D5.1 Baseline Monitoring and Plan for Riva del Garda Demo

Fondazione Bruno Kessler (FBK)

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Author	Masoud Manafi
Reviewers	Diego Viesi, Silvia Ricciuti, Francesco Ghionda (FBK), Luciano Lucchi (CDG/AGP), Aldo Bronzini, Valentina Lever (AGS), Davide Righini, Luc Pockele (HYDRA), Annagiulia Debattisti (HIREF), Lucia Cano, Raquel Simon, Yolanda Lara, Isabel Guedea (ENDEF), Matteo Gerola (Energenious), Stefano Barberis, Carlo Alberto Niccolini (UNIGE), Silvia Trevisan, Andrew Martin (KTH)
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Dissemination level		
SEN	Sensitive, limited under the conditions of the Grant Agreement	☐
PU	Public, fully open	☒

Nature of the deliverable		
R	Report, document	☒
DEM	Demonstrator, pilot, prototype, plan designs	☐
DEC	Websites, patents filing, press & media actions	☐
DATA	Datasets, microdata, etc.	☐
DMP	Data management plan	☐
ETHICS	Deliverables related to ethic issues	☐
SECURITY	Deliverables related to security issues	☐
OTHER	Software, technical diagram, algorithms, models, etc.	☐

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1. Introduction

This report constitutes **Deliverable 5.1**: *Baseline Monitoring and Plan for Riva del Garda Demo*, developed as the first task in work package 5 (WP5), T5.1, led by FBK with the support of all partners involved in the Work Package 5.

The deliverable provides a comprehensive overview of the demo site, analysing the current energy flows and demand profile within the district heating network while reporting on general activities undertaken during the project's first year at the Riva del Garda demo site. Additionally, it reviews the future deployment plans for the USES4HEAT innovative technologies and establishes a baseline to track progress throughout the project timeline. A detailed action plan, complete with timelines and responsibilities, has been defined, including a review of the technical and non-technical aspects to be considered.

The document is organized into the following sections:

- **Section 2**: Offers an overview of WP5 and its coordination with other tasks and work packages. It outlines the project's main objectives in this WP, details of activities undertaken, and describes the methods used for data collection and baseline monitoring.
- **Section 3**: Reviews the local area, including the demo site and district heating network, and examines the geological studies and available data for the region.
- **Section 4**: Outlines the current situation at the demo site, with an analysis of energy flows and the supply to the district heating network.
- **Section 5**: Highlights the USES4HEAT demonstration plan, focusing on the deployment of technologies.
- **Section 6**: Identifies the technical requirements and non-technical specifications that need to be considered as the project progresses.
- **Section 7**: Describes the demonstration-specific timeline, detailing milestones, reporting periods, and the risk assessment process. Methods for risk mitigation are also outlined.
- **Section 8**: Summarizes the main conclusions from the activities carried out in **Task 5.1** and reviews the next steps for the project.

This deliverable serves as a critical reference for tracking the project's progress, ensuring alignment with its objectives, and supporting the successful deployment of innovative technologies.

2. Work Package 5, Main Objectives and Baseline Monitoring

2.1. Work Package 5 and Coordination with Other Tasks and Work Packages

Work Package 5 (WP5) is a key work package within the USES4HEAT project, aimed at implementing, assessing, and optimizing innovative energy solutions at the Riva del Garda demo site in Italy. Building on the foundations established in WP2 and WP3, WP5 focuses on designing, developing, and deploying enabling technologies and energy management strategies that will serve as the core of the demo site's energy system. The main objectives of WP5 are to develop hardware-level innovations such as Aquifer Thermal Energy Storage (ATES), groundwater heat pumps (GWHP), and hybrid solar panels (PVT), which will be integrated into the site, tested under real-world conditions, and monitored to assess their performance. This will allow the team to validate the overall project approach, using key performance indicators (KPIs) defined in T2.1.2 and in parallel with T5.1 to track progress and success.

The work package is structured into four main tasks that progressively build toward the operational deployment of these technologies (Figure 1). Task 5.1, which runs from months 1 to 12, focuses on baseline monitoring and planning. This task involves collecting essential data from the demo site, including GIS-based data, in-situ measurements, and performance metrics, to establish a baseline that will help track project progress and inform future decisions. This initial data gathering is crucial for identifying current energy and material flow bottlenecks, and for setting the stage to implement the necessary modifications to improve efficiency.

In Task 5.2 (months 7-24), the development and realization of enabling technologies will take place. This task involves the design and construction of prototypes for the ATES system, high-efficiency heat pumps, and hybrid solar panels. Each technology will be developed in close collaboration with main project technology providers, including HYDRA, HIREF, ENDEF. HYDRA will focus on improving the drilling technology for ATES wells, with innovations like the Easy-Drill system for faster and safer drilling in challenging conditions. HIREF will develop and deploy a new high-temperature groundwater heat pump connected to both the ATES and the district heating network (DHN) to increase energy efficiency. ENDEF will integrate hybrid solar panels into the demo site, aiming to boost both thermal and electrical energy production. These panels will be tested and validated to determine the most efficient designs for long-term operation.

Task 5.3 (months 13-30) focuses on the engineering, planning, and installation of the enabling technologies at the demo site. This includes the integration of the hardware into the local industrial and energy grids, ensuring that the various components (ATES, GWHP, PVT panels) work in synergy with existing systems. Detailed engineering activities—such as hydraulic, electrical, and data connection work—will be carried out to ensure seamless operation. The task also includes the commissioning of all hardware and software components and the development of a monitoring and control system, in alignment with the KPIs established in T2.1.2. A risk and safety assessment will also be carried out to guarantee that all installation processes meet safety standards.

Finally, Task 5.4 (months 31-48) involves the experimental campaign and critical assessment of the demo system's performance. This task aims to evaluate the overall impact of the system, including its environmental, techno-economic, and social aspects (in synergy with WP6). It will use monitoring data to validate the simulation models developed in WP2 and assess the overall effectiveness of the USES4HEAT approach. A key aspect of this task is to gather lessons learned throughout the demonstration, which will be documented and presented in the final project handbook and workshop (as from T7.2). These insights will inform future applications of the system, providing guidance for the scaling up and replication of these technologies for decarbonization and energy security in other regions.

Through these coordinated tasks, WP5 will not only demonstrate the feasibility and effectiveness of the USES4HEAT technologies but will also provide valuable data and insights into their potential for future widespread adoption. The successful implementation of WP5 will significantly contribute to the decarbonization of the energy sector and the development of sustainable, efficient energy storage solutions that can be replicated globally.

The following USES4HEAT partners are actively involved in the demonstration activities under WP5, each contributing with their specific roles (Table 1).

PARTNER	ROLE
Fondazione Bruno Kessler – FBK	**Demo Team/WP5 Leader – Beneficiary** – FBK leads this WP and coordinates demo baseline monitoring, realization of key technologies and experimentation. In this WP FBK supports all the WP5 partners in research and development, obtaining demo permits, realization, and monitoring. FBK further critically assesses the impact of USES4HEAT project specified in Task 5.4. Active collaboration with all the WP5 partners and the WP leaders (mainly WP3 & WP2) is ensured to reach out specific objective defined by USES4HEAT project.
GARDA CARTIERE S.P.A. – CDG	**Beneficiary** – CDG with AGP and AGS act as a demo owner and organize the task on engineering, installation, and commissioning. They are responsible for supervision of executive design, permits and construction of USES4HEAT solutions in demo site. Detailed engineering activities, monitoring, safety, and risk assessment will be carried out for a successful integration of the solutions. Active collaboration with FBK, HIREF, HYDRA, ENDEF, Energenius, SAI, GeoAlp is ensured.

ALTO GARDA POWER SRL – AGP	**Beneficiary** – AGP with CDG and AGS act as a demo owner and organize the task on engineering, installation, and commissioning. They are responsible for supervision of executive design, permits and construction of USES4HEAT solutions in demo site. Detailed engineering activities, monitoring, safety, and risk assessment will be carried out for a successful integration of the solutions. Active collaboration with FBK, HIREF, HYDRA, ENDEF, Energenius, SAI, GeoAlp is ensured.
ALTO GARDA SERVIZI SPA – AGS	**Beneficiary** – AGS with AGP and CDG act as a demo owner and organize the task on engineering, installation, and commissioning. They are responsible for supervision of executive design, permits and construction of USES4HEAT solutions in demo site. Detailed engineering activities, monitoring, safety, and risk assessment will be carried out for a successful integration of the solutions. Active collaboration with FBK, HIREF, HYDRA, ENDEF, Energenius, SAI, GeoAlp is ensured.
HIREF SPA	**Beneficiary** – HIREF leads the activities for their respective technology deployment. In this way HIREF is responsible for design, development, and realization of a new GWHP in the WP5 demo site with respect to the specific objectives defined by USES4HEAT project. Research support and active collaboration with CDG, AGP, AGS, SAI and FBK is ensured.
ENERGENIUS SRL	**Beneficiary** – Energenius acts as technology provider, and, as such, collects and analyses data from demo sites to define a tailored monitoring and control architecture considering the specification of the technologies and assets to be installed at the demo site. Research support and active collaboration with CDG, AGP, AGS and FBK is ensured.
HYDRA SRL	**Beneficiary** – HYDRA leads the activities for its respective technology deployment. In this way HYDRA is responsible for the construction of two ATES wells in the WP5 demo site, developing and improving the drilling technologies with respect to the specific objective defined by the USES4HEAT project. Research support and active collaboration with CDG, AGP, AGS, GeoAlp and FBK is ensured.
ENDEF ENGINEERING SL	**Beneficiary** – ENDEF leads the activities for its respective technology deployment. In this way ENDEF is responsible for design, manufacturing, and validation of PVT solar panels to be connected to ATES/DH system with respect to the specific objectives defined by the USES4HEAT project. Research support and active collaboration with CDG, AGP, AGS, SAI and FBK is ensured.

STUDIO ASSOCIATO DI INGEGNERIA – SAI	***Supporting partner (NO Beneficiary)*** – SAI supports engineering design to reach an optimal integration of innovative technologies with the current components already installed at the demo site. Support in research and obtaining demo permit with active collaboration with CDG, AGP, AGS, HIREF, ENDEF, GeoAlp and FBK is ensured.
Studio Geologico Associato GeoAlp – GeoAlp	***Supporting partner (NO Beneficiary)*** – *GeoAlp* supports geological study and design in WP5 to find an optimal solution for ATES design. In addition, it provides research support to obtain demo permits. In relation to these activities and for the design of the injection system and the wellhead, GeoAlp is supported by DTESS and IF Technologies (two Dutch companies specialized in ATES systems).

Table 1. Partners involved in the WP5 with their specific roles.

It is important to note that, for the current work package, Energenius and CARTIF are responsible for tasks related to the intelligent energy management system and predictive operation and maintenance, which are connected to Work Package 3. Their efforts include analysing historical and real-time data from the demo site. However, their contributions are documented in the corresponding deliverables under Work Package 3.

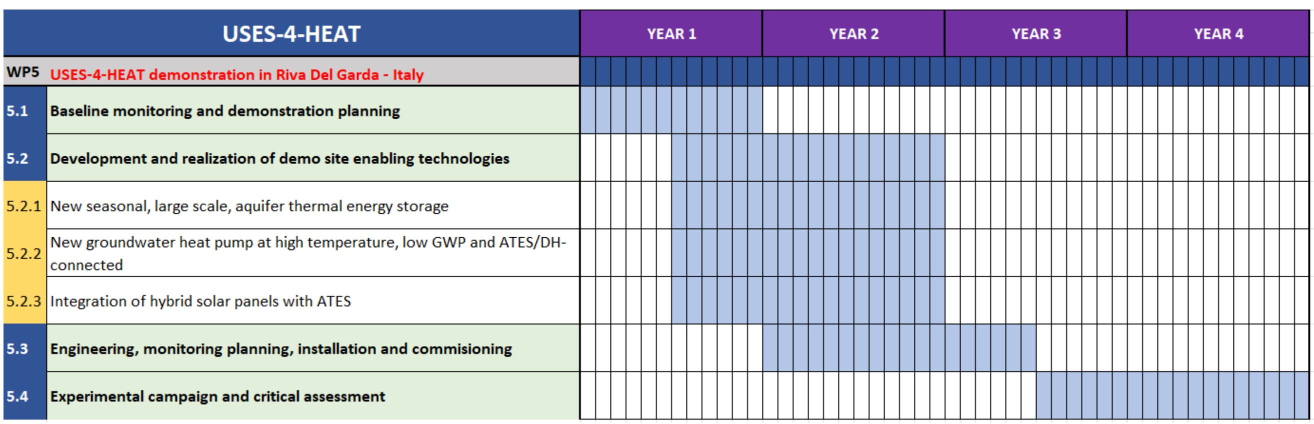

Figure 1. Work package 5 Gantt chart.

2.2. Main Objectives of the Project

To address the challenges associated with realizing the innovative USES4HEAT technologies, the consortium has identified five main objectives, three of which are directly related to WP5 and can be summarized as follows:

- MO1: Develop and demonstrate an innovative, large-scale, cost-effective seasonal Aquifer Thermal Energy Storage (ATES) system for decarbonized heating supply, achieving a Technology Readiness Level (TRL) of 8.

- MO2: Develop and demonstrate key enabling technologies at TRL 8 to decarbonize, enhance flexibility, increase availability, and improve the robustness of the heating sector, ensuring integration with seasonal ATES systems.
- MO3: Develop and demonstrate intelligent energy management systems at TRL 8, leveraging AI, big-data analytics, and predictive operation and maintenance (O&M) for optimized performance.

These main objectives are further divided into specific objectives, each contributing to the overall goal and tracked through precise Key Performance Indicators (KPIs). For more detailed information about the KPIs and the monitoring approach, refer to Deliverable 2.1: USES4HEAT Layouts and KPI Definitions.

2.3. Data Collection Process and Baseline Monitoring

In the framework of WP5, extensive data has been collected to support the analysis, categorization, and monitoring of the associated activities. These data include experimental measurements, sensor outputs, model simulations, literature reviews, geospatial datasets, documentation, and reports. Efforts to gather these data involved preparing questionnaires, accessing historical data from the demo site power plant, and organizing meetings with key stakeholders. Since the project began in mid-December 2023, numerous activities have been implemented to establish a foundation for project development and collaboration. The main initiatives are outlined below:

1. **Online Meetings with Demo Owners**: Discussions to define engineering and geological design proposals (December 2023–January 2024).
2. **Informal Conference Call with WP5 Partners**: Introduction of the new European project to representatives of the Autonomous Province of Trento (January 8, 2024).
3. **Tender Evaluation Meeting**: Online meeting with demo owners (AGP/AGS) to compare tenders for engineering and geological design (January 9, 2024).
4. **Demo-Site Visit**: Partners involved in WP5 gathered on-site to discuss approaches, alternative options, and project timelines (January 16, 2024).
5. **Proposal Finalization**: Completion of a general proposal with AGP for engineering and geological design, including constraints, responsibilities, and timelines for tender submissions (January 26, 2024).
6. **Questionnaire Introduction**: Presentation of a questionnaire prepared by UNIGE and reviewed by FBK to the demo owners for site-specific data collection (February 5, 2024).
7. **Monthly Progress Meetings**: Establishment of regular update meetings held on the second Wednesday of each month to review project progress and address potential issues (from February 2024).
8. **Online Portal Development**: Launch of the USES4HEAT online dashboard by Energenious and uploading historical data from the AGP power plant starting from January 2020.

9. **Data Collection File Preparation**: Creation of an Excel file to compile data not only for WP5 but also for modelling activities in WP2 (February 20, 2024).
10. **Geological and Design Discussions**: Regular meetings with partners (AGP, Geoalp, Hydra, SAI, FBK) to discuss geological and integration design, drilling methods, and materials required for ATES construction (April–August 2024).
11. **Stakeholder Workshop**: Organized by AGS with support from FBK to engage local stakeholders, industrial experts, and institutional representatives (March 2024).
12. **Preliminary Geological and Engineering Design Proposal**: Geoalp and SAI prepared the preliminary design, which was reviewed by AGP and FBK (March 2024).
13. **Technical Table Request**: Submission of a request to establish a technical table with representatives of the Autonomous Province of Trento (PAT) to present the project and discuss permitting approaches for ATES construction (April 19, 2024).
14. **First Technical Table Meeting**: Initial meeting with PAT to discuss project details and strategies for permitting (May 2024).
15. **Second Technical Table Meeting**: Follow-up meeting with PAT to further address permitting processes (June 2024).
16. **KPIs definition:** Several meetings were held with the partners (SAI, AGP, UNIGE, Energenius, FBK, IVL) to discuss and gain a clear understanding of the KPIs and explore potential methods for their measurement (Summer 2024)**.**
17. **Integration Review with DTESS**: Involvement of DTESS to review geological and integration designs for ATES and its components (September 2024).

These activities have established a collaborative framework, ensured the alignment of stakeholders and provided the necessary data to guide the project’s technical and operational objectives.

3. Riva Del Garda Demo site

3.1. Riva Del Garda, Italy

Riva del Garda is a town and municipality located in northern Italy, within the Trentino-Alto Adige region, at the northernmost point of Lake Garda and approximately 70 meters above sea level. Positioned at the southern edge of the Italian Alps and surrounded by mountains, the town enjoys a distinctive geographical and environmental setting. Tourism forms the backbone of its economy, drawing approximately 3.5 million visitors annually. In addition to its tourism sector, Riva del Garda is home to one of Italy's prominent industrial clusters in paper milling, further underscoring its economic importance. From an energy perspective, Riva del Garda is strategically positioned within the Sarca Basin (Figure 2), a region renowned for its significant hydroelectric potential. The nearby hydroelectric plants at Ponale and Torbole contribute substantially to the area's energy supply. The Ponale facility, with a turbine capacity of 120 MW and a pumping capacity of 48 MW, generates between 133 and 165 GWh annually, depending on operational conditions. The Torbole plant provides an additional 112 MW of capacity, producing approximately 300 GWh annually. Other notable hydroelectric plants within the Sarca Basin include Santa Massenza, which was Europe's largest hydroelectric facility at the time of its construction (1947–1957). Santa Massenza has a capacity of 350 MW and produces 640 GWh annually. Additional smaller facilities include Nembia (13 MW, 30 GWh/year), Fies (1 MW, 3 GWh/year), and Dro (1 MW, 3 GWh/year). Beyond hydroelectricity, distributed photovoltaic (PV) systems contribute to the renewable energy mix of the region. Within Riva del Garda, PV installations with an aggregate capacity of 2,378 kW generate approximately 3.0 GWh annually. Neighboring municipalities also enhance the region's PV production, with Arco and Nago-Torbole contributing 5.4 GWh/year (4,347 kW) and 0.7 GWh/year (597 kW), respectively. Energy consumption in the region is heavily influenced by the methane gas requirements of the local paper mill cluster, comprising four major industrial facilities. These include: (i) Cartiere del Garda S.p.A., part of the LECTA Group, with an annual energy consumption of 970 GWh; (ii) Fedrigoni in Linfano (FEDRIGONI Group) consuming 240 GWh annually; (iii) Arconvert (FEDRIGONI Group), with 19 GWh annual consumption; and (iv) Fedrigoni in Varone (FEDRIGONI Group), utilizing 180 GWh annually.

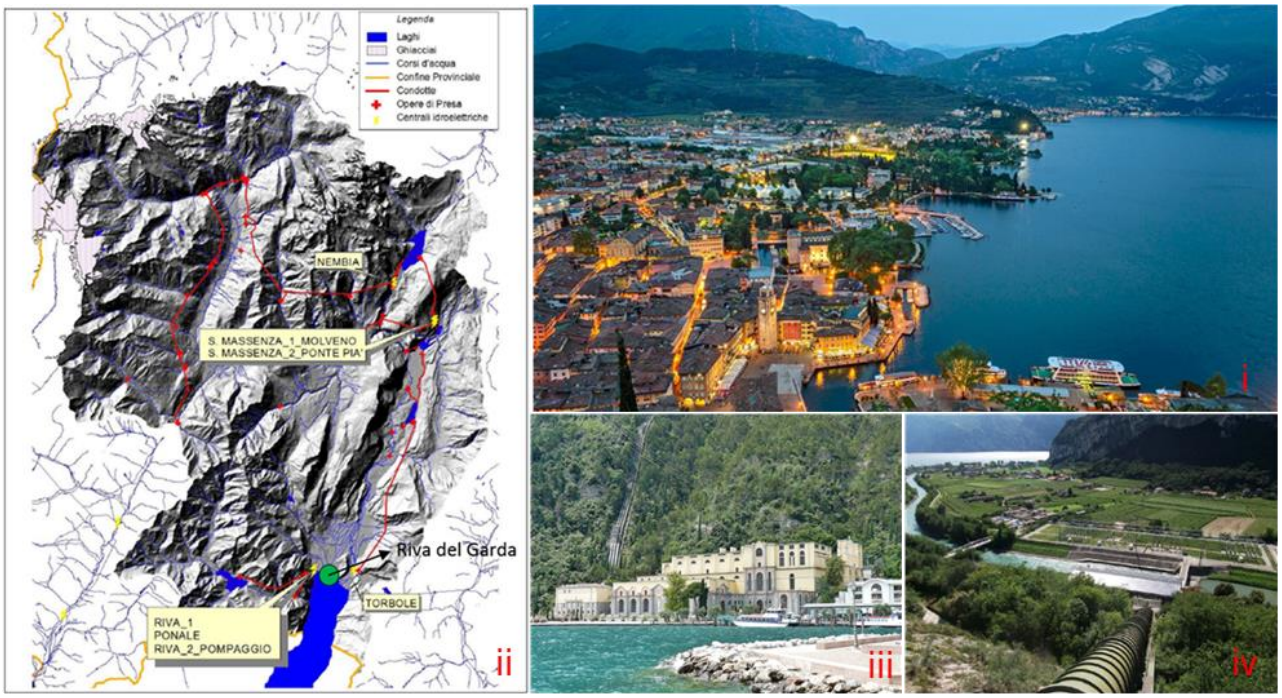

Figure 2. View of town Riva del Garda (i); Planimetric representation of the hydroelectric system of the Sarca Basin (ii); Ponale hydroelectric power plant (iii); and Torbole hydroelectric power plant (iv).

3.2. Location Climate

Riva del Garda is classified within Climate Zone E, with average degree days approximating 2,276, as defined in *Il D.P.R. n. 412 del 26 agosto 1993, Allegato A*. The average monthly weather patterns are illustrated in Figure 3. During winter, temperatures typically fluctuate around 0°C and rarely fall below -5°C. In contrast, summer temperatures seldom exceed 25°C. The average relative humidity is approximately 70%.

In terms of solar irradiance, the region experiences an average of 9.5 hours of sunlight per day during the summer months. Ground-level solar irradiance can reach up to 1 kW/m² in June, as detailed in Figure 4.

