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USES4HEAT

D4.1 USES4HEAT Baseline monitoring, plan and basic engineering Litomerice Demo site

CUS

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Abbreviations and acronyms

Acronym	Description
BHE	Borehole Heat Exchanger
BTES	Borehole Thermal Energy Storage
CHP	Combined Heat and Power
CST	Concentrating Solar Thermal
DHN	District Heating Network
DHW	Domestic Hot Water
HEX	Heat Exchanger
HVAC	Heating, Ventilation and Air Conditioning
HP	Heat Pump
RES	Renewable Energy Source
STC	Solar Thermal Collectors
TES	Thermal Energy Storage

1. Introduction

This report constitutes Deliverable 4.1: Baseline Monitoring and Plan for Litoměřice Demo, developed as the first task in work package 4 (WP4), T4.1, led by CUS with the support of all partners involved in WP4. This is a revised version of the original D4.1, including the full description of the new demonstration site in Litoměřice and adaptation to the relevant key enabling technologies.

The deliverable provides an overview of the demo site and the pre-engineering work toward its sizing and operational optimization considering not only the main waste heat source but also additional heat generation opportunities. The document presents also the main background behind the project, analyzes the current energy flows and demand profile within the district heating network while reporting on general activities undertaken during the project's first year and the contribution of the key partners.

This document serves as a technical basis for integration of solar thermal systems and key technologies to be developed and financed within USE4HEAT. For a broader context of integrating the solar systems into the overall energy system, technical requirements for components and related building modifications are summarized.

The described work is part of the planned system extension of the local energy system built within the framework of the SYNERGYS project. The SYNERGYS project (2023-2027/2028) focuses on the energy and economic transformation of the coal region of the Ústí nad Labem Region. Its goal is to address the high dependence of the energy sector on fossil fuels and to develop human resources for new energy sectors. The main output is the development of a new international research and testing facility for renewable energy sources with a focus on geothermal energy and renewable energy sources and their integration into the existing district heating system of the city of Litoměřice.

The USE4HEAT project (2023-2027) focuses on the use of seasonal storage for heat from renewable energy sources and its reuse in district heating systems. Its goal is to verify in particular the efficiency of heat storage in relation to the temperature level of the connected systems (solar thermal collectors, heat consumption).

Within the framework of both projects an in the full integrated energy system, a set of energy sources will be implemented, including in particular a deep geothermal source, shallow underground heat storage, a hydrogen electrolyzer connected to a photovoltaic power plant, a large-scale solar thermal system, high-temperature heat pumps and other complementary technologies for their effective integration and long-term monitoring. These technologies will be demonstrated and tested in a real environment over a long period of time so that they can be replicated and used in other locations as competitive renewable energy projects. In addition to scientific and research benefits, the project will also provide a functional pilot system for supplying municipalities with renewable heat.

Chapter 2 summarizes the concept of the SYNERGYS energy system, and explain the planned extension in the context of USE4HEAT. Chapter 3 describes the solar thermal system for USE4HEAT project, including the targeted layout of collector arrays, expected parameters, control and monitoring items, and other requirements and conditions related to the delivery of the entire technology. Chapter 4 shows results

from preliminary simulations of the USE4HEAT system which serve for the optimization of the final design (collector area, number of boreholes etc.) and prediction of the system performance.

2. Base energy system – SYNERGYS

The complex energy system of the SYNERGYS project integrates innovative technologies of various types. It consists of a number of sub-systems focused on the supply of renewable energy. The systems are interconnected, using geothermal energy and long-term energy storage in the form of thermal storage in the rock environment, electrical energy in batteries or hydrogen storage. The entire system is implemented within the framework of a comprehensive building permit (currently in progress) and an issued environmental impact assessment (EIA, with a result "no impact on the environment").

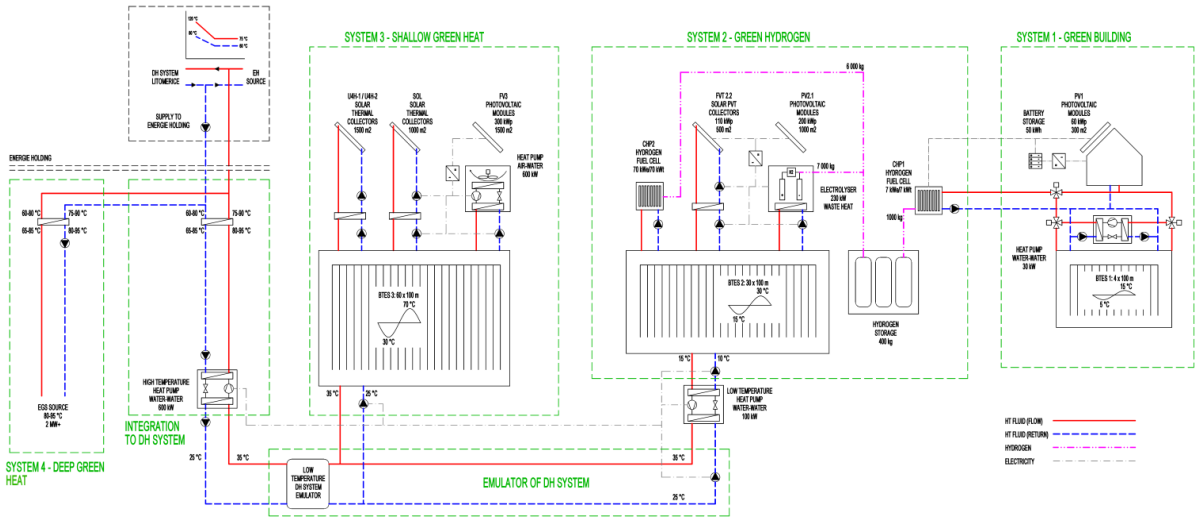

Figure 1 Simplified diagram of a complex system within the project SYNERGYS (see also Annex)

2.1. System 1 – Green building

System 1 (green building) focuses on the concept of so-called energy-plus buildings and will be implemented within the existing building of the RINGEN research centre. The energy system design intends to achieve a positive energy balance, when the production of renewable energy is higher than energy consumption, not only based on annual data, but also on hourly balance, i.e. a positive balance in every hour of the year. The system consists of a **ground source heat pump** with a heating capacity of approximately 30 kW intended for heating and cooling, a **photovoltaic system** with a peak output of at least 60 kWp (with an area of approximately 300 m^2, with an east-west orientation) located on the flat roof of the RINGEN building and a **hydrogen fuel cell CHP1** (approximately 7 kWe) for supplying the building with heat and electricity. The ground source heat pump is connected to the **borehole field BTES1** (borehole thermal energy storage) with 4 boreholes approximately 100 m deep for heat removal from space cooling in summer and for heat extraction in winter for space heating (operating temperature range from 5 to 15 °C). The PV system is combined with a **battery storage** (approximately 50 kWh) for efficient use of the PV system's production for electricity supply to the building. The hydrogen fuel cell uses the accumulated hydrogen (System 2) from the seasonal hydrogen storage with a total capacity of approximately 400 kg for simultaneous production of heat and electricity for the building in winter, when

the PV system has reduced output and the heat pump requires electrical energy for operation. The battery storage is also used in winter to compensate for possible discrepancies in production of electricity by the fuel cell while currently covering the building's heat demand.

Note: Currently, a heat pump system for heating and cooling the building, including the borehole field BTES1, has already been implemented.

2.2. System 2 – Green hydrogen

System 2 aims at energy-efficient production of green hydrogen. The main component is a **hydrogen electrolyzer EL** with a nominal electrical input of approximately 230 kW connected to large **photovoltaic system** (PV, peak electrical output of approximately 250 kWp, east-west orientation) and a **photovoltaic-thermal system** (PVT, peak electrical output of approximately 200 kWp, south orientation). Waste heat from cooling the electrolyzer and heat from cooling the photovoltaic-thermal collectors is supplied to the **underground thermal storage BTES2** formed by a field of ground boreholes. The use of heat from cooling the electrolyzer increases the efficiency of utilization electric energy, similarly the use of heat from PVT collectors increases the efficiency of utilization available solar energy. Compared to conventional PV modules, the cooling of PV cells also increases the production of electricity. Most of the heat from the electrolyzer and PVT collectors is accumulated in the BTES2 storage from spring to autumn and in the winter the heat is pumped by a low-temperature water-to-water heat pump with a nominal thermal output of approximately 100 kW (W20/W45) to the low-temperature heating network (CHP emulator). In BTES2, an operating temperature range between 15 and 30 °C is considered. The hydrogen produced by the electrolyzer (approx. 7000 kg/year) will be primarily stored in a **pressure accumulator** with a total capacity of approx. 400 kg, which serves both as an approximately two-week accumulator for the **hydrogen fuel cell CHP2** with an electrical output of approx. 70 kWe and with the combined production of electricity and heat to support local systems (approx. 6000 kg of hydrogen per year) and as a hydrogen seasonal storage for the **hydrogen fuel cell CHP1** with an electrical output of approx. 7 kWe for the RINGEN building (with a consumption of approx. 1000 kg of hydrogen per year). The heat from the 70 kWe fuel cell is also stored in the BTES2 storage facility.

Note: The design, engineering and implementation of BTES2 is the subject of separate public tender.

