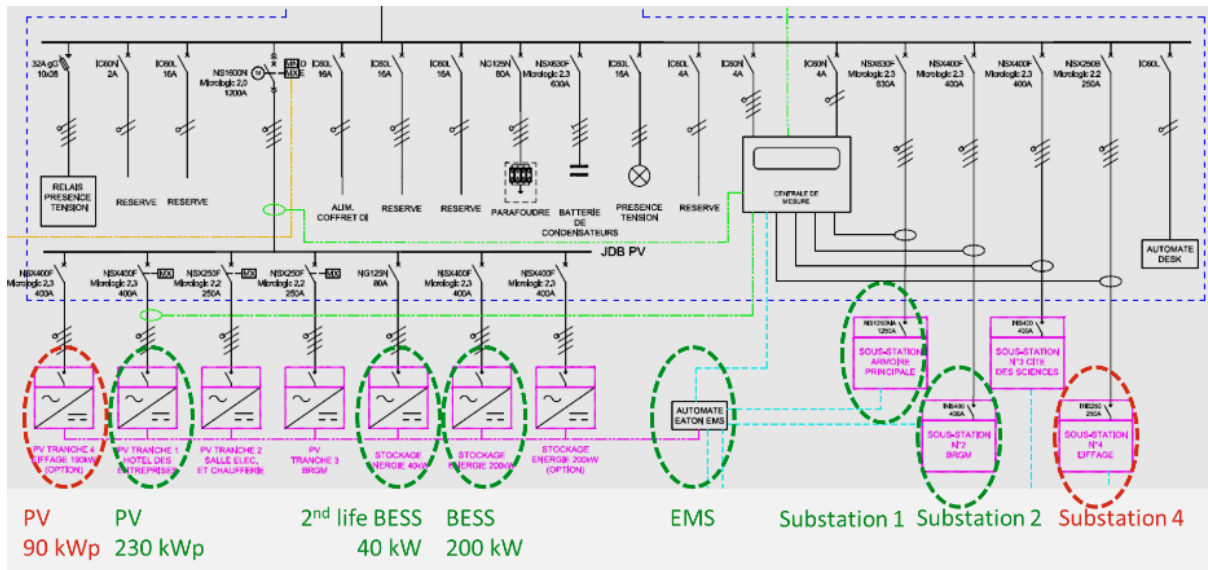


Figure 3-2 - Scheme of the electric switch board of the DHNC and assets' connection progression - pre-existing assets (green) and the ones ready for connection (orange). Source: DALKIA

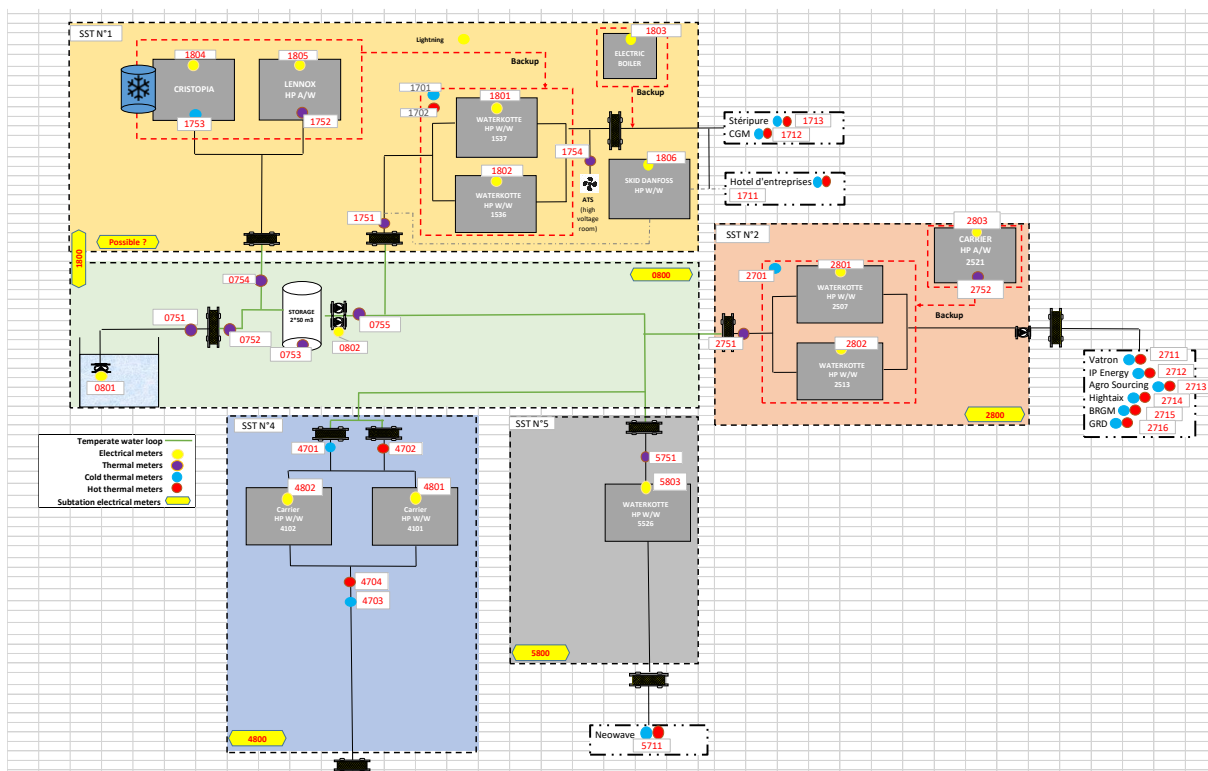


Figure 3-3: Simplified scheme of the Gardanne DHCN and operational substations. Source: DALKIA

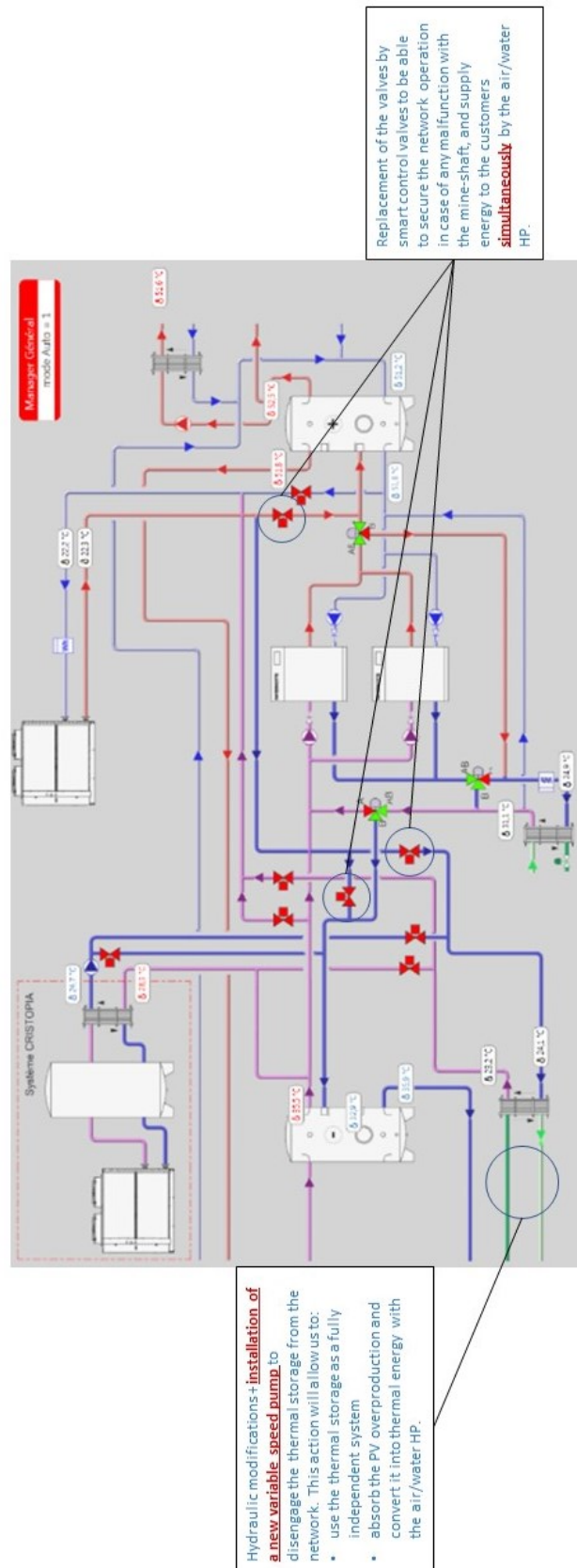


Figure 3-4: Main hydraulic modifications for the energy solidarity action on Substation 1 with smart control valves, variable speed pumps and the added heat exchanger. Source: DALKIA

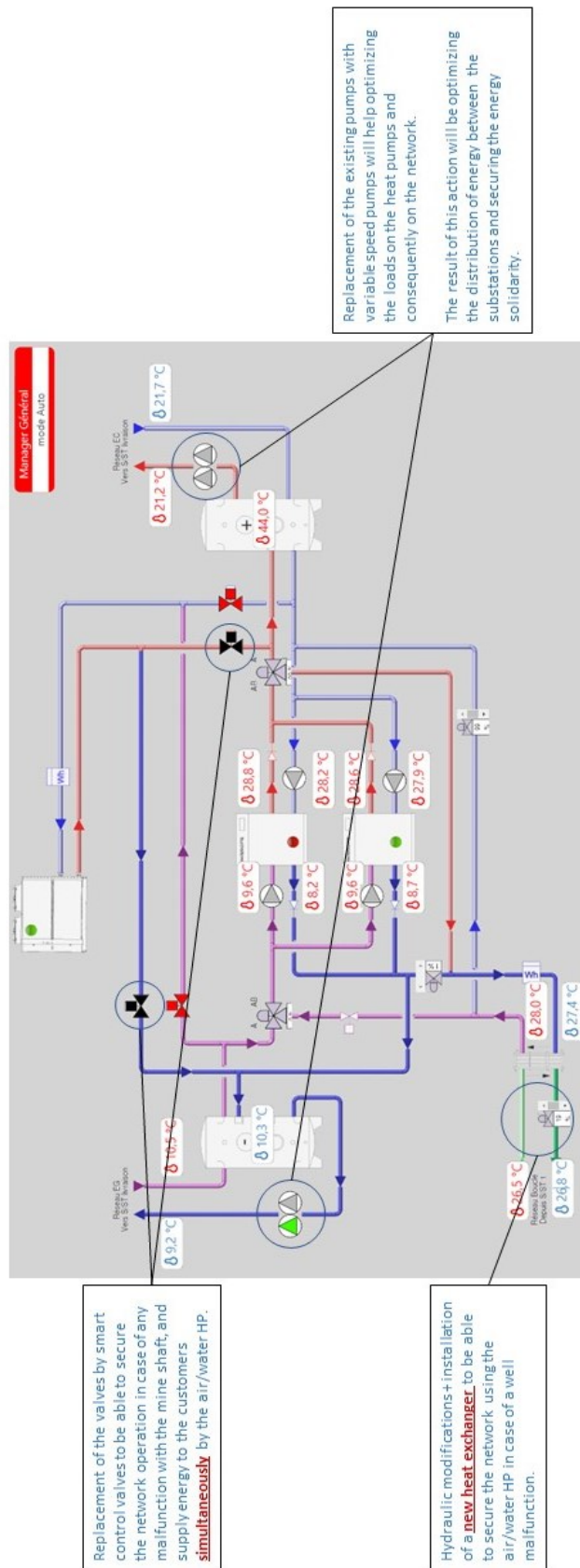


Figure 3-5: Main hydraulic modifications for the energy solidarity action on Substation 2 with smart control valves, variable speed pumps and the added heat exchanger. Source: DALKIA

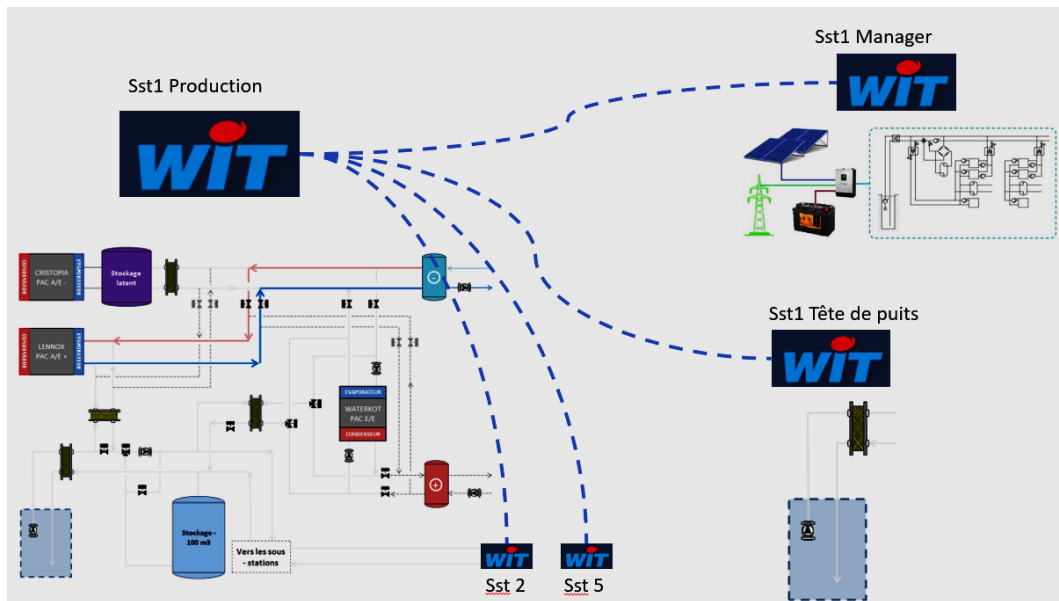


Figure 3-6: Overall SCADA system architecture for the substation 1, showing the 3 automation systems implied. Source: DALKIA

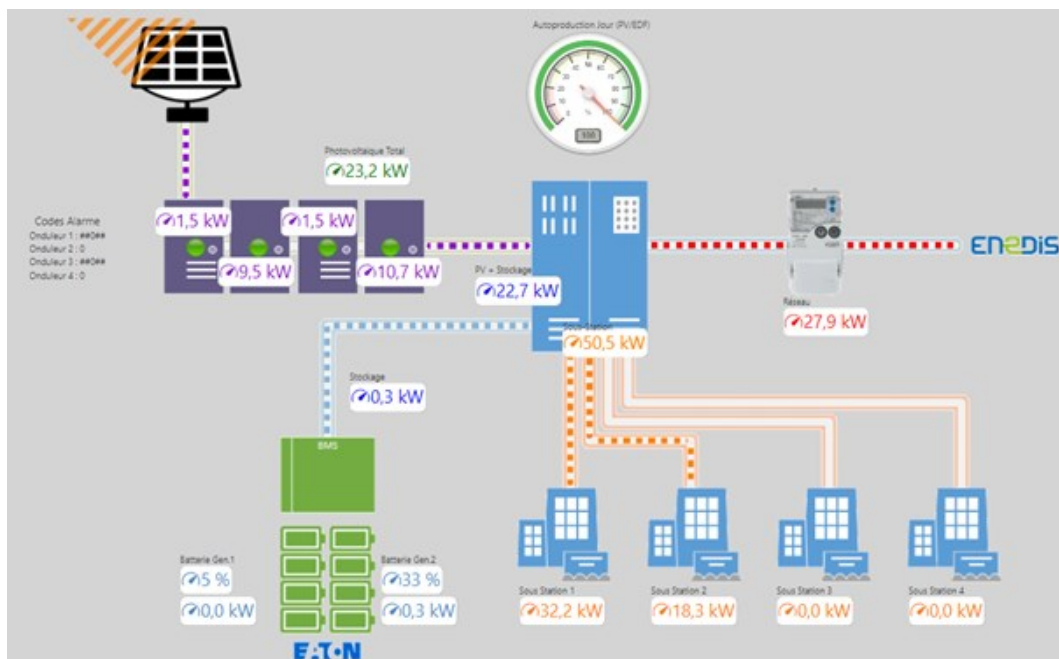


Figure 3-7: Screenshot of the storage control interface in Gardanne. Source: DALKIA

The following figures present a selection of technical drawings and renderings related to the House of Energy. In yellow, new spaces or new elements are highlighted.

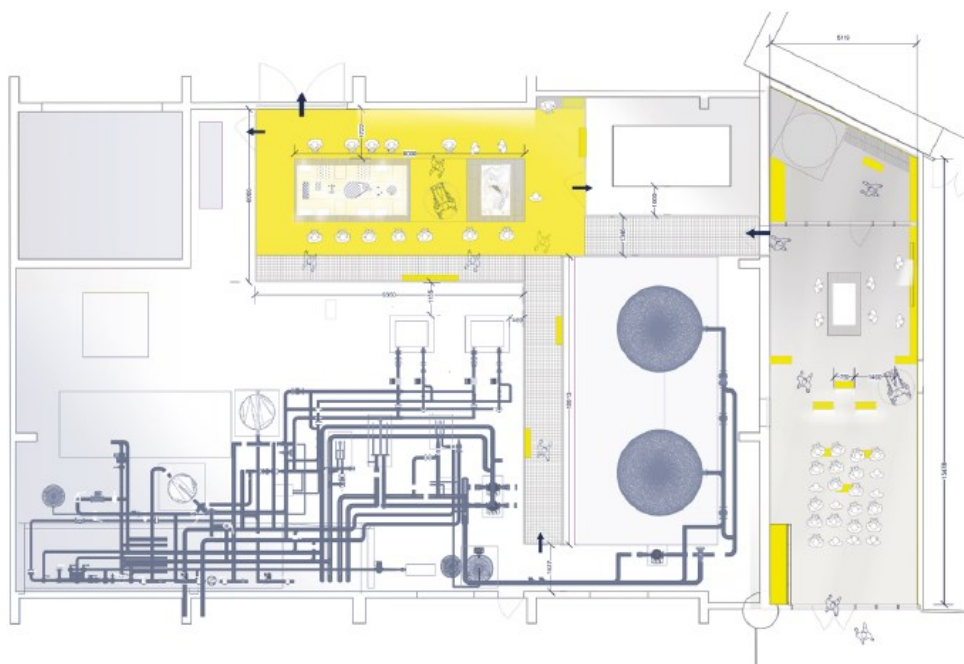


Figure 3-8: House of Energy general plant - On the right the introduction area and in the centre-left, the substation with its current installations. In yellow, new spaces or new elements are highlighted. (Source: Energie Solidaire)

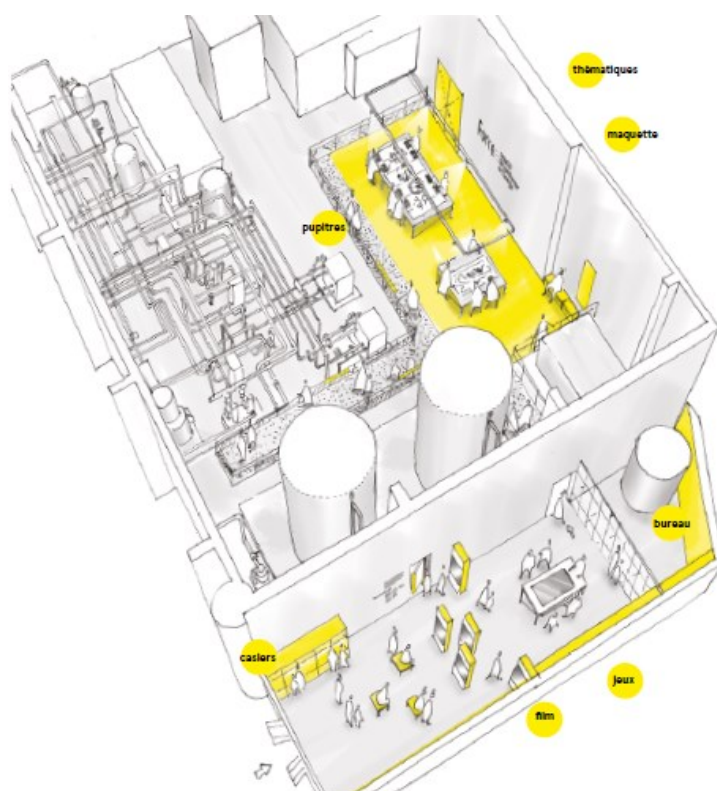


Figure 3-9: House of Energy general axonometry (Source: Energie Solidaire)