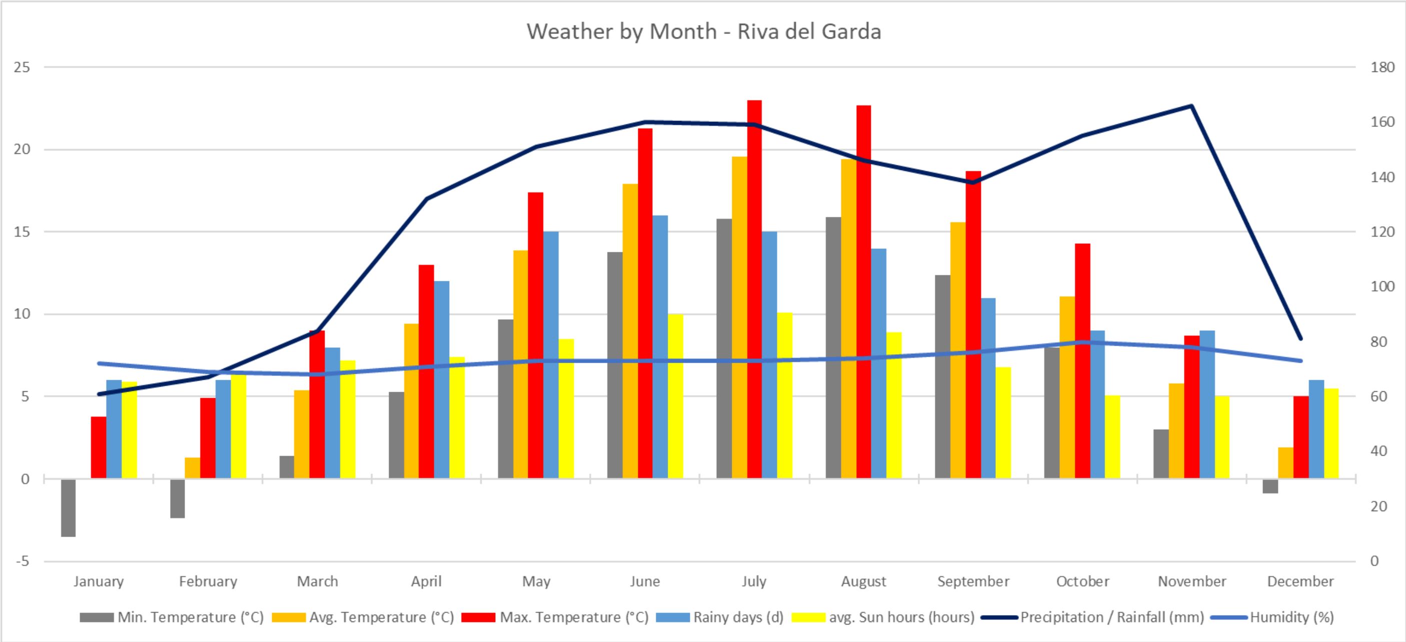

Figure 3. Climate data for the Riva del Garda spanning 1991 to 2021[climate-data.org].

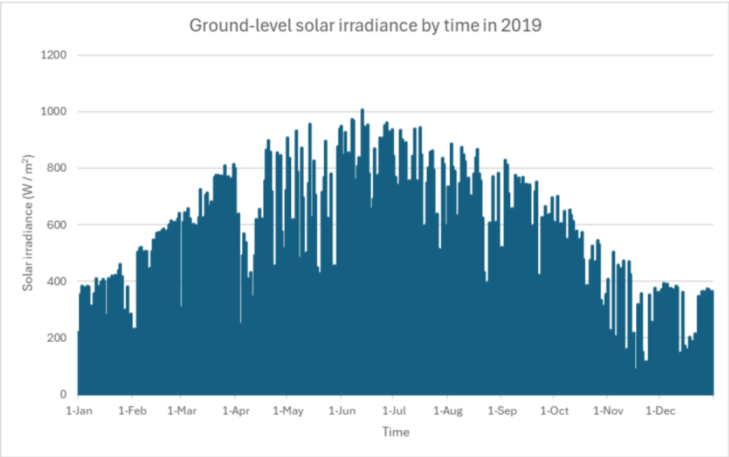

Figure 4. Surface-level incident shortwave radiation flux, considering cloud cover and aerosols in Riva del Garda for 2019 [Renewables.ninja].

3.3. Geological and Hydrogeological Framework of the Area

With reference to the study conducted by Studio Geoalp, this chapter provides an overview of the geological and hydrogeological framework of the area, which is essential for the design of the ATES system.

3.3.1. Geological Framework

The northern termination of the Benacense Depression, which includes the plains of Riva and Arco and the surrounding ridges, vividly illustrates the enduring impact of geological processes on the region's terrain. During the Jurassic period (Mesozoic), this area was characterized by a tectonic escarpment: to the east, the Alto di Trento (Trento Ridge), a raised zone covered by a shallow sea, and to the west, the deeper Lombard Basin. These distinct regions were separated by the Ballino Line, a sedimentary fault that extends from Lake Garda to Campiglio. The Sarca Valley, aligned with NNE-SSW tectonic trends, reflects these ancient tectonic processes and continues to shape the valley's evolution.

During the Messinian period, significant base-level lowering led to the carving of deep valleys, with paleo-channels extending well below the present sea level. This depression, filled with fluvial sediments up to 430 meters thick (Felber et al., 1998), provides strong evidence for the region's genesis through Messinian erosion (Figure 5). Over time, the valley was reshaped by multiple glaciations, acquiring the flat-bottomed profile observed today, interrupted by the isolated ridge of Monte Brione.

Post-glacial sedimentation rates, calculated through carbon 14 isotope dating on organic wood fragments from deep drilling, reveal an infill of 130 meters over approximately 12,600 years, at a rate of 0.01 m/year (Felber et al., 1998**)**. Prior to this infill, Lake Garda was much larger, extending far into the Sarca Valley. Estimates suggest the lake's level was more than 50 meters higher than its current level. As the lake retreated, the formation of the alluvial plain between Arco and Riva occurred, initially through delta fan progradation, followed by braided stream dynamics and the eventual eastward shift of the Sarca River channel.

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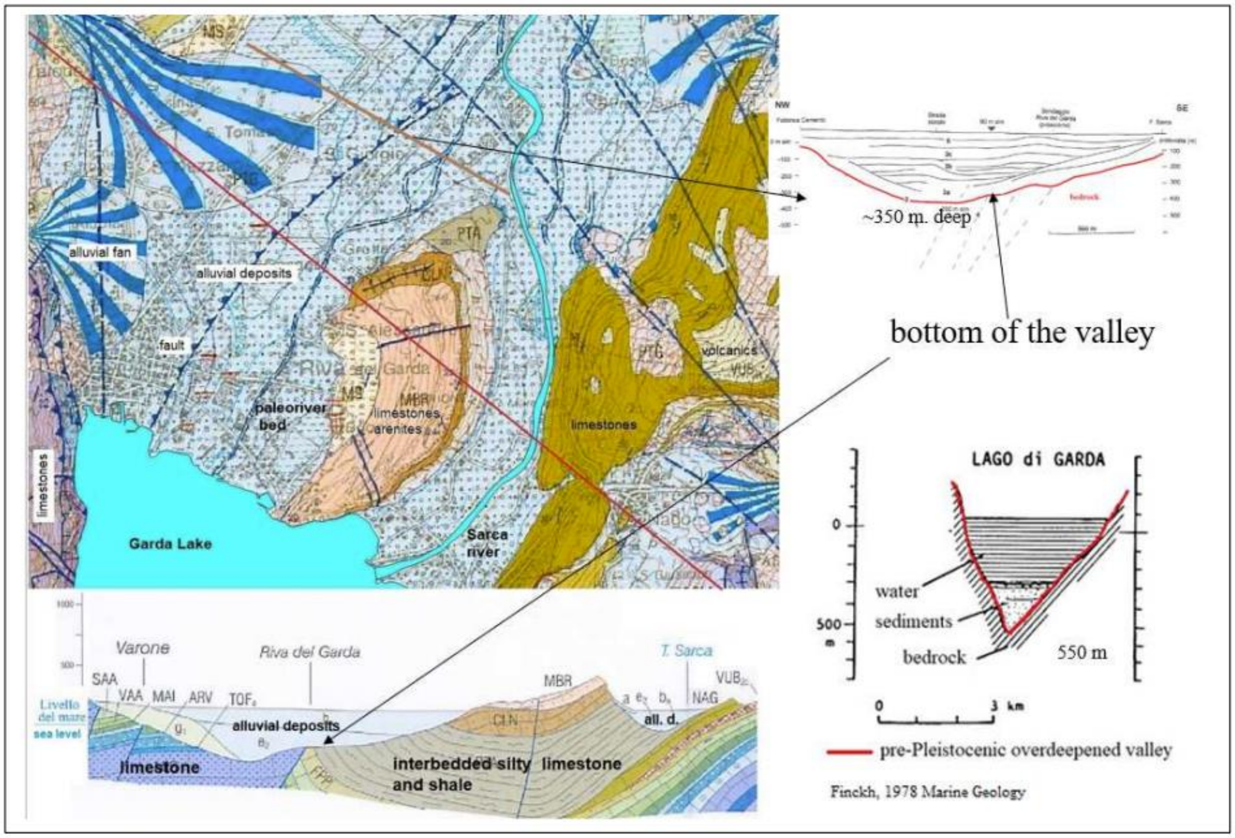

Figure 5. Geological structure of Riva del Garda.

The sedimentary history of the area provides the geological model for the infill of the Gardesana Valley in the project area. The stratigraphic succession derived from the geological evolution (Figure 6) includes:

- bedrock mainly calcareous – dolomitic, with a valley profile, affected by faults.
- fluvial deposits in correspondence with the ancient valley axis. Made up of gravels and sands and gravels and debris blocks.
- landslides on the sides of the valley; - glacial and fluvioglacial deposits, linked to glacial advances and retreats, given by gravels immersed in abundant silty-clayey matrix with gravelly horizons.
- lacustrine deposits, made up of sandy silts and clays; these deposits, considering the extension reached by Lake Garda in the Holocene deglaciation phase, are present under the entire plain between Riva del Garda and Arco.
- alluvial fan and torrential delta deposits given by coarse gravels and sands.

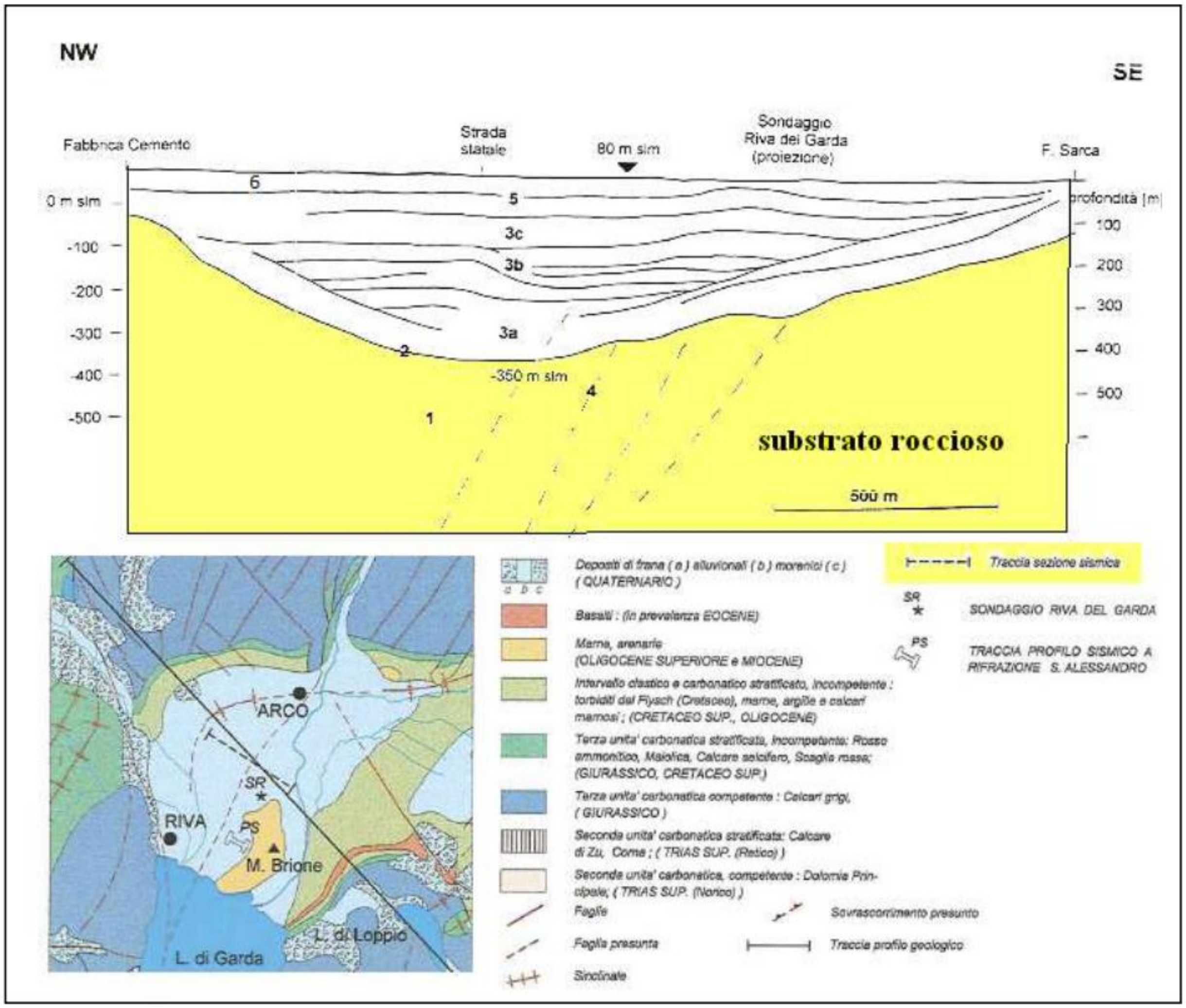

Figure 6. Seismic section (from Felber et al., 1998, with modifications). Profile interpretation legend:1: bedrock; 2: top of bedrock; 3a: glacial deposits; 3b: cemented sands; 3c: fluvial deposits; 4: faults; 5: lacustrine facies deposits; 6: fluvial and torrential alluvium. The trace of the seismic section is shaded in the geological diagram.

This model is confirmed by geophysical investigations (Benvenuti et al., 1970; Felber et al., 1998) and stratigraphic data from deep wells in the area between Riva del Garda and Arco. Specific examples (Figure 7) include:

- An exploratory well drilled in San Giorgio di Arco by the Geological Service of the Autonomous Province of Trento (PAT), which reached a depth of 448 meters, encountering bedrock at 223 meters.
- A water well drilled to 128 meters in the industrial area of the Cartiere (PAT code 501).
- A borehole (called pozzo fonte Brione) at Park Hotel Du Lac, drilled to 176 meters, encountering bedrock at 161 meters (PAT code 36715).

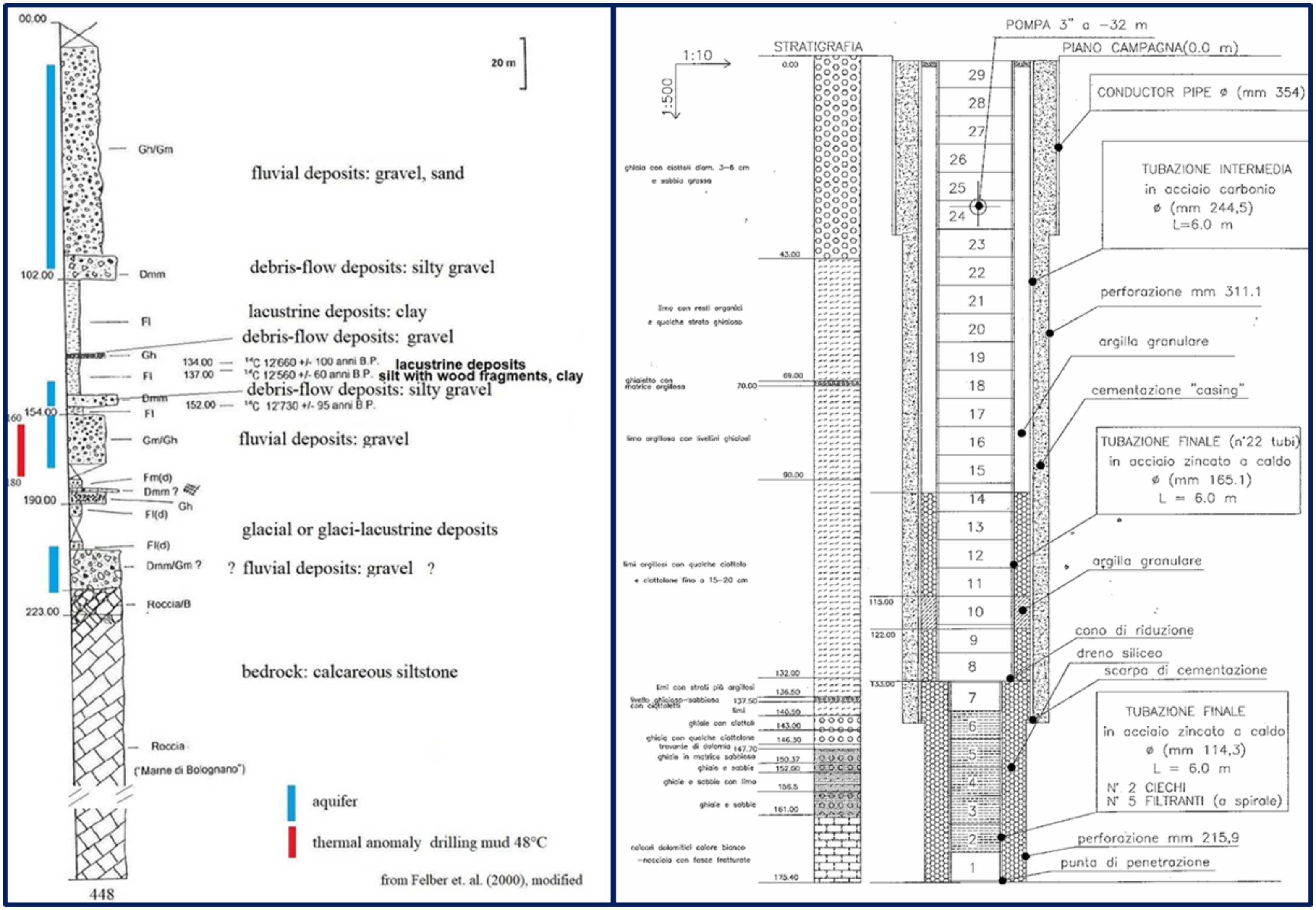

Figure 7. Stratigraphy of the deep exploratory well in San Giorgio di Arco with sedimentological interpretation (left); construction scheme with stratigraphy of deep well called Fonte Brione drilled at Park Hotel Du Lac (right).

The sedimentological history of the area provides the geological model of the filling of the Garda Valley in the project area. The stratigraphic succession expected at the drilling site of the two ATES wells is as follows (Figure 8):

- fill soil(not indicated in figure 3.1): given by coarse gravels with anthropogenic elements, with an expected thickness of about 2 – 3 meters.
- delta fan and alluvial deposits given by coarse gravels and sands. The thickness of these deposits, home to a rich aquifer, is close to 53 meters. They are unconsolidated deposits, locally they have conglomerate crusts near the range of oscillation of the groundwater level. In the surroundings of the project area, the groundwater level fluctuates around 5 m from ground level. In a previous drilling carried out with mud circulation near the project area, strong absorption of the drilling mud was observed.
- lacustrine deposits, consisting of alternating sandy silts and clays. The thickness of these deposits is estimated at around 100 meters.
- glacial and fluvioglacial deposits, given by gravels immersed in an abundant silty-clayey matrix with gravelly horizons; the gravelly levels are home to the aquifer, the objective of the ATES project; the presumed thickness is 15-20 meters.
- river deposits. They consist of gravels and sands and gravels and debris-flow blocks on the sides of the valley. Probably present in correspondence with the ancient pre-glacial valley axis, with weak cementation, aquifers, with a presumed thickness of 5 meters.
- bedrock, consisting of limestone and dolomite, affected by fracturing of tectonic origin, with upper limit around 170 m depth.

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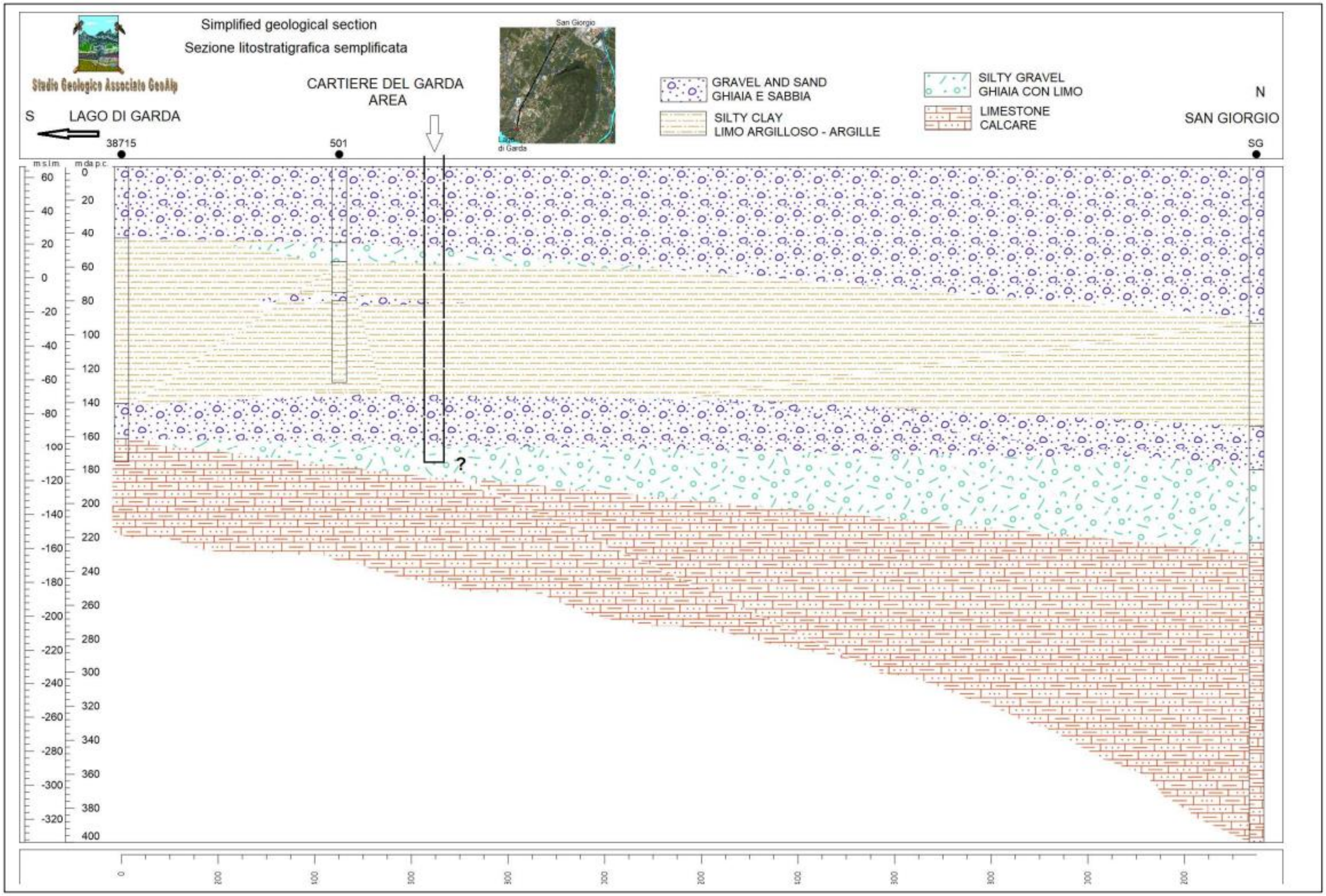

Figure 8. Interpreted stratigraphic section of the subsurface geology between San Giorgio di Arco and Lake Garda.

3.3.2. Hydrogeological Framework

In the Sarca Valley, a multi-layered aquifer system is characterized by overlapping aquifers separated by silty clay levels with low or negligible permeability. The conceptual hydrogeological model of the area identifies the following complexes:

1. **Holocene Aquifer Complex**
    - Composed of deltaic, fluvial, and torrential alluvial deposits consisting of gravel and sandy gravel, locally interspersed with conglomerate crusts.
    - Exhibits high permeability with marked horizontal anisotropy.
2. **Holocene Aquitard Complex**
    - Composed of lacustrine sediments with low permeability.
3. **Pleistocene Aquifer Complex**
    - Consists of glacial and fluvioglacial deposits, comprising gravel embedded in a silty-clay aquitard matrix.
    - Displays medium to low permeability and pronounced anisotropy.
4. **Pre-Pleistocene Aquifer Complex**
    - Includes valley-bottom gravel alluvium and landslide deposits with conglomerate cementation.
    - Exhibits medium to high permeability but has limited lateral extent.
5. **Bedrock Complex**
    - Fractured limestone and dolomite, likely acting as an aquifer on the western side of the valley but as an aquitard on the eastern side.