2.3. System 3 – Shallow green heat

System 3 (shallow green heat) consists of three systems for the production of fully renewable heat connected to seasonal thermal storage in the **borehole field BTES3**. The first system is a **large-scale solar thermal system (SOL)** with a total gross collector area of approximately 1000 m^2, which produces heat by direct conversion of solar radiation. The second system is a **combination of a PV system** with a PV module area of approximately 1500 m^2 (approximately 300 kWp) supplying electrical energy for the operation of **high-temperature air-source heat pump (PV-HP)** with a heating capacity of approximately 600 kW (A20/W80) for the production of fully renewable heat from the ambient. The production of usable heat by pumping from the ambient air utilizes only renewable electrical energy thanks to the adaptation of the heat pump power input to the PV system power output from approximately 15 % to 100 % (heat pumps

with compressor power control). The third system (implemented with funds from the USE4HEAT project) is a **solar thermal system (U4H)** consisting of two subsystems: U4H-1 consisting of flat-plate solar collectors with a total gross area of 1000 m^2; U4H-2 consisting of concentrating solar collectors tilted around the horizontal axis with a total gross area of up to 500 m^2. All three systems (SOL, PV-HP, U4H) supply heat mainly from spring to autumn to the **seasonal underground thermal storage BTES3** consisting of a field of ground boreholes. In winter, heat removal from BTES3 is carried out directly to the low-temperature heating network (DH system emulator) at a temperature level of 25 °C (System 5: integration).

Note: The design, engineering and implementation of BTES3 is the subject of separate public tender.

2.4. System 4 – Deep green heat

System 4 (deep green heat) is based on the **stimulated geothermal system EGS** (Enhanced Geothermal System). It is assumed that two deep wells (injection and production) will be created, which will be connected by a fractured heat exchanger created at a depth of approximately 3.5 km. By means of closed water circulation, heat can then be drawn from this depth permanently at a temperature level of 90 to 100 °C with an output of approximately 2 MW depending on the flow rate given by the final permeability of the underground geothermal exchanger. Part of the electricity consumption for the circulation of water in the exchanger will be covered by a **hydrogen fuel cell CHP2** with an output of 70 kWe (System 2).

Note: The design, engineering and implementation of System 4 (EGS) is the subject of separate public tender.

2.5. System 5 – Integration

The low-temperature district heating network (district heating system emulator) integrates System 2 and 3 and interconnects the BTES2 and BTES3 thermal storages. Heat will be pumped by a low-temperature heat pump with a heat capacity of approximately 100 kW (W20/W45) from the BTES2 and supplied directly from the BTES3. The emulator will physically simulate a low-temperature DH network at operating temperatures of 25/35 °C (with the possibility of reducing to 5/10 °C or increasing to 60/30 °C). Such a temperature level is not yet available in Litoměřice DH system, however, the emulator will open a research opportunity for systematic experiments with 4th and 5th generation district heating networks. The heat from BTES2 and BTES3 available in the low-temperature DH emulator will be used for the high-temperature DH system in Litoměřice using a high-temperature water-water heat pump with a nominal heat output of approximately 500 kW (W45/W95), which will enable the supply of heat with a usable temperature of up to 95 °C.

Surplus production from individual PV systems will be used within the site in the summer and will reduce the overall energy demand of the technologies, especially in System 4, or will be converted into heat in an electric boiler with heat output of approximately 150 kW (not shown in the diagram) and delivered to the seasonal storage facility BTES3.

Note: The design, engineering and implementation of System 5 is the subject of separate public tender.

3. Solar Thermal System Integration

Within the frame of SYNERGYS complex energy system, both solar thermal system SOL and solar thermal system U4H will be realized. The design, engineering and implementation of solar thermal system SOL and U4H-1 will be subject of a public tender. The design, engineering and implementation of solar thermal system U4H-2 will be provided by Absolicon

3.1. Campus

The energy system of the SYNERGYS project and the USE4HEAT project will be implemented in part of the former "Jiří z Poděbrad (George of Poděbrady)" barracks at address Na Vinici 2318 in Litoměřice (see Figure 2), which is located in the immediate vicinity of the exhibition zone "Zahrada Čech (Czech Garden)". The campus consists of a number of buildings, mainly former garages for heavy military equipment, and is owned by the city of Litoměřice (project partner, SYNERGYS consortium member). In 2007, a 2.1 km deep geothermal test well PVGT-LT1 was drilled there.

Figure 2. Aerial map of part of the Jiří z Poděbrady barracks area dedicated to SYNERGYS project

Figure 3. Research centre RINGEN.

In 2019, after the reconstruction of one of the buildings, the RINGEN research centre (Research INfrastructure for Geothermal ENergy) was opened, see Figure 3. The main purpose of the research centre is to develop and test methods for utilizing the energy potential of deep geothermal heat, technologies for stimulating rock permeability for the creation of artificially created underground geothermal systems based on EGS (Enhanced Geothermal Systems), as well as methods for seismic monitoring.

3.2. Layout of solar systems

Figure 4 shows the situation of solar photothermal systems in the area. Collector field of SOL system will be placed on the roof of building II, collector field of U4H-1 system will be placed on the roof of building III and concentrating collectors of U4H-2 system will be installed on the ground. The floor plan dimensions of buildings II and III are 25 m x 90 m. The height of each building is 5.3 m above the terrain.

Figure 4. Layout of solar thermal systems within the SYNERGYS campus.

Figure 5. Building II: current state of the roof (similar to building III).

Figure 5 shows the current state of the roof surface of buildings II and III, which must be reconstructed as part of the solar systems delivery, together with the drainage of rainwater in accordance with the documentation for the building permit. The installation of solar collector arrays on the roofs is assumed to be on a supporting structure attached to the feet anchored to the supporting elements of the building in accordance with the static calculation. The placement of solar collectors in the arrays is assumed with a slope of approximately 30° (SOL array, U4H-1 array) in a southwest orientation in accordance with the orientation of the building roofs. The spacing between the collectors must take into account the solar altitude of 20° (at winter solstice, see Figure 6) to limit the mutual shading. Concentrating collectors installed on the ground will be placed on the supporting construction delivered by supplier.

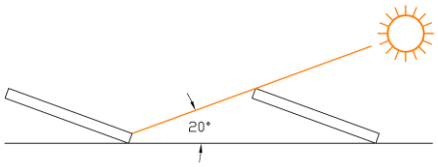

Figure 6. Distance between collectors eliminating the mutual shading.

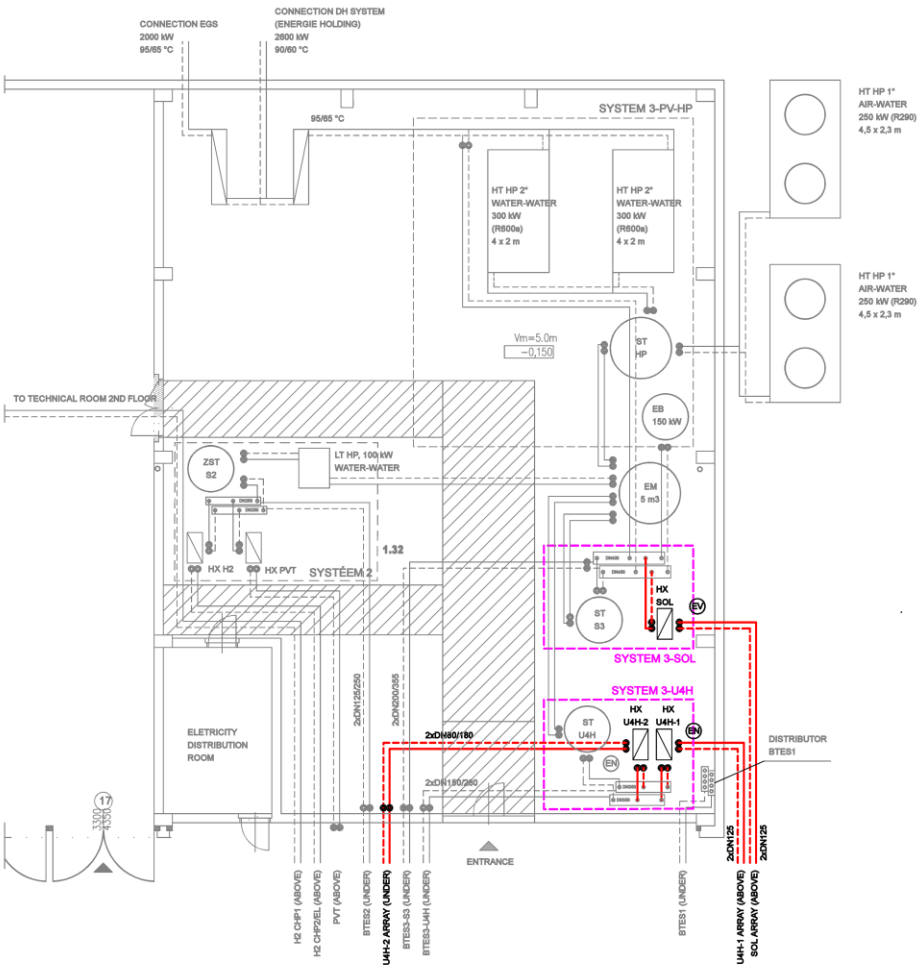

Figure 7. Floor plan of the technology room with a space dedicated to solar thermal systems.

It is assumed that pipelines from SOL, U4H-1 and U4H-2 collector fields will be brought to the central technology room in building I separately. In the central technology room, approximately 5 m x 4 m floor space is defined for the installation of heat exchangers, pumps, safety and expansion devices and other accessories of the collector fields (see Figure 7) for each system (SOL, U4H). It is assumed that solar collector circuits will be connected to their own hydraulic manifolds (transfer point and interface of the system delivery), which will be prepared as part of another public tender/contract. In addition to the SOL solar thermal system technology, other parts of the SYNERGYS energy system will be gradually installed here and will be connected to the hydraulic manifolds, such as heat sources, BTES ground borehole fields, BTES circuit expansion devices, etc.

The current state of the technology room is shown in Figure 8. Exterior of building II is shown in Figure 9. Other documents for the buildings (I, II, III) are available in the building permit documentation. At building I (RINGEN center), the metal door will be removed and the southern wall with roller shutter doors will be built.