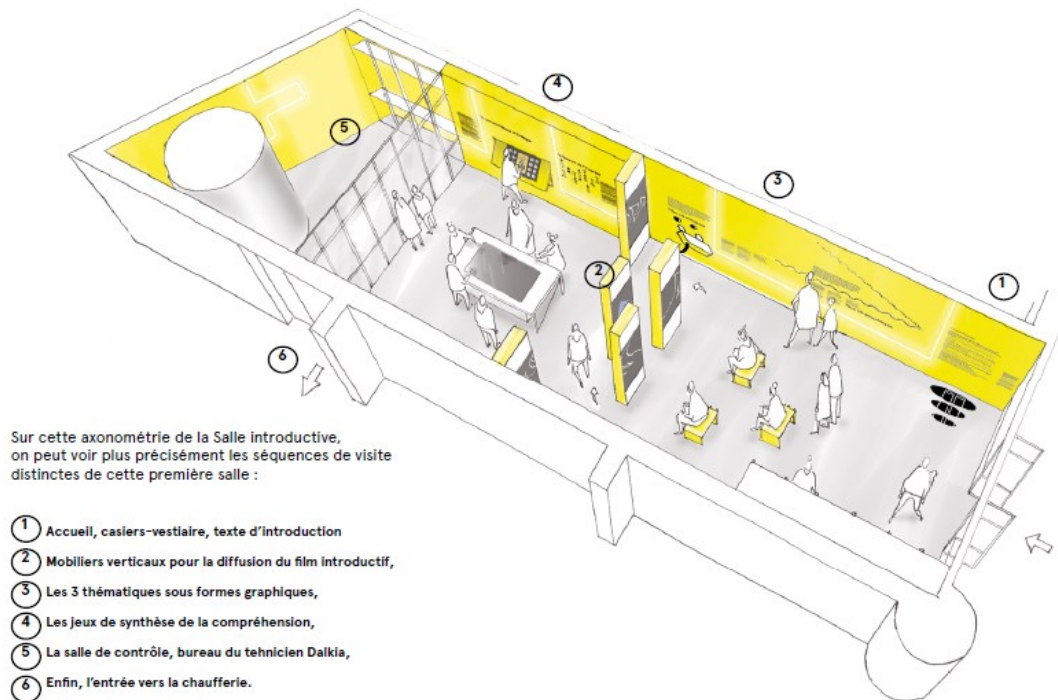


Figure 3-10: House of Energy introductive room axonometry (Source: Energie Solidaire)

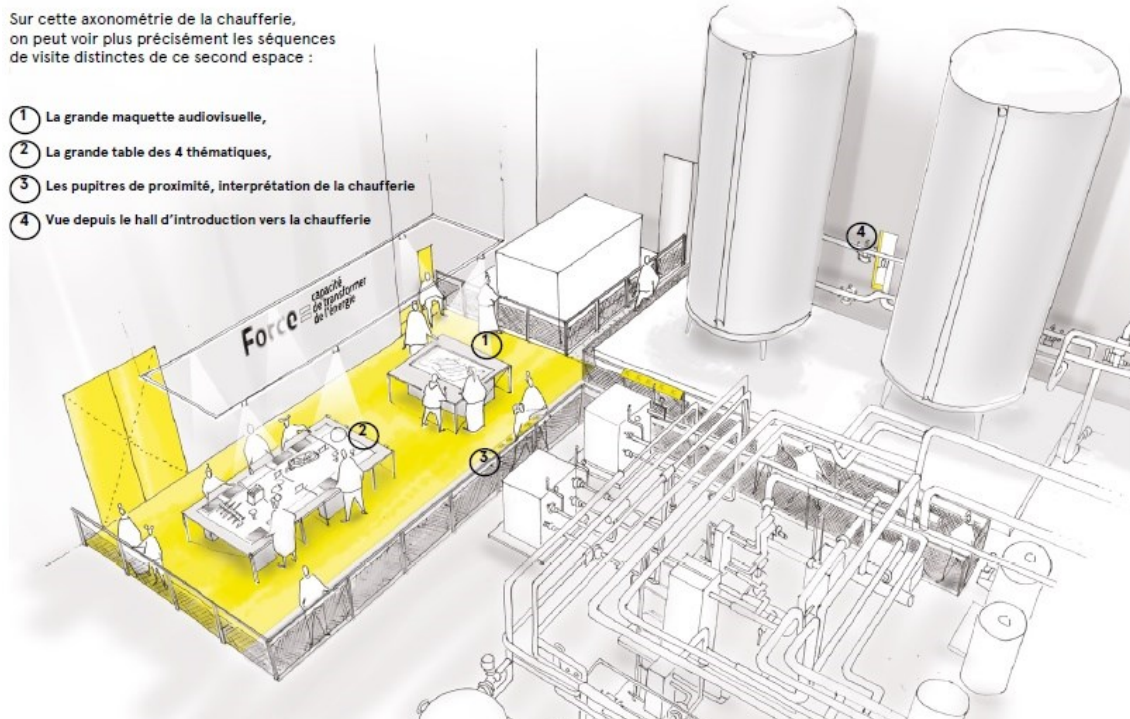


Figure 3-11: House of Energy substation axonometry (Source: Energie Solidaire)

3.5 Pictures of the Construction Works

Besides the mineshaft, PV is the main RES of the DHCN of Gardanne. The current installation is concentrated on one main building Figure 3-12. Once the neighbouring buildings will be delivered, additional roof-top PV installations will feed RE into the DHCN.

In Figure 3-13, the main substation (Substation 1) is shown. It hosts the main assets for the operation of the DHCN, with various thermal storages (hot water tanks, ice-storage) and electric storage as well as the main hydraulic system and control of the DHCN. In the foreground, the 2 main HPs of the substations are shown.



Figure 3-12: View on the House of Science and its roof-top PV field, from the top of the mine-shaft elevator tower (Source: EDF)



Figure 3-13: View on the main substation as operated today (Source: EDF)



Figure 3-14: View of the introduction area of the HOE. Source: ENSOL



Figure 3-15: View of the introduction area with the visualization of the developed pedagogic media. Source : ENSOL



Figure 3-16: View of the substation area with the dedicated interactive tables and their installed media. Source : ENSOL

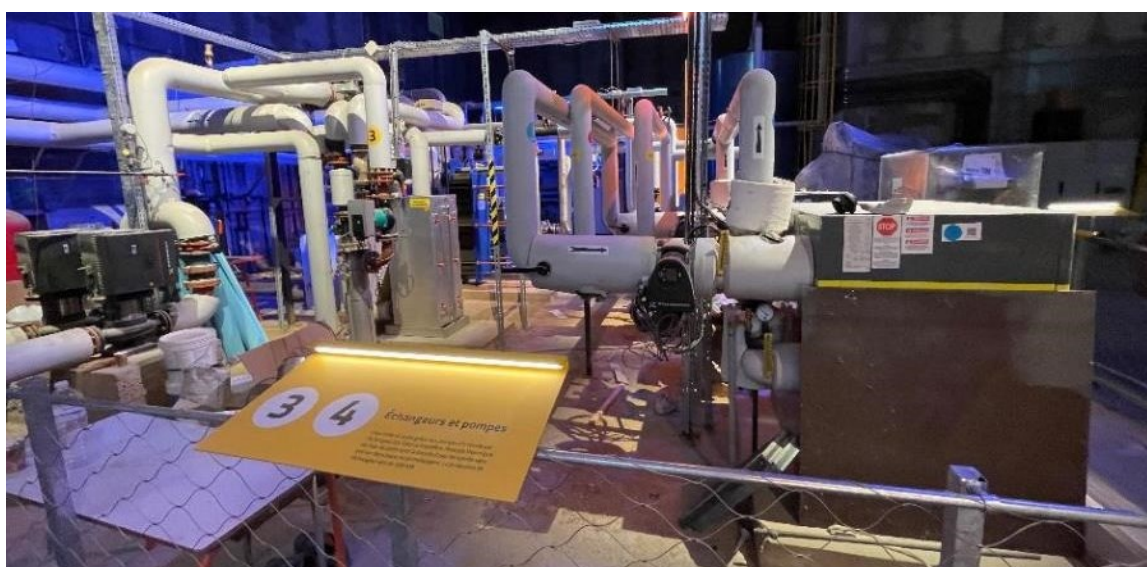


Figure 3-17: View on the substation and the developed dynamic lighting design for explaining the substation's working principle. Source: ENSOL



Figure 3-18: View of the substation area with the dedicated interactive tables. Source: ENSOL

4 Helsingborg, Sweden

4.1 Description of the demonstration site

This demonstration site is located in the district of Drottninghög in Helsingborg (Sweden), and consists of a newly built, small-size, heating and cooling network supplying energy to four new apartment blocks (5 to 7 floors and 110 apartments, with a total living area of 7,795 m², see Figure 4-1). The construction has been implemented by Tornet, who are specialized in construction and management of affordable rental properties, with a commitment to energy efficiency, responsible material utilisation, and sustainable product choices.



Figure 4-1: The four multifamily homes and the energy centre building

The Energy Centre at the core of the small network consists of a thermal substation and a 6-pipe distribution network designed to cover the demands for DHW, SH, and SC. Figure 4-2 shows a simplified P&ID of the system: the energy system interfaces with the Helsingborg DHN network (purple lines) via two counterflow HXs—one dual-stage HX to meet DHW demand (red lines) and one for SH demand (orange lines). The system uses two identical hot water tanks, each with a capacity of 750 litres: a high-temperature TES dedicated to meeting DHW peak loads and a low-temperature buffer that interfaces with the SH system and preheats DHW.

The Energy Centre also integrates a 4-pipe geothermal HP, equipped with a variable-speed compressor and a de-superheater that recovers heat from DHW preparation for space heating purposes. For sake of simplifying the system description, the latter is represented as two separate HPs. The HP is used solely for heating, while SC is achieved through free cooling (blue lines): heat is extracted from the building via the Air Handling Units (AHU) and directed to the boreholes.

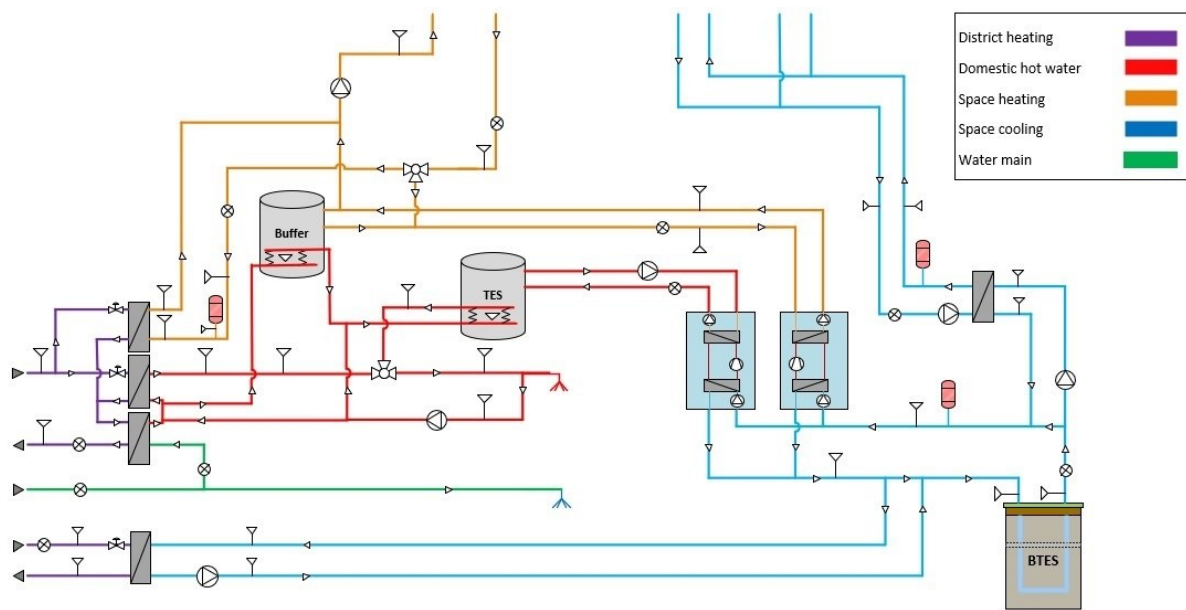


Figure 4-2. Layout of the Torne Energy Centre in Helsingborg

4.2 Objectives of the demonstration activity

The project involves three partners: INDEPRO, tasked with strategic planning, ARVALLA, overseeing construction management, and EURAC who developed an optimised RBC for the management of the boreholes field. The project aims to achieve the following objectives:

- Installation of a standardized substation, streamlining construction processes through the deployment of standardized design.
- Integration of a geothermal HP in the substation aimed to minimise the import of energy from the district heating network.
- Integration of PVT panels, reducing electricity consumption from the grid and charging the boreholes field in summer.
- Integration of a state-of-the-art smart monitoring and control hardware and software.
- Assess management strategies aimed to select the most effective way of sourcing heat for the buildings, between the DHN and the borehole field.

4.3 Description of the Results Achieved

The REWARDHeat demo site in Helsingborg stands out due to the close collaboration in its design between the DH operator and the local energy system owner, a partnership that significantly streamlined the construction process. Additionally, the flexibility of Swedish legislation allowed the project to proceed with a single municipal permit, enabling the realisation of such a complex system—one of the key takeaways from this demonstration.

The implemented system in Helsingborg is highly flexible, allowing real-time selection of the most optimal energy vector—either DH or electricity for heat pump HP operation—based on economic and environmental performance indicators. In winter, the system primarily relies on the HP for space heating and DHW preparation, with DH covering only peak demands. Conversely, during

summer, DH becomes the preferred energy source due to favourable pricing, while HPs are turned off. Waste heat from building cooling is then redirected to recharge the boreholes.

Free cooling alone does not suffice to offset winter heat extraction from the boreholes. To address this, the system employs a recharging strategy, capturing solar thermal energy with PVT panels and recovering waste heat from the AHUs' exhaust duct, providing a steady thermal power of 15kW. This recovered heat is used primarily at the HP evaporator for DHW and space heating delivery, keeping the HP frequently active to capture most of the building's recovered heat. Excess heat that the HP cannot utilise is directed to the boreholes, balancing some of the extracted energy.

Despite these strategies, borehole energy input still does not fully balance extraction. Although there is a connection between the DH network and the boreholes, which could potentially supply DH energy to the ground, regulatory constraints currently prevent its operation (see bottom left of Figure 4-2). An in-depth assessment (Deliverable 5.9) explored control strategies that would balance borehole energy through DH charging during summer at affordable rates, reducing primary energy use across the system.

By exchanging 20kW between DH and boreholes from April to September, with a borehole's outlet temperature limited to 15°C (allowing implement free cooling), sufficient energy can be stored to meet borehole extraction needs during winter. This approach reduces long-term electricity consumption (a projected 4% reduction over 10 years) but increases DH usage by 33%. Financially, for this approach to break even over 10 years, the DH price between April and September must not exceed 8 €/MWh.

Table 1. Primary energy consumption of the system without BTES charging and with BTES charging (20kW from April 1st to September 30th) with the new monthly data for primary energy factor

	Qth_DH = 0kW			Qth_DH = 20kW (1 st April – 30 th September)		
	Thermal energy from DH [MWh]	Electrical energy consumption [MWh]	Primary energy [MWh]	Thermal energy from DH [MWh]	Electrical energy consumption [MWh]	Primary energy [MWh]
January	15.4	14.5	32.5	15.0	13.6	30.6
February	10.6	14.7	32.3	10.6	14.2	31.2
March	8.6	14.8	33.4	7.9	15.0	33.7
April	1.5	11.8	26.0	6.1	11.8	26.1
May	7.2	4.8	10.1	15.7	4.8	10.9
June	12.2	0.5	2.0	22.3	0.5	2.9
July	12.0	0.6	2.0	21.9	0.6	2.9
August	11.5	0.5	1.9	21.8	0.5	2.8
Septemb	7.0	3.2	6.7	16.2	3.1	7.5
October	1.1	10.9	19.5	1.1	10.5	18.7
Novemb	2.6	14.4	30.9	2.6	12.9	27.7
Decemb	11.4	15.4	39.3	9.2	14.4	36.6
	101.1	106.0	236.5	150.4	101.8	231.4

As primary energy factors for DH are particularly low in summer, charging the BTES with DH energy during these months decreases electricity demand in winter, providing positive environmental effects, including lower CO₂ emissions.

Boreholes can serve as viable thermal storage under certain conditions, but effective control requires collaboration with DH and electric grid authorities. Pricing for energy vectors should reflect renewable content and vary seasonally. An initial breakeven analysis, using informed assumptions on DH pricing and primary energy factors, indicates modest system benefits. Improved performance could be achieved with detailed hourly analyses and active energy centre control, optimising flexibility and enhancing system-wide benefits.

4.4 Technical Drawings

The following Figures present a selection of the technical drawings for the construction of this demonstrator:

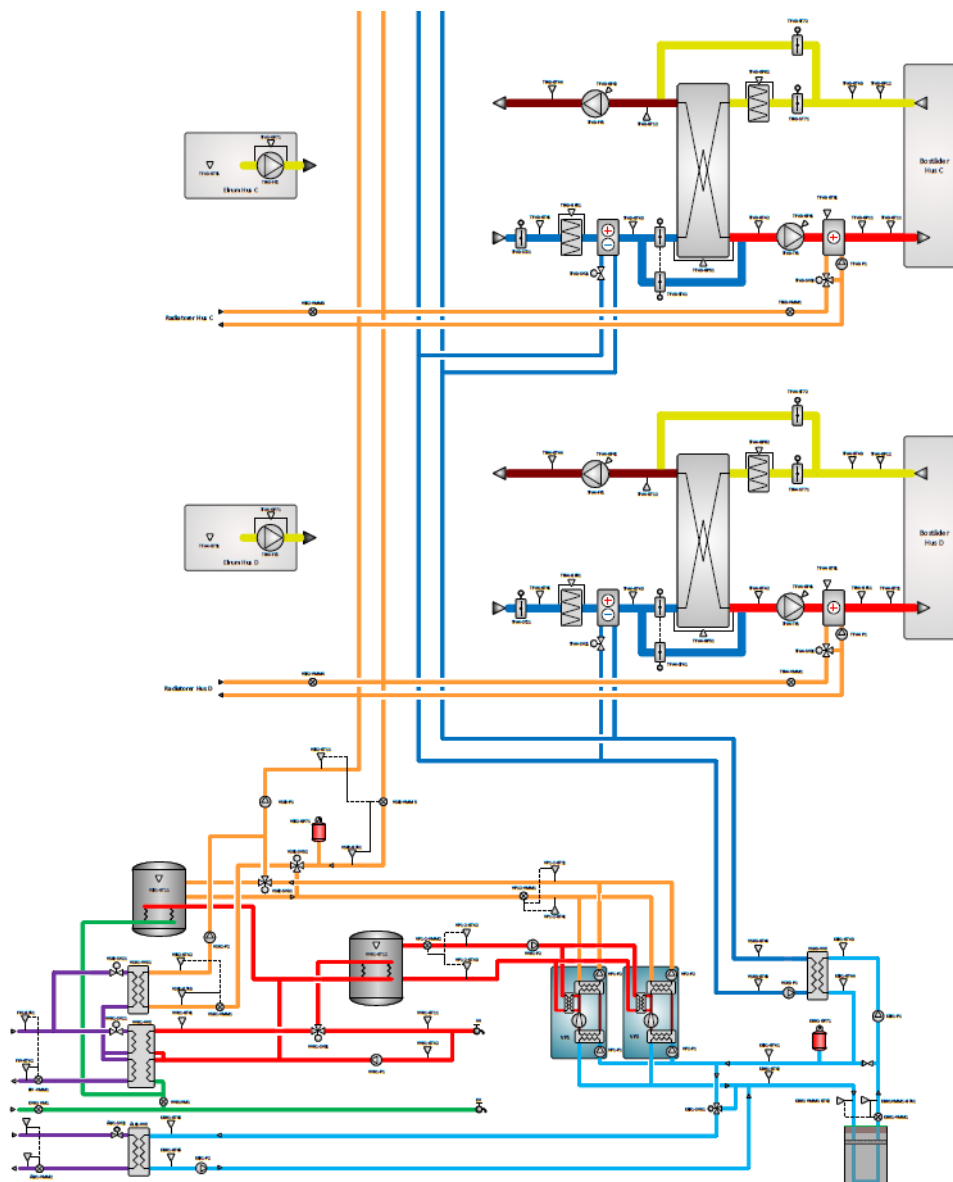


Figure 4-3: Overall Principle Scheme

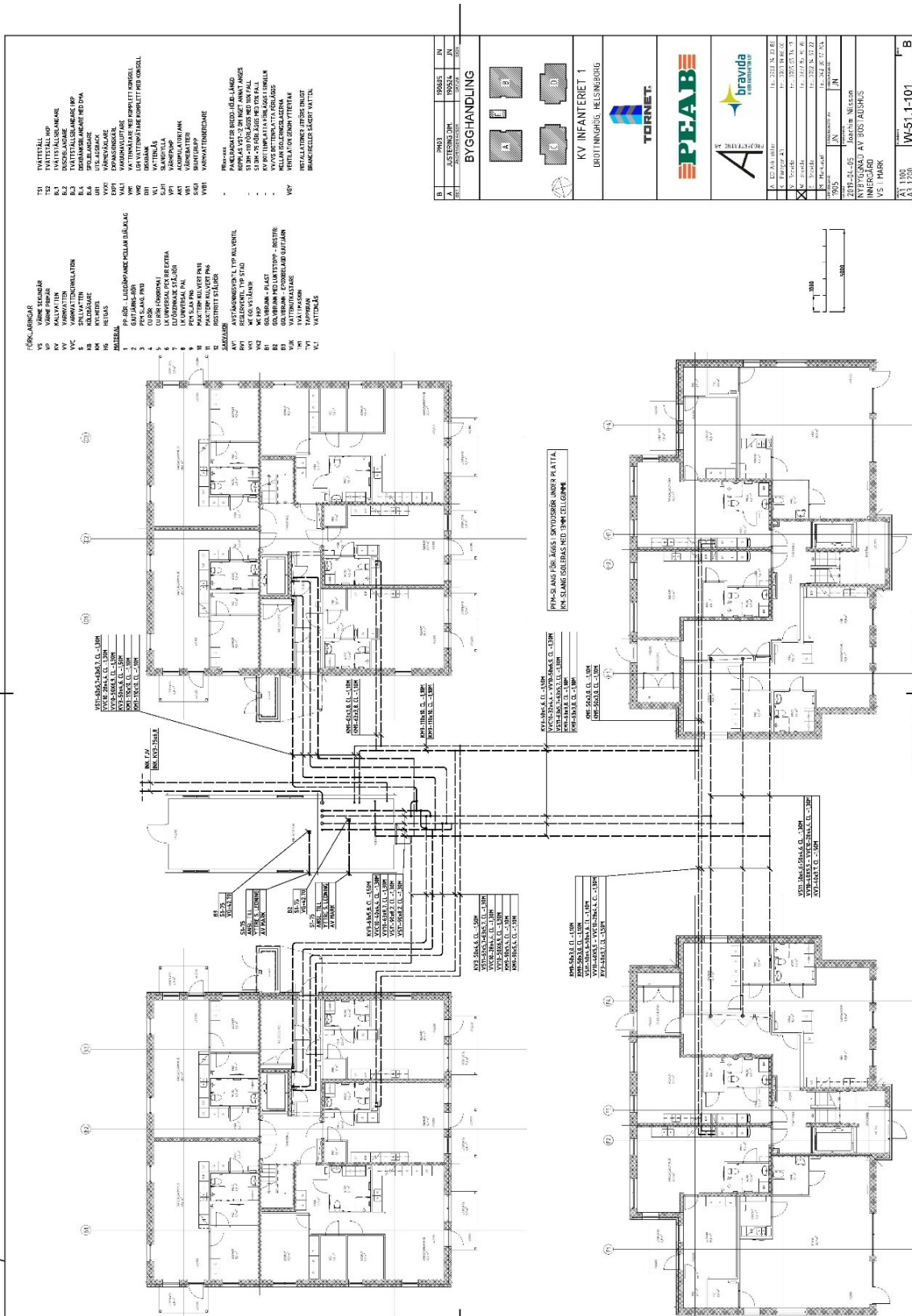
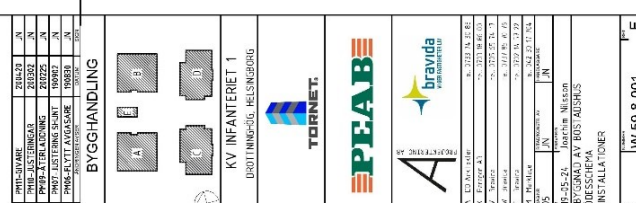


Figure 4-4: Overall Layout with Four Buildings



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4.5 Pictures of the Construction Works

The following Figures present a selection of h taken on site:

- Figure 4-6 shows the DH piping installation;
- Figure 4-7 and Figure 4-8 show the HBG 4 buildings;
- Figure 4-9 shows the energy central;
- Figure 4-10 shows the heat exchanger for boreholes.



Figure 4-6: District Heating Piping



Figure 4-7: HBG 4 Buildings



Figure 4-8: HBG 4 Buildings



Figure 4-9: Energy Central



Figure 4-10: Heat Exchanger for Boreholes

5 La Seyne-sur-Mer, France

5.1 Description of the demonstration site

The demonstration site located in La Seyne-sur-Mer is a DHC network operated at different temperature levels to accommodate different needs encountered along the expansion. The DHC network is operational since 2008, while DALKIA took over ownership and management starting 2019. The network was extended along the project elaboration, as shown in the map of Figure 5-1, and the number of customers raised from 4 to 14 in 2024.

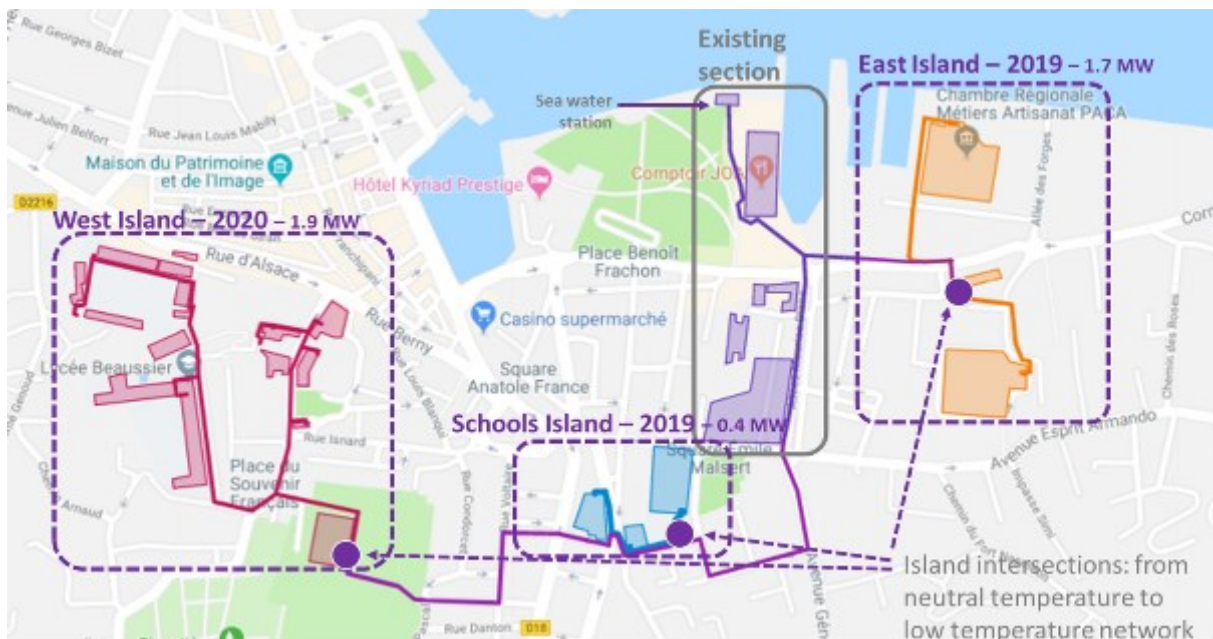


Figure 5-1: Expansion at the demonstration site in La Seyne-sur-Mer.

The neutral-temperature DHCN initially set up uses seawater as energy source and sink, and allows to cover both heating and cooling needs, as it is operated between 13-24°C, the temperature varying over the year according to the seawater temperature and the extent of heating and cooling, partially loads balancing out over the network. The buildings connected to this network are set up with substations exploiting water-to-water heat pumps to draw or reject thermal energy from/into the network.

The networks stemming from the core one are conceived as semi-decentralised ones, as substations integrating large HPs connect the extensions, as represented in Figure 5-2. Depending on the energy uses of the buildings integrated in the subnetworks, those can be operated in heating mode only or provide both heating and cooling.

While SH and, eventually, SC loads are consistently covered by the DHCN, DHW preparation is addressed occasionally. In most cases, the secondary network operator ensures the DHW preparation via existing or refurbished means. In 3 substations, gas boilers are still present and falling under the public delegation of service contract of DALKIA and are used basically as back-up: in HLM PRESENTATION (residential building) gas is used as back-up or when the gas is cheaper than electricity, taking COP of the systems into consideration; in School Malsert gas is only used as back-up; in School Jaurès gas is used for heating and DHW as HPs are sub-dimensioned and do not reach the needed set temperature, and are thus used for preheating the return flow of the boiler.

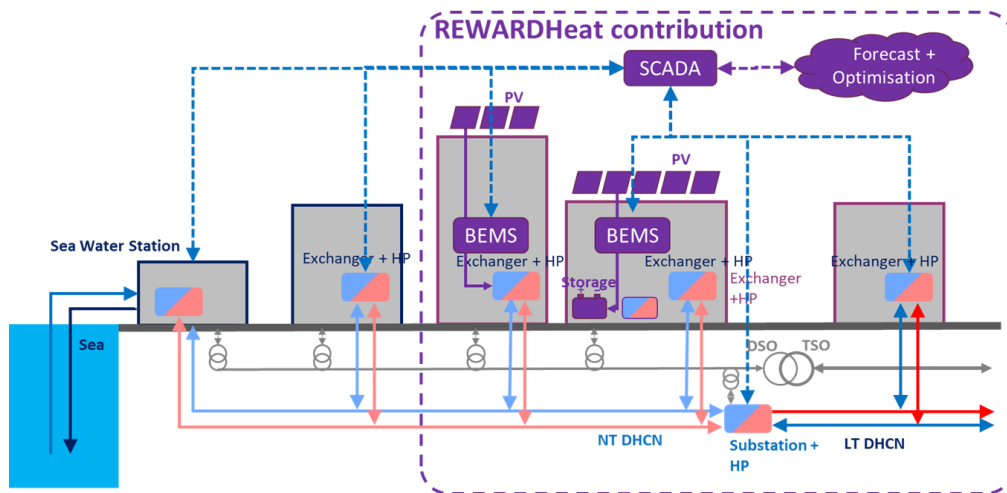


Figure 5-2: Overview of the technologies that will be implemented at the demo case of LSSM.

5.2 Objectives of the demonstration activity

The project involves two partners: DALKIA, who owns and manages the DHCN, and EDF who developed the advanced control tools and implemented them in DALKIA's platforms. Overall, the project aimed to improve the energy efficiency of the DHCN through new equipment installation and advanced control strategies integration. Particularly, the following objectives have been pursued:

- Replacement of the seawater filters and installation of variable speed pumps at the central pumping station in order to reduce flow, raise the temperature difference between supply and return temperature, hence lower electricity consumptions overall;
- Upgrade of the PLCs and the functional analysis implemented at the central pumping station and all customer substations. These have been improved continuously along the project elaboration, thanks to the feedback received while modelling or simulating the network substations for forecast, optimisation or simulation purposes;
- Establishment of a reliable 4G communication link between substations and the SCADA system, along with an upgrade of the entire DALKIA's ICT infrastructure to enhance the reliability and stability of data flows;
- Development and deployment of a centralised, advanced supervision and control system based on model predictive based optimisation techniques.

5.3 Description of the Results Achieved

Over the project duration, the DHCN has reached its full capacity, and the renovation of the sea-water central pumping station, together with the SCADA system upgrade have been accomplished. In 2023, the network produced 2.3 GWh of heating and 1.5 GWh of cooling respectively.

Figure 5-6 shows the new sea water filters, which replace the previous devices and require less maintenance, thereby reducing downtimes at the pumping station. These filters remove major impurities from the sea water loop before it enters the heat exchangers and exchanges heat with the main low-temperature (LT) loop.

Figure 5-7 displays the variable speed pumps at the pumping station. These pumps are crucial for the network's operation and are the primary consumers of electricity. Three pumps control the sea water loop, while another three manage the LT loop.

Figure 5-8 and Figure 5-9 illustrate the main Energy Management System and the automation systems of several substations, respectively. These systems include metering and control automation. The main EMS for the pumping station operates independently within the overall SCADA system, whereas the substation automation system has a simpler architecture, requiring fewer metering and control devices. Thanks to the project, the entire system has been overhauled and improved in terms of data quality and signal stability.

Figure 5-10 shows that the pumping station has also been modernised from a design perspective. It has been refurbished and equipped with educational materials to facilitate visits and explain the system's working principles.

The SCADA system interface is accessible via the Armada Casino substation, where all information from the pumping station and other substations is consolidated before being sent to the Regional Control Centre of DALKIA. Figure 5-11 shows the installation with the dedicated PC within the substation and includes a couple of screenshots of the different SCADA control interfaces, allowing navigation among the individual assets of the DHCN.

Additionally to updating the overall system, most of the effort in REWARDHeat was devoted to upgrading the control system (see Deliverable 5.9). Also in this case, all the goals initially agreed were achieved:

Load Forecasting: EDF's ForecastHeat® software, upgraded for this project, allowed for accurate load forecasting across distributed substations. With a forecast error averaging under 12%, the software performed well for most substations, although some displayed unpredictable consumption patterns due to metering and data aggregation issues, which were addressed during DEMIX commissioning. The software's predictive accuracy improved significantly by adding factors like occupancy rates and calendar events, particularly useful for high-demand sites like the Casino. A valuable side effect of load forecasting was a clearer understanding of asset performance, which led to improvements in SCADA operation and automation.

Modelling: DHCN models were shifted from linear (MILP) to non-linear programming (MINLP) modelling, which enhanced the system's ability to optimise temperature and flow rates accurately within the decentralised network. MINLP modelling offered quicker, more precise calculations by handling complex interactions, which traditional linear methods struggled with. The modelling approach used Dymola-Modelica to retain transparent cause-effect relationships, helping the team identify potential operational issues. This new method achieved rapid and reliable results, providing a solid foundation for system efficiency.

Optimisation: EDF's Clevery® tool powered the optimisation component, initially using MILP before transitioning to the more flexible MINLP to accommodate dynamic system behaviours. Various optimisation strategies were tested, with minimising electricity costs proving most effective. Cost optimisation allowed for a balance between operational savings and system efficiency by adjusting electricity use during peak and off-peak times. This approach streamlined the temperature and

flow rates across the network while responding to real-time changes, such as adjusting heat pump performance based on energy costs.

The project revealed several important insights. Balancing model complexity with usability for operators was crucial, as was incorporating resilience for data outages. The switch to non-linear solvers, while computationally demanding, provided needed accuracy and speed, proving essential for future scalability. Using physical models (white-box) allowed for clear tracking of cause-effect relationships, which made troubleshooting and commissioning much easier. However, control constraints from SCADA and regulatory limits highlighted the need for greater flexibility in operational setups. Fibre-optic networks proved more reliable for data transmission than 4G, reinforcing the need for stable infrastructure to support real-time operations.

In essence, this project demonstrated how adaptable forecasting, advanced modelling, and flexible optimisation can significantly enhance the efficiency of decentralised DHCNs. Continued development will focus on refining these solutions for broader use in next-generation energy networks.

The DEMIX platform, validated at TRL 6, is now undergoing real-life testing towards TRL 7 and preparing for industrialisation to reach TRL 8, paving the way for scalable, replicable energy management in other networks. Overhauls of data systems improved reliability and allowed DALKIA to monitor and control the network remotely, with the main EMS and substation automation feeding directly into the SCADA.

5.4 Technical Drawings

The following figures show the available technical drawings:

- Figure 5-3 and Figure 5-4 show respectively the simplified global architecture for scalability and replicability of DEMix and the implemented architecture at the demo site.
- Figure 5-5 shows the scheme of the DHCNs with technical information of each substation

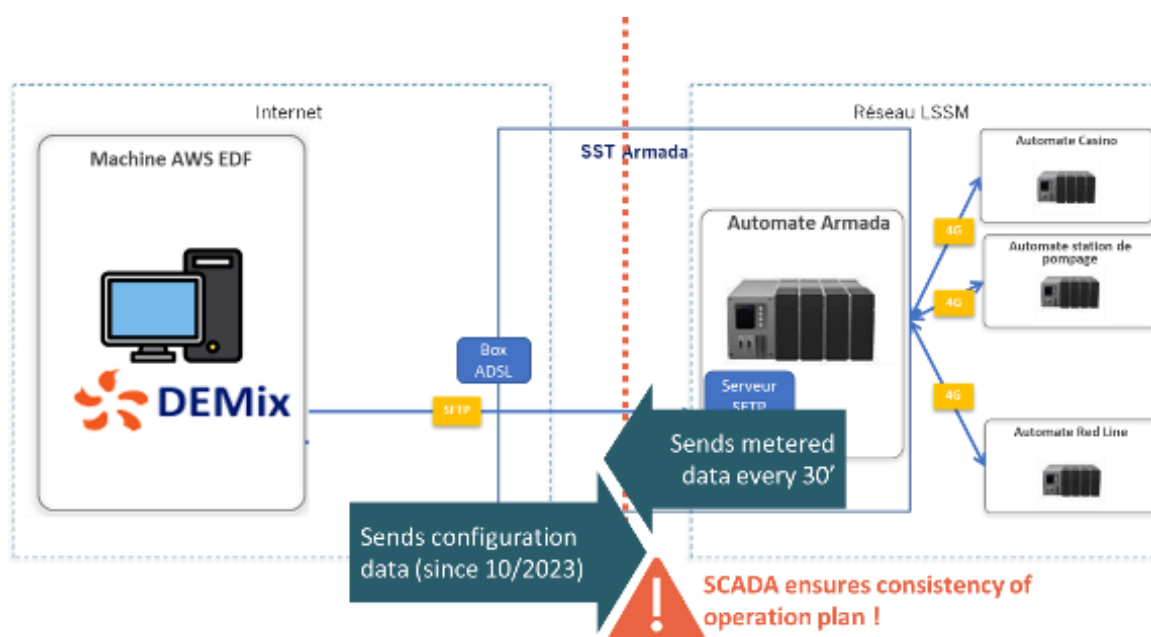


Figure 5-3: Implemented architecture for the demo site for the demonstration purposes. Source: EDF

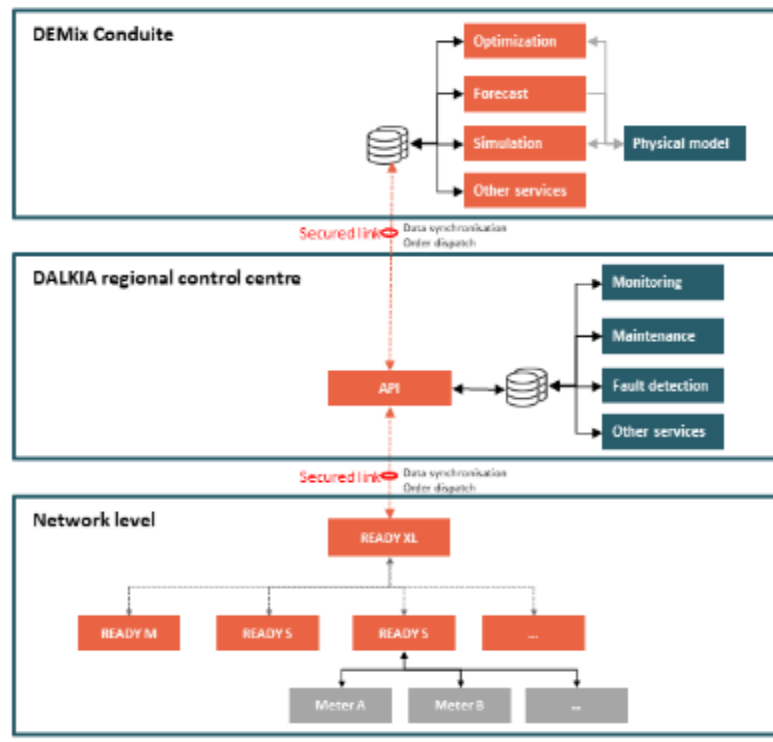


Figure 5-4: Simplified global architecture for scalability and replicability of DEMix. Source: EDF