Regarding the Holocene Aquifer characteristics, this aquifer extends from Lake Garda to Dro and hosts a highly transmissive phreatic water table. This aquifer has been extensively exploited and studied. Significant recharge sources include:

- Subsurface contributions from karstic carbonate mountain ranges.
- Subalveous seepage from the Sarca River and lateral streams.
- Rainwater infiltration, enhanced by the high permeability of surface sediments.
- Irrigation water infiltration.

Figure 9 shows the hydrogeological map of the groundwater table in the area between Riva del Garda and Arco, with the flow directions shown. Note the cone of depression produced by the pumping of the Garda paper mills. Piezometric data spanning over 50 years reveal minimal variations in undisturbed water levels, which remain stable at around 66 meters above sea level in the Riva area. However, localized depressions in the water table are evident near the industrial extraction zones.

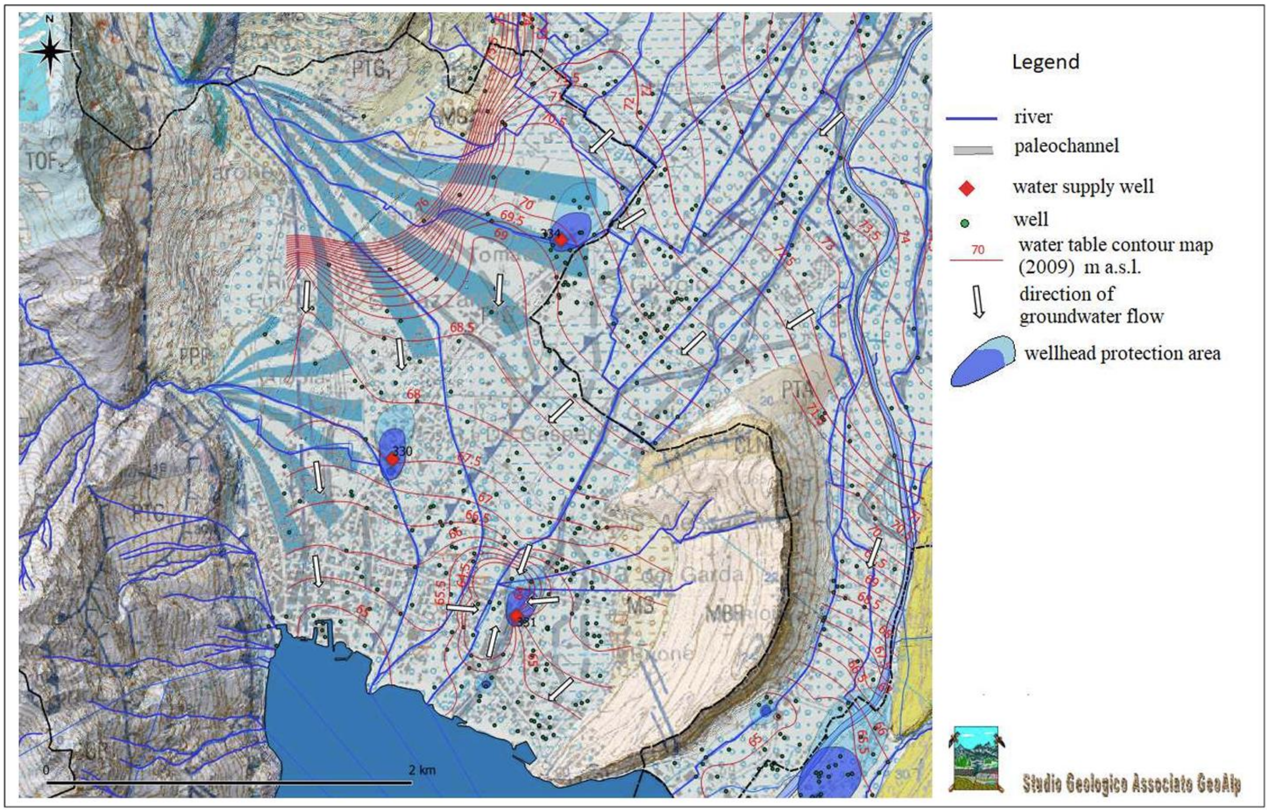

Figure 9. Hydrogeological map of the area.

With respect to the deep aquifer**,** Limited information exists for the confined aquifer located below lacustrine silts. Data are primarily derived from boreholes such as San Giorgio well, where the static level of the confined aquifer is close to the phreatic aquifer level and by using the limited available data from pumping test in Hotel du Lac, it is possible to roughly estimate transmissivity values between 130–160 m^2/day. Assuming a 25-meter aquifer thickness, hydraulic conductivity is estimated in range between 5 x 10^{-5} m/s and 6.2 x 10^{-5} m/s. This value, compatible with layers of sand or gravel with silt, must, however, be considered very conservatively, as the lowering/flow rate diagram of the flow rate test for well in Park Hotel Du Lac shows a broken pattern, which suggests influx from multiple aquifers.

Hydrogeochemical analysis (Figure 10) highlights significant differences between the aquifers. Specifically, the confined aquifer shows higher concentrations of sulphates (SO_4^{2-}) and chlorides (Cl^-) compared to the phreatic aquifer, underscoring their distinct hydro chemical profiles. Moreover, some insights related to the current available monitoring data are mentioned here:

- The PAT Geological Service provided long-term groundwater level recordings from two piezometers in Riva del Garda:
- Piezometer 365, located near the provincial wastewater treatment centre, covers several decades. Data (Figure 11) reveal a general decline in levels over time, with fluctuations of approximately 3.3 meters.
- No temperature or level records exist for the deep confined aquifer, limiting assessments of its relationship with Lake Garda.

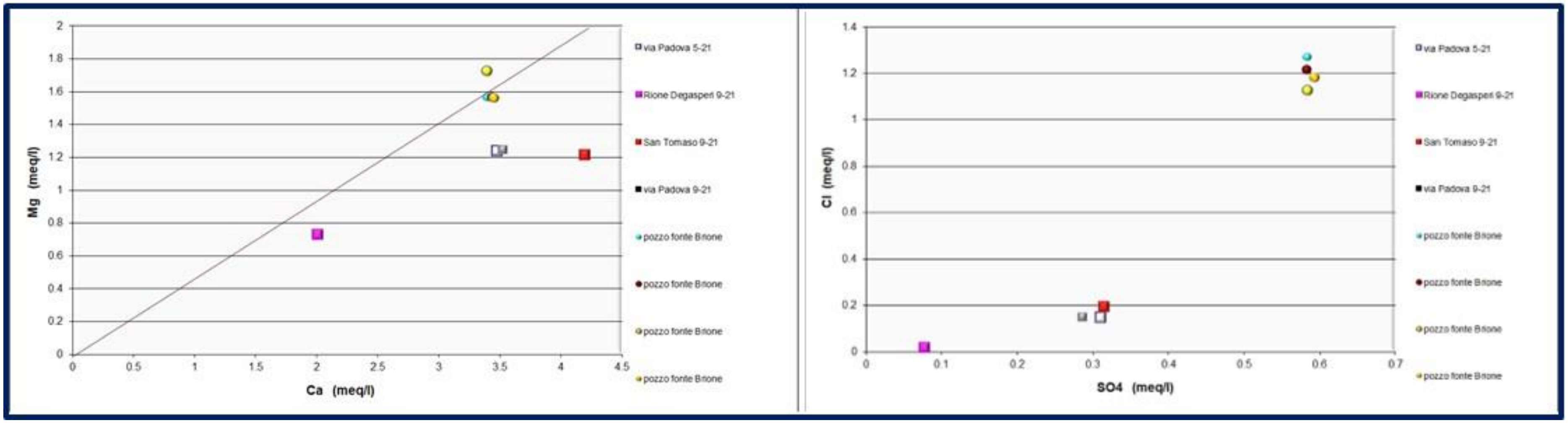

Figure 10. Correlations diagrams for the concentration of particles between the wells in the unconfined aquifer and the one in deep confined aquifer for: SO4 and Cl (left); Ca and Mg (right).

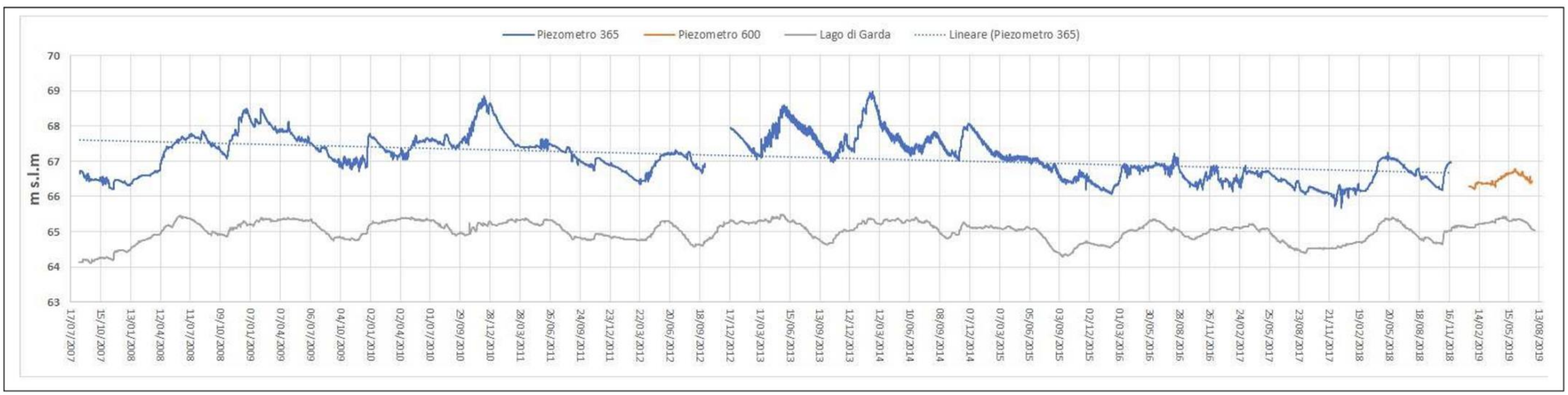

Figure 11. Water table level data from piezometer located in Riva del Garda at PAT purifier from 2007 to 2018 and comparison with the levels in the lake Garda.

3.4. Site Overview

Alto Garda Power Srl (AGP), established through a partnership between Cartiere del Garda SpA (CDG) and Alto Garda Servizi SpA (AGS), operates a combined cycle cogeneration plant designed to meet the electrical and thermal energy demands of CDG and the thermal requirements of a district heating network developed by AGS for the Municipality of Riva del Garda. As previously noted, CDG consumes approximately 970 GWh annually, accounting for about 70% of the total energy consumption within the local industrial cluster. The cogeneration plant is located adjacent to the CDG facility (Figure 12). The project is situated within the Municipality of Riva del Garda, in the industrial complex that includes the Cartiere del Garda production site (parcel number 2270 CC Riva) and the AGP facility. Ownership of AGP is divided between Cartiere del Garda SpA, which holds an 80% stake, and Alto Garda Servizi SpA, which owns the remaining 20%.

Figure 12. 3D view of AGP plant (i); top view of demo site by highlighting the location of AGP (ii).

3.5. District Heating Network

The district heating network in Riva del Garda is operated by Alto Garda Servizi (AGS), a multi-utility company with both public and private stakeholders. AGS is deeply integrated within the local community, with 57% of its shares owned by the Municipality of Riva del Garda and 8% by the Municipality of Alto Garda and Ledro. The company is responsible for managing various technological networks and systems, including electricity distribution, the water cycle, public lighting, natural gas supply, and the district heating network.

Development of the district heating network began in 2007, and it now serves 311 user substations through a total network length of 17 km, comprising 27 km of double pre-insulated pipes (Series 1) as it highlighted in the Figure 13. The system operates with a nominal supply temperature of 90°C and a return temperature of 65°C, under a maximum network pressure of 16 bar. Heating is provided for approximately 183 days per year. However, due to the significant demand for domestic hot water, particularly from the city's tourist and hospitality sectors, heat load requirements remain substantial even during the summer months. The system is designed to operate at a minimum ambient temperature of 12°C for district heating purposes.

The proximity of the paper mill within the town provides a logistical and energy efficiency advantage, as the district heating circuit's pumping and pressurization station is located within the AGP plant. The main power supply for the network utilizes insulated DN450 PN25 pipes, which connect directly to the AGP plant. The network also features a continuous leak detection system for both supply and return pipes, ensuring efficient and safe operation.

Each delivery point in the network is equipped with a water-to-water heat exchanger and a regulation valve, which adapt heat transfer to user-specific needs while minimizing return pipe temperatures. Upon completion of the network's development, it is designed to deliver a maximum thermal power of approximately 45 MW and supply up to 80 GWh of thermal energy annually. The system circulates hot water at a flow rate of 1,500 m^3/h.

The district heating network in Riva del Garda supplies approximately 50 GWh of thermal energy annually, with a maximum power capacity of 23 MW. The network serves a diverse range of clients (Figure 14), including domestic users (35%), hotels (35%), cooling systems powered by absorption chillers at customers' premises (5%), and other users (25%).

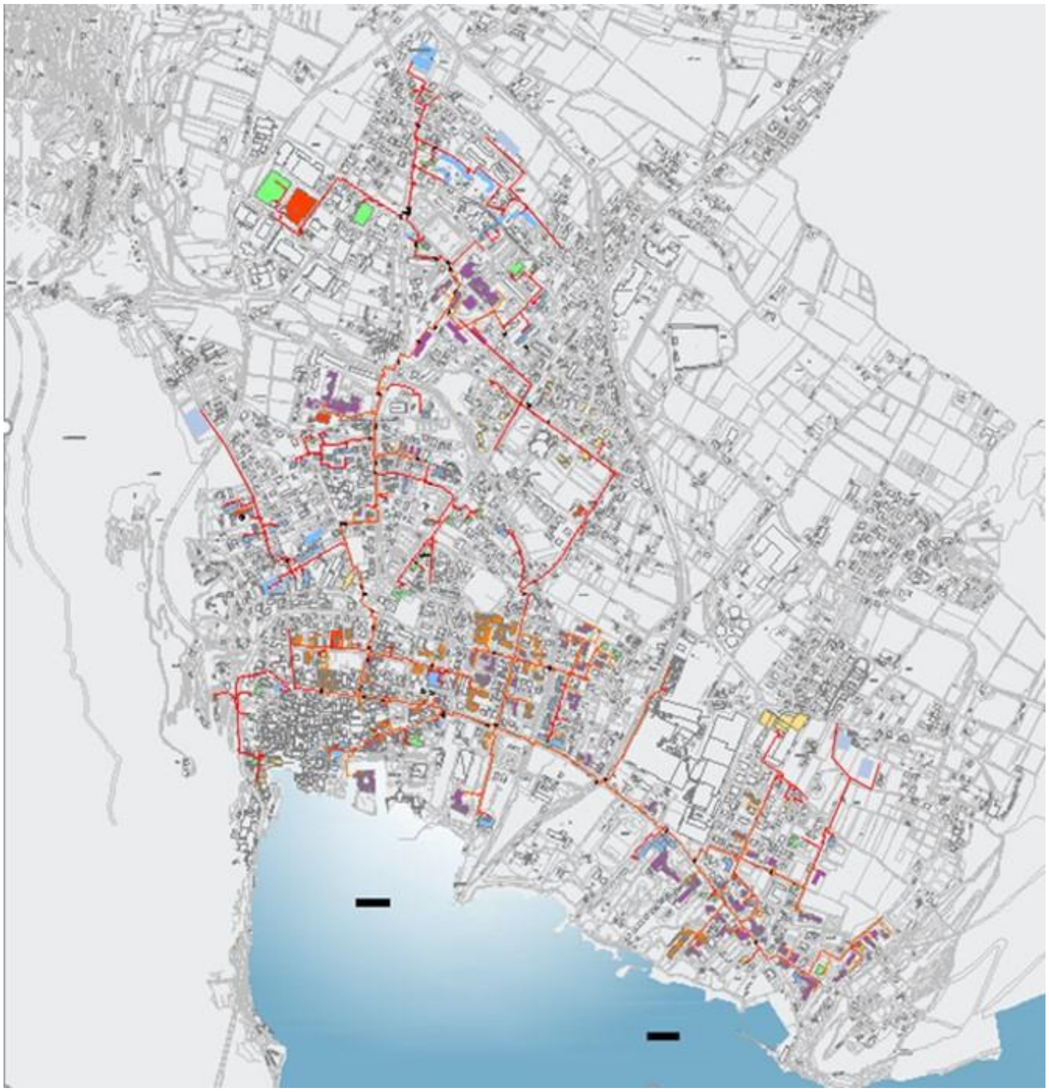

Figure 13. District heating network in Riva del Garda.

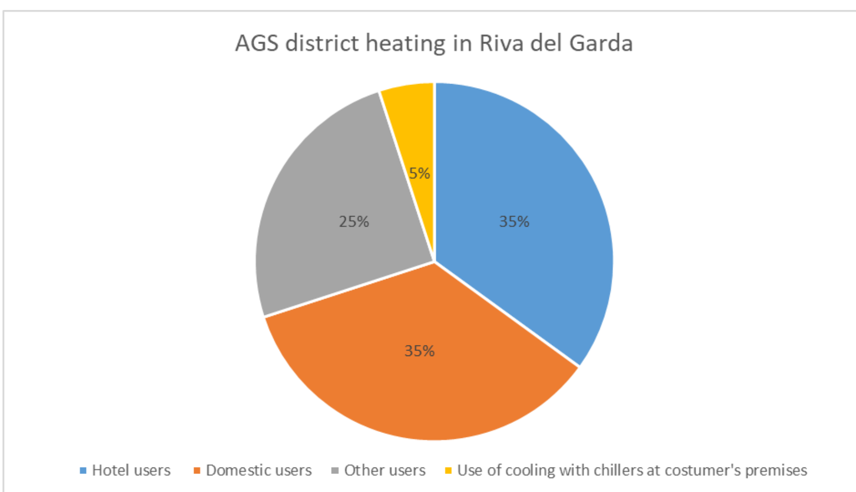

Figure 14. Share of district heating demand in different sectors.

Figure 15 illustrates the daily supply profile for the district heating network in 2023. The data reveal that the network's maximum demand peaked at 300 MWh during the 7th and 8th of February 2023. In contrast, summer demand fluctuated around 125 MWh. Although some measurement discrepancies occurred due to sensor disconnections, the data clearly show significant demand spikes during local fairs, events, and periods of increased tourist activity. These surges are primarily attributed to the increased use of absorption chillers by network consumers, which results in greater heat demand from the network.

The final heat exchanger in the heat recovery steam generator (HRSG), known as the Waste Heat Thermal Recovery (WHTR) system, has an average capacity of 180 MWh/day available to supply the network. However, by looking at the graph it can be roughly estimated that during the summer months, approximately 9.5 GWh of this potential remains unused due to lower demand. In winter, when demand exceeds the WHTR capacity, the additional energy requirements are met by other components, mainly heat pumps and steam-to-water heat exchangers.

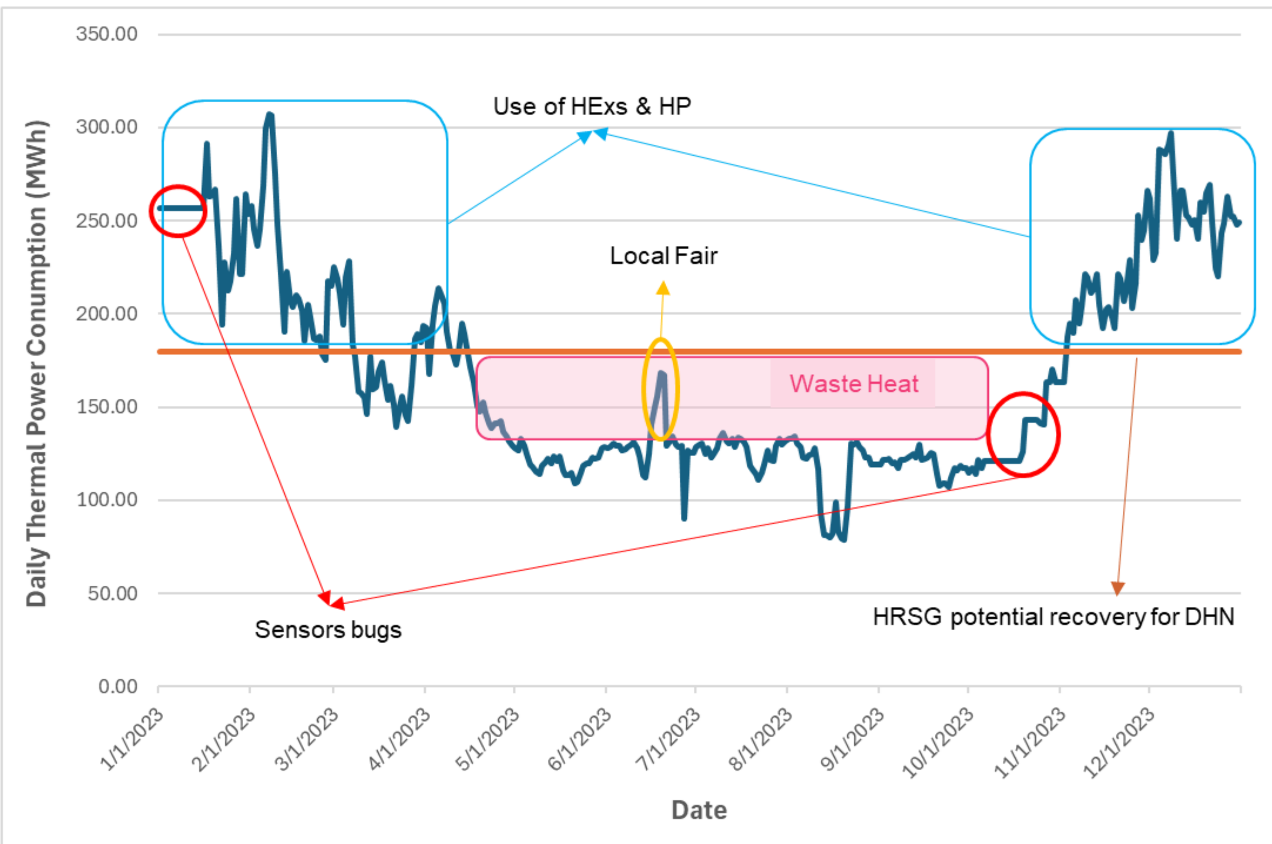

Figure 15. Daily supply profile for district heating network, highlighting the HRSG potential, available excess heat during the summertime, and the utilization of heat pump and heat exchangers to meet the peak demand during wintertime.

4. Material and Energy Flow Analysis

As outlined in Subchapter 3.4, the district heating network in Riva del Garda is supplied by the AGP cogeneration plant. This chapter analyses the primary energy streams involved in the supply, focusing on the components used and the types of fuel sources employed. As shown in Figure 16, the AGP plant consists mainly of a gas turbine, heat recovery steam generator (HRSG), cold condenser, gas compressors, heat pump, and heat exchangers. Additionally, an absorption chiller in the paper mill area utilizes thermal energy produced by the AGP plant to meet internal cooling demands during the summer months. Regarding the components related to the district heating system, the plant operates in two modes: cogeneration mode and non-cogeneration mode, both of which are analysed in the subsequent subchapters.

4.1. General Description of the Plant

4.1.1. Main Components Operating in Cogeneration Mode

The AGP plant cogeneration plant operates as a combined cycle system, featuring a gas turbine (TG) with an electrical output of approximately 47 MWe under ISO conditions. The exhaust gases from the turbine are directed into a HRSG, which includes a post-combustor. This configuration produces high-pressure steam (45 to 50 bar), low-pressure steam (4.1 bar), and hot water at 90°C in successive stages (Figure 16).