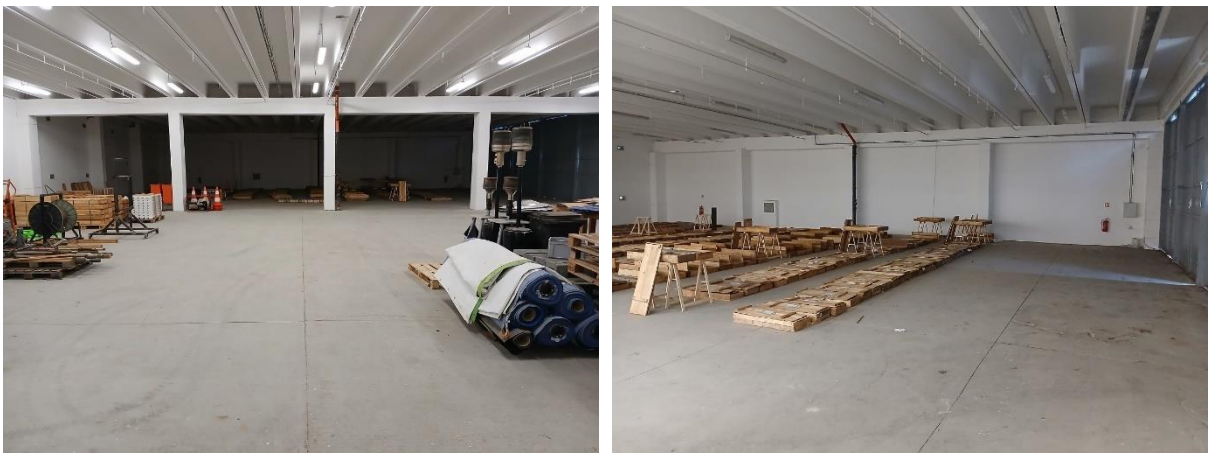

Figure 8. Building I (RINGEN): interior space for technology room.

Figure 9. Building II: facades (lef: northern facade with metal doors, right: western facade).

3.3. U4H-1 solar system

The implementation of solar thermal system U4H-1 is assumed as a **public tender** using the **Design & Build** method. In this chapter, the design, project and operational assumptions of the system are specified together with the requirements for system delivery by contractor.

3.3.1. Overview integration U4H-1

The solar thermal system U4H-1 consists of an array of large-scale solar collectors with a total gross area of at least 1000 m^2 consisting of collectors with a minimum area of one collector of 10 m^2. The U4H-1 array is located on the flat roof of building III on a supporting structure that is part of the design and delivery of the contractor. The collector loop is operated with antifreeze mixture (propylene glycol – water), the secondary loop is separated by plate heat exchanger (HX U4H-1) and operated with water.

The technical requirements for elements of the solar thermal system technology are given in Chapter 3.3.2. For solar thermal collectors that are the subject of the delivery, an efficiency defined by the specific annual heat gain is required. The solar collector array is connected to the manifold M-U4H in the technology room of building I via a plate heat exchanger(s) with a defined heat transfer efficiency.

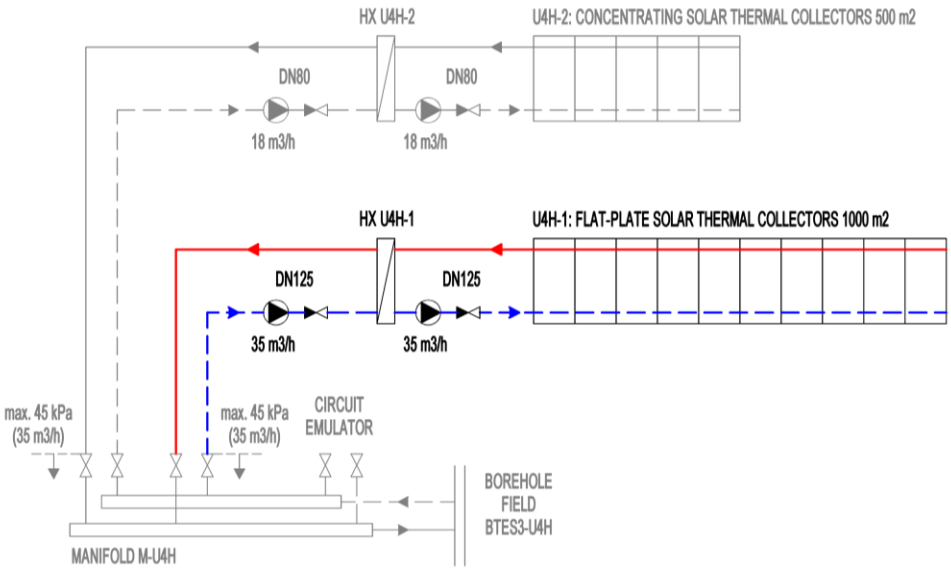

Figure 10. Hydraulic connection of U4H-1 system to common manifold M-U4H.

The simplified diagram in Figure 10. Hydraulic connection of U4H-1 system to common manifold M-U4H. indicates the assumed hydraulic connection of solar thermal system to common manifold M-U4H (assumed flow rates indicated). The hydraulic scheme is indicative. Contractor should design a safe and reliable system with low demands of regular service and maintenance. The boundary of the solar thermal system U4H-1 delivery is the shut-off valves on the hydraulic manifold M-U4H. The delivery includes the pipes, heat insulation, pumps, necessary safety valves and expansion devices for the collector circuit, ensuring protection against excessive steam production during the possible summer stagnation of the glycol circuit and safe, stable and trouble-free operation of this circuit in the entire range of expected

operating pressures (low and high). The design of U4H-1 subsystem in the technology room also includes construction modifications in the area of building I necessary for the installation of the technology. The delivery of the system includes also sensors for long-term monitoring of operating variables (defined in 3.3.3).

3.3.2. Required parameters

Basic parameters of solar systems that must be met:

- solar thermal system U4H-1 consists of large-scale solar thermal collectors with a gross collector area of at least 1000 m² at a slope of 30° with a spacing determined for a solar altitude of 20°;
- solar system hydraulics is designed for a specific flow rate of at least 35 l/h.m² gross collector area;
- circulation pumps have variable speeds with the possibility of their control by an external signal;
- heat transfer fluid (propylene glycol) will be used with a freezing point of -32 °C;
- solar collectors used must have a valid Solar Keymark certificate issued in 2015 or later;
- thermal insulation of the pipes must meet the condition of the maximum value of the heat transfer coefficient *U* [W/m.K] according to Table 1;

Table 1. Required maximum U-value for piping in solar collector loop

Item	DN40 to DN65	DN80 to DN125	DN150 to DN200
U-value [W/m.K]	< 0,30	< 0,35	< 0,40

- specific heat transfer rate of heat exchanger for collector loop (related to 1000 m^2): *UA* > 140 kW/K at input temperatures 60 °C (primary collector loop, mixture propylene glycol-water 50/50 %, min. flow rate 35 l/h.m^2) and 40 °C (secondary circuit, water, min. flow rate 35 l/h.m^2).

The required minimum annual specific solar heat gain of the solar collector, related to the gross collector area, is given in Table 2. The values are given in the Solar Keymark report or are calculated with the Scenocalc tool based on the data given in the test report for the climatic conditions of Würzburg (south, slope 35°) and the annual average operating temperature in the collectors of 25 °C, 50 °C and 75 °C. The requirement for minimum heat gain must be met for all three temperature levels.

Table 2. Required performance figures of solar thermal collectors for climate conditions of Würzburg (Solar Keymark report, Scenocalc)

Item	25 °C	50 °C	75 °C
Annual specific solar heat gain [kWh/m^2.a]	> 750	> 550	> 350

3.3.3. Sensors and monitoring

The system delivery will include sensors for long-term monitoring of operating variables, especially energy flows for monitoring the efficiency and performance parameters of the system (heat output, temperatures and pressures in the system's sub-parts) listed in Table 3. The accuracy class required for the installed sensors is in accordance with Table 3. The outputs will be transmitted to the local control system, together with the outputs from the main devices (ModBus communication from circulation pumps, control valve positions). The local control communication interface will enable connection to a superior control and monitoring system (CMS) for setting control variables and collecting data from the central CMS.

Table 3. Minimum required quantities to be monitored within solar thermal system U4H-1

Quantity	Accuracy class	Sensor
heat output of collector loop U4H-1 (on secondary side)	class 1	calorimeter (flow rate, temperatures)
temperature of collectors in array U4H-1	class A	Pt1000
pressure of fluid in array U4H-1	0,6 %	membrane manometer
temperatures at HX at collector loop U4H-1 (input, output)	class A	2xPt1000
temperature in manifold M-U4H	class A	1xPt1000 (in sleeve)
electric power input of U4H-1 system	≤ 1 %	wattmeter

3.3.4. Control

The delivery of the system U4H-1 includes automatic control of the collector loop operation, which supplies the heat to the manifold M-U4H through the heat exchanger HX U4H-1 based on the temperature difference between the collector array and the manifold (return flow distributor). The manifold M-U4H is hydraulically connected to the ground borehole field BTES3-U4H as a part of the delivery of System 5 (Integration, SYNERGYS). The control system will ensure safe operation (limitation of external setting of values outside the safe operating range).

The control and monitoring system of the system U4H-1 will be open for remote setting of basic operating parameters (operating modes, flow rate control in circuits, temperature differences, etc.) with the transfer of measured and set data to a superior data processing and management system. The CMS will be connected via API to the data network of the RINGEN building (energy systems laboratory). It is expected from contractor to provide a complete map of Modbus registers, including their addressing, data types and a description of the meaning of individual values.