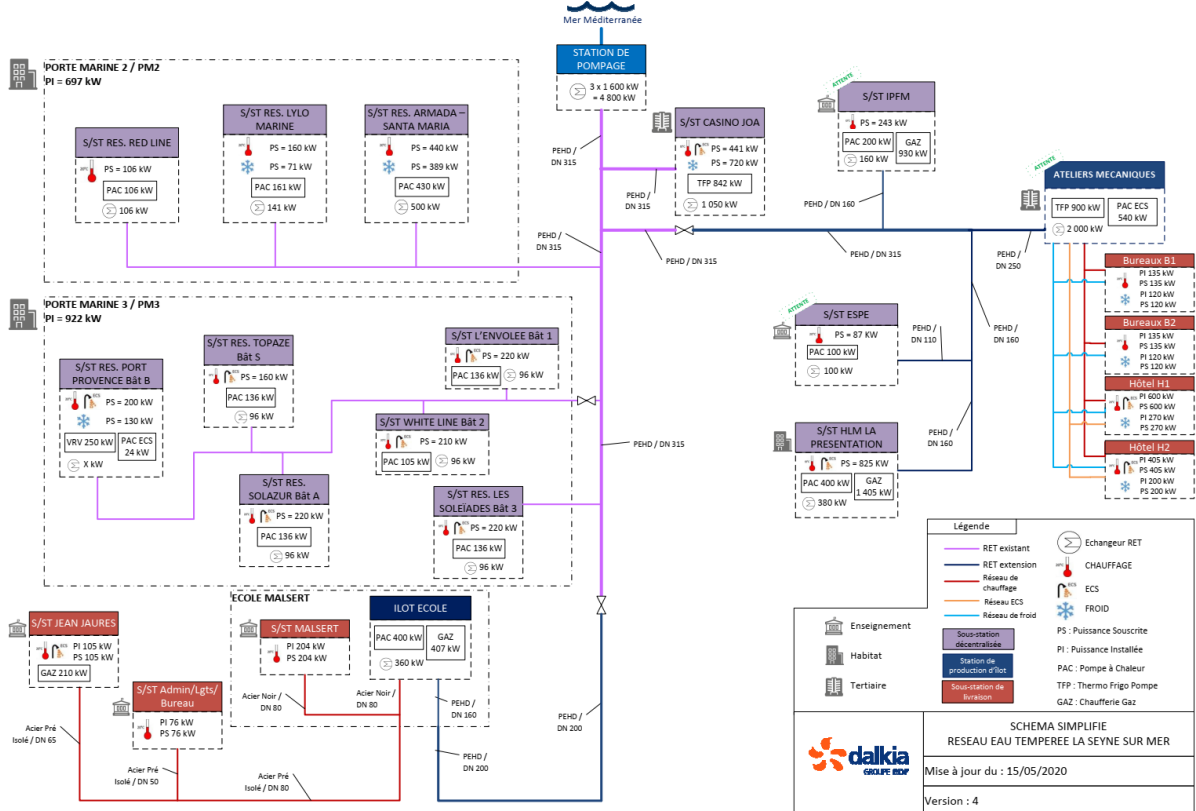


Figure 5-5: Scheme of the La Seyne-Sur-Mer DHCNs. Source: DALKIA

5.5 Pictures of the Construction Work



Figure 5-6: Replaced sea-water filters in the pumping station. Source: EDF.



Figure 5-7: Variable speed pumps in the pumping station. Source: EDF.



Figure 5-8: Implemented automation system on the pumping station - it works as an own EMS within the overall SCADA system. Source: EDF



Figure 5-9: Pictures of the automation systems deployed in the substation. Source: EDF.



Figure 5-10 : Pictures above shows the pumping station after changing the sea water filters and below, as it's today, enabling public visits with associated communication material (panels) and secured access to the pumping station components. Source: EDF.

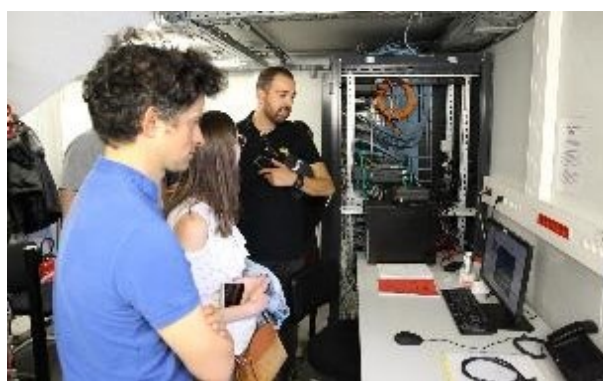
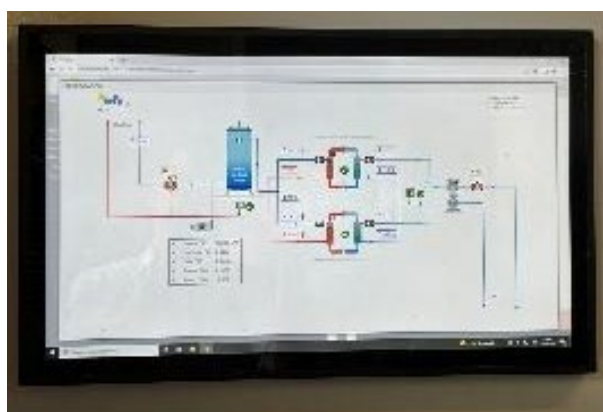


Figure 5-11: Pictures of the installed central supervision in the Armada substation and pictures of some SCADA visualizations (left: overall DHCN with its substations; right – individual substation). Source: EDF.

6 Milan, Italy

6.1 Description of the demonstration site

The demonstration site in Milan is a newly built neutral-temperature DHCN, set up by the utility company A2A. This innovative system, located near the Parco della Resistenza in the southern part of the city, uses groundwater as an energy source. Groundwater is pumped from aquifer monitoring wells beneath the park and distributed to the three buildings involved in the project. Using heat pumps, the energy from the water is harnessed to heat indoor spaces in winter and produce domestic hot water, while in summer it can be used for cooling. This system reduces electricity usage and takes advantage of waste heat produced by the buildings themselves.

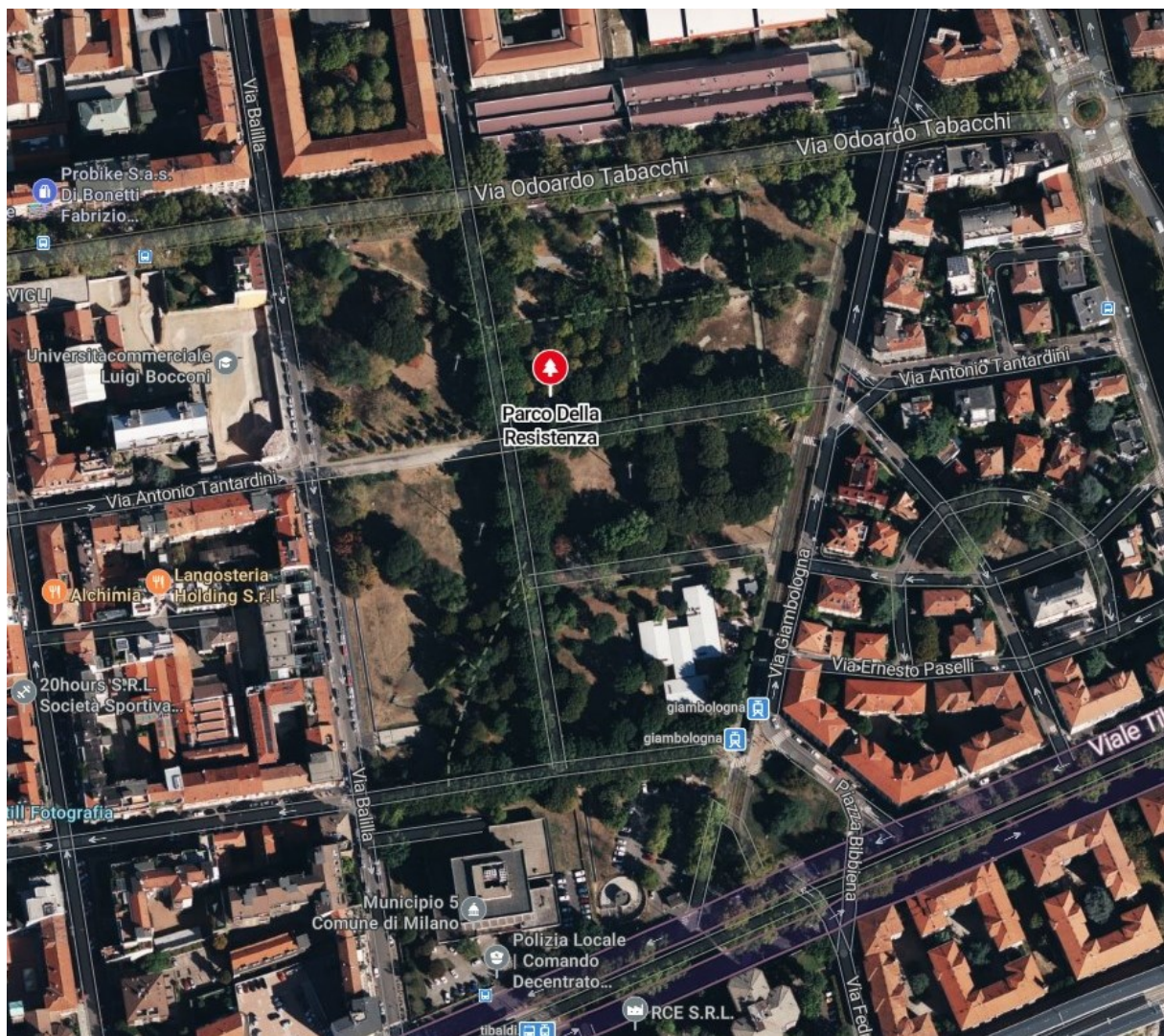


Figure 6-1: Aerial view of the area concerned with the demonstration site

Heat from the water wells is distributed at around constant 15°C along the year. A kindergarten (via Giamologna), a municipal centre (via Tibaldi) and a multifamily home (via Balilla) are the first users of the DHC network. While the first two only require space heating and DHW being covered, the municipal centre also requires space cooling in summer.

An interception pit collects water from the primary groundwater channel, supplying it to the DHCN. The main distribution substation has been installed in the technical room of the kindergarten, alongside the heat pump-integrated substation dedicated to that building. Additional dedicated heat pump-integrated substations have been installed at the municipal building and a multifamily residence.

At the project's start, the buildings used gas boilers for heating: the kindergarten with a 90 kW boiler, the municipal centre with a 1,000 kW boiler and a reversible heat pump for heating and cooling, and the residential building with an 80 kW oil boiler. While the newly installed substations now supply the majority of heating and cooling needs, the gas boilers at the kindergarten and municipal centre remain as backups for peak loads and any substation malfunctions. The oil boiler at the residential building, however, has been removed.

All required permits were obtained from the Municipality of Milan, including permissions for public land use for piping installation, as well as groundwater withdrawal and discharge, though these involved significant delays. Originally, the construction was intended to be completed by Month 24 of the REWARDHeat project (September 2021), but actual completion occurred in October 2023.

6.2 Objectives of the demonstration activity

In the framework of the REWARDHeat project, the following objectives have been pursued:

- Design and set up of the groundwater intakes and installation of the new neutral-temperature DHC network
- Installation of heat pump integrated substations at each of the three buildings
- Implementation of monitoring and control hardware and software
- Investigation on contractual models adapted to the local context.

6.3 Description of the Results Achieved

During the project elaboration, A2A finalised the design and implementation of the neutral temperature DHC network, according to the principle scheme in Figure 6-3. Water at approximately 15°C is distributed through the network to the three buildings, where heat pumps raise the temperature to the required level for the heating systems or dissipate waste heat from air conditioning in summer.

Interception pits: groundwater heat pumps typically require the construction of two wells—one for water extraction and another for its return to the receiving body. In this case, however, existing wells were available, simplifying the installation process. Nevertheless, the configuration of these wells did not guarantee consistent, direct use of the flow rate, as the pipelines exhibited significant flow and pressure fluctuations.

The technical solution involved constructing a small interception pit to house a buffer tank and two submersible circulation pumps, which handle distribution to the main heat exchanger of the DHC network and discharge water back into the receiving body (Figure 6-4).

Network energy distribution station: a main distribution station is installed in the technical room of the kindergarten, as this is the building located closest to the interception pits (Figure 6-5), designed to transfer heat from the water well and distribute energy to users. A primary heat exchanger hydraulically separates the DHC network from the well water, preventing potential contamination in either direction and minimising corrosion on the network side. Distribution

pumps regulate the supply temperature to an optimal set point, while a 3m³ buffer tank decouples the primary distribution flow from the secondary, enabling effective load balancing. This setup helps match warm and cold thermal loads across the network, accommodating any temporal load mismatches.

Kindergarten substation: The substation is designed to meet the school's heating needs via the heat pump (110 kW heating capacity, Figure 6-6). The heat pump controls the two circuit pumps based on the control signal received by the overall BMS.

A temperature sensor located downstream of the heat pump's output adjusts the pump's activation and modulation to maintain the set temperature. As the heat pump has a lower capacity than the existing boiler, a cascading setup was planned. The new unit provides most of the energy, while the gas boiler backups when supply temperature cannot reach the set 70°C agreed by contract.

Water circulation within the heat pump's condenser is sustained by a bypass with a normally open shut-off valve. This interface between the new and existing circuits ensures that, in the event of maintenance or a malfunction of the heat pump, the existing boiler will activate to meet the user's thermal load needs.

Municipal Centre substation: This system is designed to provide thermal energy to the civic centre through two new heat pumps: one reversible unit (450 kW heating capacity) for both heating and cooling, and a second (300 kW heating capacity) in cascade for raising the supply temperature for end-users (Figure 6-7).

The heat pumps serve two circuits—high and low temperature—with priority given to the low-temperature circuit. The reversible heat pump (Pdc 11) controls the pumps at the evaporator and condenser circuits according to its own operating logic. The unit start based on a signal from a temperature sensor installed on the supply manifold of the low-temperature circuit.

Likewise, the non-reversible heat pump (Pdc 15) operates evaporator and condenser distribution pumps. Its startup is dependent on signals from the circulation pumps on the user side and available power on the evaporator side, which may not always be guaranteed.

Summer Operation - The summer mode is straightforward since the cooling capacity of Pdc 11 aligns well with current needs. The new units is connected in parallel to the existing roof mounted chillers, which are normally bypassed by closing two isolation valves.

Winter Operation - In winter, power distribution must be carefully managed since the thermal output of the reversible heat pump matches the peak demand of the low-temperature circuit, which is therefore prioritised. If Pdc 11 operates at full capacity Pdc 15 is off and the high-temperature circuit relies solely on boilers, which cover extraordinary peak loads.

As demand decreases in the low-temperature circuit, pump EPS-16 adjusts accordingly, allowing EPS-14 to activate and draw part of the flow. The high-temperature exchanger preheats the return water entering the boilers. The interface between the new and old circuits ensures that, in the event of maintenance or malfunction, thermal loads are covered by activating the existing generators.

Multifamily home substation: The operating logic of the residential substation is designed to meet the space heating uses of the condominium, as DHW is produced in the single apartments (Figure 6-8). The heat pump (92 kW heating capacity) installed controls the two distribution pumps according to its own operating logic, whilst the heat pump itself starts based on a BMS signal. A

temperature sensor on the user circuit supply line regulates the pump's activation and modulation to maintain the setpoint temperature.

Two 45 kW backup electric boilers are installed to back up the heat pump in case of malfunctions, ensuring continuous service to the users. When activated, the boilers will follow a simple logic to maintain their internal temperature at the setpoint.

The activities at the Milan demo site have successfully demonstrated the feasibility of using groundwater—abundantly available in many European cities—as a source for building heating and cooling through heat pumps. Establishing a neutral temperature DHC network minimises heat losses during distribution from source to buildings, which is particularly beneficial during part-load operation.

This solution has enabled the three buildings to largely phase out fossil fuels, resulting in a substantial reduction in greenhouse gas emissions associated with their heating and cooling systems.

6.4 Technical Drawings

The following Figures present a selection of technical drawings related to this demonstrator:

- Figure 6-2 and Figure 6-3 show the overall system layout
- Figure 6-4 and Figure 6-5 shows the water intakes layout and the distribution substation P&I diagram
- Figure 6-6, Figure 6-7 and Figure 6-8 shows the P&I diagrams of the substations at the three buildings