The system also incorporates a back-pressure steam turbine (TV) with two intermediate bleeds and a steam exhaust pressure of 4.3 bar. The electrical power generated at the alternator terminals ranges between 4.9 and 8.2 MWe, depending on the steam turbine's operating conditions. Additionally, the plant features a condenser cooled by well water, which serves as a reservoir for surplus steam at 4.1 bar to accommodate the sudden and unpredictable demands of the paper production process.

Low-pressure steam, drawn from the turbine and supplemented by steam generated by the recovery steam generator, is supplied to the industrial processes of the paper mill. The system also includes a thermal energy generation section and a hot water pumping station, which provide heating through the district heating network. This network serves the winter and summer air conditioning needs of civil users in Riva del Garda, including the paper mill. The facility is connected to Terna's national electricity grid via a high-voltage substation operating at 132 kV.

4.1.2. Main Components Operating in Non-cogeneration Mode

The AGP plant also includes three traditional auxiliary fire-tube boilers, which use natural gas as fuel to generate hot water at 90°C for the district heating network. These boilers serve as an additional source of thermal energy and provide backup for the district heating system.

During periods of maximum demand for the district heating network, the auxiliary boilers can operate in modulation mode to meet peak heat requirements. Additionally, these boilers are activated when part or all of the cogeneration plant is offline, typically during scheduled maintenance shutdowns, which generally occur in August, December, and around Easter.

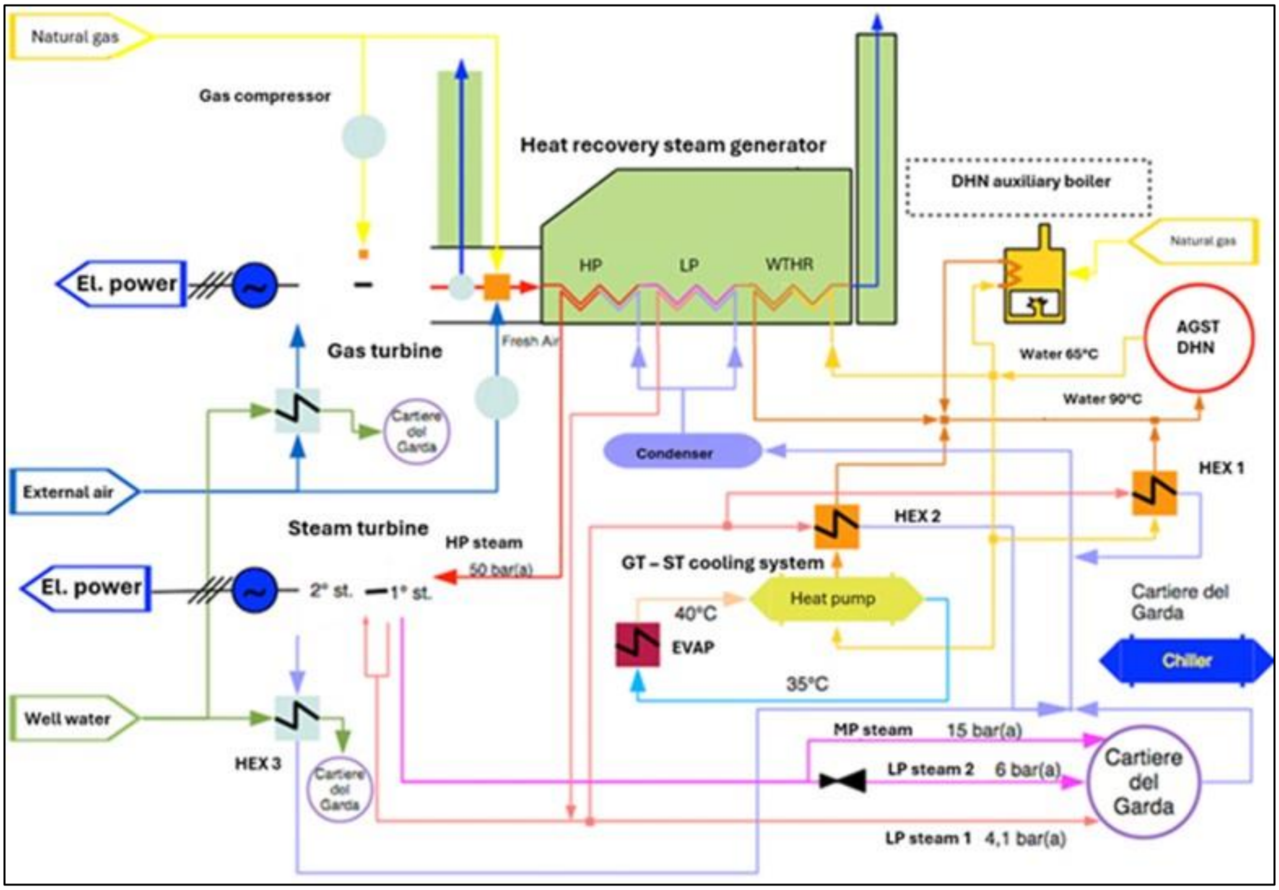

Figure 16. Simple schematic of AGP plant highlighting the current working components with the main energy streams.

4.2. District Heating Supply

This section provides a detailed analysis of all components involved in supplying the district heating network (DHN). With both operational modes of the plant previously introduced, it is essential to examine the overall contribution of each component. In 2023, the plant supplied the DHN with a total thermal energy output of 61.54 GWh. The demand was met with contributions of approximately 68% from the Waste Heat Thermal Recovery (WHTR) system, 20% from heat exchangers, 10% from boilers, and 1% from the heat pump (Figure 17). Figure 18 illustrates the hourly distribution of total supply power to the DHN. Although some measurement errors with constant values are present, the data indicates that the maximum power supply reached 17 MW during the first week of February 2023. While, in summer demand fluctuated within a lower range of 2.5 to 4.5 MW, with higher values observed during the daytime and lower values at night. The yearly average supply profile is approximately 7 MW, which is slightly below the current WHTR potential of 7.5 MW.

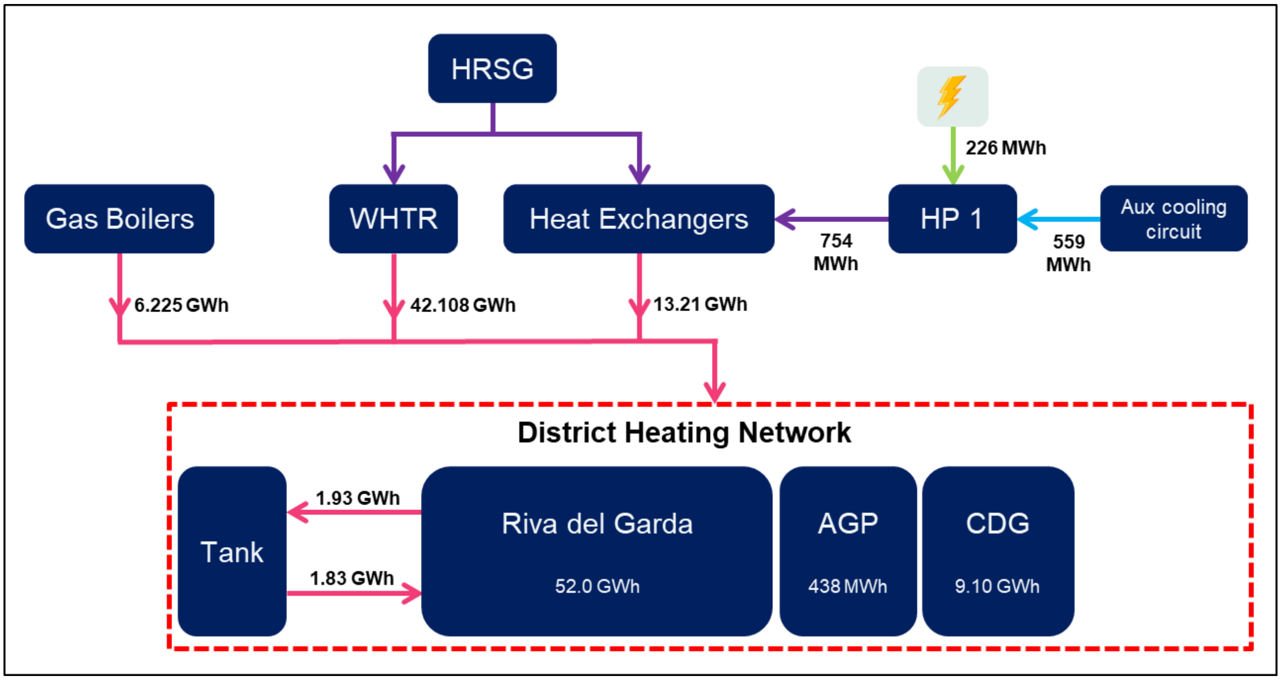

Figure 17. A simple schematic illustrating the energy flows supplying the district heating network in Riva del Garda for the year 2023.

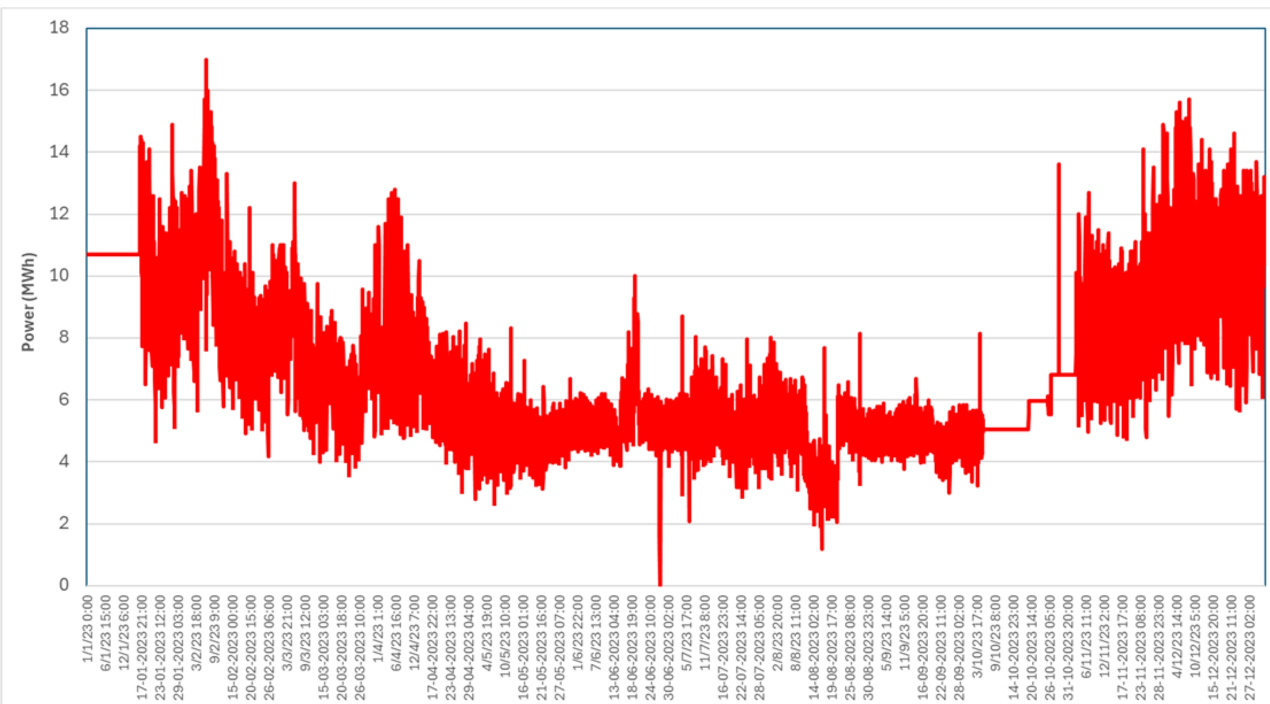

Figure 18. Hourly supply profile for the district heating network in Riva del garda in 2023.

4.2.1. Waste Heat Thermal Recovery (WHTR)

As shown in Figure 16, the cogeneration plant includes a heat recovery steam generator (HRSG), which consists of several key stages:

- **Superheater coil**: Generates high-pressure steam at 45 bar and 428°C.
- **Two evaporators**: Produce steam at two different pressures (45 bar and 4.1 bar).
- **Two economizers**: Preheat the water coming from the condenser to the deaerator and from the deaerator to the low-pressure evaporator.
- **Third economizer (Waste Heat Thermal Recovery, WHTR)**: Connected to the district heating network, this component recovers waste heat from the exhaust gases.

The WHTR economizer captures thermal energy from exhaust gases before they are released into the atmosphere. This component has a potential output of approximately 7.5 MW, which can increase to 8.5 MW during periods of higher plant production (Figure 19). If this thermal energy is not recovered, the exhaust gases are released to ambient at temperatures exceeding the minimum design threshold of 75°C.

Since daytime energy demand is higher than nighttime demand, the use of a storage tank facilitates the recovery of additional waste heat during the period from mid-October to mid-April. However, this recovery is not feasible during the warmer months. As illustrated in Figure 20, and considering the plant's operating hours—approximately 7732 hours for the HRSG for one working year and by considering the period from the mid-April to mid-October—the total amount of unrecovered waste heat is estimated at 7.4 GWh. This corresponds to an average waste energy output of 1.672 MW during plant operation in this period.

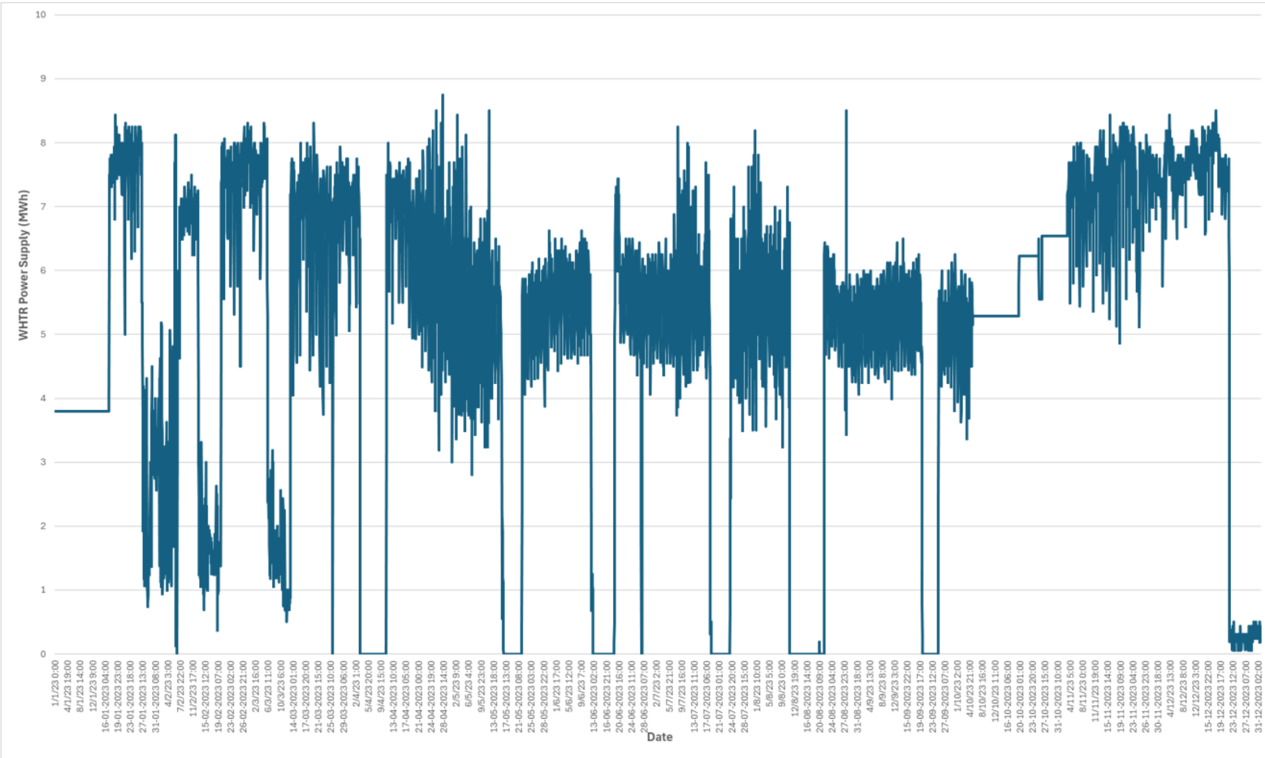

Figure 19. Hourly profile for WHTR supplying the district heating network in Riva del Garda in 2023.

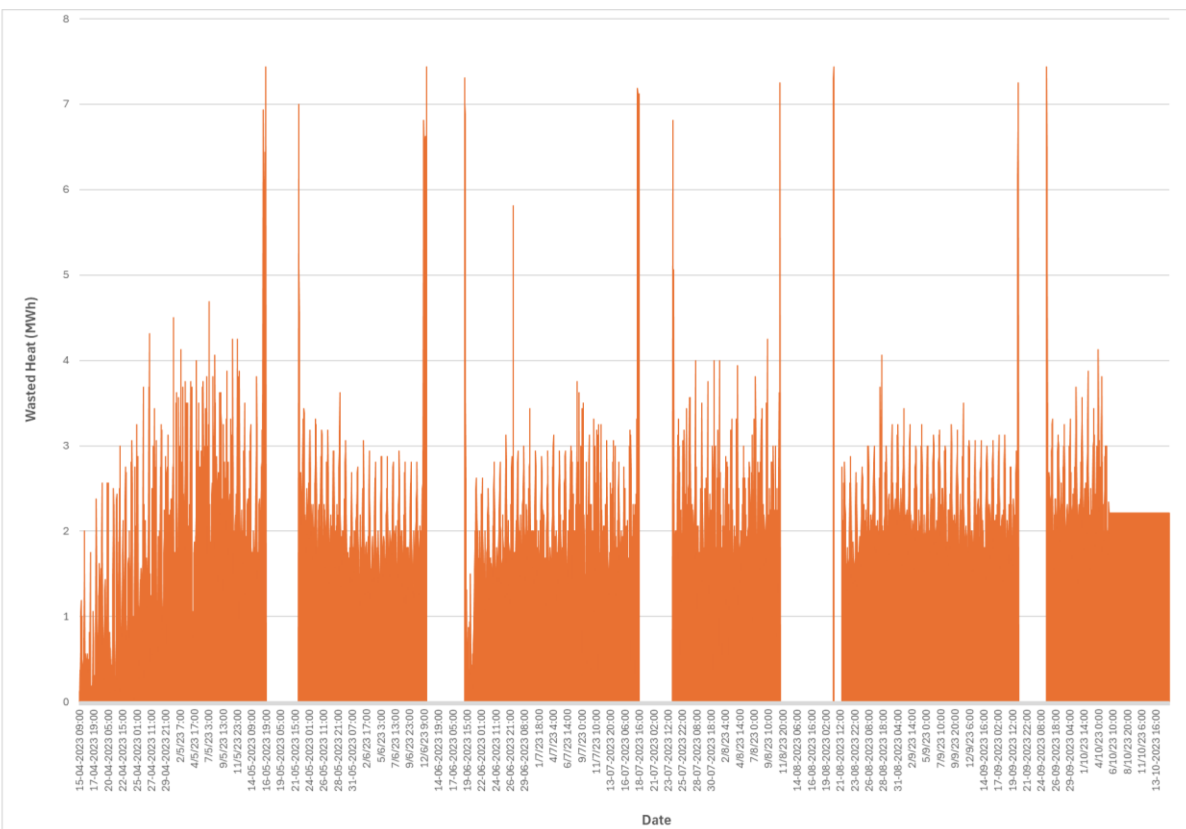

Figure 20. Hourly profile for wasted heat from AGP plant in Riva del Garda in 2023.

4.2.2. Heat Pump

Currently, an active heat pump (HP) is in operation, extracting heat from the closed cooling circuit of the rotating components of the power plant, including the steam turbine, gas turbine, and gas compressors. The extracted heat is then supplied to stream which then pass from a steam/water heat exchanger to provide water at the desired temperature of 90°C. When the heat pump is not operating, the waste heat from the cooling circuit is redirected to the paper mill, where it is used for conditioning the felts.

The nominal design specifications of the heat pump are as follows:

- **Evaporator**:
    - Inlet/Outlet temperature: 40/35°C
    - Input power: 1 MW
- **Condenser**:
    - Inlet/Outlet temperature: 65/78°C
    - Output power: 1.3 MW
- **Coefficient of Performance (COP)**: Approximately 4.00
    - Nominal power consumption: 325 kW

In practice, the heat pump operates primarily during peak demand periods. Based on Figure 21 which is showing the energy profile for the current HP, the total working hours for the year 2023 is equal to 1009 h, with an average COP of about 3.085 with total amount of energy supplied to the network equal to 754 MWh.

Figure 21. Hourly profile for 2023 of the existing heat pump at the AGP plant, illustrating the cooling energy extracted from the evaporator (green line), electricity consumption (yellow line), and output energy delivered to the condenser (blue line). The vertical axis represents energy in kWh, while the horizontal axis corresponds to the date.

4.2.3. Heat Exchangers

Excluding the WHTR unit in the HRSG, there are two additional steam/water heat exchangers that supply heat to the district heating network. The first heat exchanger, shown in Figure 16, has a maximum capacity of 13 MW and directly feeds the network. It is located between the supply and return collectors but operates with lower efficiency. The second heat exchanger is designed to work in conjunction with the heat pump, delivering heat with reduced losses and also capable of feeding the district heating network via a bypass valve, even when the heat pump is not in use, with higher utilization typically observed in wintertime.

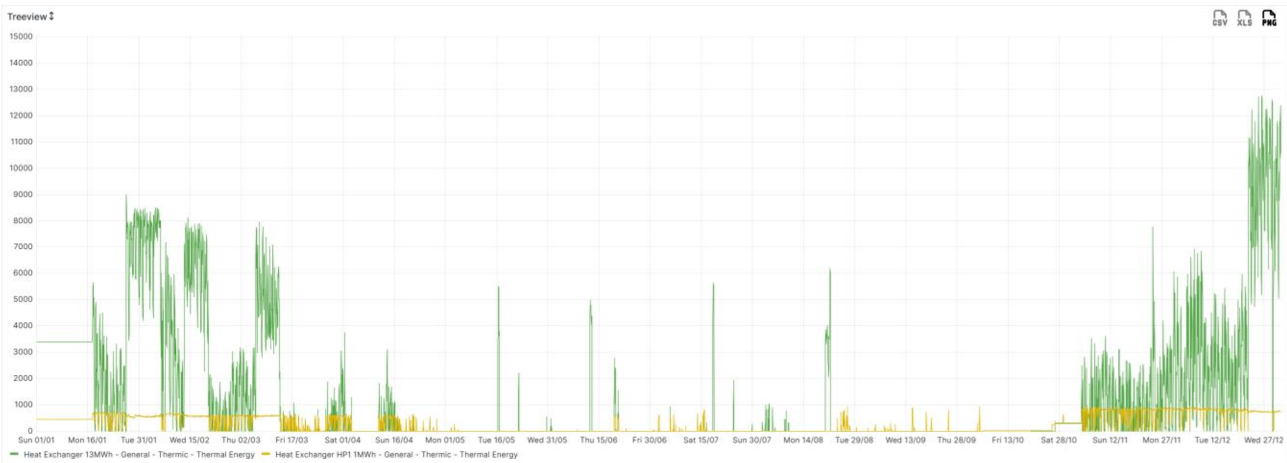

Figure 22. Hourly profile for 2023 of the current heat exchangers at the AGP plant, illustrating the delivery thermal energy for heat exchangers 1 (green line) and 2 (yellow line). The vertical axis represents energy in kWh, while the horizontal axis corresponds to the date.