3.3.5. Scope of delivery

The performance of the public contract includes the execution of construction and assembly works on given roof of building III and in the technology room in building I to the extent specified in the project documentation for the building permit. The contractor is obliged to carry out the following activities in particular:

Reconstruction of the surface of the affected roofs, including:

- removal of the existing non-compliant roof layer to the necessary extent,
- implementation of new roof waterproofing including related layers,
- ensuring the connection of the waterproofing layer to roof details, penetrations and structural elements.

Reconstruction of roof drains, including:

- replacement or repair of existing roof drains,
- ensuring their proper connection to the drainage system,
- implementation of the roof slope according to the project documentation.

Design and delivery of supporting structures for solar thermal collectors, including:

- preparation of static design of supporting structures including assessment of wind and snow loads,
- preparation of project documentation of supporting structures,
- delivery, assembly and anchoring of supporting structures in accordance with project documentation and applicable technical standards,
- ensuring compatibility of supporting structures with the designed solar collector technology.

Implementation of solar photothermal systems

- preparation of project documentation for the implementation of solar systems,
- installation of solar collectors on roofs and their interconnection and hydraulic balancing,
- installation of plate heat exchangers, circulation pumps and their appropriate interconnection,
- installation of safety and security (expansion) devices, ensuring protection against excessive steam production during the summer stagnation period and ensuring safe, stable and trouble-free operation of the system.

Reconstruction and modification of access routes to roofs, i.e.:

- ensuring safe access for installation and subsequent maintenance of the technology,
- possible installation of walkways, ladders, climbing elements or other devices according to the project documentation,
- compliance with the requirements for the safe movement of people on the roof.

Compliance with the documentation for the building permit (DBP)

- all work must be carried out in accordance with the project documentation for the building permit and the relevant technical regulations; **the exception is the size of the solar systems, which is defined in the tender documentation**,
- any deviations or proposals for alternative solutions must be discussed in advance in writing and approved by the client and the DBP designer.

Commissioning the solar system

- commissioning,
- successful test operation for a period of 30 days,
- training of the operator,
- handover of documentation of the actual implementation, audit books and other related documentation.

Due to the outdoor location of solar thermal collectors, the supplier must ensure comprehensive protection of the installation against freezing (use of appropriate antifreeze), lightning and generally against weather conditions.

The delivery also includes protection of accessible parts of pipes and fittings against burns of people (thermal insulation, covers), protection of equipment and distribution systems against damage by animals, ensuring mechanical stability of the structure according to the relevant standards for wind and snow loads, implementation of fire and electrical safety of related technologies and creation of safe conditions for operation and maintenance of the equipment (access, drain and vent fittings). All measures must be carried out in accordance with applicable technical standards and regulations.

3.4. U4H-2 solar system

Solar photothermal system U4H-2 will be **implemented by member of USE4HEAT project consortium**. The solar thermal system U4H-2 consists of an array of concentrating solar collectors with a total gross area up to 500 m^2. The complete solar system U4H-2 will be designed by a supplier (Absolicon, member of USE4HEAT consortium). The U4H-2 array is located on the ground indicated at Fig. 3.3 on a supporting structure that is part of the design and delivery of the supplier. Design will be coordinated with Czech Technical University in Prague.

The solar collector array is connected to the manifold M-U4H in the technology room of building I via a plate heat exchanger with a defined heat transfer efficiency (defined by supplier). The technical requirements for other elements of the solar thermal system technology are defined by supplier.

The simplified diagram in Figure 11 indicates the assumed hydraulic connection of solar thermal system to common manifold M-U4H (assumed flow rates indicated). The hydraulic scheme is indicative. Supplier should design a safe and reliable system with low demands of regular service and maintenance. The boundary of the solar thermal system U4H-2 delivery is the shut-off valves on the hydraulic manifold M-U4H. The delivery includes the pipes, insulation, pumps, necessary safety valves and expansion devices for the collector circuit, ensuring protection against excessive steam production during the possible summer stagnation of the glycol circuit and safe, stable and trouble-free operation of this circuit in the

entire range of expected operating pressures (low and high). The design of U4H-2 subsystem in the technology room also includes construction modifications in the area of building I necessary for the installation of the technology. The delivery of the system includes also sensors for long-term monitoring of operating variables (defined by supplier, indicated in Chapter 4).

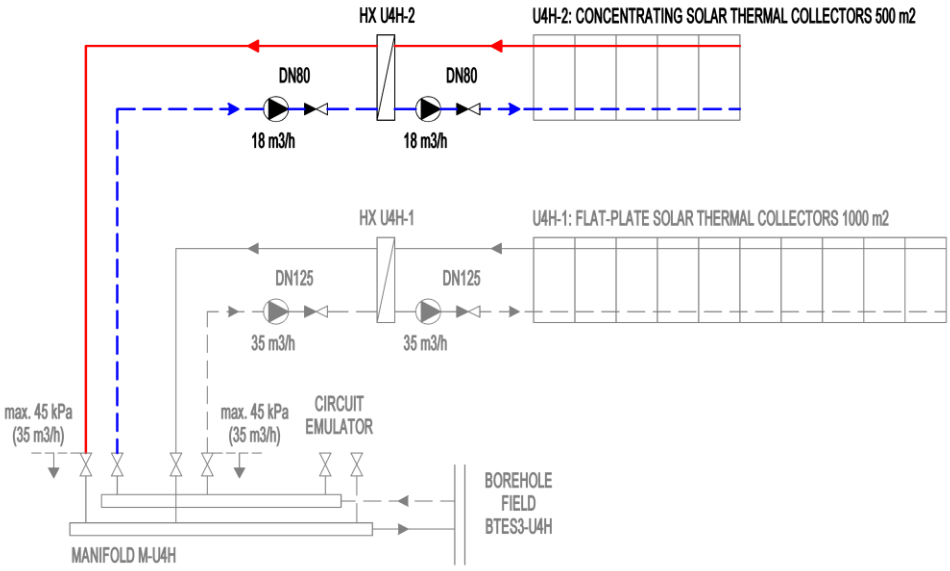

Figure 11. Hydraulic connection of U4H-2 system to common manifold M-U4H.

3.5. Integration of USE4HEAT system

Both solar thermal systems are connected through common manifold M-U4H with seasonal underground storage BTES-U4H with a field of boreholes (see Figure 12). Number of boreholes is a subject of optimization (simulation in TRNSYS under development). Solar thermal systems supply the heat and charge the storage volume to temperature cca 50 °C in average, with maximum supply temperatures considered up to 80 °C. Discharge of the borehole field will be realized by low temperature district heating system emulator, a water circuit with temperature level 35/25 °C (in basic design) equipped with a water storage. High temperature heat pump extracts the heat from the emulator (evaporator side) and release it at 90 °C to DH system of the city (Litomerice).

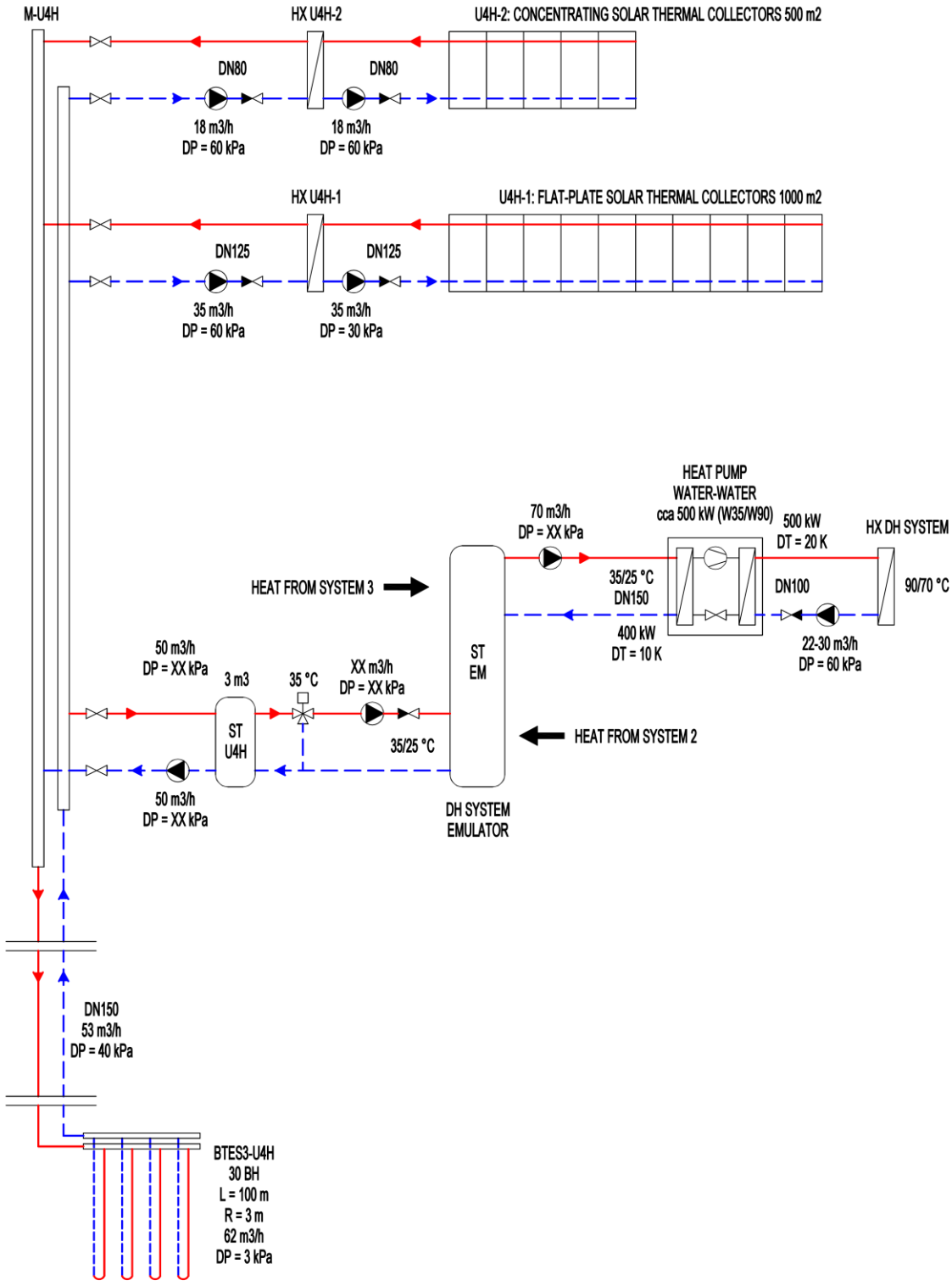

Figure 12. Hydraulic integration of U4H system to SYNERGYS system (extracted from complex scheme in Annex).