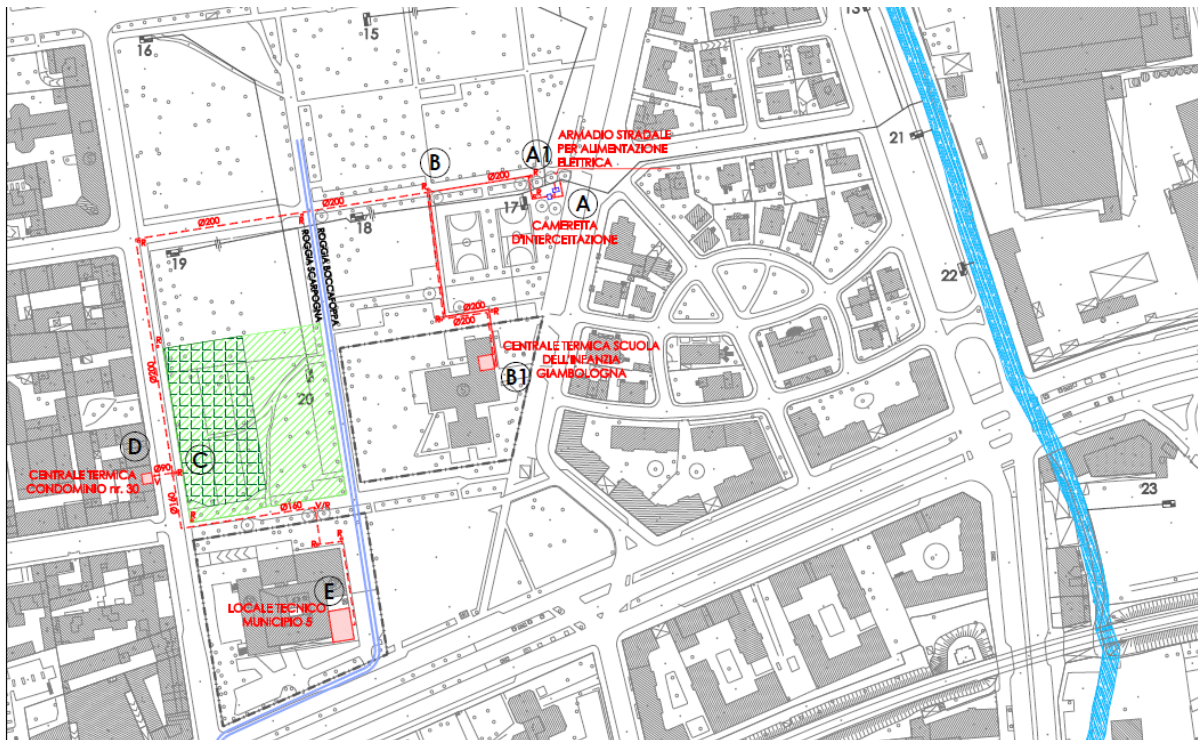


Figure 6-2: Overall DHC network Layout

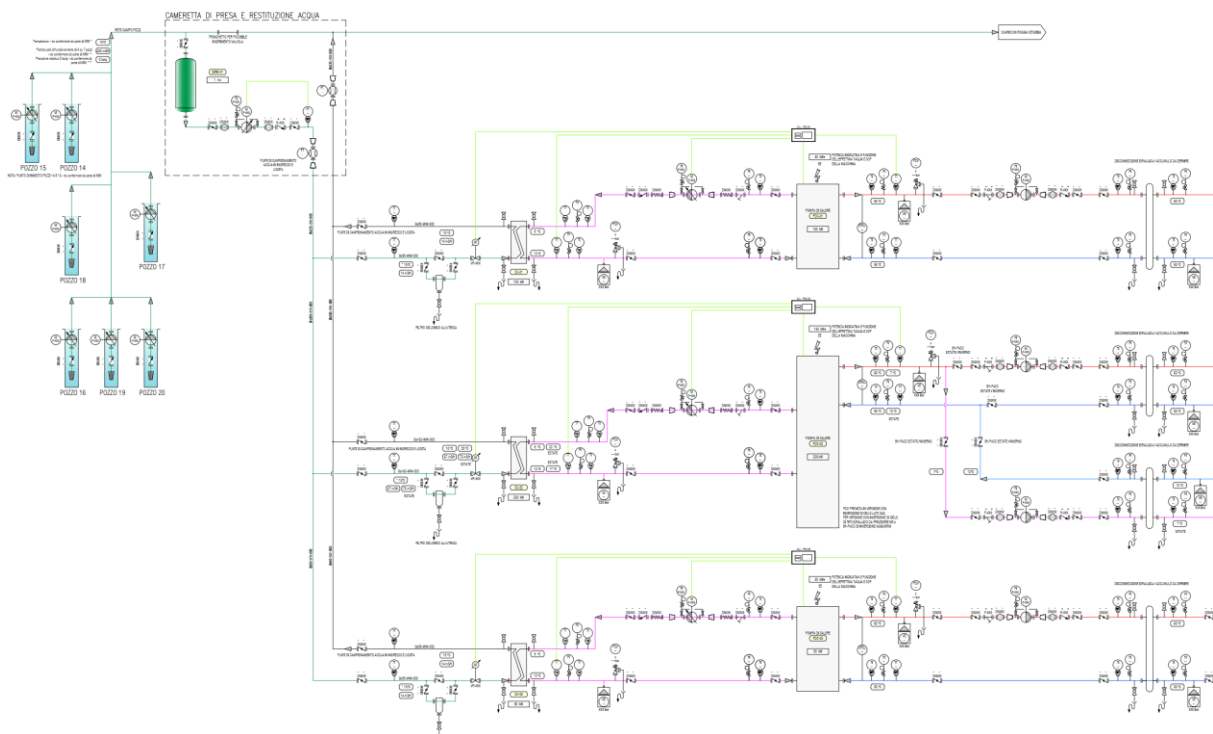


Figure 6-3: Overall system principle diagram

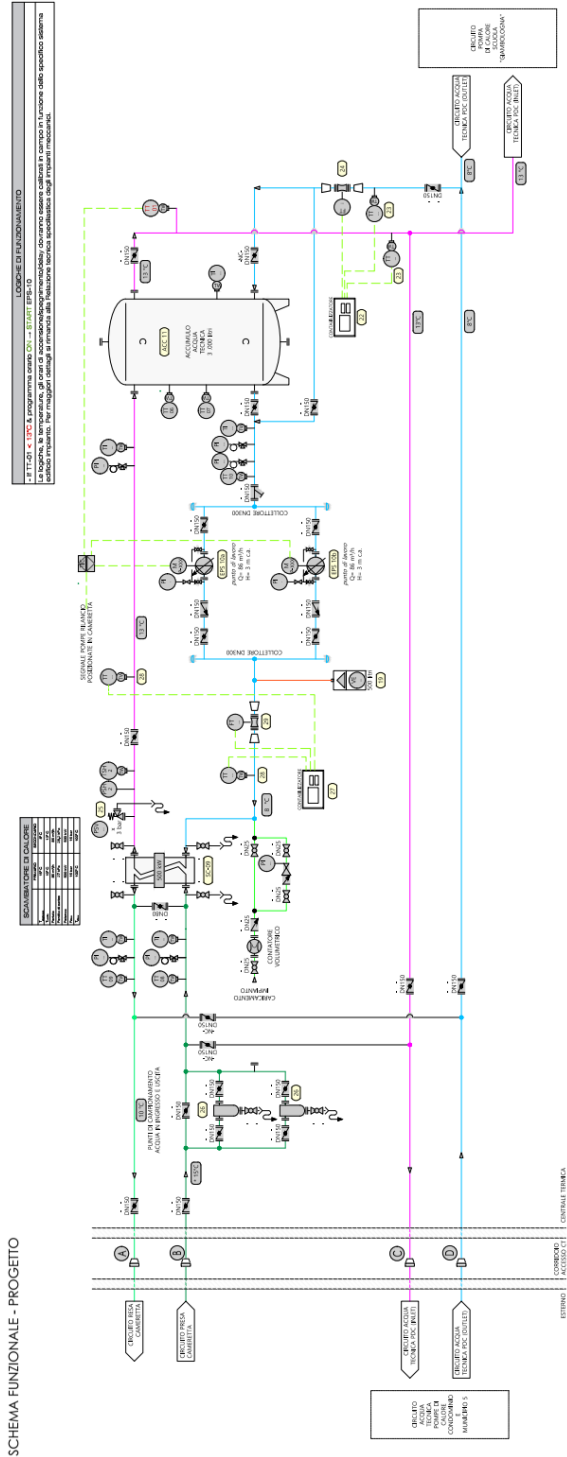


Figure 6-5: Central distribution substation P&I diagram

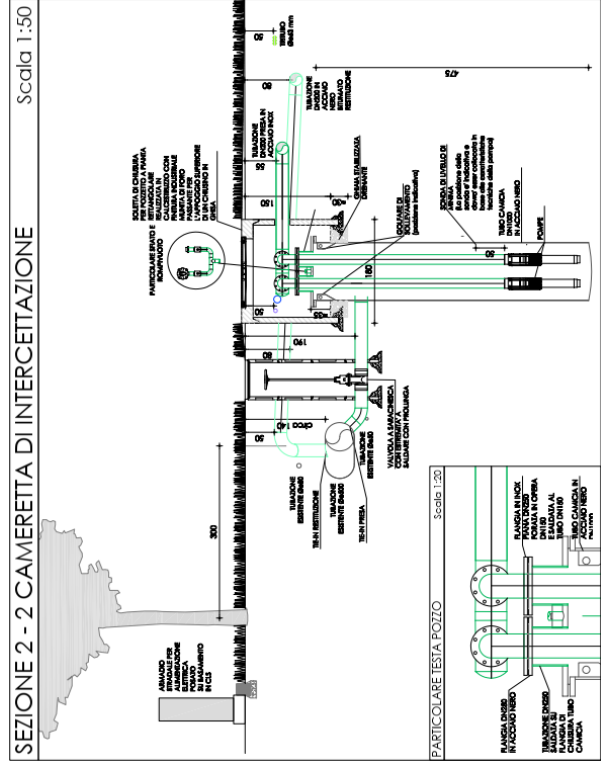


Figure 6-4: Water Intakes Layout

SCHEMA FUNZIONALE STATO DI PROGETTO

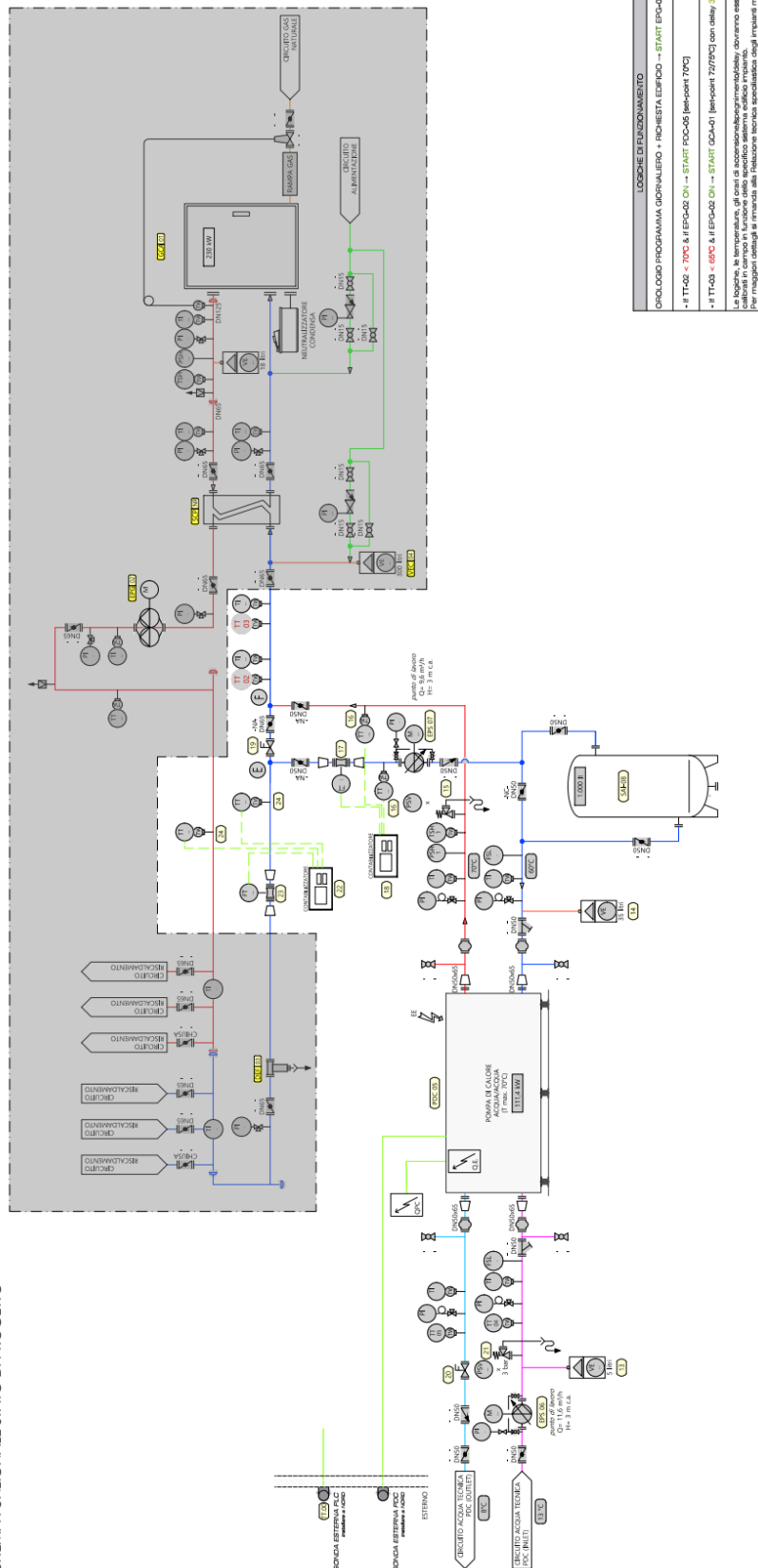


Figure 6-6: Design of Kindergarten Substation

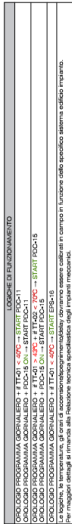


Figure 6-7: Design of Municipal Centre Substation

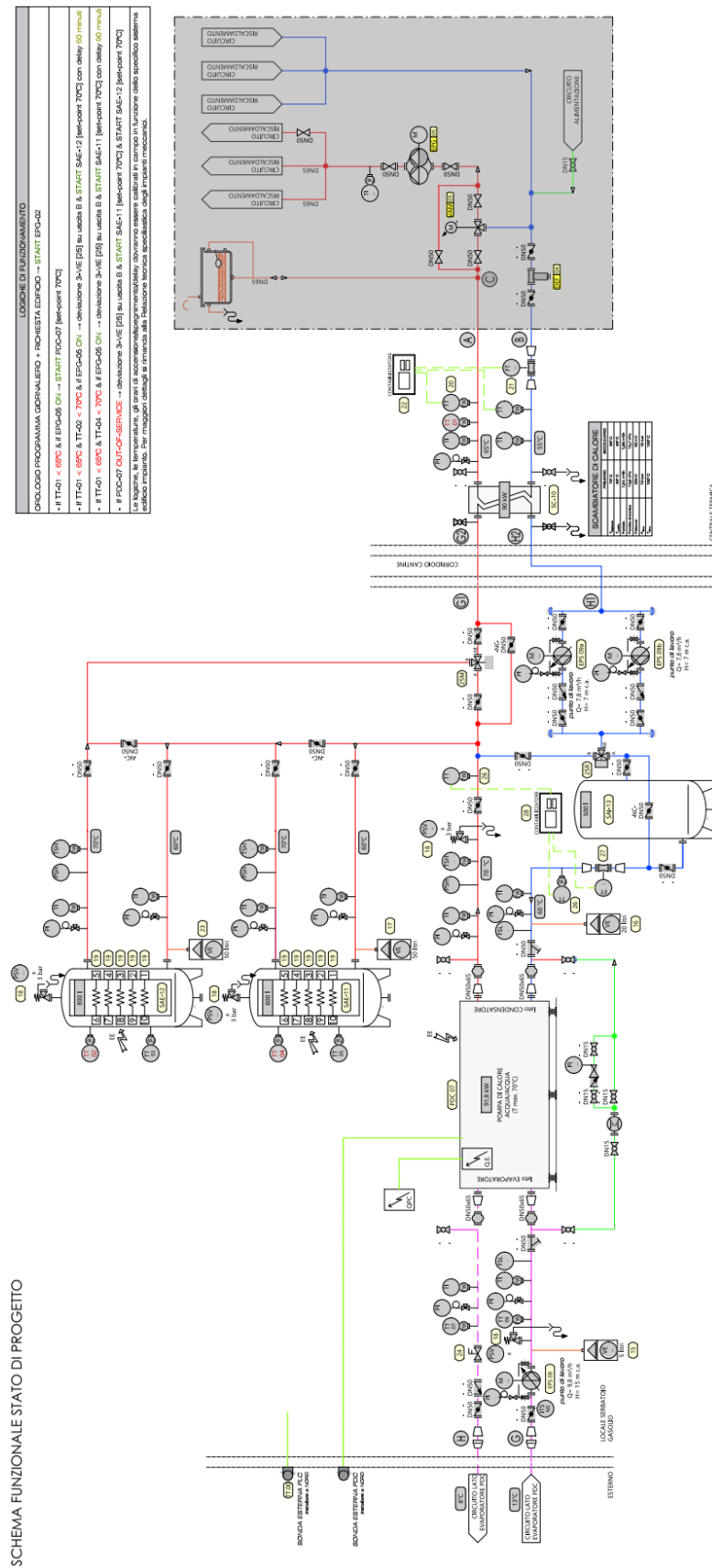


Figure 6-8: Design of Residential Building Substation

6.5 Pictures of the Construction Works

The construction works for the groundwater intakes and the installation of the neutral-temperature DHC network started in December 2021 and were completed in October 2023. The following Figures show a set of views of the site.



Figure 6-9: View of New Interception Pit



Figure 6-10: View of the central distribution substation



Figure 6-11: View of the central distribution substation



Figure 6-12: View of the Municipal building substation



Figure 6-13: View of the Municipal building substation

7 Mölndal, Sweden

7.1 Description of the demonstration site

The demonstration site in Mölndal features a newly constructed, small-scale, low-temperature district DHC network, developed as the extension of a nearby existing high-temperature DHN. This original network supplies heating to old tertiary and residential buildings and is connected to the Gothenburg DH backbone. Due to the characteristics of these buildings, the supply temperature is high, at around 80°C, with a limited temperature drop.

To optimize the return temperature to the backbone, the newly built low-temperature section, which serves both newly built tertiary and residential buildings, has been connected to the return line of the existing network via a heating central constructed underground. As such, this new network operates at temperatures below 60°C, which effectively lowers the return temperature to the backbone to below 50°C.

The new heating central is also equipped with geothermal heat pumps that generate heating during periods of low electricity costs, while also enabling space cooling distribution to the tertiary buildings, thus boosting both utility and energy efficiency, by allowing to select the most environmentally friendly and affordable energy vector on an hourly basis. Additionally, since the network's distributed temperature is insufficient for DHW preparation, booster heat pumps are installed in each building to meet DHW requirements. Meanwhile, space heating and cooling are generated centrally, as described.

Figure 7-1 shows the area concerned with the REWARDHeat project in the red contour, right to the south of the existing city quarter. Six new multifamily homes, together with one hotel have been connected to the new network: the residential buildings only receive heating, while the hotel also receives cooling.

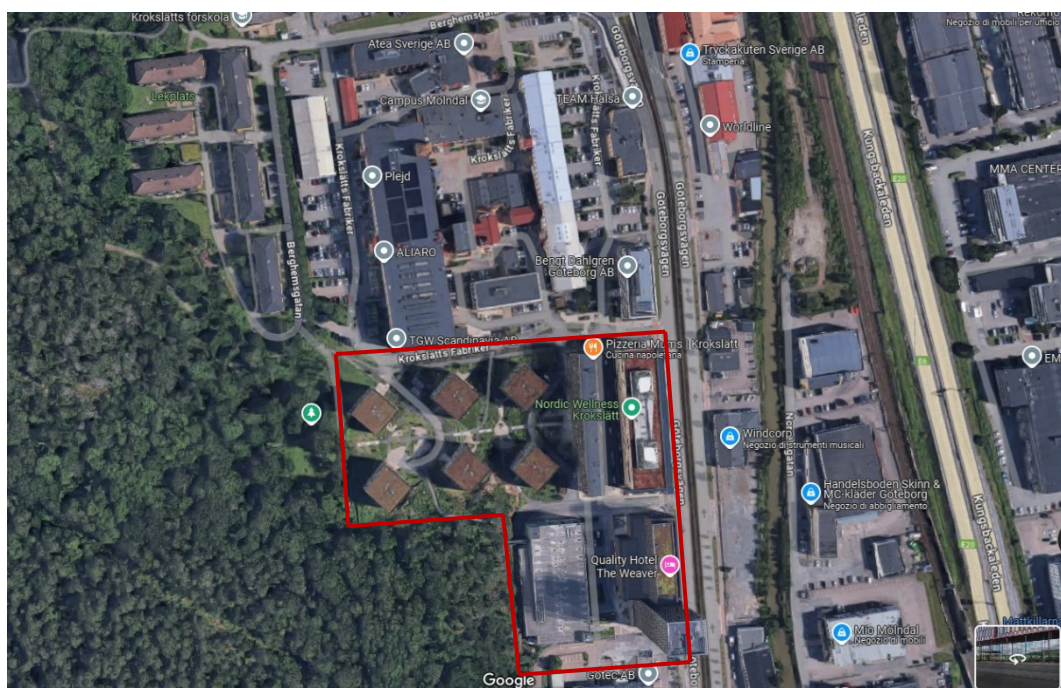


Figure 7-1: Newly built city quarter concerned in the REWARDHeat project



Figure 7-2: Newly connected multifamily buildings



Figure 7-3: Newly built and connected hotel

7.2 Objectives of the demonstration activity

The main beneficiaries of the project include INDEPRO, responsible for feasibility studies, and ARVALLA, which managed procurement and installation activities. Beyond the primary project partners, other key stakeholders are Husvärden (the property owner) and Mölndal Energy DH along with Krokslätt Energi AB, which serve as the backbone network owner and energy distribution manager respectively.

Efforts to enhance heating and cooling efficiency for the buildings have focused on the following actions:

- Establishing a central energy system with boreholes and a geothermal heat pump.
- Connecting the newly constructed energy central to the existing district heating network.
- Equipping each building with substations that include booster heat pumps for optimal energy delivery.

7.3 Description of the Results Achieved

During the REWARDHeat project, a new heating central was established, along with the installation of a geothermal field and associated heat pumps, as well as substations for multifamily homes and a hotel. The secondary loop from the heating central operates below 50°C, sometimes reaching as low as 30°C, depending on weather conditions. Space heating is supplied directly from the central system, while DHW is prepared in each building using booster heat pumps.

Figure 7-5 presents a simplified P&I diagram of the heating central, showing three geothermal heat pumps (each with a thermal capacity of 630 kW) on the left. Thermal energy is distributed to buildings after being buffered in a series of five large TES tanks, enabling flexible heat pump utilisation. The connection to the pre-existing network is marked by K18-K21 in the diagram's bottom right corner. Free-cooled or chilled water (using an additional water-to-water chiller, shown at the diagram's bottom right) is distributed directly to the hotel and other tertiary buildings, and returns at a higher temperature to recharge the boreholes.