4.2.4. Storage Tank

In the general design of the district heating network, two storage tanks with a total capacity of 1,200 m³ are planned. Currently, one tank with a capacity of approximately 600 m³ has been installed near the AGP plant, while the second tank is planned for future installation to further optimize the short-term balance between production and consumption within the district heating system. The existing tank is typically filled with hot water during off-peak hours (21:00–06:00 and 09:00–18:00), maximizing the utilization of cogenerative thermal sources. During peak demand hours (06:00–09:00 and 18:00–21:00), the tank is discharged, supplying hot water to the network and reducing reliance on auxiliary boilers (Figure 23). As shown in Figure 24, the storage tank is generally in operation from mid-October to mid-April. During off-peak hours, when demand is lower than the WHTR potential (7.5 MW), the excess heat from the WHTR is stored in the tank. This stored heat is often sufficient to meet peak demand even during the coldest days, eliminating the need for auxiliary boilers. Based on historical data from AGP (Figure 17), the total heat losses from the storage tank in 2023 were approximately 100 MWh.

Figure 23. Hourly profile for the first half of December 2023 of the current storage tank at the AGP plant, illustrating the energy exported to the grid (yellow line) and imported from the grid (green line). The vertical axis represents energy in kWh, while the horizontal axis corresponds to the date.

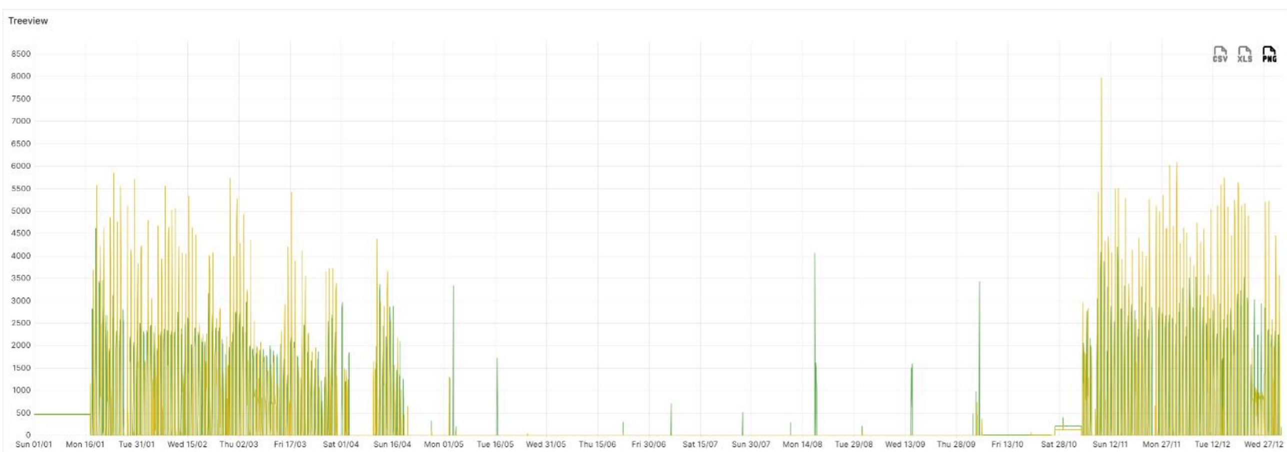

Figure 24. Hourly profile for 2023 of the current storage tank at the AGP plant, showing the energy exported to the grid (yellow line) and imported from the grid (green line). The vertical axis represents energy in kWh, while the horizontal axis corresponds to the date.

4.2.5. Auxiliary Boilers

The AGP power plant includes three traditional auxiliary fire-tube boilers that use natural gas to produce hot water at 90°C for the district heating network. These auxiliary boilers are part of the non-cogeneration system and provide a supplementary source of thermal energy. They primarily serve as a backup during periods of very high peak demand and when the cogeneration plant is offline for scheduled maintenance, typically occurring in August, December, and around Easter. To date, two of the three planned boilers have been installed and are operational, while the third boiler is planned for future integration as part of the network's expansion. The installed boilers have capacities of 15 MW and 14 MW, respectively, and are positioned between the supply and return collectors of the district heating network. As shown in

Figure 17, the total thermal energy produced by the two operational boilers in 2023 was approximately 6.2 GWh, with a total natural gas consumption of 540,948 Sm^3 (Figure 25).

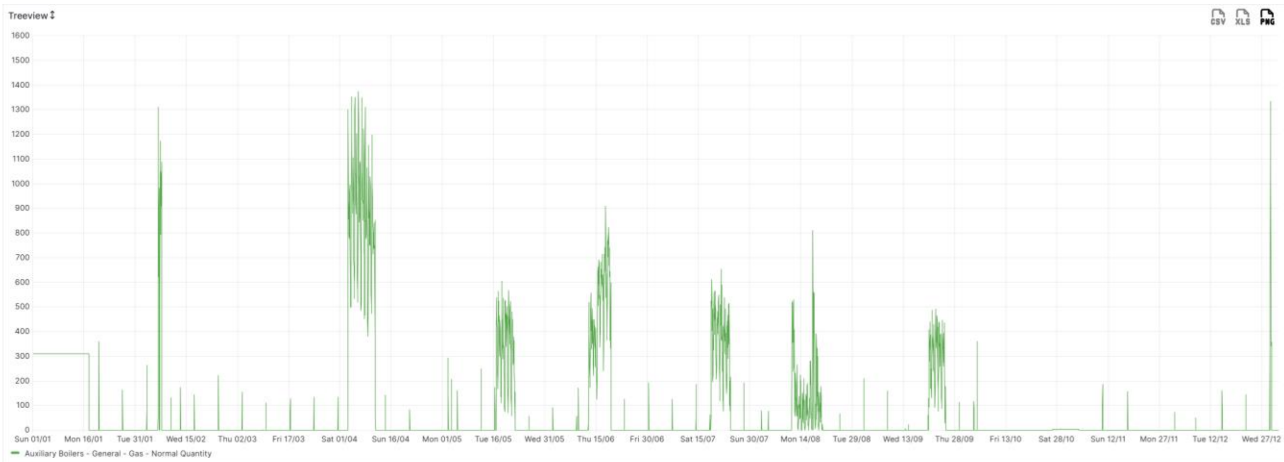

Figure 25. Hourly natural gas consumption profile for 2023 of the auxiliary boilers at the AGP plant. The vertical axis represents natural gas consumption in Sm^3, while the horizontal axis corresponds to the date.

5. Demonstration plan

5.1. Overview

As discussed in Chapter 2, the primary objective of the demonstration plan at the Riva del Garda Demo site is to develop and implement an ATES system functioning as a seasonal storage solution to utilize waste heat and enhance the efficiency of the district heating supply. This system is integrated with a new groundwater heat pump, which increases system flexibility, and hybrid solar (PVT) panels, which contribute to a greater share of renewable energy in the system (Figure 26). This chapter focuses on the key design aspects of these systems, while detailed specifications for each technology will be included in Deliverable 5.2: Development of Enabling Technologies for Riva del Garda Demo. The general plan involves charging the ATES system primarily with waste heat (>95%) and to a smaller extent with energy from PVT panels (<5%), using two distinct heat exchangers. During the discharging phase, the stored energy will be recovered via a heat exchanger and supplied to the heat pump, which will directly feed the district heating network, as illustrated in Figures 26 & 27. For further details on engineering layouts, refer to Deliverable 2.1: USES4HEAT Layouts and KPIs Definition (D2.1).

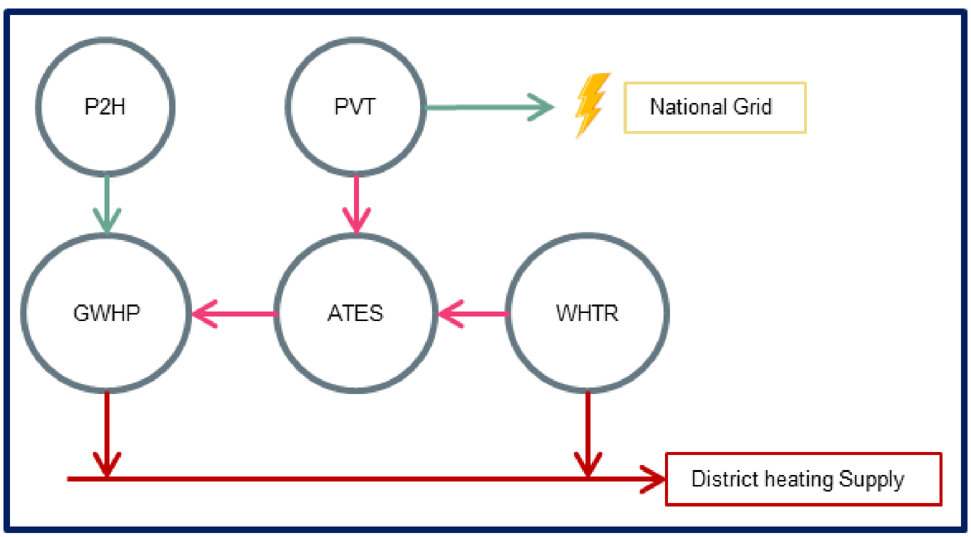

Figure 26. General conceptual flow scheme planned for the integration of technologies at the Riva del Garda demo site.

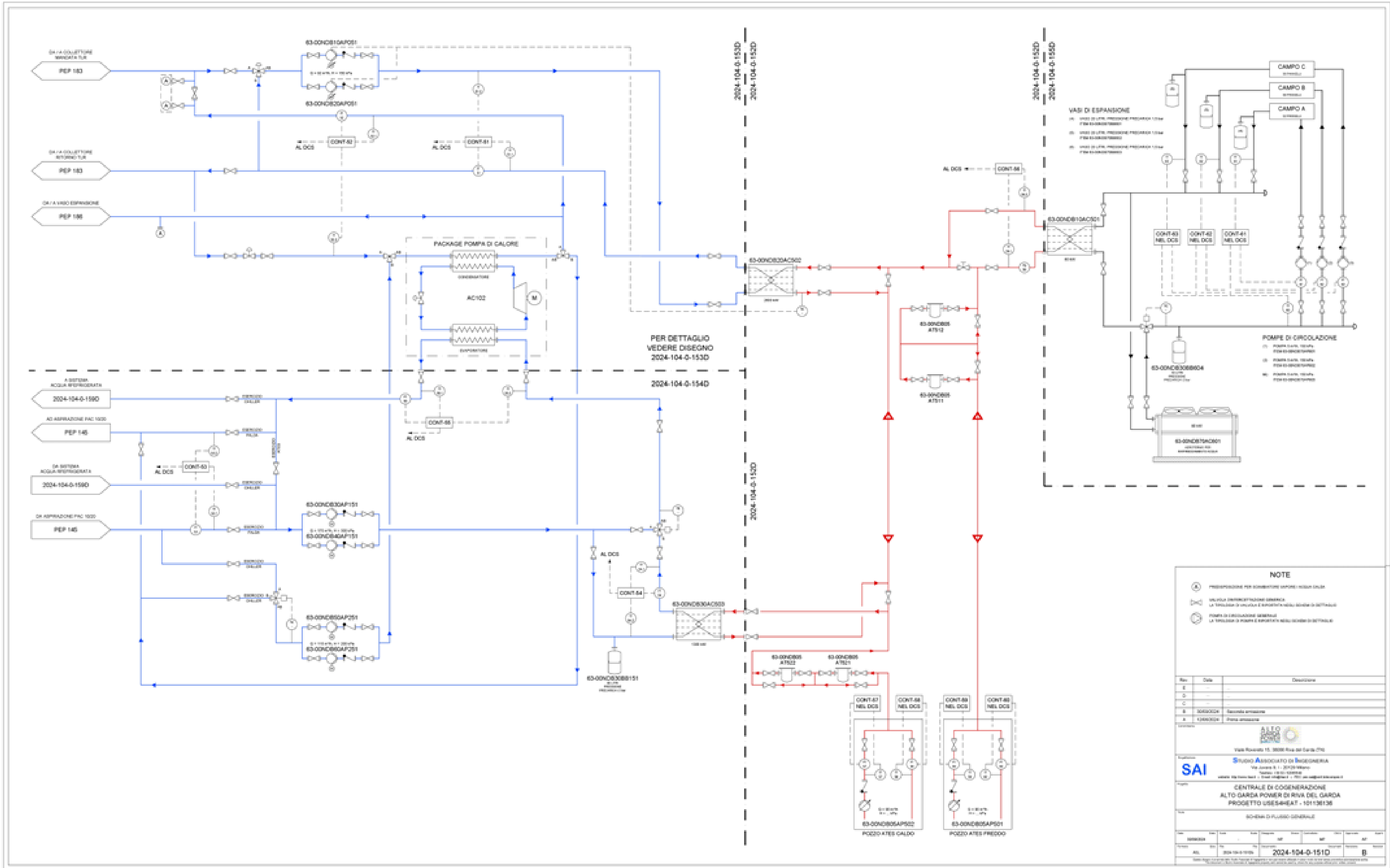

Figure 27. P&ID for the integration of USES4HEAT technologies at the Riva del Garda demo site (preliminary design).

5.2. Development and Realization of Demo Site Enabling Technologies

5.2.1. New seasonal, Large-scale, Aquifer Thermal Energy Storage

To store thermal energy underground during the summer for utilization in the winter months, the USES4HEAT initiative aims to construct an ATES system with a storage capacity of maximum 7.8 GWH_{th}. This energy will primarily be sourced from the WHTR system and the thermal power generated by hybrid solar panels. Geological studies, as detailed in Chapter 3, have identified the second aquifer, located at a depth of approximately 145 to 170 meters (with a thickness of about 25 meters), as a suitable site for heat storage. The water temperature in the second aquifer is expected to be around 14°C. It should be noted that it is planned to finalize the design for the ATES system by the end of December 2023.

5.2.1.1. General specifications

The ATES system will be charged for a maximum capacity of around 7.8 GWH_{th} which is covered mostly by WHTR. In the preliminary design, The ATES system will operate in nominal mass flow rate equal to 24 l/s and based on the following seasonal configuration in the Table 2.

Operation Type	Hot well (°C)	Cold Well (°C)	Equivalent working hours (h)
Charging Mode (Summertime)	40	14	3000
Discharging Mode (Winter)	38 – TBD	14 – TBD	2500-3000
Storage Standstill	-	-	2800 (total)

Table 2. General configuration of the ATES system operation.

5.2.1.2. Wells placement and design

Initially, a two-well configuration, similar to an open-loop geothermal system, was proposed. This setup involved injection into the hot well and extraction from the cold well. However, due to the very low efficiency of this approach, it was decided—after extensive discussions—to adopt a standard two-well ATES system with reversible operation scenarios. The decision to avoid more complex configurations, such as four-well or six-well systems, was based on the additional construction costs associated with these setups. Figure 28 illustrates the different well configurations, ranging from the initial two-well setup to a six-well configuration, with recovery efficiency increasing progressively from (a) to (e).

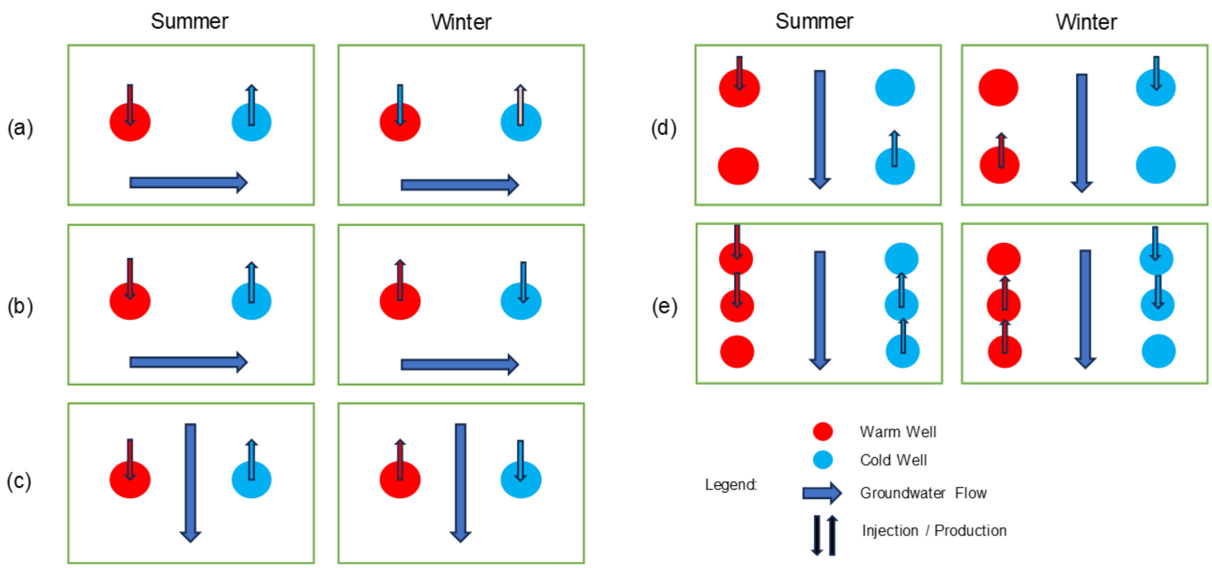

Figure 28. Different well placement settings, showing: (a) Initial two-well setting adopted to this project; (b) two-well setting in the direction of groundwater flow with low efficiency; (c) two-well setting for recovery maximization; (d) four-well setting; and (e) six-well setting.

The placement of the wells was recently updated to reduce the distance between them, thereby significantly lowering the budget required for hydraulic and electrical connections, as previously reported in D2.1. For this updated configuration, three locations near the AGP power plant were selected for well installation. Simulations conducted by FBK assessed the ATES system's response to these placements (as detailed in D2.1). The three proposed locations are shown in Figure 29, with respective distances of approximately 116 m, 140 m, and 211 m.

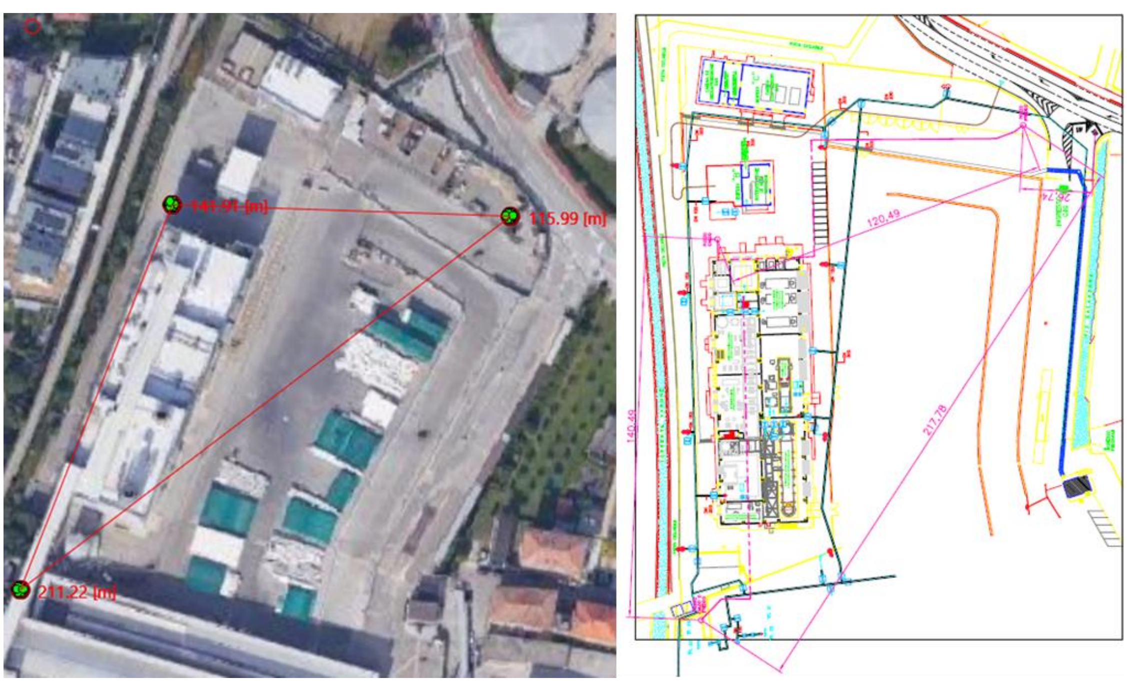

Figure 29. Final proposed locations for the construction of ATES wells.

It was agreed to drill a cone-shaped borehole, with a 400 mm diameter from the surface to a depth of 54.0 meters, tapering to a 350 mm diameter from 54.0 meters to 200 meters. This design, proposed by Geoalp and later revised by DTESS, is depicted in Figure 30, which presents the current plan for constructing the ATES system.

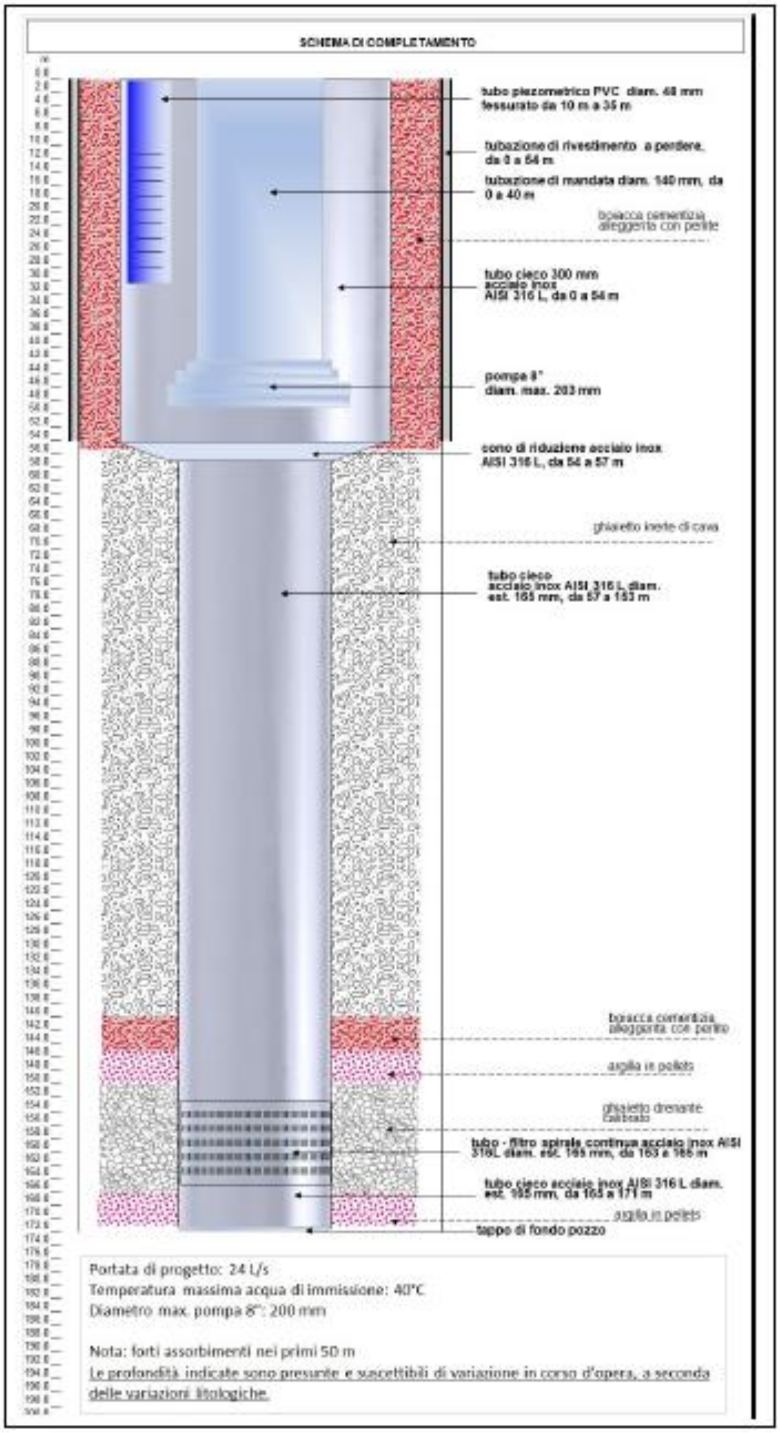

Figure 30. Preliminary construction scheme for the ATES wells.