3.5.1. Hydraulics

Fig. 3.11 shows the hydraulic scheme of the main parts of the integration. The complete scheme of SYNERGYS system extended by USE4HEAT system is shown in Annex (Fig. 4.4). The discharge of the borehole field BTES3-U4H dedicated to the system U4H will be realized through a storage tank ST U4H. The water storage separates hydraulically the circuit of borehole field and emulator, thus allowing sufficient and stable flow rate through the boreholes during operation. The heat from storage tank ST U4H is extracted by emulator circuit with controlled temperatures. Emulator of low temperature DH network is a central part of SYNERGYS system, other subsystems (system 2, system 3) supply the low potential heat to water storage tank ST EM. The required temperature in the emulator storage tank is maintained by a heat pump (high temperature HP), which transfer the heat to Litomerice district heating system connection (HX DH system, Energie Holding company).

3.5.2. Borehole field

The borehole field dedicated for USE4HEAT system (BTES3-U4H) will form one storage volume with the borehole field of the SYNERGYS project in the System 3 (BTES3-S3). Possible thermal interaction can finally increase the efficiency of both BTES volumes due to reduction of boundary thermal losses.

The borehole storage layout alternatives are indicated in Figure 13. Both borehole fields BTES3 parts (S3, U4H) can be divided into three regions: 1 central (interior) region and 2 boundary (exterior) regions. In each region a cluster of boreholes connected in parallel into one manifold will be installed (cluster indicated in Figure 13). While boreholes in one cluster will be always connected in parallel, clusters can be connected in series or in parallel for charging and discharging mode (see Figure 14). Serial charging of the borehole field part proceeds from the centre to boundary, i.e. hot fluid supply to the central cluster, cold fluid output from boundary cluster. Thus, significantly higher temperature in the centre (red colour in Figure 13) of the borehole field can be reached than in the boundary region. Serial discharging proceeds in other way (from boundary to centre) but without change of flowrate direction within the individual boreholes. The flowrate is preheated at boundary region and heated to higher temperature in the central region and higher usability of extracted heat can be reached. The horizontal temperature stratification due to serial connection of clusters also reduces the thermal losses of the entire borehole field and could increase the efficiency of the seasonal heat storage.

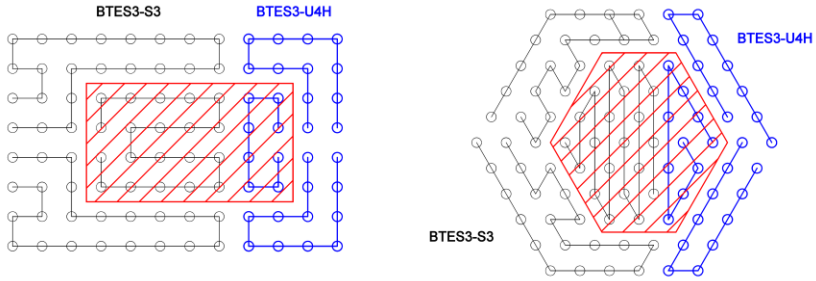

Figure 13. Targeted geometry and hydraulic layouts of BTES3: rectangular, hexagonal.

The hydraulic connection of central cluster of boreholes applies 5 valves (see Figure 14) in total which are seasonally set. The charging of seasonal heat storage is supposed to be active from April to October, discharging from October to April. Figure 14 indicates which valve is closed (C) and open (O) to provide the serial charging, serial discharging or parallel connection of clusters.

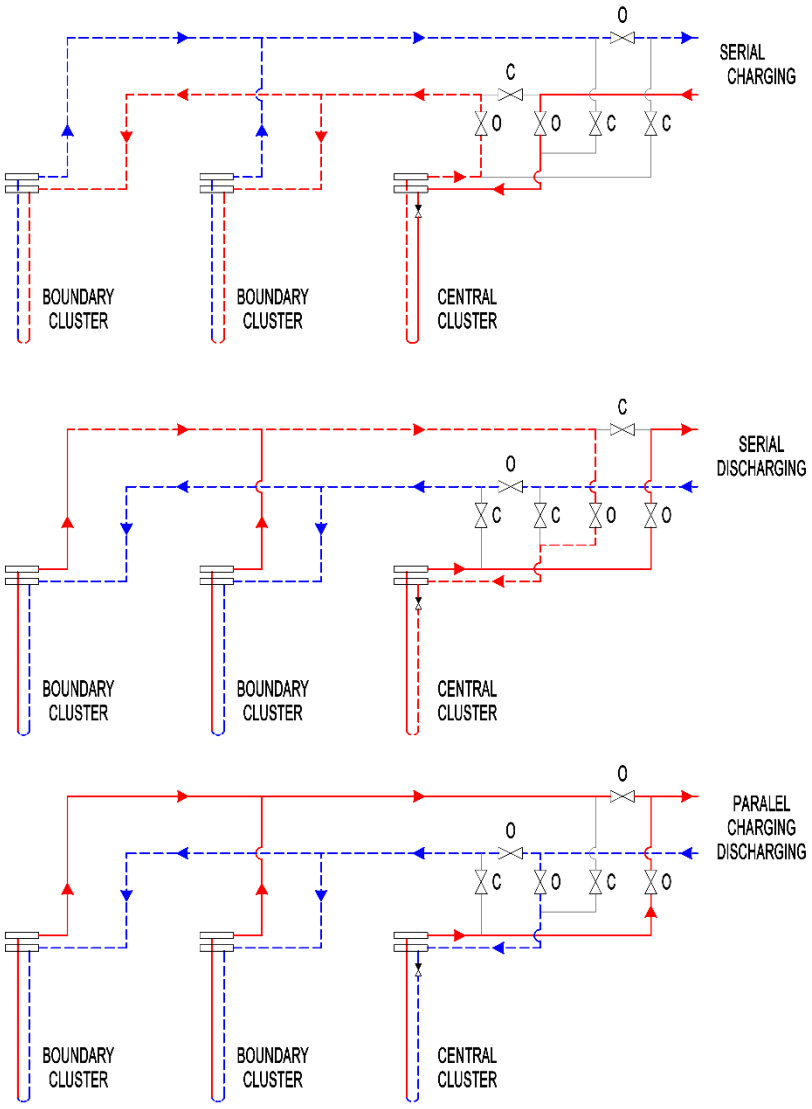

Figure 14. Hydraulic connection of the clusters of BTES3 parts

The sizing of the boreholes field has been optimized considering the total length of the BTES, depth (50 and 100 m), and low or high solar production from the CST field (blue and red curves, respectively). The most relevant KPIs for the BTES field optimization are the overall efficiency (as from Figure 15) and it is important also to monitor the heat supply to the low temperature DHN (as from Figure 16). Driven by the efficiency targets, optimal total BTES field length of 6000 m has been obtained. Thus, 60 boreholes of 100 m depth are planned. Overall UTES efficiency above 70 % are foreseen.