The system incorporates a smart management strategy that dynamically selects between DH and heat pump heating based on forecasted system COP, as well as hourly electricity and DH energy prices provided in day-ahead communications.

Figure 7-6 illustrates the principle layout of substations at the residential buildings with typical operating conditions. During mild autumn weather, space heating is provided at below 40°C directly from the central warm water supply, while DHW is generated via a local 139 kW heat pump. This setup includes a booster configuration: when the inlet temperature is sufficiently high, the VV1 heat exchanger preheats cold tap water, which is then mixed with the hot water produced by the heat pump. This configuration achieves high COPs even with DHW supplied at approximately 60°C.

A similar setup is installed at the hotel, where high DHW demand is managed by two 139 kW heat pumps and 10 x 300-litre TES units connected in series. This allows peak loads to be covered efficiently, with electricity use optimised for cost-effective times (as illustrated in Figure 7-7).

The project received all necessary permits, including building and drilling permissions for boreholes, from the Municipality of Mölndal. A single tender was conducted to select a general contractor responsible for borehole drilling, heat pump installation, and the free cooling system. Public district heating companies managed the construction and provided the piping

infrastructure, while DH substations, control equipment, and related components were procured through competitive bids within the general heating installation contracts.

7.4 Technical Drawings

The following Figures present a selection of the technical drawings for the construction of this demonstrator:

- Figure 7-4 presents an overview of the area
- Figure 7-5 presents the energy central P&I diagram
- Figure 7-6 presents the multifamily homes substations principle scheme
- Figure 7-7 presents the hotel substation principle scheme.



Figure 7-4: Overview of the Area

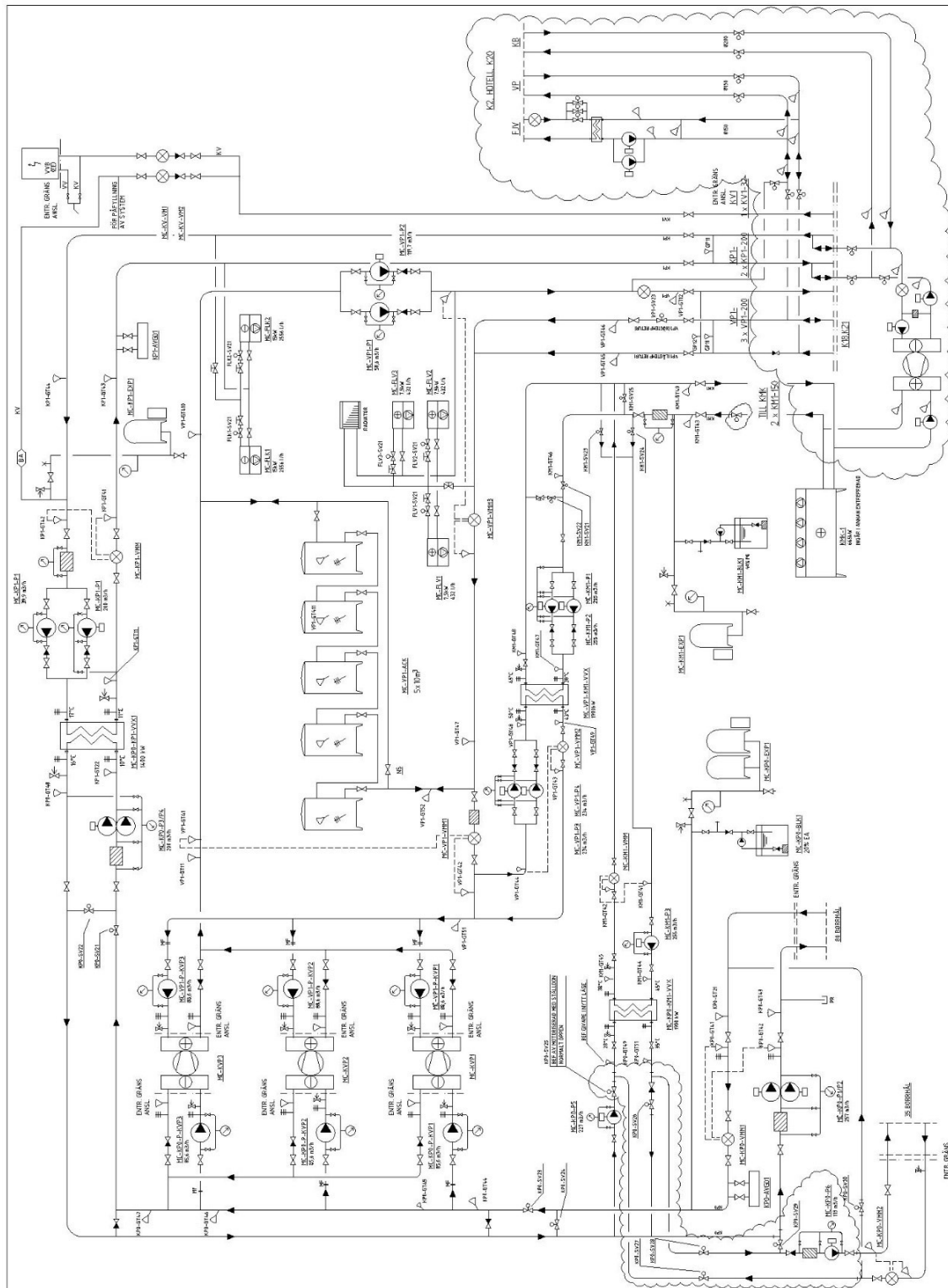


Figure 7-5: Energy central P&I diagram, including connection to the existing DH network and geothermal heat pumps

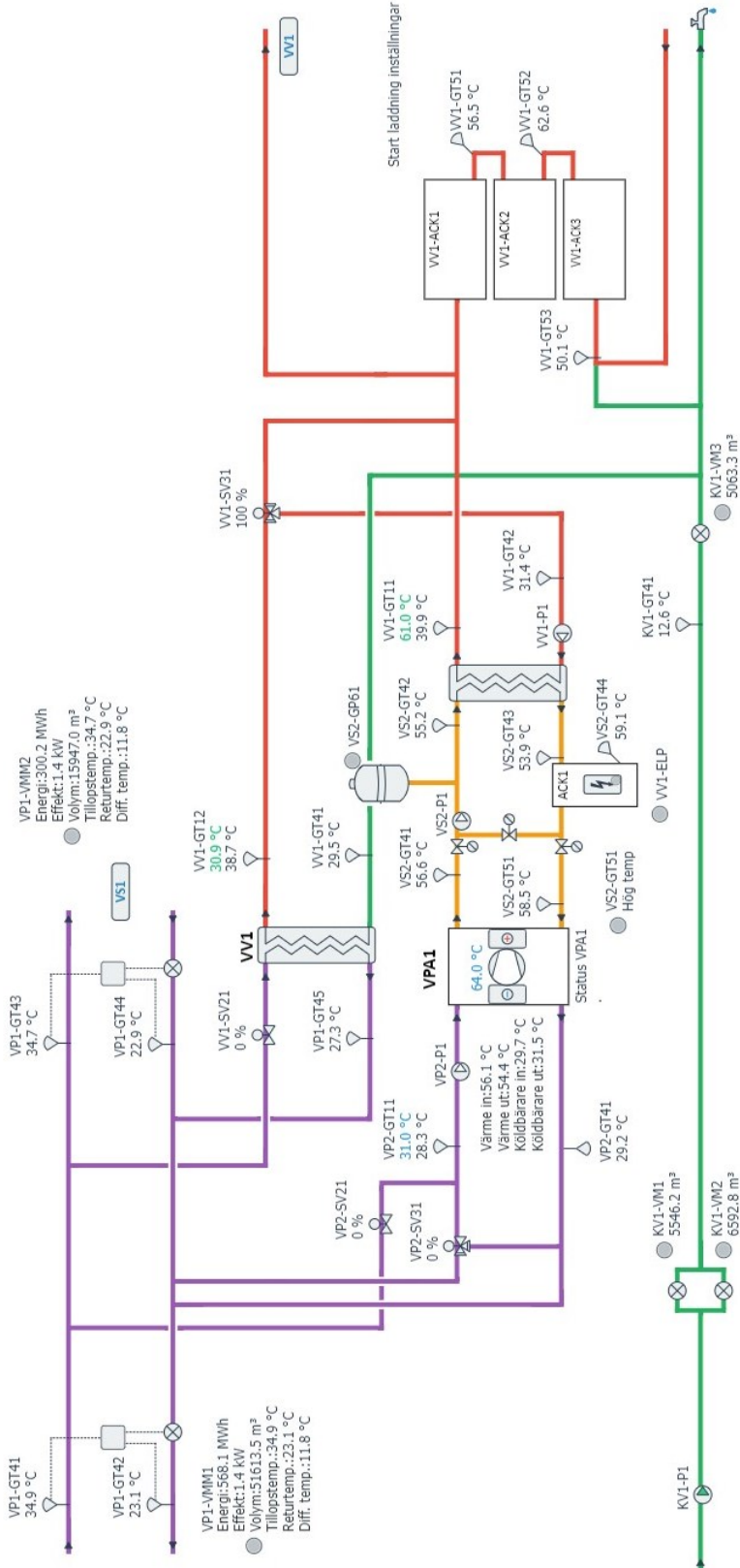


Figure 7-6: Multifamily Homes Substations Principle Scheme and typical operation parameters, through user graphical interphase



Figure 7-7: Hotel Substation Principle Scheme and typical operation parameters, through user graphical interphase

7.5 Pictures of the Construction Works

The following Figures present a selection of pictures taken on site:

- Figure 7-8 shows the piping to boreholes in the energy central
- Figure 7-9 shows one of the heat pumps set up in the energy central
- Figure 7-10 shows the piping to the new hotel building
- Figure 7-11 shows a few details of the booster substation installed at the hotel building.



Figure 7-8: Piping to Boreholes in the Energy Central



Figure 7-9: Heat Pump in the Energy Central



Figure 7-10: Piping Installed to Connect the Hotel to the Energy Central



Figure 7-11: Booster Heat Pump installed at the Hotel (left); Heat Exchanger to the Local DH Network at the Hotel (centre); Piping to 10 TES in Series (right)

8 Szczecin, Poland

8.1 Description of the demonstration site

Szczecin's demonstration site is located on the Łasztownia river island, and constitutes the first case of low temperature, hybrid DHC network in Poland.

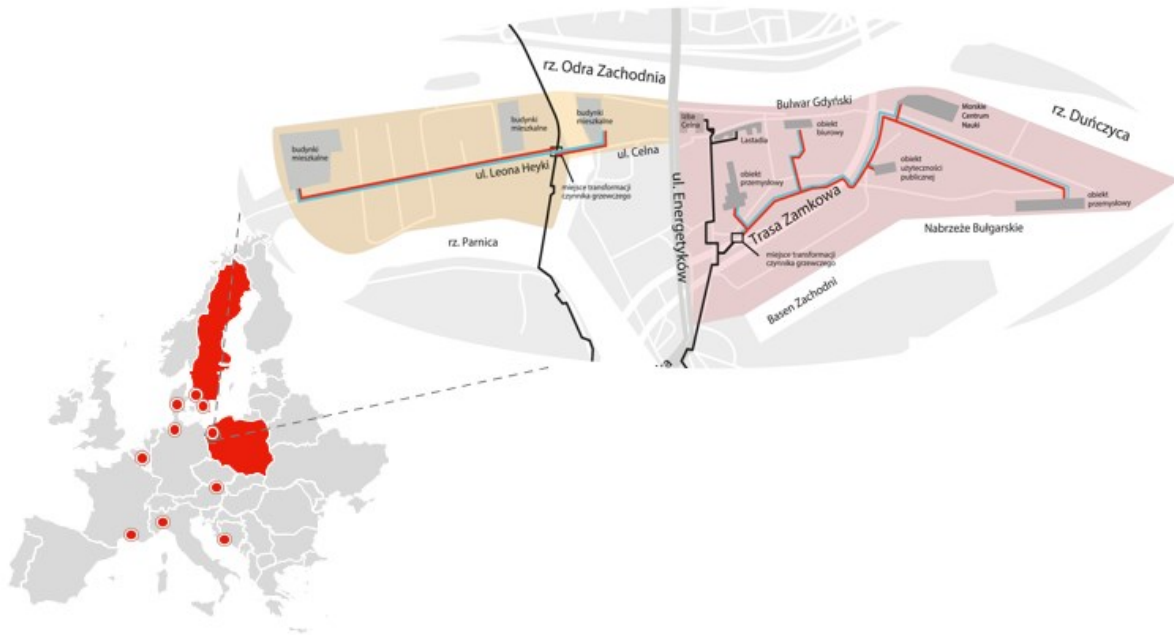


Figure 8-1: Łasztownia Island. On the Right, red highlighted, the area interested by the REWARDHeat Project

The newly developed network follows the E.ON ectogrid™ concept. Typical operating temperatures range from 30-50 °C at the supply pipe in summer and winter, respectively, and 25-35 °C at the return. A Heat Balancing Station (HBS) connects the new network to the existing high-temperature district heating (DH) system and adiabatic coolers, enabling the distribution of both heating and cooling to users. Currently, the HBS supplies the Maritime Science Centre (MSC) with approximately 400 kW for heating and 600 kW for cooling. The system is designed to accommodate future expansions, supporting 3450 kW for heating and 2250 kW for cooling, as the DHC network approaches its nominal capacity.

The MSC's space heating and DHW loads are covered with direct heating in winter. Polyvalent, 4-pipes, water-water chillers cover DHW and space cooling needs in mid- and summer seasons and reject waste heat into the network. The chillers draw water from the network's return pipe, ensuring the condenser operates within its permitted temperature ranges throughout the year.

All assets on the secondary side at the MSC are supervised by a local BMS and managed by the building energy manager. Both, HBS and MSC transfer data in two directions to and from the DHC network SCADA system.

Figure 8-2 provides an overview of the general system layout on Łasztownia. On the left, it illustrates the installation at the HBS, including a water tank used for storing excess heat. On the right, the MSC is depicted, with a green line indicating the ownership boundary.

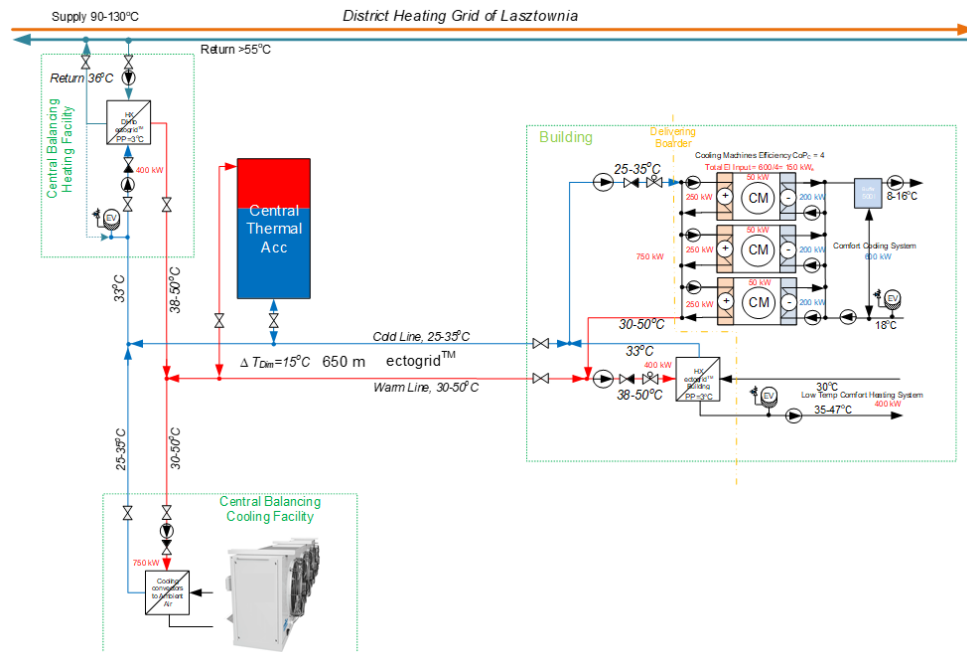


Figure 8-2: Scheme of the low temperature DHC network on Łasztownia Island in Szczecin

8.2 Objectives of the demonstration activity

The scope of the demonstration activity is to supply heating and cooling to the MSC. The MSC needed thermal capacity was calculated in about 400 kW @ 45/35°C for what concerns heating, and 600 kW @ 7/12°C for cooling. Specifically, the objectives pursued during the project are:

- Development and set up of the initial low temperature DHC network backbone;
- Construction of the Heat Balancing Station (HBS) and set up of the first customer substation;
- Implementation of the HBS management system, aimed to optimize mass flow and temperature in the network based on demand side loads assessment.
- Assessment and improvement of the solutions implemented and development of recommendations for replication
- Analysis of the available waste heat on the island from identified potential sources: a chocolate factory and a food cold storage facility.

8.3 Description of the Results Achieved

Along with the REWARDHeat project, SEC achieved to set up the new DHC network as described above.

Figure 8-3 depicts the HBS, which connects to the grid and includes two active facilities that provide both heating and cooling. The heating facility features a plate heat exchanger, which reduces DH temperatures while delivering necessary heating power. The cooling facility uses adiabatic air coolers for efficient cooling. Additionally, a 20m³ passive balancing reservoir enables energy storage and stabilises pressure within the grid.

The HBS is designed to maintain optimal temperatures in the warm and cold pipes through the ectocloud™ system. This system controls the average temperature of the thermal buffer tank to ensure consistent heating or cooling within the specified temperature range. By managing storage temperatures, the system maximises efficiency for both heating and cooling and minimises reliance on the conventional DH backbone during colder months.

Automation programming is implemented to support smooth HBS operation, with the ectocloud™ system enabling dynamic, intelligent control. The automation system adapts to real-time demands, optimising the heating and cooling processes within the required temperature range for energy-efficient management. The local control at HBS performs three key tasks in real-time:

- Producing the right amount of heating and cooling loads,
- Switching between heating and cooling based on grid demand balance,
- Supplying the correct temperature to the network's cold or warm pipes as directed by ectocloud™.

Figure 8-4 presents a P&I diagram illustrating the interface between the DHC network and the MSC. Here, the local control system addresses the building's heating and cooling needs while regulating energy returned to the network at the appropriate temperature. This enables internal heat recovery by the building's chillers, maintaining optimal temperatures for energy balancing and waste heat recovery, which is expected to play an increasingly important role in the future.

To achieve this, the substation delivers hot water for heating through the hot pipe (shown in red) and supports chillers through the cold pipe (shown in blue). While the building typically requires either heating or cooling, this setup allows the system to provide both simultaneously if needed. The hot pipe can supply high temperatures, and the cold pipe ensures temperatures compatible with chiller operations.

Figure 8-5 shows the overall heating and cooling system installed at the MSC, connected to the DHC network.

8.4 Technical Drawings

The following Figures present a selection of the technical drawings for the construction of this demonstrator:

- Figure 8-3 shows the P&I diagram of the HBS installed, according to the principle scheme in Figure 8-2
- Figure 8-4 shows the P&I diagram of the substation connecting the MSC to the low temperature network
- Figure 8-5 shows the P&I diagram of the overall heating and cooling system at the MSC.