The proposed amendments to the design by DTESS, pending confirmation by new geologist are as follows:

- **Material Change**: Replace stainless steel pipes with PVC, except for the **1**40 mm delivery pipe between the submersible pump and the collector in the well house.
- **Screen Modifications**: Weld a wire-wrapped screen in the perforation area and extend the screen length to 25 meters.

The design for the well housing remains under review and must be finalized and confirmed by new Geologist to minimize the footprint of the ATES system, it is currently proposed to use an Finish type for the well housing, with only ventilation pipes visible on the surface (Figure 31). The use of injection valves, previously suggested by FBK and approved by DTESS, has been incorporated into the system proposal. For pump selection, two E8P95/3A+MAC635A Caprari pumps are currently proposed, but the final decision will be made following the results of the well pumping tests.

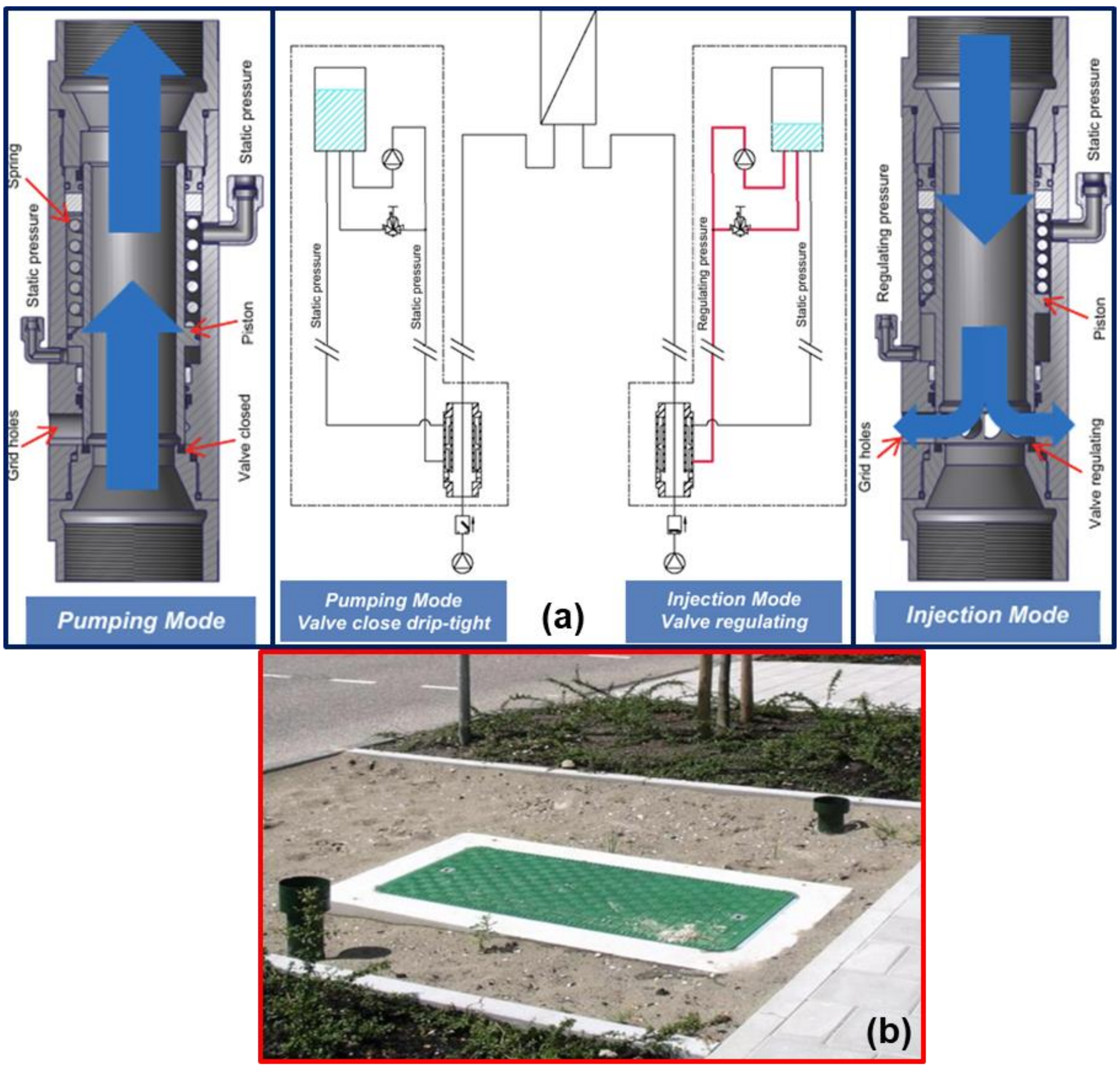

Figure 31. (a) Simple schematic of the injection valves proposed for installation in the ATES system; (b) Underground Finish type of well housing proposed for construction.

Table 3 outlines the types of backfilling materials proposed for filling the gap between the pipe and the borehole walls. These materials are designed to enhance the well's stability, improve filtration in the perforation area, and ensure effective separation between the two aquifers.

Hole/Casing Diameter (mm)	From (m)	To (m)	Annulus backfill	Length (m)	Volume (m^3) (+10% arr.)
400/300	0.00	54.0	Light-weight cement	54	4.4
350/165	54.0	140.0	Quarry gravel	86	8.2
	140.0	145.0	Light weight cement	5	0.5
	145.0	150.0	Clay pellets seal	5	0.5
	150.0	167.0	Calibrated siliceous SATAF gravel pack	17	1.7
	167.0	171.0	Clay pellets seal	4	0.4
			Quarry gravel reserve	20	2.0

Table 3. List of proposed backfilling materials based on depth for the construction of the ATES system.

Regarding the drilling method, Geoalp initially proposed using the ODEX drilling method, which is particularly effective in challenging conditions, such as unconsolidated or collapsing formations. This method allows for faster penetration in hard rock without the use of drilling mud. However, this kind of drilling method is not only complex, but also very costly and reduce the cost effectiveness of the project and after further discussions with Hydra and DTESS, HYDRA proposed to implement a direct drilling method using a double drilling head with a torque of 20,000 Nm for casing pipes and 10,000 Nm for drill rods. Additionally, the double head will be equipped with a vibrating system that will enhance drilling speed and , most importantly, enable casing pipe extraction. Drilling fluid (AIR-WATER) will be used, which will be fully recycled through a closed-loop recovery system, minimizing environmental impact. Various types of drilling equipment will be employed, including TRILAM and OPEN/CLOSED TRICONE bits for water drilling and traditional down-to-hole hammers or ODEX system for air drilling. . For the drilling process, Hydra will modify the drilling machine (shown in Figure 32), which was previously developed for the Cheap-GSHPs and GEO4CIVHIC, H2020 projects.

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Figure 32. Drilling machine (Joy 5) previously developed by HYDRA in the projects Cheap-GSHPs and GEO4CIVHIC.

5.2.2. New Groundwater Heat Pump at High Temperature, Low GWP, and ATES/DH-connected

Based on the data provided by Studio SAI, a preliminary design for the unit has been developed. The design includes the following main components:

- Compressors
- Inverters associated with the compressors
- Evaporator
- Condenser

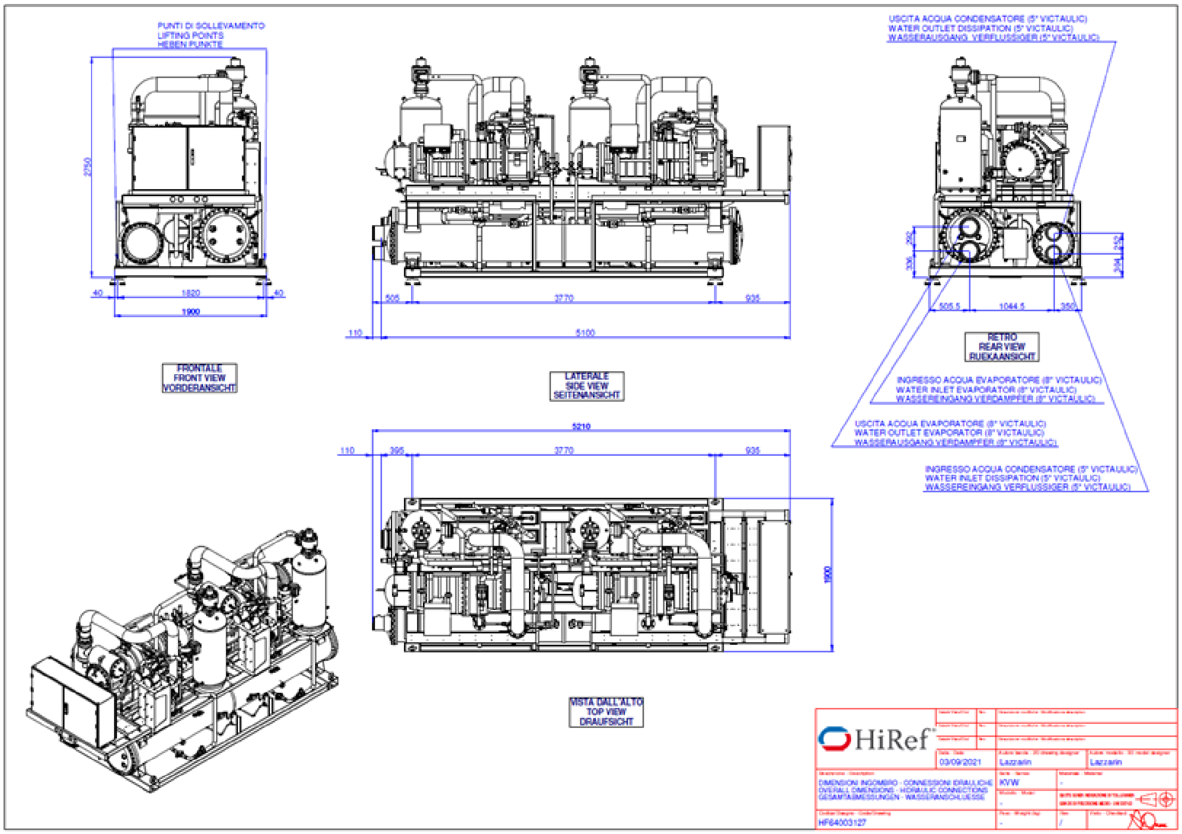

Figure 33. Preliminary drawings for groundwater heat pump will be developed by HIREF in the Riva del Garda Demo.

The design was developed to accommodate additional options, enabling the heat pump to operate independently of the ATES system if necessary. R515B was selected as the working fluid due to its low Global Warming Potential (GWP) of 299 (<300). Three primary operating conditions for the heat pump were considered, as outlined below:

- Feeding district heating and supplied by ATES with a COP of up to 3.14.
- Feeding district heating and supplied by currently available groundwater with a COP of up to 2.66.
- Operating as an emergency chiller, supplied by available groundwater with a COP of up to 3.77.

The simulation results for the corresponding operating conditions were conducted by HIREF and are summarized in Table 4. For a more detailed technical description and information on the various operations, please refer to Deliverable 2.1.

Operation	Characteristic	Unit	Value
Wintertime (Heating) ATES-connected 65/80°C, 28.5/22°C	Heating capacity	KW	1795.2
	Water flow condenser side	l/h	102924
	Water pressure drop condenser side	kPa	TBD
	Cooling capacity	KW	1264
	Water flow evaporator side	l/h	167239
	Water Pressure drop evaporator side	Kpa	TBD
	Total absorbed power	KW	571.8
	Total absorbed current	A	970
	Working fluid	-	R515B (GWP=299)
	COP	-	3.14
Wintertime (Heating) Groundwater-connected 65/80°C, 13/9°C	Heating capacity	KW	1364.3
	Water flow condenser side	l/h	78220
	Water pressure drop condenser side	kPa	TBD
	Cooling capacity	KW	888
	Water flow evaporator side	l/h	190922
	Water Pressure drop evaporator side	Kpa	TBD
	Total absorbed power	KW	512.7
	Total absorbed current	A	872
	Working fluid	-	R515B (GWP=299)
	COP	-	2.66

Summertime (Chiller) Groundwater-connected 45/55°C, 12/7°C	Heating capacity	KW	1327.3
	Water flow condenser side	l/h	114151
	Water pressure drop condenser side	kPa	TBD
	Cooling capacity	KW	1000
	Water flow evaporator side	l/h	172000
	Water Pressure drop evaporator side	Kpa	TBD
	Total absorbed power	KW	352.4
	Total absorbed current	A	599
	Working fluid	-	R515B (GWP=299)
	COP	-	3.77

Table 4. Simulation results for the heat pump under three different operating conditions.

5.2.3. Integration of Hybrid Solar Panels with ATES

Regarding the installation of PVT panels, the initial proposal during the planning phase consisted of 415 m² on the roof of the AGP plant for PVT panels, with an estimated annual electricity production of approximately 100 MWh and a peak power of around 84 kW (Figure 34). Since January 2024, several factors have emerged that limit the available space for the installation of PVT panels on the roof, such as space constraints and safety regulations. These factors have been under discussion and analysis for the installation of panels in the three available areas (Figure 35). This topic is discussed in greater detail in the next subchapter, which covers both technical and non-technical requirements. For more information on all proposals, please refer to Deliverable 2.1.

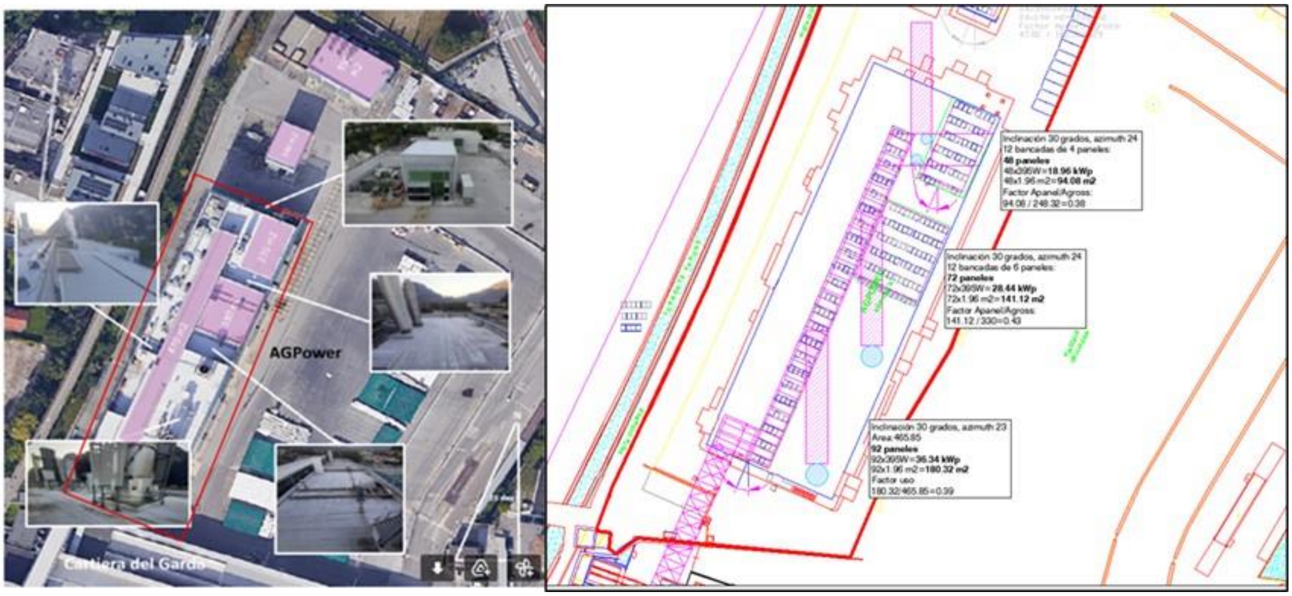

Figure 34. Schematic of the initially proposed locations and the corresponding number of panels planned for installation at the Riva del Garda Demo site.

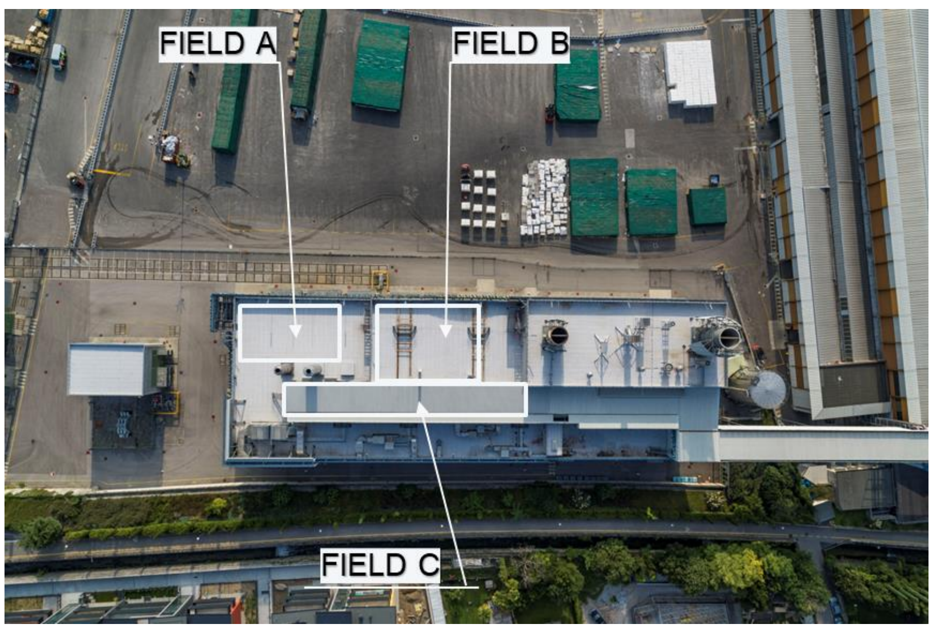

Figure 35. Top view of Alto Garda power, indicating the proposed locations for installing the PVT panels at the Riva del Garda Demo site.

As further technical and non-technical restrictions emerged, work was carried out on different approaches which led to reducing the number of panels and increasing their nominal power. The second approximation implied a 23,5% reduction of the peak power installed. This redesign was done after visiting the AGP building and finding out its possibilities. Another 3rd approximation came up after non-technical limitations., which led to a 35 % reduction of peak power installed. Finally, the 4th approximation included 104 PVT with a nominal power of 600 W of each. This still constitutes a reduction of 25,5 % of the peak power installed compared with the initial proposal. To address this issue and mitigate the reduction of the estimated annual energy production, other potential installation areas are currently under investigation, as shown in Figure 36. This topic is discussed in greater detail in the next chapter, which covers both technical and non-technical requirements. For more information on all proposals, please refer to Deliverable 2.1.

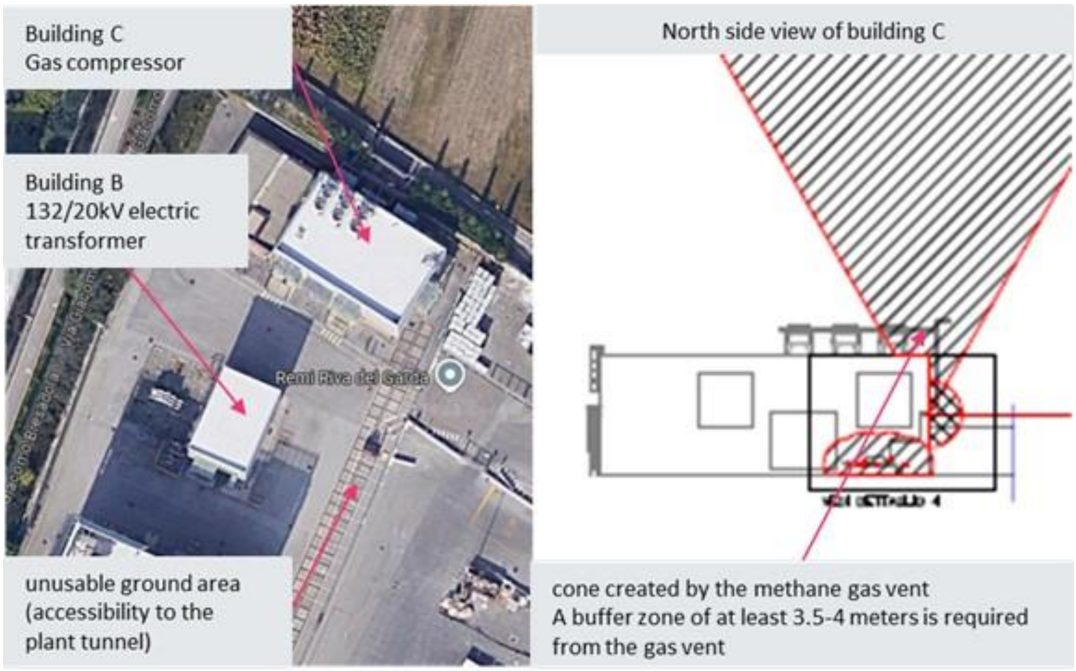

Figure 36. Alternative positions for PVT panels installation at the Riva del Garda Demo site.

Due to integration challenges with the internal use of electricity generated by the panels (including connection costs and limited operating time), the produced electrical energy will be exported to the grid. The integration with the ATES system consists of the thermal energy generated by the heat absorbers, which will circulate within an internal circuit and be transferred to hot water through a heat exchanger. The thermal system of the PVT panels will be working during the warmest four months of the year (from mid-May to mid-September). Hydraulic and electrical drawings were carried out from the latest approach as illustrated in Figure 27 and Figure 37.

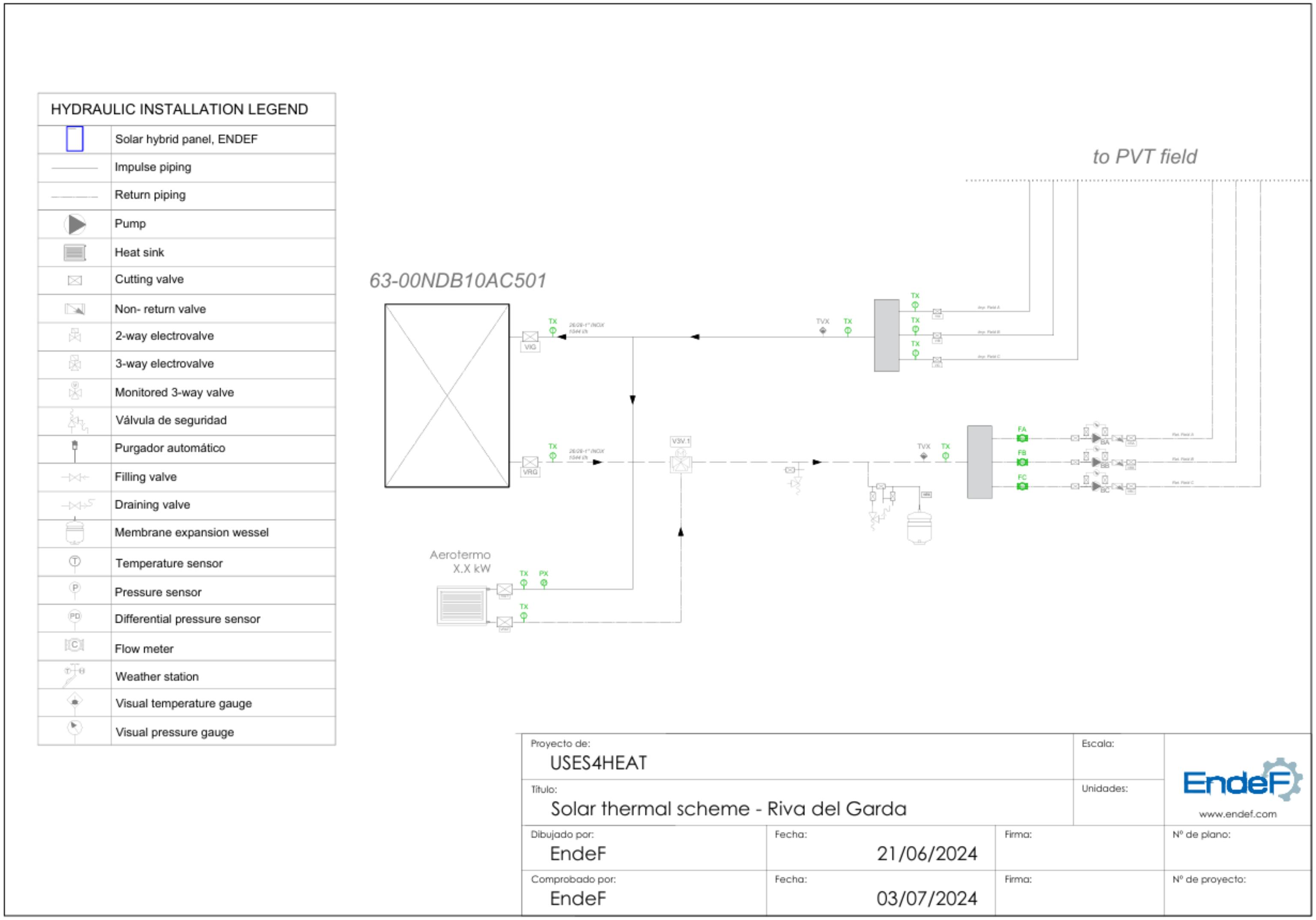

Figure 37. P&ID for the integration of PVT panels with the heat exchanger connected to the ATES system.