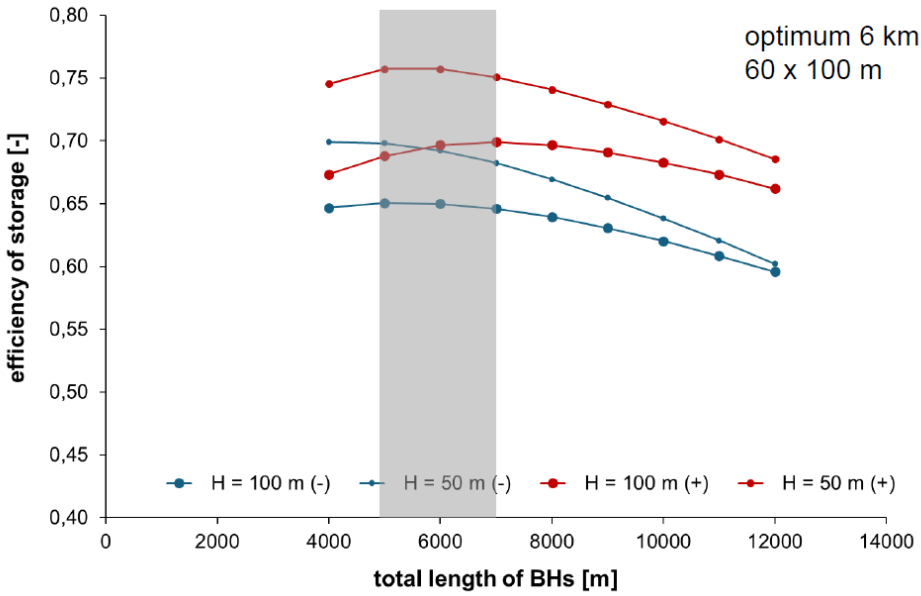

Figure 15. Optimized BTES sizing based on overall storage efficiency

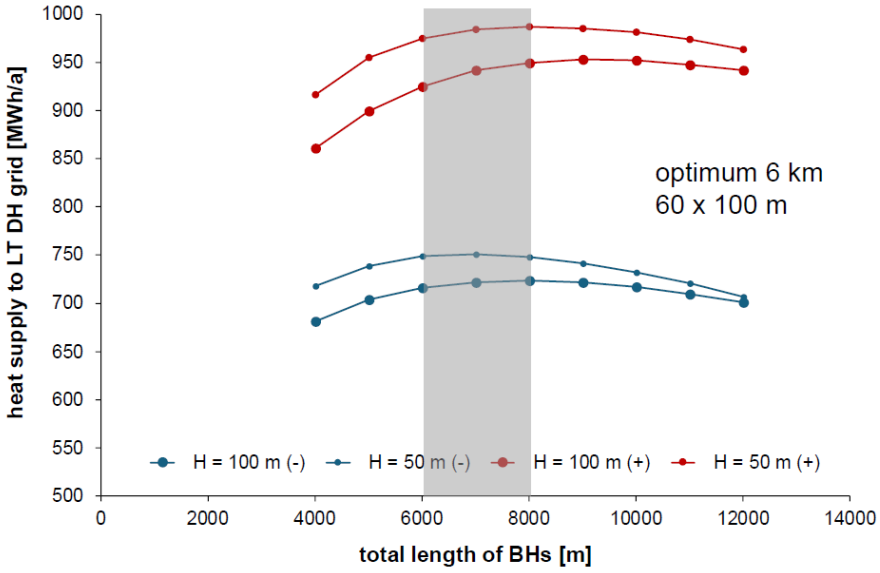

Figure 16. Optimized BTES sizing based heat supply to low temperature DHN

4. Borehole collectors

One of the key investigations that need to be made is to find the right material for the collectors in the ground. Material for collectors that are able to withstand temperatures of 90-95 degrees over time is not available in the market. This material needs to be developed.

Hallingplast is a key partner within WP5, and its main role is to develop and provide the innovative pipes, named Thermex HT-Collectors, suited for the planned high temperature borehole installation. Hallingplast

is performing tests of a new type of pipe, using a combination of materials in a multilayered pipe that is both flexible and can withstand high temperatures over time. The pipes are made of a layered structure with inner PPS layer which is oxygen-tight high-temperature resistant material, preventing degradation of the external layer, non-soluble, mechanically stable, providing mechanical strength and resilience. The external layer of PE-RT (commodity grade Polyethylene material) gives more flexibility, facilitates the installation and protects the PPS, the pressure bearing inner layer, during installation.

A critical aspect for the pipe is to determine the lifetime expectancy of the pipe-system under design-condition. For plastic material, this is normally done under elevated temperatures, and then the obtained values are extrapolated to give expected lifetime at service temperature. Such tests are performed according to ISO standards to find the failure-time and -modes of plastic pipes at different temperature levels, but the test-times would be far too long to give value within the end of the project. A sketch of the testing approach and typical outcomes is shown in Figure 17

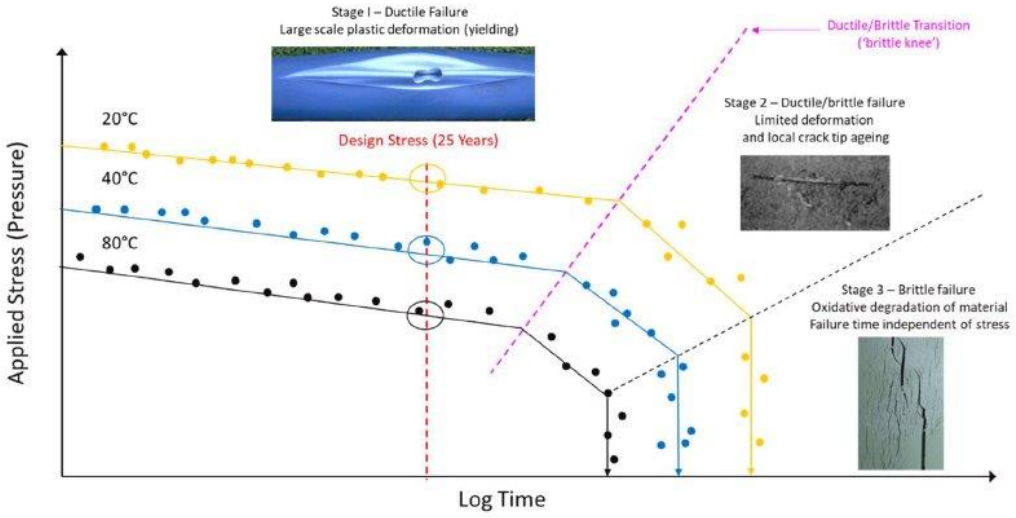

Figure 17: BTES piping testing example

Several extrusion trials have been performed so far on the pipe design with good results. The final design of the pipe and adequate extrusion parameters will be consolidated once the BTES design and testing program is finalized. As of now, Hallingplast has produced solid walls PPS-pipes in 40 x 3.7 mm and 63 x 5.8 mm for the initial pressure, material and fusion testing.

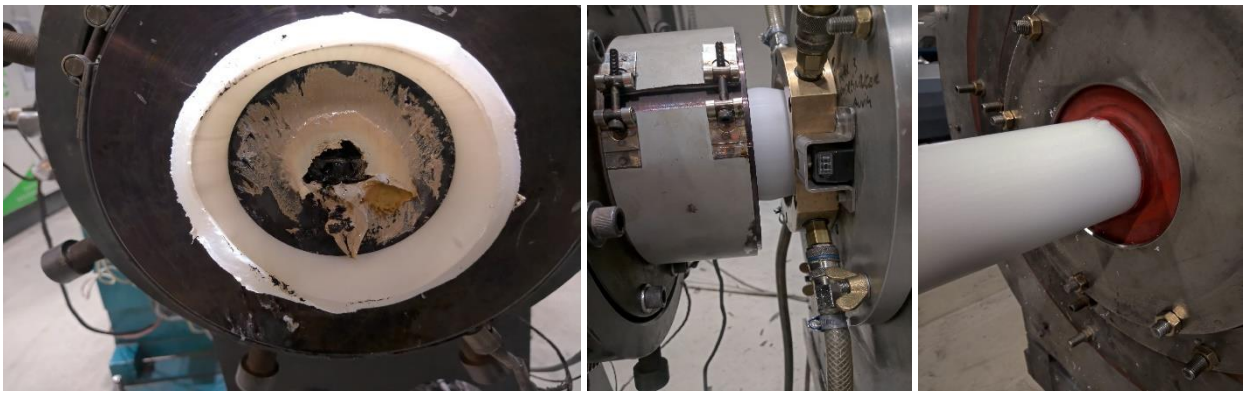

Figure 18: Picture of the multi-layered pipe extrusion process

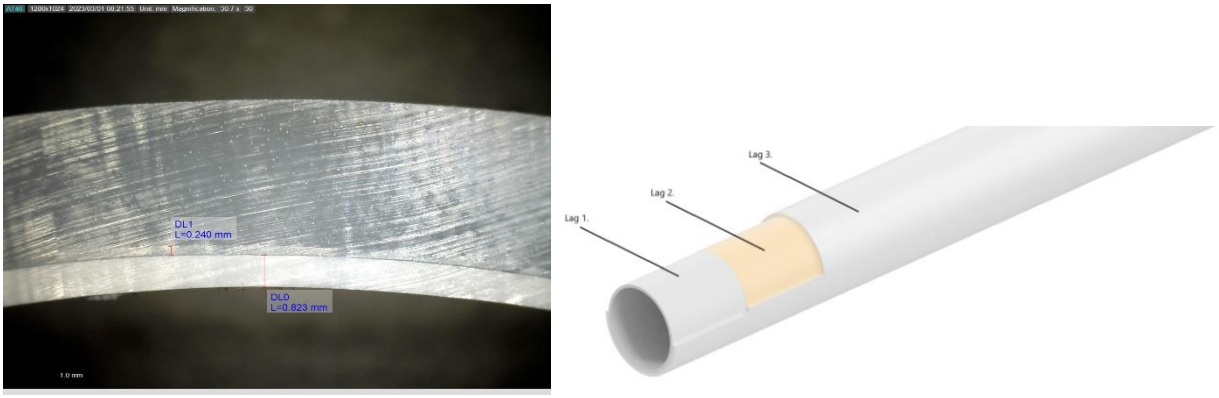

Figure 19: Multi-layer plastic pipe

To guarantee ease of installation and reduced pipe work, welding and connections are also made to obtain a system-wide solution for the full borehole heat exchangers and related above-ground pipe network. Testing includes welding the pipe with standard fusion techniques and connection with metal adaptors.

Figure 20: Testing welding connections

In cooperation with industry-leading polymer experts, Hallingplast has defined a test-program that consists of several tests that will be performed on the pipes. The test program consists of:

- Pressure testing at 3 temperature levels, 140°C, 120°C, 95°C. This test is carried out at a third party facility.
- Fuson trial
- Water absorption testing, followed by mechanical testing of material
- Falling weight impact test
- Pipe flexibility test
- Longitudinal reversion
- Resistance to weathering
- Testing of pipe with chosen fittings/pars in the form of a pipe system.

Hallingplast has already produced solid wall pipes in the high temperature resistant material to be used for pressure testing and welding trials. Initial burst-pressure testing at 140°C showed the below results indicating burst pressure higher than 25 bar, in line with the initial expectations. The long term testing with lower stress level at 3 temperatures (140°C, 120°C, 95°C) started in April 2025 with the goal of ensuring long term resistance of the chosen pipe configuration and materials selection.