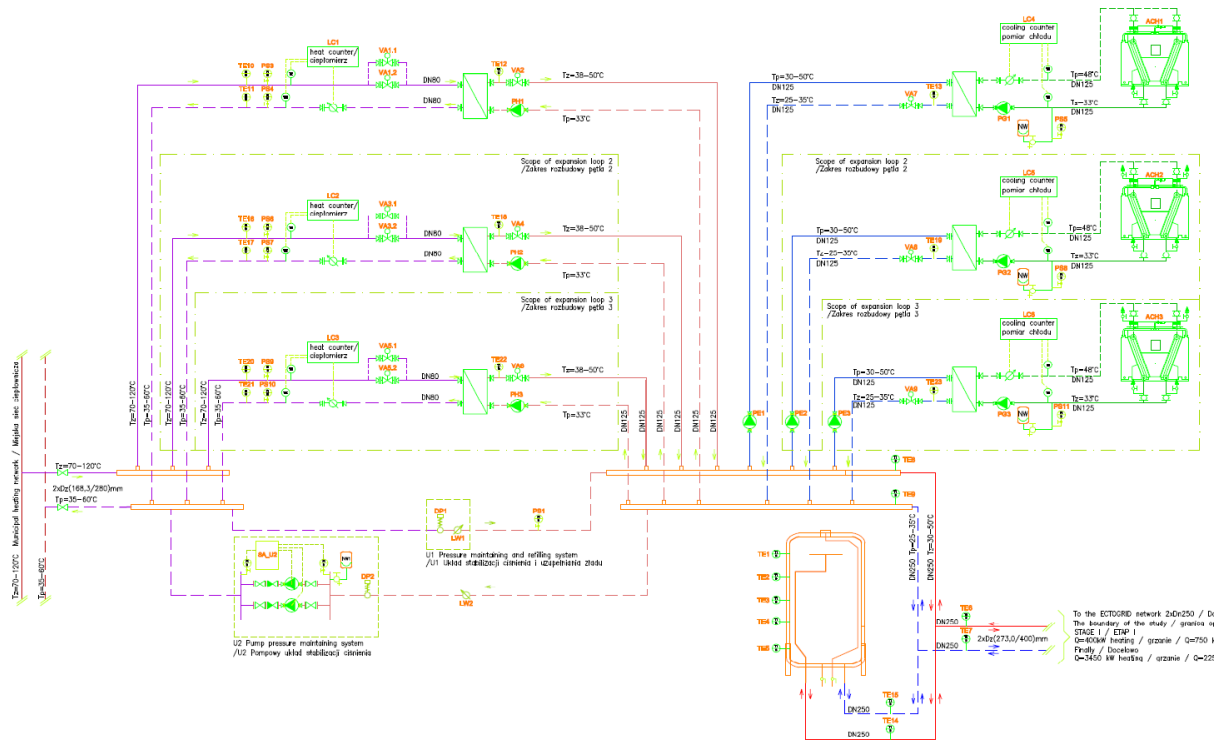


Figure 8-3: P&I diagram of the HBS

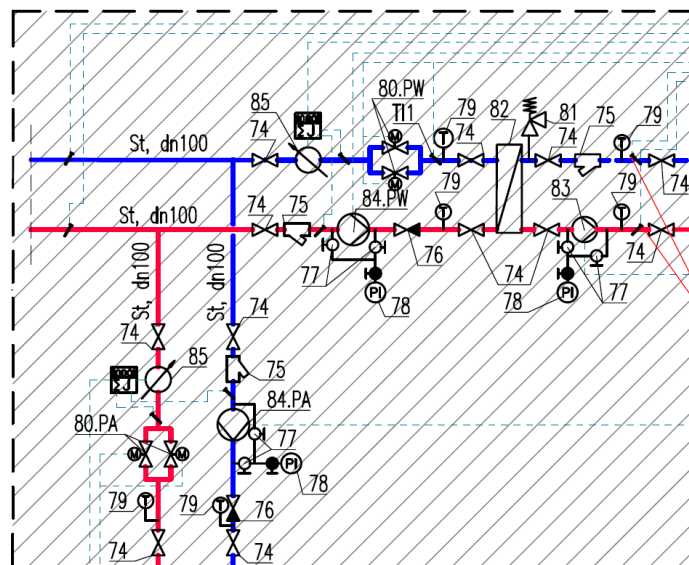


Figure 8-4: P&I diagram detail of the of substation in MSC

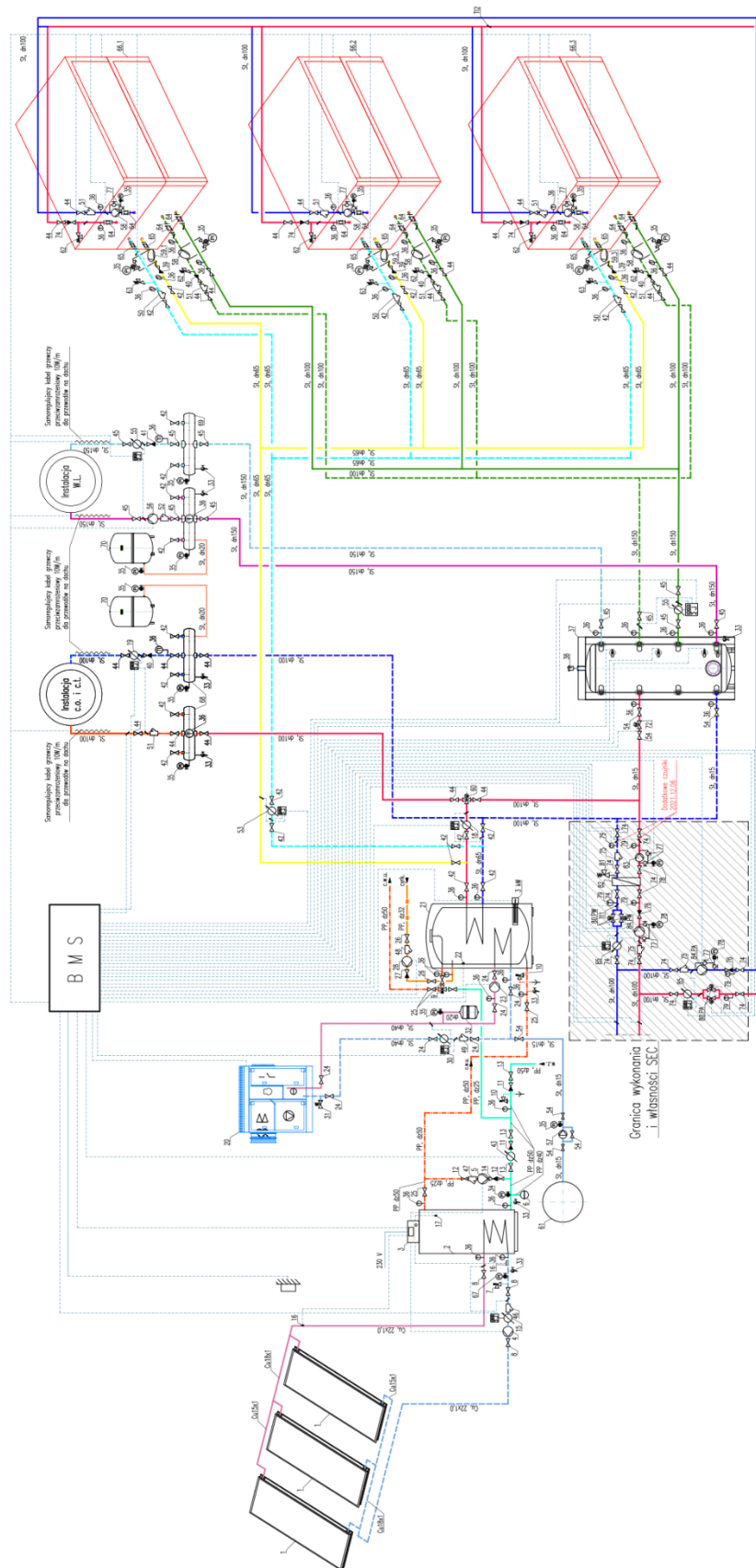


Figure 8-5: P&I diagram of the heating and cooling plant at the MSC

8.5 Pictures of the Construction Works

The following Figures present a selection of pictures taken on site:

- Figure 8-6 shows the HBS finalised
- Figure 8-7 shows the substation at the MSC
- Figure 8-8 shows a detail of the switchgear cabinet with E.ON Energy Manager in the MSC substation. All input and output signals from peripheral sensors, meters, BMSs and actuators are collected in local control units and transferred via E.ON Energy Manager to Ectocloud™, which is E.ON cloud service.
- Figure 8-9 show the low temperature DH network pipelaying
- Figure 8-10 show the waste heat meters in the chocolate factory. The chocolate factory will be used as a waste heat source in the future. During the REWARDHeat project, a waste heat audit took place to estimate the waste heat potential and heat meters were installed.



Figure 8-6: Heat Balancing Station



Figure 8-7: Substation under construction at the MSC

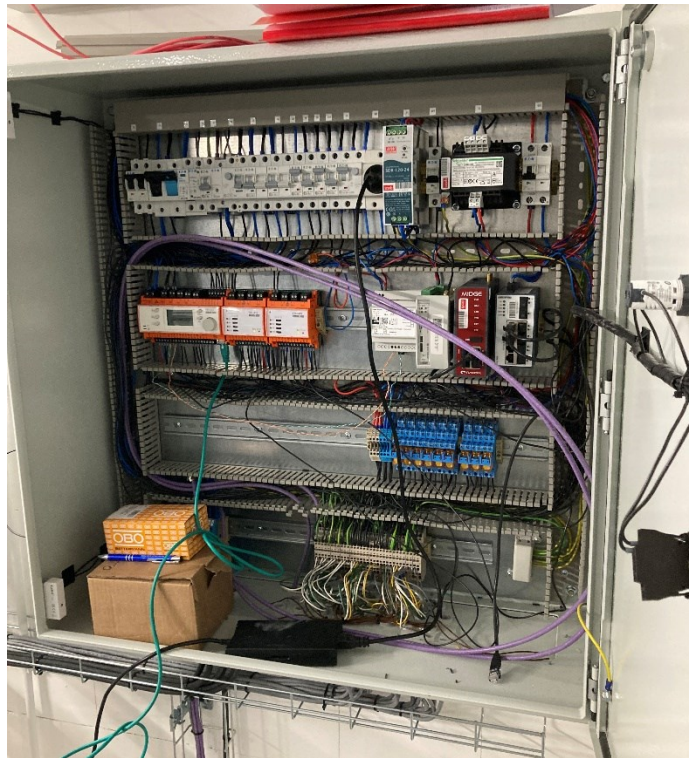


Figure 8-8: Substation at the MSC – switchgear cabinet under construction with E.On Energy Manager

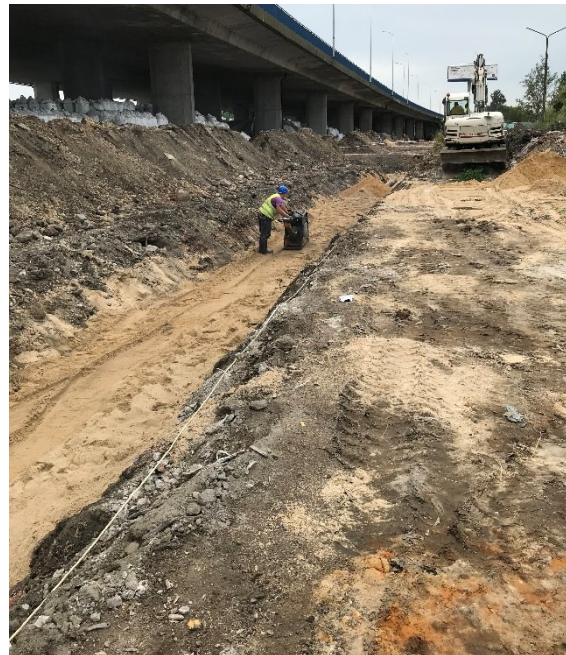


Figure 8-9: Low Temperature DH Network under Construction



Figure 8-10: Waste heat meters at the chocolate factory, collecting data from 11.2021.

9 Topusko, Croatia

9.1 Description of the demonstration site

The area of Topusko is rich in thermal springs. The concessionaire for the extraction of geothermal hot water is Health Spa Topusko and Top-Terme LCC, who manage a large healthcare structure including hotels, mud baths and swimming pools.

Heating and DHW preparation for all buildings and facilities takes place inside the central thermal station (CTS, Figure 9-1): geothermal water is collected from the TEB-4 well @ 62 °C and used to condition technical water to the different temperature levels needed; technical water is then distributed from here to the uses.

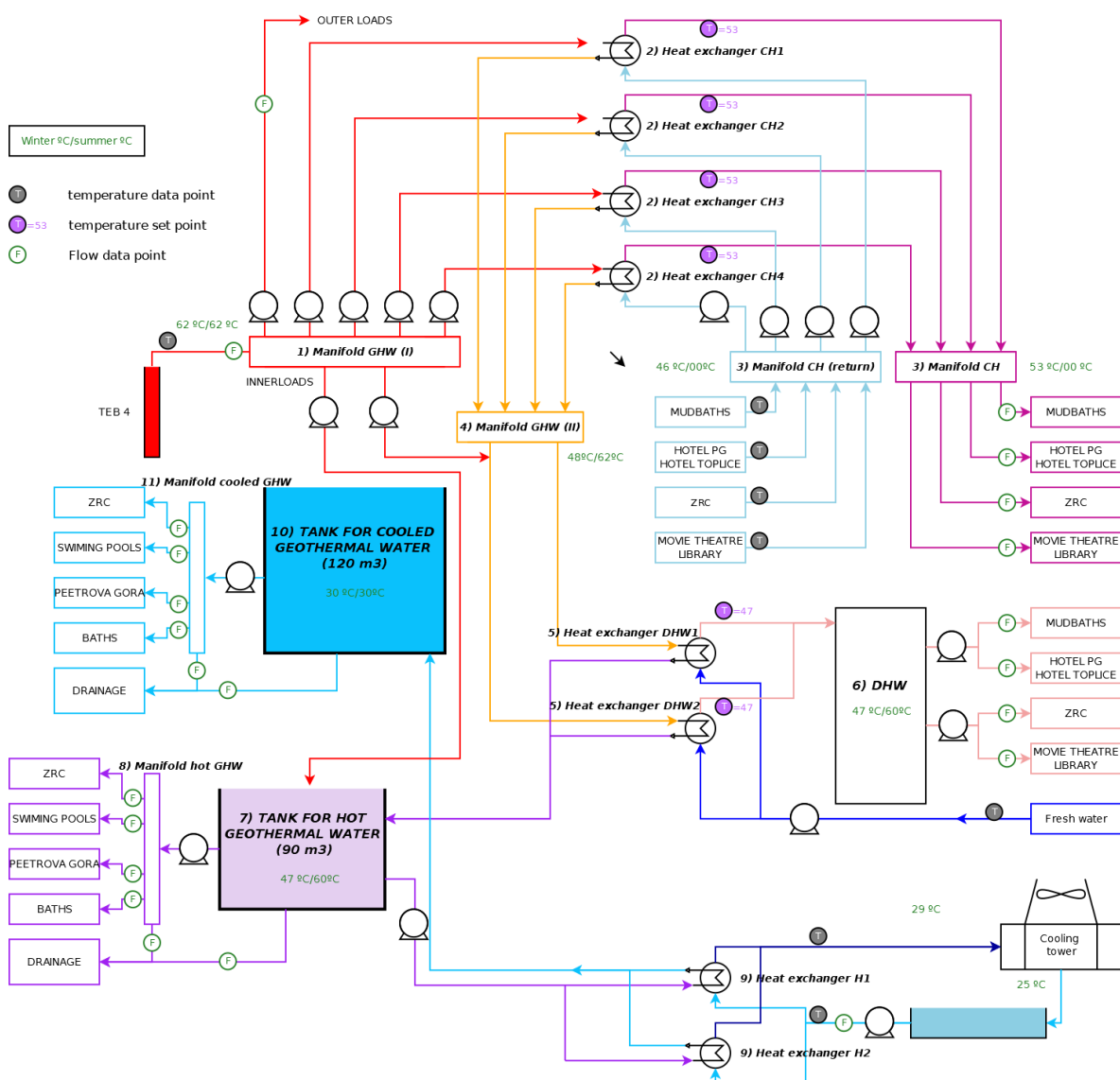


Figure 9-1: Scheme of energy facilities in Topusko.

Four heat exchangers, 712 kW_{th} capacity each, generate heating for all buildings @ 50°C. From here, geothermal water is cascaded to the heat exchangers devoted to the preparation of DHW stored @47 °C in one 10m³ TES, and further distributed to the water storages for balneology and

swimming pools. Two concrete tanks store water at high temperature ($90 \text{ m}^3 @ 47^\circ\text{C}$) and low temperature ($120 \text{ m}^3 @ 30^\circ\text{C}$). In the latter case, water is preliminary cooled by means of a wet cooling tower. Water from the two TES is distributed to baths or swimming pools where it is mixed to obtain the needed temperature level.

In addition to distributing geothermal and technical water throughout the healthcare facility, high electricity consumption is also required to operate the wet cooling tower. This demand is particularly pronounced during the summer when there is no need for space heating, hence higher temperature water is available after DHW preparation.

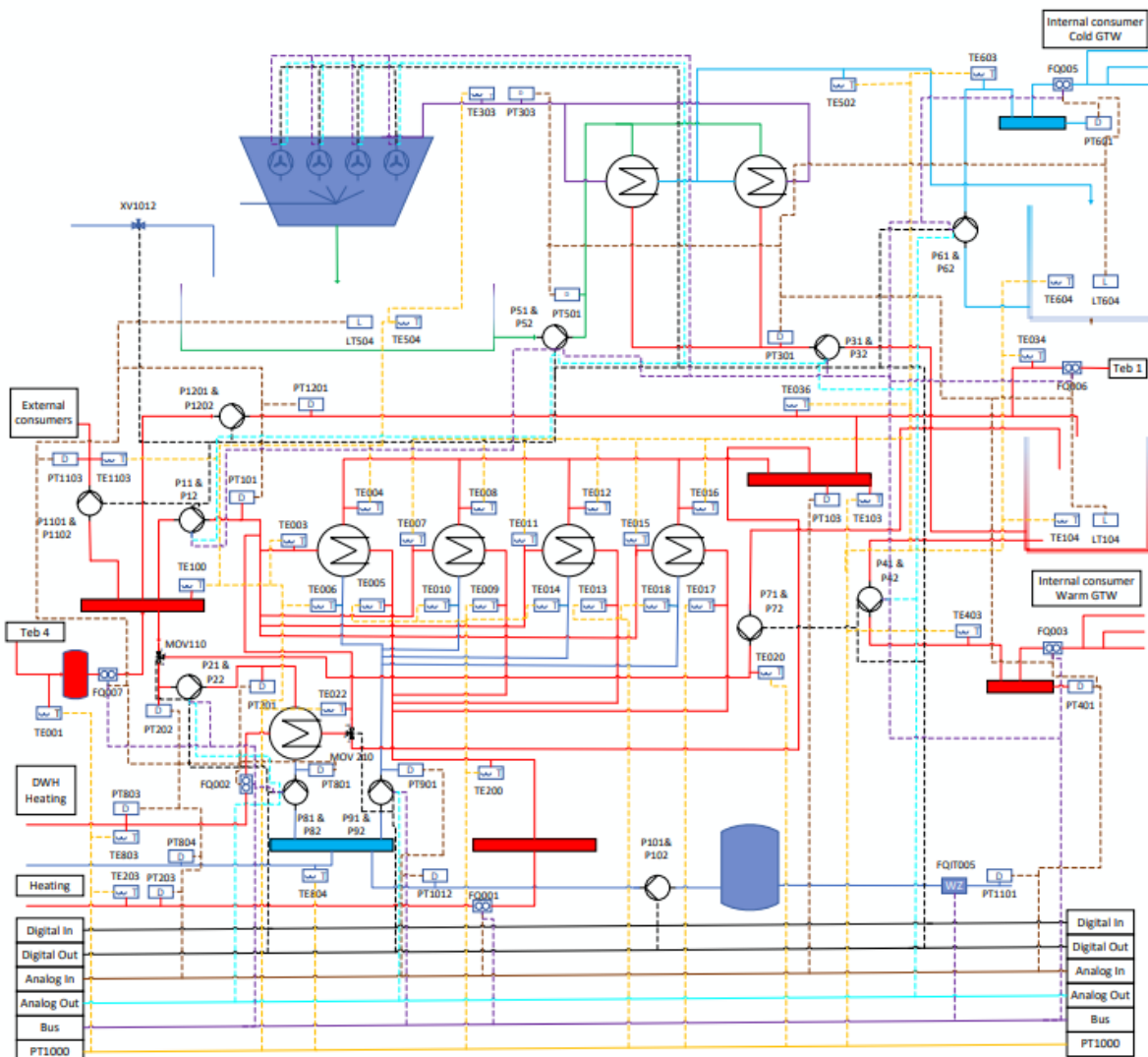


Figure 9-2 – Scheme of the central heat station (CTS) with flow chart of the control signals.