6. Technical Requirement and Non-Technical Specifications

This chapter outlines the technical and non-technical specifications (e.g., requirements, contractual aspects, permitting) that must be aligned with the overall project progress in T5.2 – T5.3 and WP2-3 to ensure the successful deployment of project activities at the demo site.

6.1. Technical Requirements and Design Aspects

In this subsection, the technical requirements for the development and realization of USES4HEAT technologies reported.

6.1.1. Realization of Aquifer Thermal Energy Storage

6.1.1.1. Well placement and design aspects

This section primarily addresses the availability of space for drilling and, more importantly, the hydrogeological properties of the underground environment. Regarding available space, as shown in Figure 38, there are five existing wells, and based on discussions with Hydra, it is not feasible to drill another borehole within 50 meters of these wells due to safety concerns. Additionally, there are two rivers—one running through the paper mill and one in the vicinity—that impose further constraints, requiring a minimum distance of 10 meters from each river. For logistical reasons, it is also not possible to block the area designated for truck and vehicle access. Furthermore, underground infrastructure owned by AGS, including electrical, natural gas, and communication connections, presents additional limitations for drilling. In terms of the drilling process itself, it is necessary to have an area of at least 36 m^2 of free space, with a height clearance of 8 meters, to accommodate the drilling machine and required equipment.

Figure 38. (i) Underground infrastructure owned by AGS and located at the Riva del Garda Demo site; (ii) Position of existing groundwater wells (pink points), rivers (blue line), and commuting area (red rectangle).

Additionally, it is important to highlight the hydrogeological properties of the underground. While data are available for the hydrogeological properties in two areas near the demo site, there is a lack of information regarding the properties of the underground at depths greater than 100 meters. This data is critical for assessing the thermal radius of the ATES wells and preventing short-circuiting between them under various operational scenarios. Therefore, it is essential to conduct laboratory tests after drilling the first borehole to determine the thermal properties of the second aquifer, hydraulic conductivity, the precise length of the target aquifer, the hydraulic gradient, aquifer transmissivity, and the maximum injection potential of water into the aquifer. These aspects have already been discussed with partners and are planned for future testing (refer to Chapter 7). For the three current locations proposed for the wells, simulations have been conducted by FBK using data provided by Geoalp (as discussed in the previous chapter). The simulations assumed homogeneous soil properties in the target aquifer. In the best-case well placement scenario, after ten years of operation, the thermal radius of the two wells would not overlap significantly, and the accumulated recovery efficiency would reach 65% (Figure 39). For further details on other locations and scenarios, please refer to D2.1.

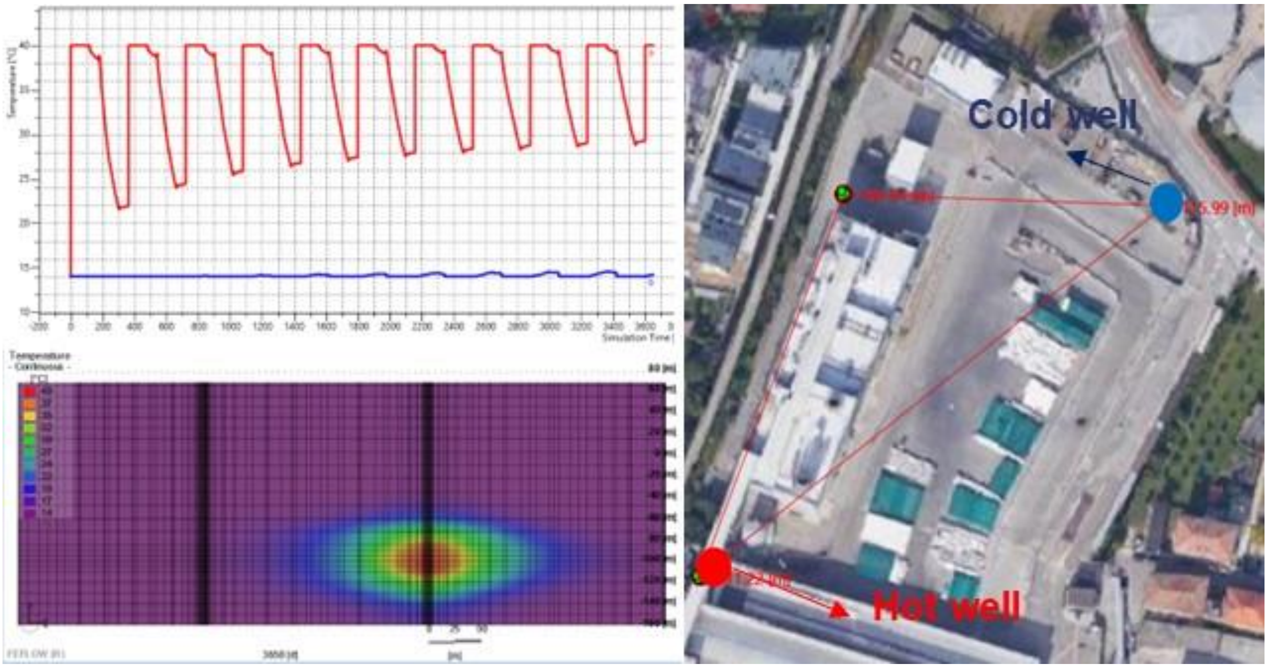

Figure 39. Simulation results for the ATES system with a mass flow rate of 24 l/s over a duration of 10 years at the Riva del Garda Demo site.

6.1.1.2. Construction aspects

In alignment with the objectives of the USES 4 Heat project, Hydra is engaged in the design and construction of the following:

JOY5 G drilling rig of new design, featuring the following specifications:

- **Dual rotary head** enabling the simultaneous advancement of both drilling rods and casing pipes. This specialized dual head will be equipped with a dual circuit for drilling fluids and a vibration system.
- **New semi-automatic loading and unloading system** for casing pipes and drill rods. This innovative system will facilitate the handling of drilling equipment without the need for operators and technicians to be in proximity to hazardous zones. All loading and unloading operations will be conducted safely using a semi-automatic remote-controlled system.
- **New drilling fluid management system**. Hydra has developed an advanced Water and Air-based drilling fluid management system that ensures the complete recovery of all drilled materials and their proper disposal.
- **Innovative drilling technique**. The newly configured JOY5 drilling rig, equipped for this specific application, will utilize a direct drilling technique with a Dual Head and Vibrating System. This new technology will allow for drilling operations to be conducted in an environmentally friendly manner, as no Bentonite muds or other chemical support systems will be employed to stabilize the borehole.

All drilling stages can be documented using a data acquisition system, enabling visualization and monitoring of the entire drilling process.

6.1.1.3. Integration with plant and operational aspects

Regarding the ATES operating conditions, several key requirements must be taken into account. As illustrated in Figures 40 and 41, the injection temperature into the hot well during the charging mode must be fixed at 40°C and not exceed this value. From a technical perspective, injecting hot water at temperatures above 40°C could enhance system efficiency; however, this limitation is imposed by permitting regulations to prevent environmental harm. Additionally, after the first year of operation, it is anticipated that recovered water from the hot well will be injected into the cold well at temperatures exceeding 14°C, reaching an average of 25°C during wintertime and extracting at around 23°C during summertime. This results in a reduced capacity to store heat at an average power of 1.6 MW during summertime, corresponding to the average waste heat power. Furthermore, the existing groundwater wells at the paper mill, which supply the AGP plant with a flow rate of approximately 600 m³/h at a temperature of 13°C, restrict operations. Reducing temperatures below this level is neither practical nor beneficial, as it negatively impacts the COP of the heat pump.

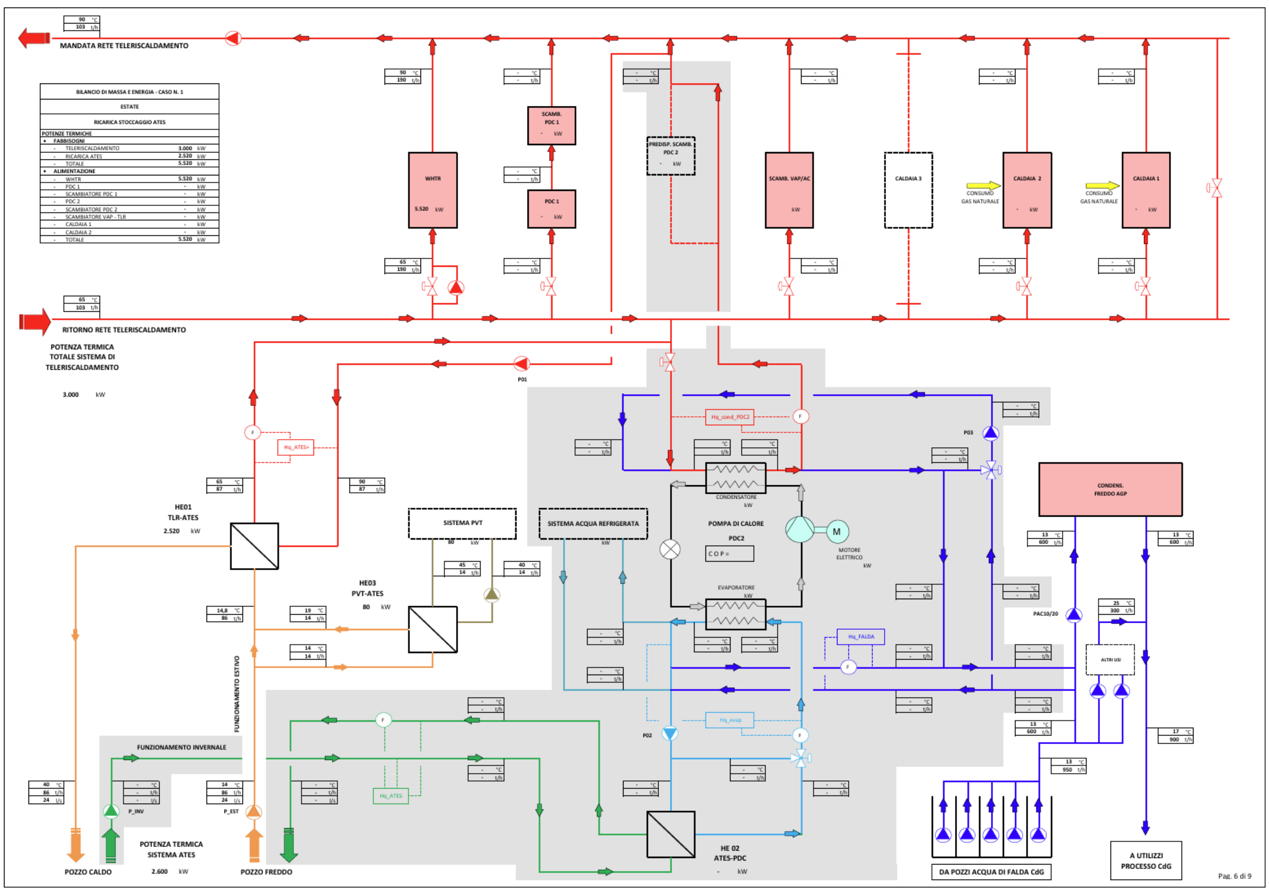

Figure 40. Preliminary conceptual flow scheme for the ATES system operating in charging mode during the summertime at the Riva del Garda demo site.

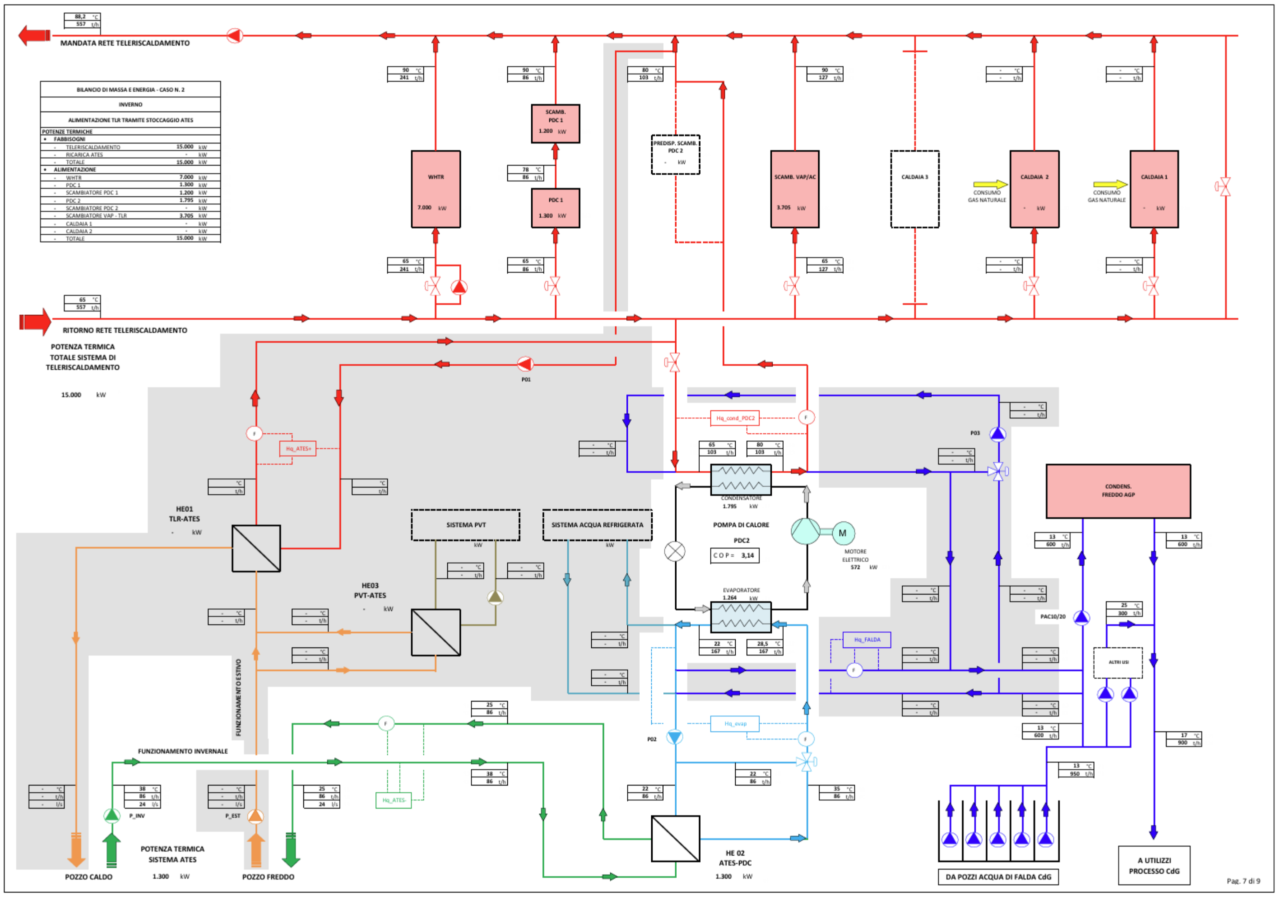

Figure 41. Preliminary conceptual flow scheme for the ATES system operating in discharging mode during the wintertime at the Riva del Garda demo site.

6.1.2. Developing Ground Water Heat Pump

The Municipality of Riva del Garda has adopted an Acoustic Classification Plan (Council Resolution No. 107, dated 27th July 2004), which defines areas with specific acoustic requirements. Although the paper mill and power plant are classified as an industrial zone, they are situated within the city, surrounded by areas designated as residential. To ensure compliance with the regulations, an acoustic study was conducted by TERA GROUP to evaluate the impact of the new heat pump in the vicinity of the plant (Figure 42). The study determined that the sound emissions of the new heat pump must be reduced by at least 15 dB to comply with daytime regulations (6:00 to 22:00). Furthermore, the heat pump must remain non-operational during nighttime hours.

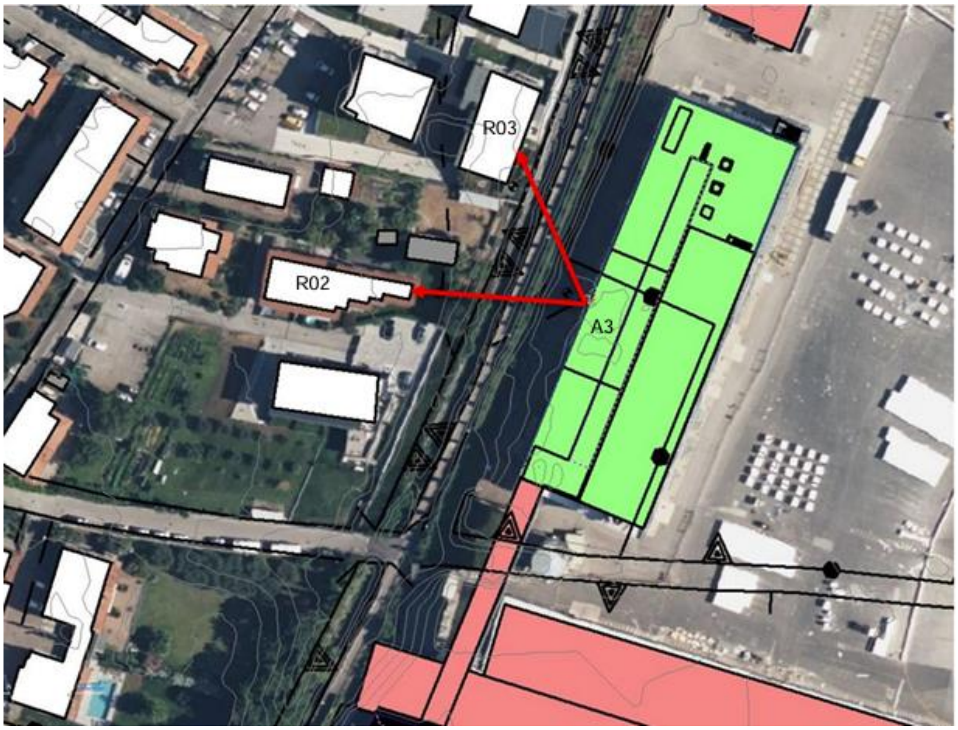

Figure 42. Area of interest with the identification of receptors involved in the acoustic study.

Additionally, due to the limited available space within the AGP plant, the heat exchangers, filters, and auxiliary components are planned to be installed above the heat pump at an elevated height of 3.2 meters (Figure 43). This arrangement is essential to ensure a stable and secure structure. Regarding the electrical supply for the heat pump, as requested by HIREF, the machine will operate on a 400 kV supply. To meet this requirement, the installation of an additional transformer in the AGP control room is necessary.

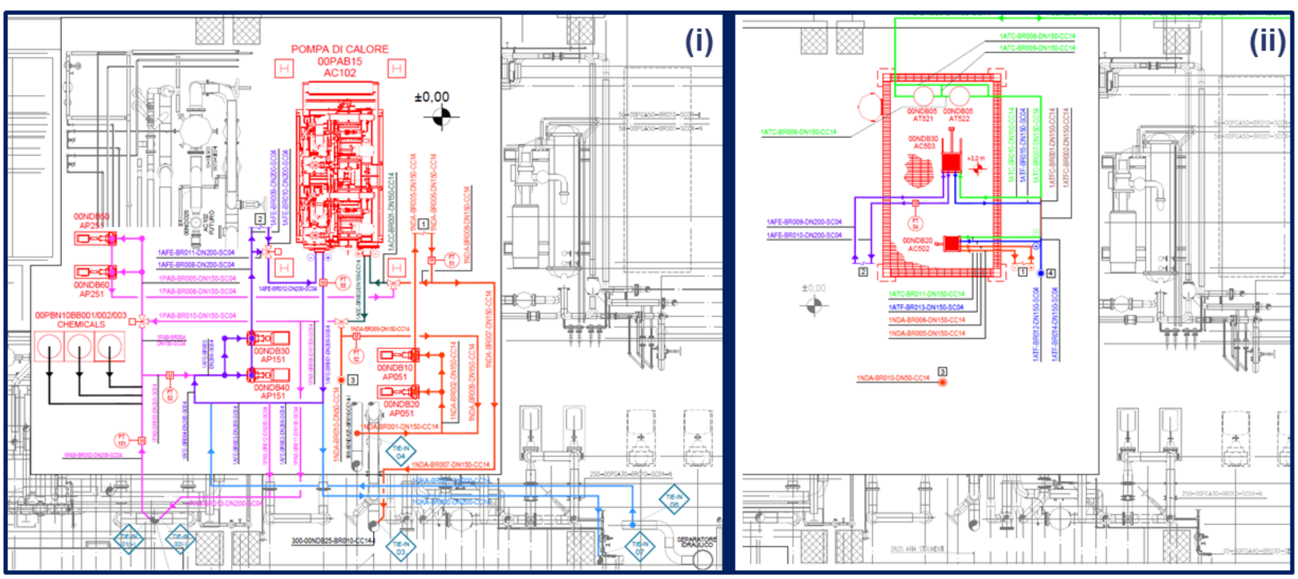

Figure 43. Planned area for the new heat pump in the room with the current pipeline at the AGP plant; (i) +0.0 m elevation; (ii) +3.2 m elevation.

6.1.3. Developing Hybrid Solar panels

The main objective of ENDEF in this project is to develop photovoltaic-thermal hybrid solar panels (PVT) by integrating new technologies from PV panels and thermal absorbers. Different designs for the absorber and the materials composing the hybrid panel will be evaluated.

During the initial stages of the project, work has been focused on the state of art, analysis and selection of materials and components. Currently, small-scale testing of materials is been conducted. The goal of these tests is to compare various adhesives, insulation materials and PV panels to maximize heat transfer throw all the layers, from the top of the PVT panel to the absorber. Once the materials and the PV technologies have been selected, complete PVT prototypes will be manufactured and tested. The prototypes will be place on a test bench, to simulate real conditions. Water will circulate in a closed circuit, maintaining realistic demand temperature, flow and pressure. Both small-scale testing and full-scale prototype testing will be validated using one-dimensional (1-D) simulations performed with Python. ENDEF's primary objective is to enhance the PV laminate and adapt the thermal absorber to achieve a 10% increase in PVT performance compared to state-of-the-art (SoA) components and ENDEF's previous products

After prototype testing, ENDEF will manufacture the final PVT panels. These panels will then be delivered to the demo site for their integration with the ATES. The installation process must follow the specifications and guidelines established by ENDEF to ensure their optimal performance.

6.2. Non-Technical requirements

To ensure progress in the project and alignment with its timeline, several requirements must be followed and carefully considered.