Notched	Burst pressure	Description
Non-notched	28,0 bar	Ductile failure of pipe
Notched	26,5 bar	Failure in notch B
Non-notched	34,6 bar	Deformation of pipe
Notched	25,8 bar	Failure in notch D

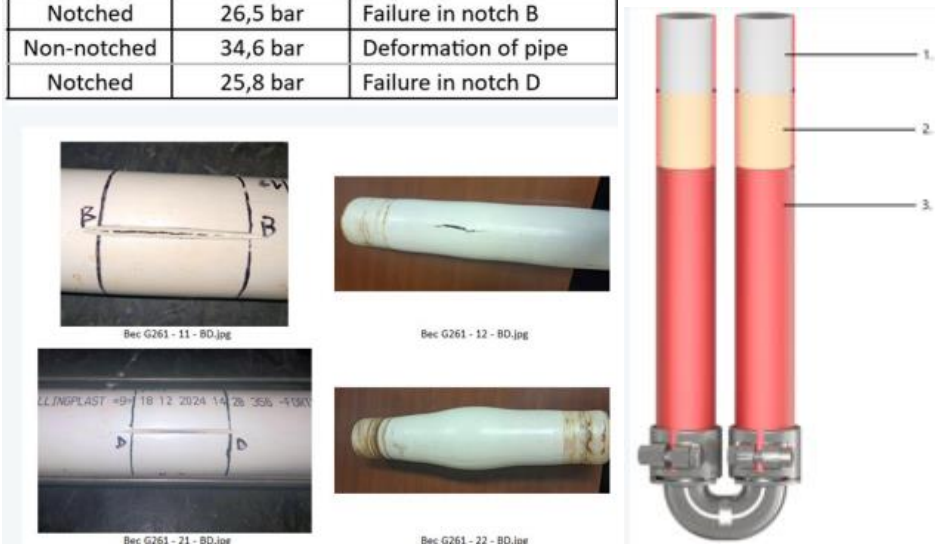

Figure 21: Pressure test – U-pipe solution (summary outcomes and photographs of samples)

Another element which needs to be resolved in the project is the fittings/ancillary parts to connect the pipes together in the bottom of the borehole to form a loop (U-bend), and in the top of the borehole to connect the pipes to the rest of the pipe system. Plastic pipes will normally have welded connections, but the high temperature resistant material has different welding properties, hence a technique suited for joining the pipes needs to be developed. Hallingplast has made trial-welds with standard fusion equipment and produced U-bends at an injection molding partner. Tests are currently ongoing with preliminary results shown in Figure 21 and Figure 22. In case of non-sufficiently reliable testing results to ensure a long lifetime of the connections with relevant safety margins, the overall plan is to use mechanical clamping fittings which are used extensively for hot-water pipes, underfloor heating pipes etc.

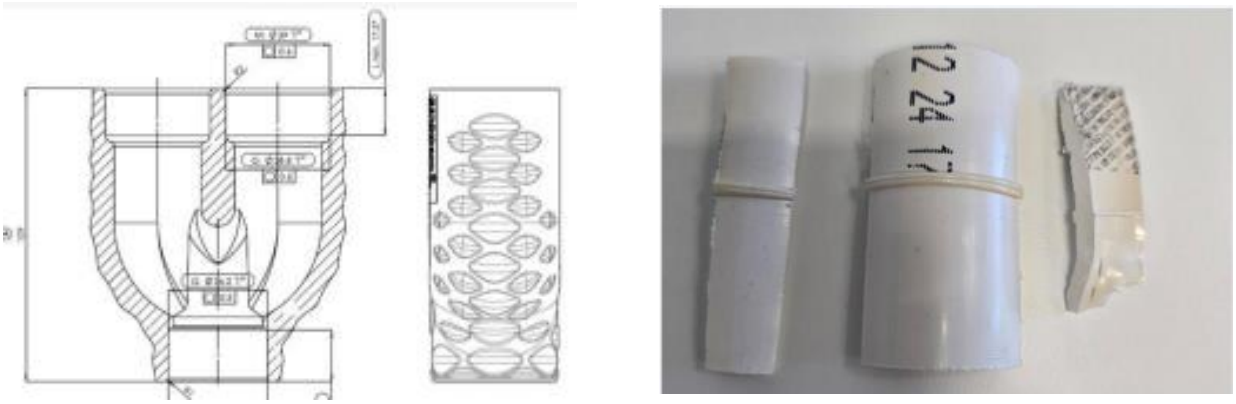

Figure 22: U-pipe solution / Some welded sections of pipes for welding test

5. Conclusions

This report includes a summary of the updated work done in WP4 (and specifically in T4.1 and T4.2) within the project so far. The report includes a full description of the new demonstration site in Litoměřice and adaptation of the relevant key enabling technologies. The main conclusions from the ongoing work are as follows:

- The targeted BTES field has about 60 boreholes of an average depth of 100 m and total length of 6000 m. The arrangement will lead to optimal BTES overall efficiency above 70%.
- The full interconnection to the existing energy system is fully described including specific modifications to the control room, hydraulic connections and key control mechanisms.
- Hallingplast has tested different types of plastic qualities to manufacture pipes that can withstand both high temperature and pressure. Different plastic qualities combined ensure both temperature resistance and flexibility. Fittings/ancillary parts to connect the pipes together in the bottom of the borehole to form a loop (U-bend), and in the top of the borehole to connect the pipes to the rest of the pipe system are under preparation and a detailed testing plan as been developed and ongoing.
- The demo site includes different solar installations. These includes flat plate collectors, PV and the concentrated solar thermal units from ABS. The planned installation is of about 500 m2. Solar thermal systems supply the heat and charge the storage volume to temperature cca 50 °C in average, with maximum supply temperatures considered up to 80 °C, and an average flow rate of 35 l/h.