9.2 Objectives of the demonstration activity

Within REWARDHeat a complete refurbishment of the CTS and of the structure's DH network has been performed, aimed to significantly increase the overall system energy efficiency. The following measures have been implemented:

- All pipelines from TEB-4 to CTS and from CTS to all uses have been replaced with insulated ones;

- CTS pipes have been substituted, constant speed pumps and wet cooling tower's fans have been replaced with inverter-controlled, variable-speed ones, and manual valves have been replaced with remotely controlled ones. This allowed to implement an active control of both mass flows and temperature set points at the CTS.

The control hardware of the whole system at the CTS has been renovated by ENISYST, as at project start the system was operated manually, including the following measures (see Figure 9-2):

- Temperature sensors have been installed along the pipelines, DHW and geothermal water TES.
- Flow meters have been installed along the pipelines to get a complete view of the water flows and the thermal energy distributed within and from the CTS.
- Electric meters have been used to measure the electricity consumption of the whole CTS and of the wet cooling tower.

Although building substations could not be substituted nor can be controlled actively as they are owned by the building owners, heat meters have been installed also and connected to the CTS via LoraWAN technology, aimed to monitor space heating delivery and DHW preparation, hence allowing to forecast future energy uses.

9.3 Description of the Results Achieved

Under the REWARDHeat project, substantial upgrades were made to the network infrastructure from the CTS to the entry points of internal consumers. Key changes included eliminating separate return pipelines, installing energy-efficient equipment, and integrating smart control and monitoring systems within the CTS.

The main supply pipeline from TEB-4 to the CTS was renewed. The new pipeline network for balneology and heating comprises a primary pipeline branching into smaller-diameter pipes customised for each consumer.

Significant changes within the CTS include reconstructing the main inlet divider for geothermal water from TEB-4, installing a sludge and sand separator with venting before entry, and reconstructing heat dividers for hot and cold geothermal water and the return heating bus. New geothermal pipelines in the CTS are made of AISI 316L stainless steel to increase durability.

Wear and tear led to the reconstruction of dividers for chilled and hot geothermal water; flow meters were installed on main output pipelines to internal consumers. DHW systems were implemented, featuring DHW tanks with internal spiral heaters at various heating substations. Additionally, five 3 m³ DHW tanks were installed across locations.

For DHW preparation, new exchangers were installed in the CTS to use geothermal energy from two sources: either directly from the main inlet divider or from the war concrete tank. A frequency-regulated circulation pump and automatic valve flow regulators were installed on the new pipeline to regulate the flow based on outlet and external air temperatures.

In addition to the system upgrades, the pre-existing control cabinet was replaced with new cabinets, housing instrumentation and the central control unit. The central control unit monitors and regulates the entire system, collecting measurements and adjusting outputs for optimal

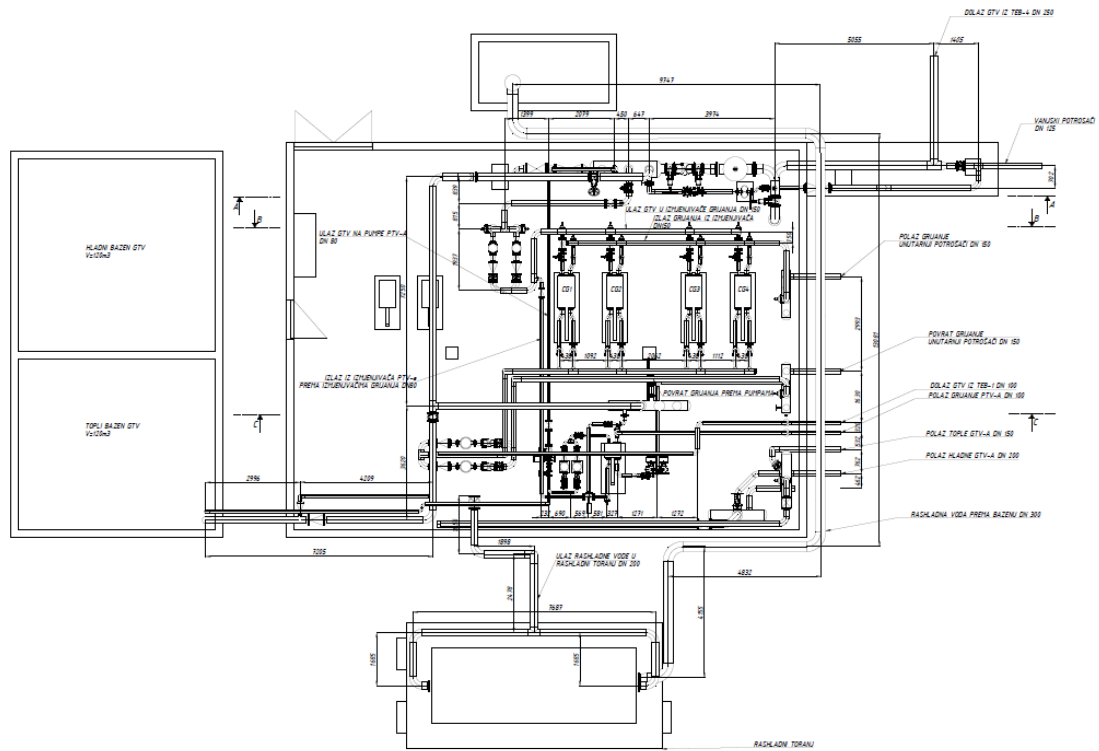


Figure 9-4: Plan of the CTS – after renovation

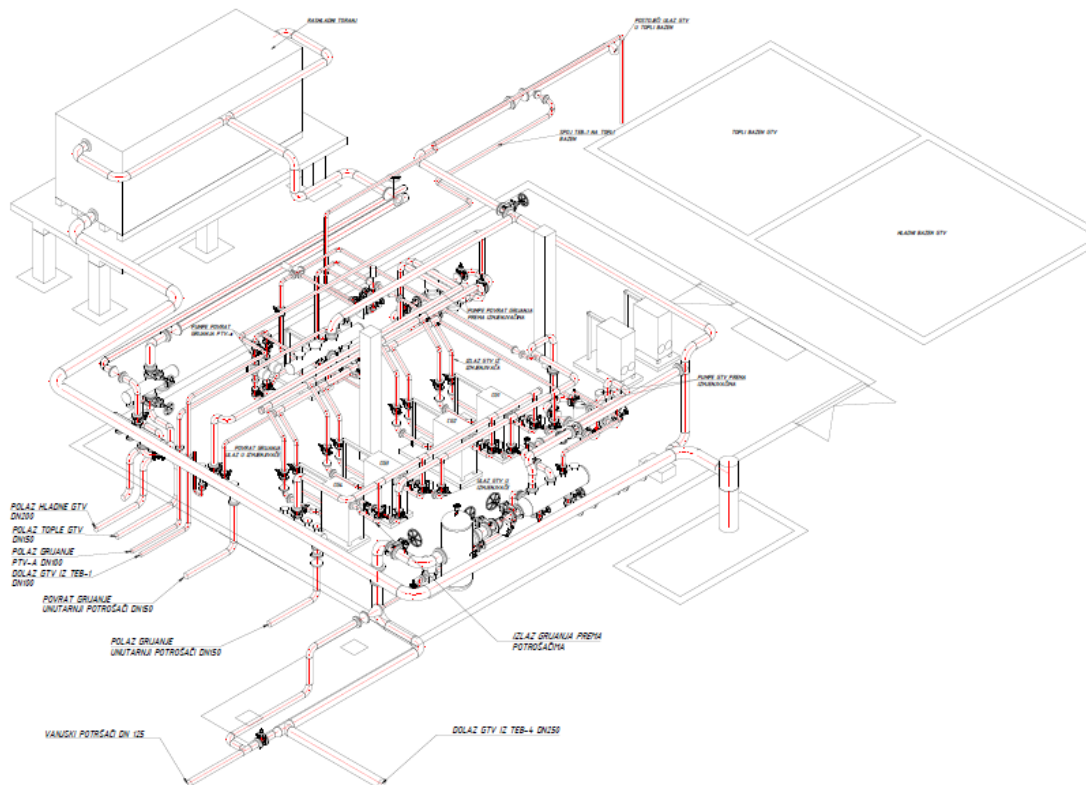


Figure 9-5: Plan of the CTS – after renovation - Isometric view

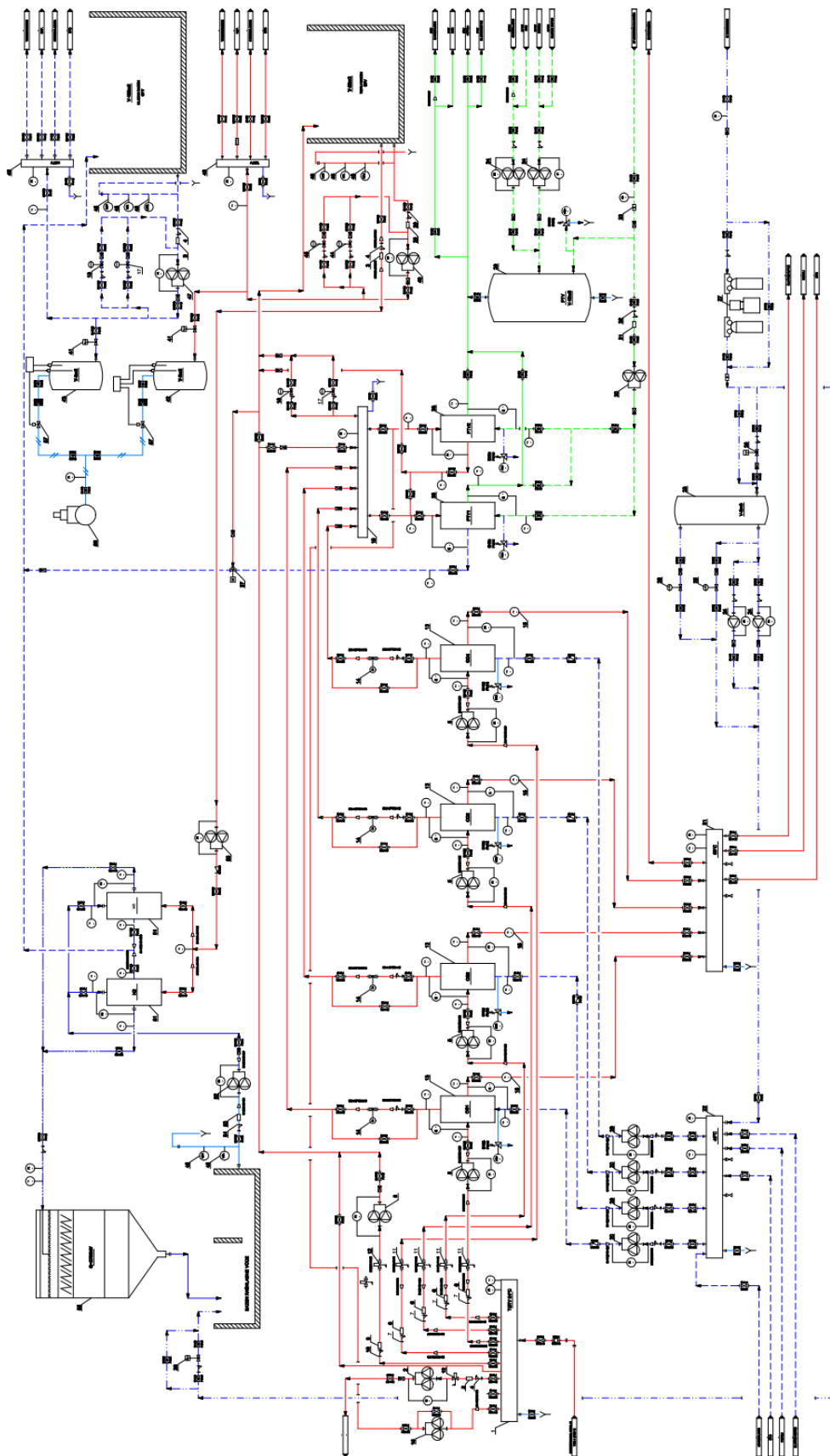


Figure 9-6: P&I diagram of the CTS – after renovation

A-A

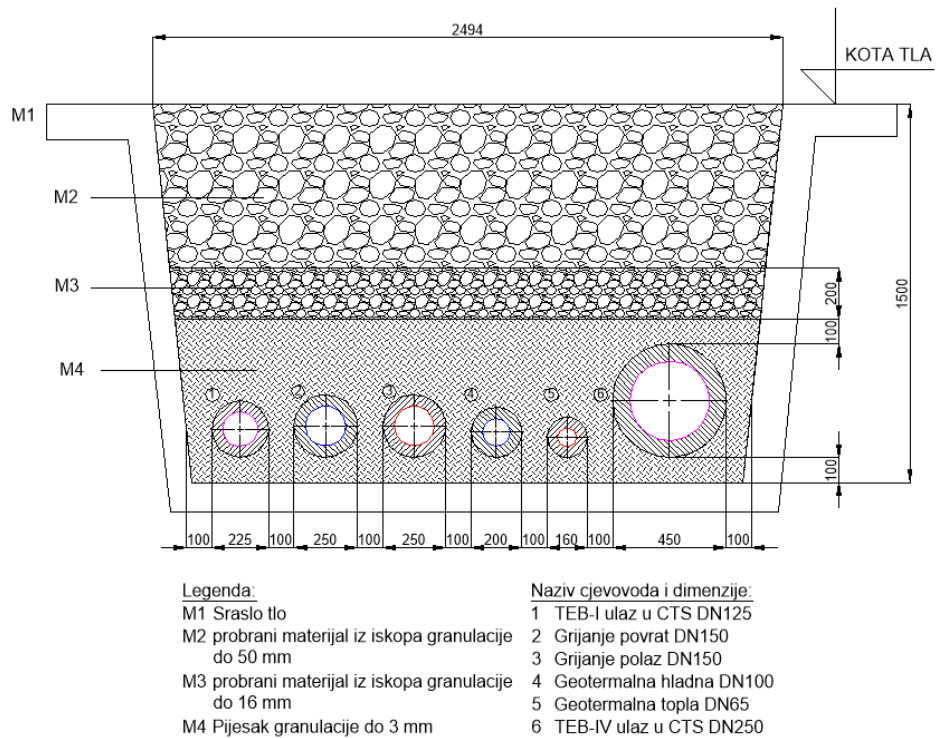


Figure 9-7: Section of the new trenches of the network that will substitute the existing ones

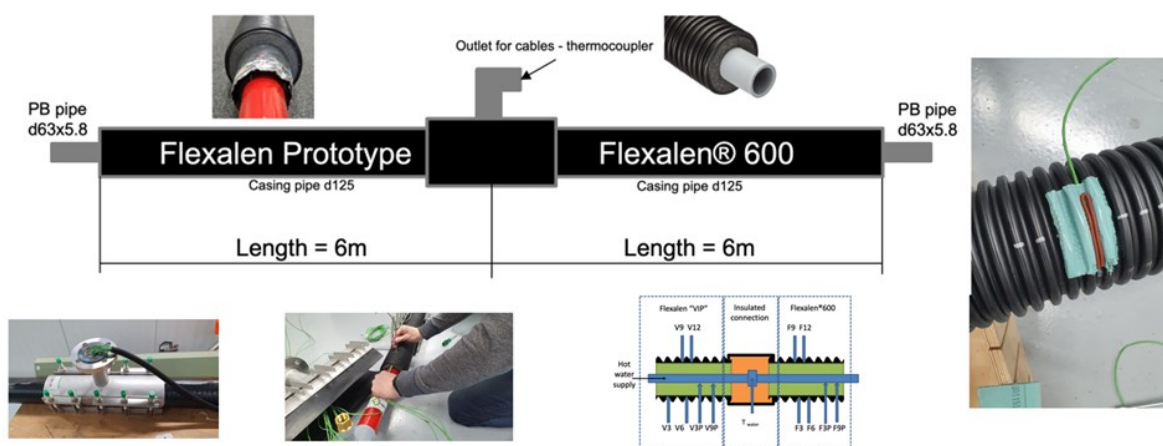


Figure 9-8: Thermaflex – Innovative pre-insulated plastic pipe for distribution of low-temperature heating

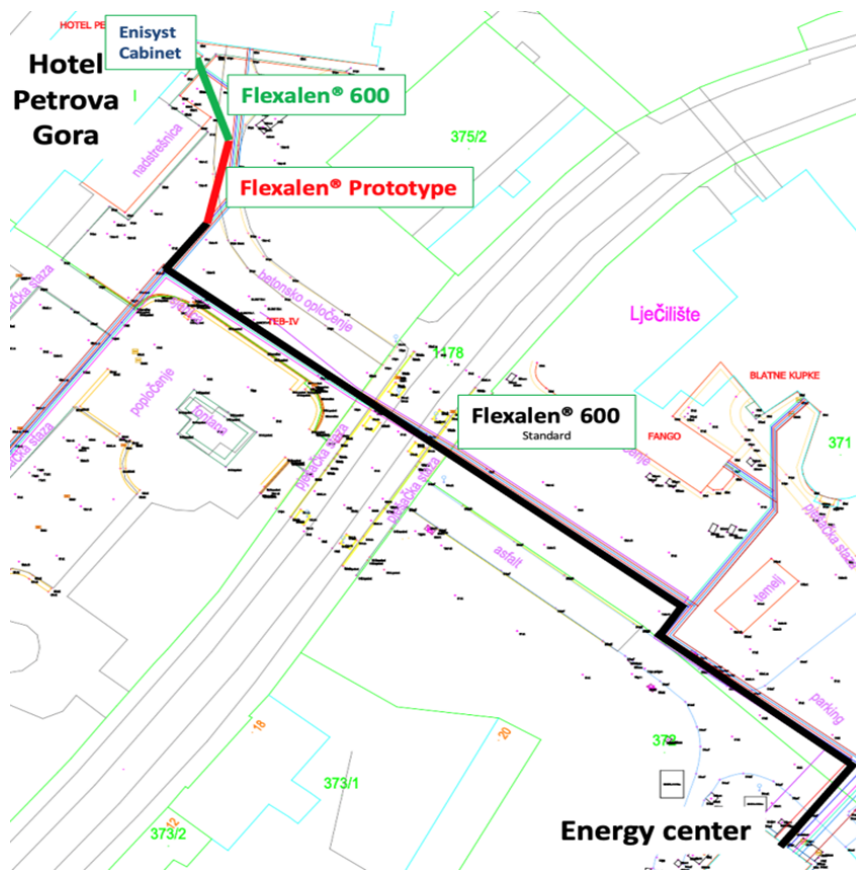


Figure 9-9: Installation location of Thermaflex Innovative pre-insulated plastic pipe

9.5 Pictures of the Construction Works

Some relevant pictures of the setups are reported in this section.

Figure 9-10 illustrates the intervention made on the open shaft at the main inlet of geothermal water located in front of the CTS. This inlet connects to the well TEB-4 and is a critical point for managing the geothermal water supply entering the central heating system. The intervention optimizes the water flow from the source well and enhances the inlet's functionality within the heating station, ensuring efficient integration of geothermal energy into the system. Figure 9-9 displays the open shaft at the main inlet where geothermal water flows into the CTS from well TEB-4.

Figure 9-12 presents an open trench with a newly installed pipeline dedicated to distributing geothermal water. This pipeline serves multiple functions, including providing geothermal water for balneology and therapy, supplying geothermal water for swimming pools, and distributing hot water for building space heating and domestic hot water through decentralized boilers.

Figure 9-13 shows the same trench with the innovative pre-insulated plastic pipe installed by Thermaflex. The pipeline includes connections for essential measurement tools, enabling testing and monitoring of the pipe's performance.

Figure 9-14 to Figure 9-16 display the newly installed heat exchangers and space heating equipment in the CTS building, prior to the completion of the new flooring. Figure 9-16 illustrates the final configuration of the system in the Central Heating Station area after all installation work was completed.



Figure 9-10: Construction works in front of CTS



Figure 9-11: The main inlet of geothermal water in CTS from source TEB-4



Figure 9-12: Open trench with new pipeline from CTS



Figure 9-13: Thermaflex innovative pre-insulated plastic pipe



Figure 9-14: New heat exchangers installed at the CTS prior to flooring work



Figure 9-15: New pipelines installed at the CTS prior to flooring work



Figure 9-16: CTS new floor, electrical cabinets and equipment