6. ANNEX

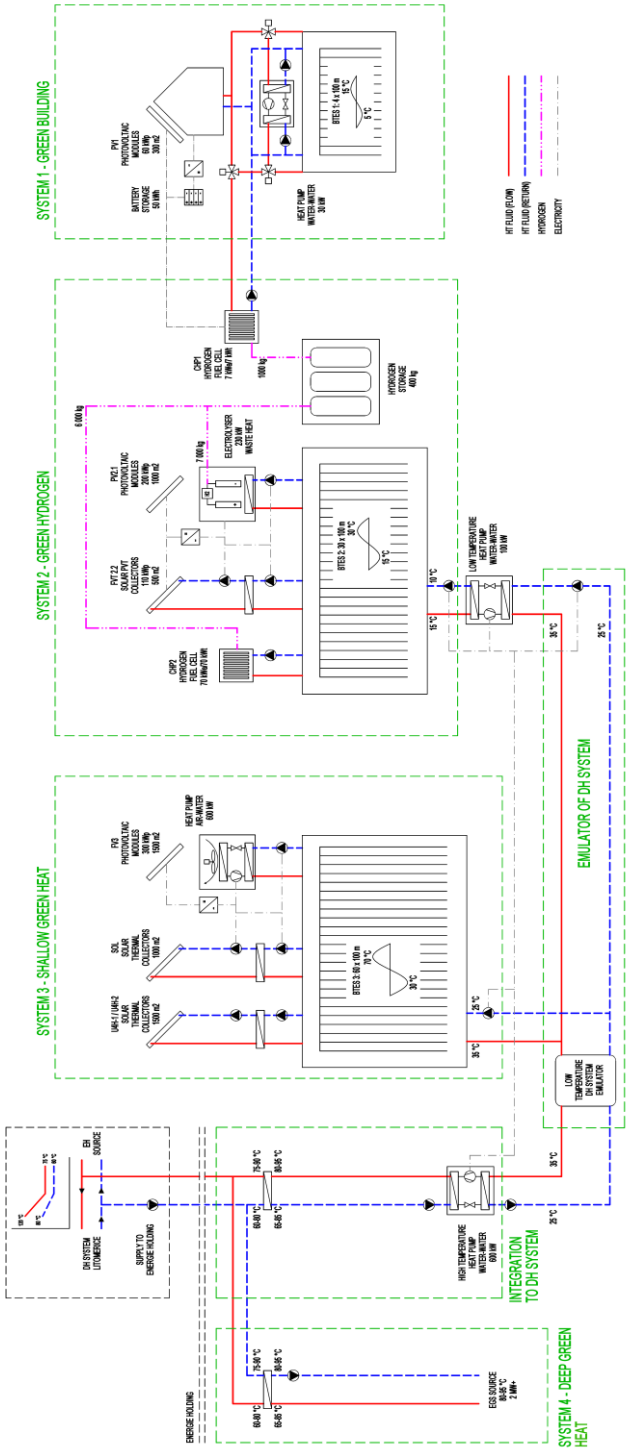

Figure 23. Simplified diagram of a SYNERGYS system

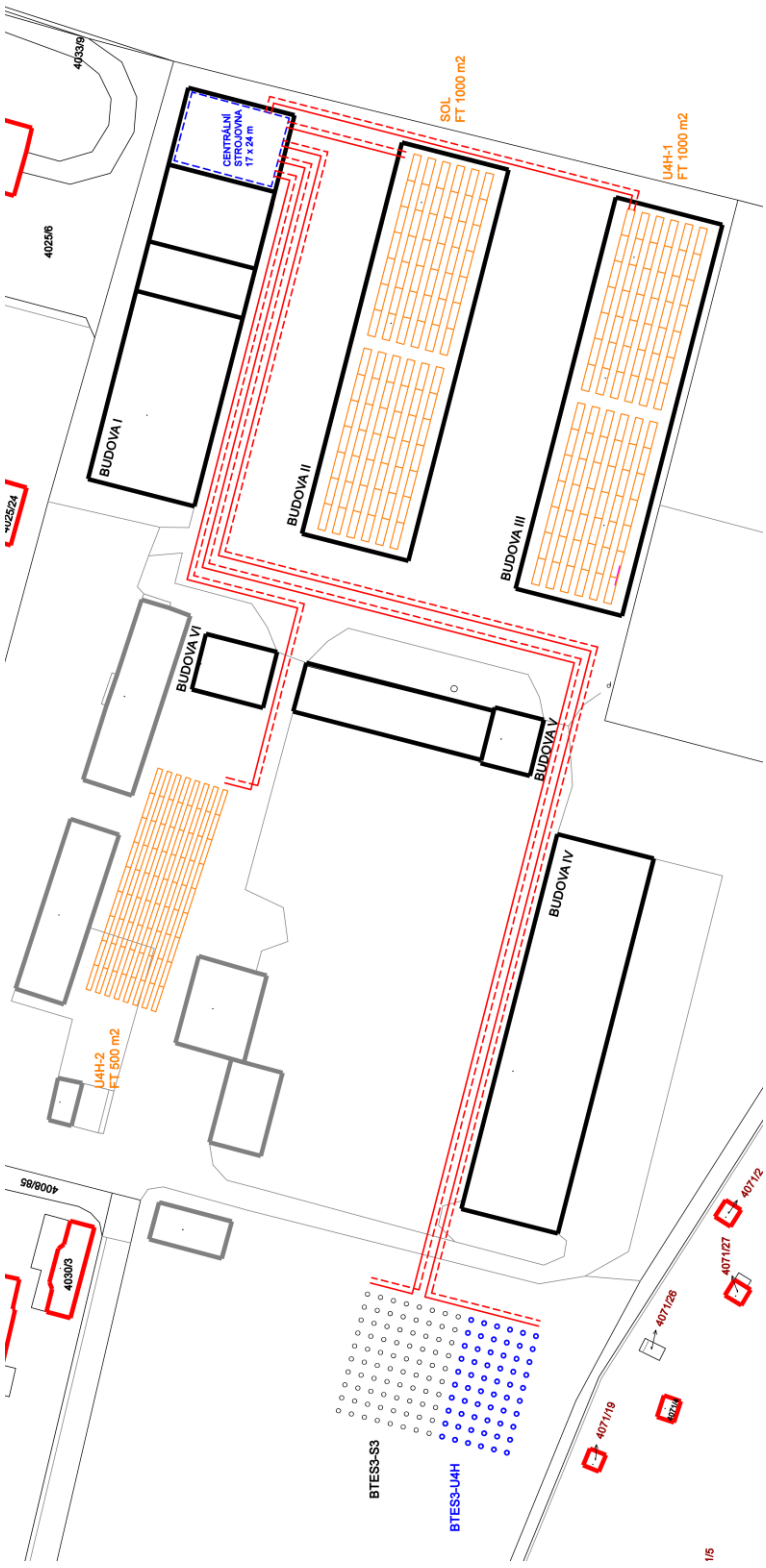

Figure 24. Layout of solar collector fields in the campus

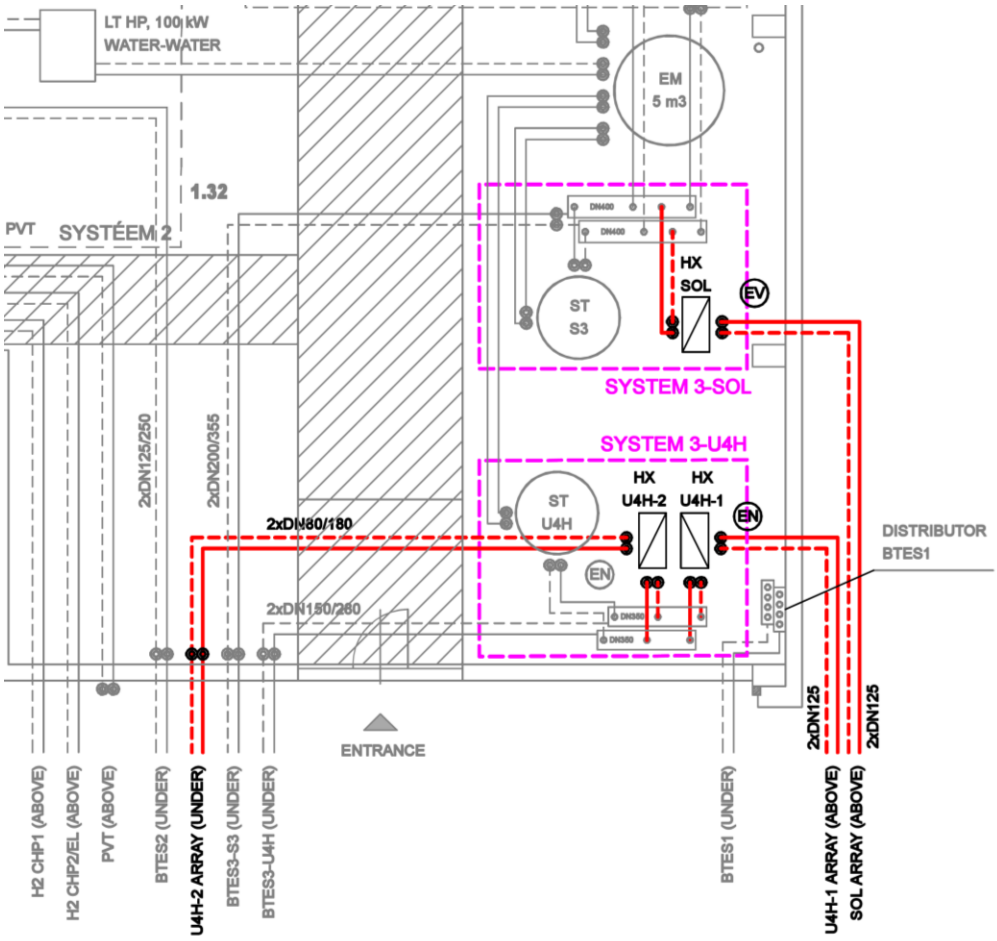

Figure 25. Layout of solar thermal components in technology room

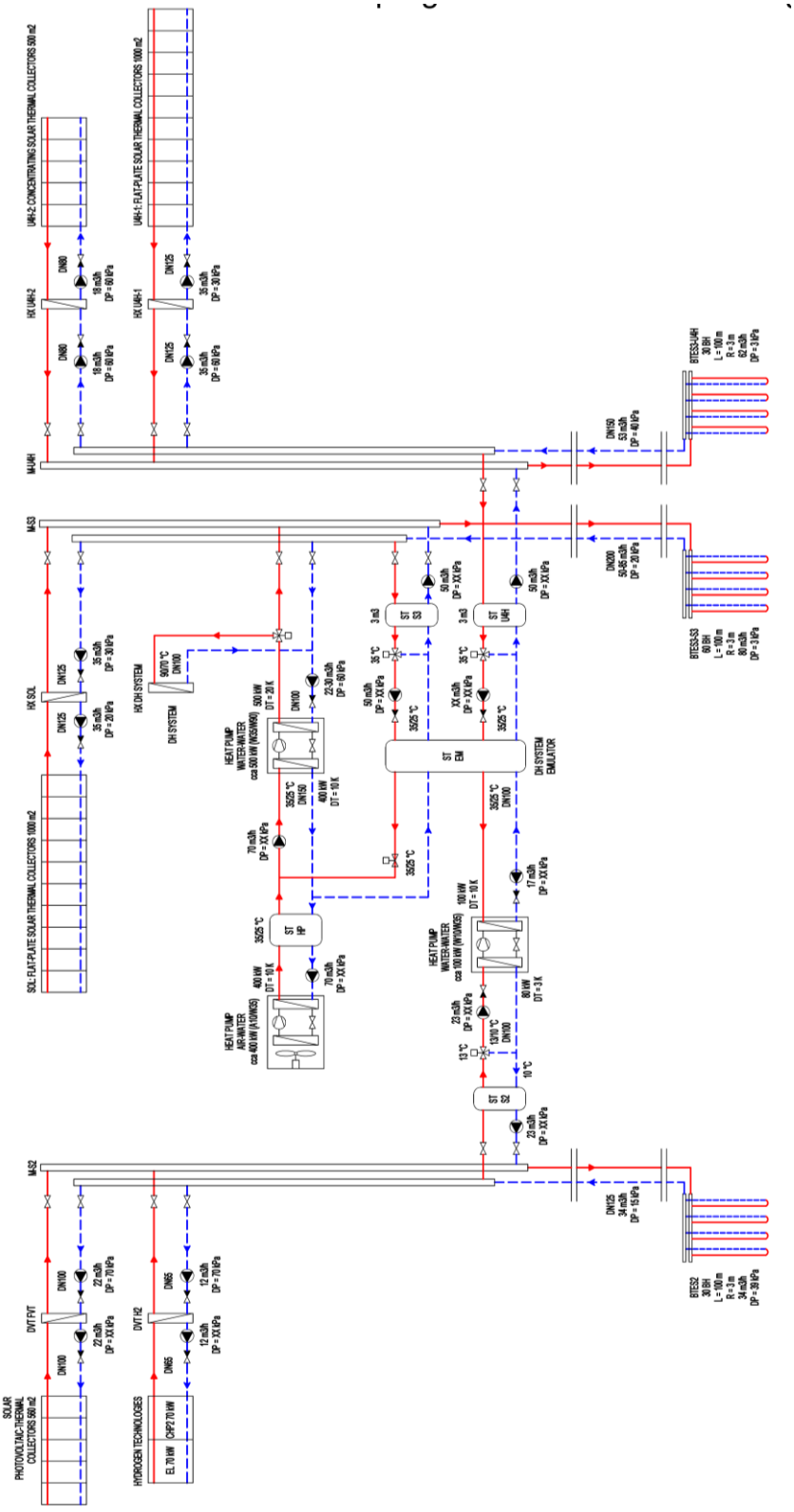

Figure 26. Hydraulic scheme for complex SYNERGYS system