6.2.1. Legal Framework and Permitting

This subchapter outlines the legal framework and challenges associated with obtaining permits for the ATES system and PVT panels. It should be noted that for the heat pump, it is only necessary to communicate with the PAT to introduce the new machine that will be integrated into the AGP plant. Additionally, to qualify for national incentives, AGP will submit a request to Gestore Servizi Energetici (GSE) for the required certifications.

6.2.1.1. Aquifer thermal energy storage

While ATES systems are widely used across Europe, particularly in the Netherlands, Italy still lacks specific regulations governing this type of underground storage system. Art.104 of Legislative Decree 152/2006 prohibits all discharges into the subsoil and into underground waters (paragraph 1) and in derogation from this prohibition establishes that the competent authority can authorize, after a preliminary investigation, certain discharges, including (paragraph 2) those of water used for geothermal purposes, provided that they are discharged into the same aquifer used for extraction. In certain regions of Italy discharges are authorized.

The Campania Region has regulated the reinjection into the aquifer with Regional Regulation no. 12 of November 2012 (no temperature constraints). The Autonomous Province of Bolzano requires that the water used in the heat exchange circuits be reinjected into the aquifer and has established a maximum temperature variation of 5°C. In Emilia-Romagna, a reinjection of the groundwater is considered admissible in such a way as to guarantee a maximum temperature variation of 6°C. In Lombardy, some provinces have defined the maximum temperature allowed for the reinjection of the water used for geoexchange and/or the maximum temperature variation allowed (between 20 and 25°C Tmax, between 3 and 5°C ΔT). In Piedmont, the Province of Turin allows a reinjection into the aquifer with a temperature that is, in maximum operating conditions, between 20°C and 22°C in the summer season and between 7°C and 8°C in the winter season.

However, current regulations established by the Autonomous Province of Trento (PAT) prohibit the reinjection of water into aquifers.

Obtaining a new concession to operate an ATES system for its entire lifetime is a lengthy process, as it requires convincing the PAT to amend existing regulations. In order to proceed with the project, a permit is required to allow full operation of the ATES system for one year for experimental research purposes. The necessary activities for progress include:

- Construction of two deep wells
- Pumping tests, along with chemical and microbiological analyses of the water and injection tests to study the deep confined aquifer
- Simulations using accurate data from samples collected from the underground
- Engineering connections and installation of the control system
- Operation for one year to obtain real-world results

This permit has been informally requested by local project partners to the PAT since the beginning of the USES4HEAT project (December 2023). To facilitate the permitting process, a Technical Table has been formed in May 2024 with the participation of CDG, AGP, AGS, Geoalp, and FBK to discuss potential solutions.

While drilling for exploratory purposes does not require a permit (only a communication to ISPRA – a national environmental authority), and to stay aligned with the project timeline, a decision was made in October 2024 (communicated in the WP5 presentation of the GA in Trento) to proceed with drilling the first well from March 2025 and collecting underground data, while keeping the PAT regularly informed about the permitting process. The plan is to begin the operation of all USES4HEAT innovative technologies by June 2026. However, it is essential to secure this operational permit for the ATES system by the end of September 2025 to realize also the second well, to conduct injection tests for both wells and to determine the optimal flow rate for the ATES system. These aspects are further detailed in Chapter 7 - Demonstration Plan, Risks, and Mitigations.

6.2.1.2. Installation of PVT panels

The proposed locations for installing the PVT panels, shown across three areas of the roof of the Alto Garda Power plant, are currently being evaluated in terms of their compatibility with fire regulations. Since AGP is subject to specific regulations outlined in Italian law, which are derived from European standards (UNI EN 13501), the evaluation also considers the requirements of Swiss Re, the insurer for the entire Lecta Group. The starting point for this analysis is the PVT Panels Layout – 4th Approximation (Figure 44), proposed by ENDEF, which involves the installation of 104 panels. This setup would provide a total power output of 62.4 kW and an estimated annual electrical production of 74.5 MWh.

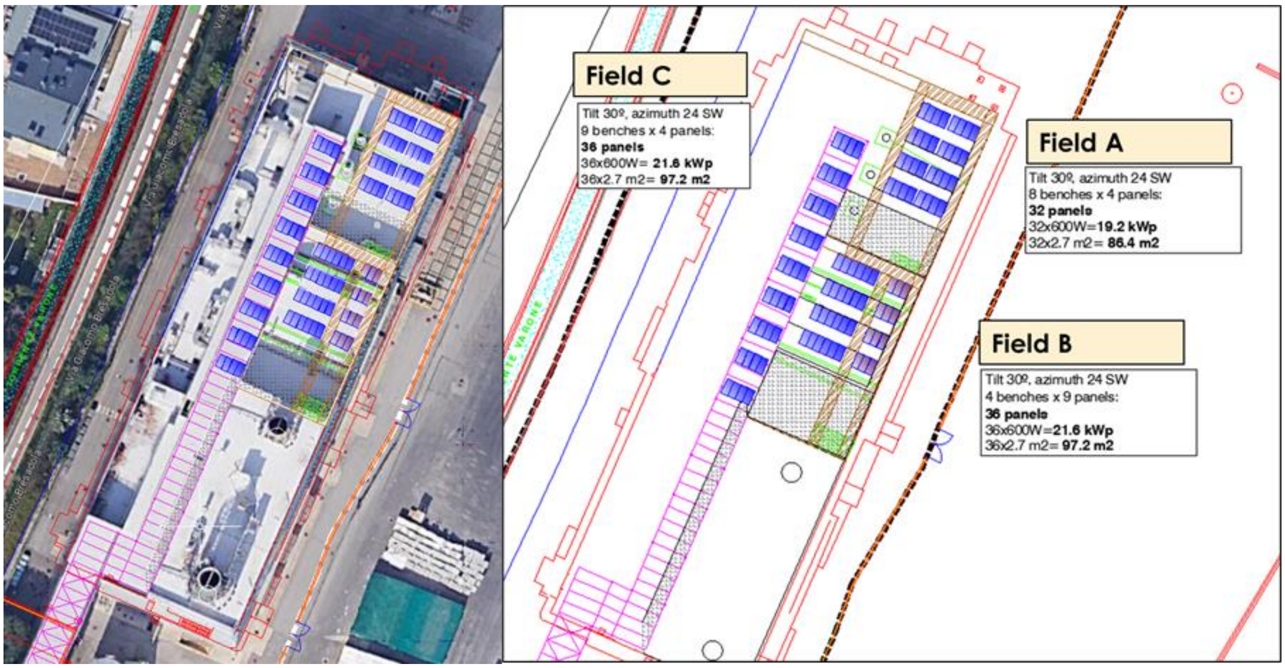

Figure 44. PVT panels fourth layout proposed by ENDEF for Riva del garda demo site.

The feasibility and extent of the photovoltaic (PV) fields to be installed on the AGP roof are primarily determined by the classification of the PV panels based on their fire reaction. This classification refers to the degree of fire participation to which the panels are subjected. According to Italian regulations, materials are assigned to classes ranging from 0 (non-combustible) to 5, based on their combustion characteristics. In the European classification system, materials are categorized from A1 (non-combustible) to F, with increasing participation in combustion.

Note: This classification is also essential for obtaining the CE marking for the product. Without this certification, the panels cannot be installed or used at the AGP site.

At the regulatory level, there are two primary constraints:

- Compliance with Italian regulations (DCPREV 1324, 7-2-20212)
- Compliance with Swiss Re insurance requirements

Both the Italian regulations and Swiss Re's requirements apply only to combustible PV panels. As most of commercially available PV panels are combustible, the following issues must be considered:

- The entire roof of the AGP facility is currently designated as a safe area with only one direct access point (via stairs) from the square below, leading to a long escape route. Installing combustible materials on the roof would compromise the safety designation of the space, necessitating the creation of shorter escape routes. For example, at least two new fire escapes with external stairs leading to the square should be installed. These matters must be discussed with the local Fire Brigade command.
- Photovoltaic panels certificated as Class 1 or 2 (according to Italian standard UNI 9177) can be installed on certified non-combustible roofs without any further restriction. However, the AGP roof is not certified as non-combustible.
- Photovoltaic panels can be installed with a non-combustible layer with a fire resistance of at least EI 30 (*) between the photovoltaic modules and the roof in case it is not certified.
- Alternatively, a specific risk assessment can be conducted to evaluate the potential for fire propagation, taking into account the external fire resistance class of the roof and the fire reaction class of the photovoltaic module. In this case, if the PV panels are certified as Class 1 (under Italian regulations), the EI screen can be omitted. However, Swiss Re always requires the installation of a non-combustible layer.
- Additionally, photovoltaic panels cannot be installed in areas corresponding to the firewalls of the floor below, and must maintain the following distances from their projection:
  - 1 meter to comply with national fire regulations.
  - 5 meters to comply with Swiss Re's requirements: "Roof-mounted solar PV panels should be placed at least 5 meters from firewalls. This 5-meter free zone should be covered with non-combustible materials."

Figure 45 shows the areas where photovoltaic panel installation is not feasible due to these distance requirements, and the resulting impact on the number of panels that can be installed. Based on this plan, the following results are obtained:

- Compliance with Italian legislation:
  - Field A: No reduction.
  - Field B: No reduction (with slight layout adjustments).
  - Field C: Reduction.
- Compliance with Swiss Re insurance requirements:
  - Field A: Reduction (with slight layout adjustments).
  - Field B: Reduction (with slight layout adjustments).
  - Field C: No panels can be installed.

(*) The regulations classify load-bearing and separating structures based on the building's structural stability ("R"), gas and smoke tightness ("E"), thermal insulation ("I"), for the time indicated in minutes.

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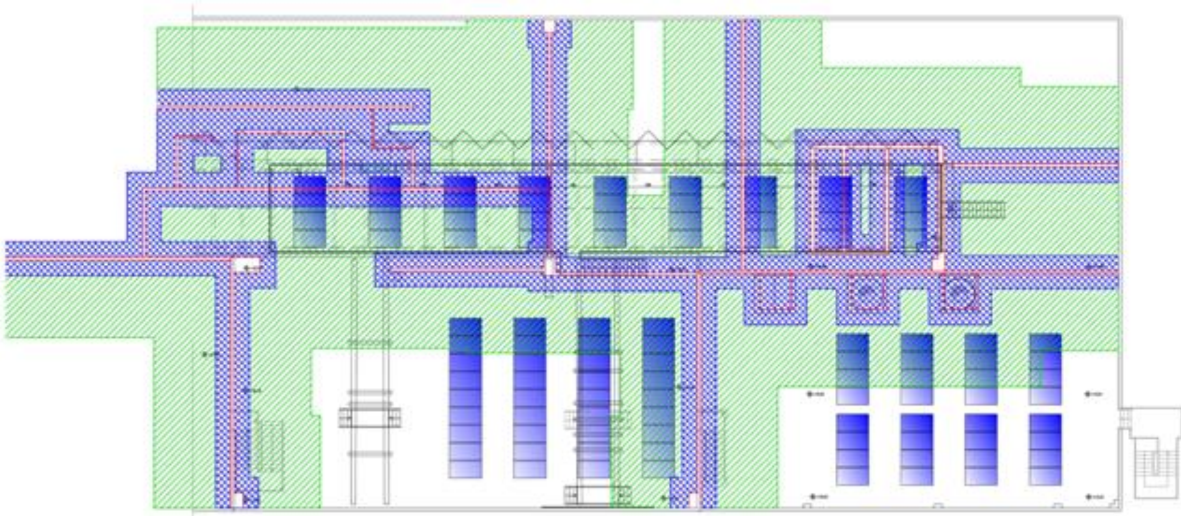

Figure 45. AGP roof layout showing buffer areas.

Given the significant challenges of installing the PVT system on the roof of the main AGP building, the possibility of installing the system on the roofs of the other two AGP buildings—designated Building B and Building C (Figure 36)—is currently under evaluation. However, this would involve a substantial reduction in the installed power capacity. These alternative installation sites must also be verified with the Fire Brigade command, particularly the area above the roof of the gas compressor building, where gas vent cones are present.

To recap and conclude, based on the PV panel classification certified by the manufacturer, the layout of the photovoltaic system will be updated with the following priorities:

- Ensure compliance with all requirements of Italian legislation and Swiss Re.
- Maximize the installed power capacity.

This updated layout will serve as the foundation for obtaining the necessary authorizations and for developing the projects related to the installation of the PVT system. As with the ATES system, ENDEF will be able to begin constructing the PVT system and suppliers will be able to implement the installation projects only after these authorizations are obtained.

6.3. Contractual Obligations

Several services need to be performed, and related contracts must be prepared and sent out for quotations from competent vendors. In September 2024, Geoalp resigned from its responsibilities due to health issues affecting their hydrogeologist. The immediate priority is to find a replacement hydrogeologist to continue with the project, finalize the design for the ATES system, conduct laboratory testing on underground samples, support the permitting process, and oversee the operation of the ATES system. To date, a request for quotations has been sent by AGP/CDG. Additionally, contracts need to be prepared for several other tasks, including the aquifer pumping and injection tests, as well as the provision and installation of hydraulic and electrical connections for the ATES, GWHP, and PVT panels.

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7. Demonstration Timeline, Risks and Mitigations

7.1. Demonstration Activities and Timeline, Milestones and Deliverables

To implement the USES4HEAT innovative technologies at the Riva del Garda demo site, a series of activities have been planned, with specific timelines and milestones as shown in Figure 46. The activities can be categorized into four key areas:

i. Baseline Monitoring and Demonstration Planning:

- Actions completed by end of October 2024, already reported in section 2.3. (1).
- Finalizing the geological design for the construction of the ATES system integrated with the GWHP – new geologist (2)
- Finalizing the engineering design for the integration of ATES, GWHP, and PVT panels with the AGP power plant – SAI (3)

ii. Development and Realization of Demo Site Enabling Technologies:

- Communicating with ISPRA to initiate drilling (first exploratory well) and preparing the site for drilling – AGP/CDG/HDYRA/FBK (4)
- Developing the drilling machine and purchasing the materials necessary for well construction – HYDRA (5)
- Starting the drilling of the first well and conducting pumping test, geophysical logs and groundwater laboratory tests – HYDRA/ new geologist (6)
- Finalizing the results and receiving the full permit for the ATES system – new geologist /AGP/FBK (7)
- Collecting all required certificates for technologies – AGP/SAI/ENDEF/FBK (8)
- Starting the drilling of the second well, performing pumping tests and injection tests – HYDRA (9)
- Constructing well housing, hydraulic & electrical equipment, and connections for the wells – HYDRA/AGP (10)
- Finalizing the design for the GWHP – HIREF (11)
- Purchasing necessary materials and equipment for GWHP construction – HIREF (12)
- Constructing and testing the GWHP and delivering it to the demo site – HIREF (13)
- Performing state-of-the-art analysis, material selection, and component testing – ENDEF (14)

- Conducting small-scale testing of materials – ENDEF (15)
- Developing and testing the prototype – ENDEF (16)
- Manufacturing and delivering PVT panels to the demo site – ENDEF (17)

iii. Engineering, Monitoring, Planning, Installation, and Commissioning:

- Following up on the permitting process and providing regular updates to the Autonomous Province of Trento – AGP/ new geologist /FBK/KTH (18)
- Preparing general contracts and requesting quotations from tenders for materials and installation of hydraulic and electrical connections – AGP (19)
- Installing GWHP, PVT panels, structures, and hydraulic and electrical connections – AGP (20)

iv. Experimental Campaign and Critical Assessment:

- Starting the one-year full operation of the system and monitoring – new geologist /SAI/AGP/FBK (21)
- Requesting a permanent permit for the operation of the ATES system with additional monitoring data – new geologist /AGP/FBK (22)
- Evaluating the local-level impact from environmental, techno-economic, and social acceptance perspectives related to WP6, validating simulation models developed in WP2, and assessing the effectiveness of the project via the KPI panel. Critically assessing the lessons learned at both technical and non-technical levels, and reporting in the final project handbook – FBK/WP5 partners (23)

Milestones and Deliverables:

In addition to the official milestones and reporting timelines outlined in Figure 46, it is necessary to define two additional internal milestones. The following milestones and deliverables, along with their respective timelines, are listed below:

- **Deliverables:**
    - *D5.1 – Baseline Monitoring and Plan for Riva del Garda Demo* [Nov 2024]: A report on baseline monitoring data and planned demonstration activities for the Riva del Garda site.
    - *D5.2 – Development of Enabling Technologies for Riva del Garda Demo* [Nov 2025]: A report on the design, development, and realization of enabling technologies, including new drilling technologies, groundwater heat pumps, and hybrid solar panels, with performance data, descriptions, and schematic drawings.
    - *D5.3 – Riva del Garda Demo Full Description* [May 2026]: A detailed engineering report on BOP, installation, and commissioning of hardware and software enabling technologies.
    - *D5.4 – Lessons Learned from the Demonstration Campaign in Riva del Garda Demo Site* [Nov 2027]: A report on lessons learned and insights for future replications from the demonstration campaign.

- **Official Milestones:**
  - *MS2 – Baseline Monitoring Data Acquired for Riva del Garda Demo* [Aug 2024]: Completion of the baseline data collection for the Riva del Garda demo site, including all relevant data and KPI reporting.
  - *MS6 – Shipping of All Enabling Technologies to the Riva del Garda Demo* [Nov 2025]: Shipment of all enabling technologies and components from HIREF, ENDEF, and HYDRA to the demo site.
  - *MS8 – Commissioning of All Hardware and Software Enabling Technologies for the Riva del Garda Demo Completed* [May 2026]: Full operational status of the Riva del Garda demo site according to the KPI plan.
- **Internal Milestones:**
  - *IMS1 – Start Drilling First Exploratory Well* [March 2025]: Full development and delivery of necessary materials and equipment to begin drilling the first exploratory well and prepare the demo site.
  - *IMS2 – Received Permit to Operate ATES System at 40°C Injection for One Year* [Sep 2025]: Approval from the Province of Trento for the ATES system to operate with 40°C hot water injection for at least one year, including 4 months of hot water injection, 4 months of cold-water injection, and 4 months of storage without operation.

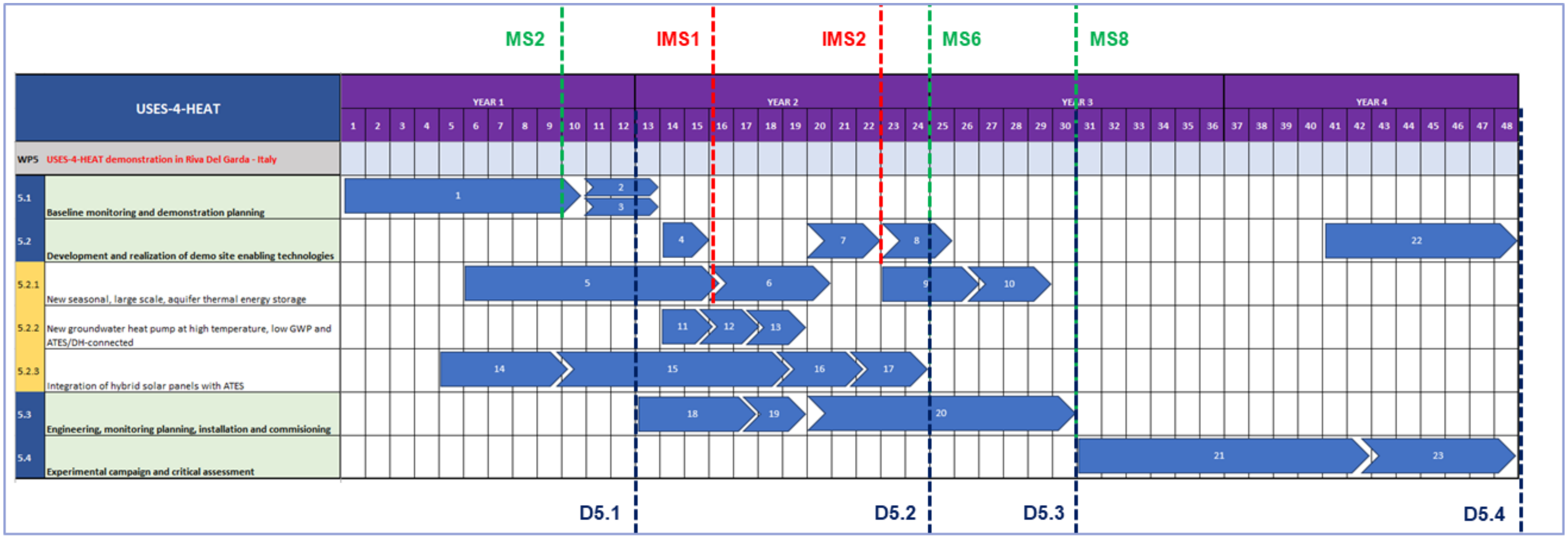

Figure 46. Timeline of future activities in Work Package 5, including milestones and deliverables.

7.2. Risks and Mitigations

In the current subchapter, the main project risks foreseen in Work Package 5 have been reviewed in Table 5, outlining the severity of each risk in the current situation and the proposed mitigation methods for the future.

#	Risk Description	Mitigation	Severity
1	Delays in key enabling technologies manufacturing and procurement	Project main innovations have been already conceptually/modelling investigated and tested (TRL5-6).	Low
2	Delay in obtaining permits at demo sites	FBK had done similar projects before. Following up the procedure is ongoing. Technical Table has been formed to analyse the impact of the project. Informing PAT regularly regarding the project progress and findings. Deadlines; M22(Sep 25) to get the permit for injection and operation - M31 (June 2026) starting the operation ATES with monitoring.	Medium
3	Delay in additional equipment procurement and demo permitting.	Conservative time estimation for the task definition. All the equipment will be order as soon as designed finalized.	low
4	Delay in construction of the UTES	Conservative time estimation has been considered in the task definition. Ensuring active collaboration of the partners involved. Start drilling first borehole (Feb/March 25 – M16 deadline) by informing ISPRA in advance. Pumping test (M20) – Drilling second borehole (M23) – Injection test (M26) – Well housing, Hydraulic & electrical equipment and connections (M26 – M29).	Medium
5	The technologies are more expensive due to inflation and materials crisis	Ensuring wisely estimation of costs of technologies realization and installation. AGP is investigating for other national incentives and plan to request funding from AGP's Board.	Medium
6	The enabling technologies do not attain the expected performances or do not function as expected	The proposed technologies have already been extensively designed and de-risked (starting TRL 5-6). Additional validation works will be carried on at the beginning of the project. The modularity of the integration schemes proposed at the demo sites ensures that even if one technology does not perform fully as expected the whole concept can be still demonstrated in its full capacity.	Low

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7	Demonstrated tech/O&M solutions are too specific to demo sites.	Thanks to partners' DH and TES expertise, it will be possible to identify how to replicate innovations in relevant cases, serving as a basis for de-risking.	Low
8	Low stakeholders' engagement for future widespread of USES4HEAT.	Partners, including EHP and IEA TPC Task participants, are experts in innovative energy systems, ensuring broad stakeholder reach through existing networks, with potential collaboration with international associations.	Low
9	WPs resources not well balanced.	PC continuously monitors and reallocates resources with WP leader approval, if needed.	Low
10	COVID-19 pandemic situation or external issues do not allow to organize meetings, etc.	Partners proficiently manage project activities using web collaboration tools for remote support, inspections, and meetings.	Low
11	Slow or ineffective communication between PMO and consortium.	Enhanced internal communication within the consortium will be emphasized at the KOM and sustained thereafter, with targeted initiatives such as problem-solving workshops if required.	Low
12	The different technologies involved in USES4HEAT demonstrations and replications have issues in integration.	Initial phases of WP5 will study and define USES4HEAT demo layouts and technology integration, leveraging flexibility and modular technologies for installation. ENDEF if actively collaborating with engineering team (SAI) for assessing different kinds of integration scheme and providing the proper certification which are align with safety restriction of AGP site.	Medium
13	The new groundwater heat pump cannot achieve the target COP at the lowest source temperature conditions (the most challenging operation).	HIREF has a wide experience in heat pump development and the proposed technology is an upgrade of existing commercial products and preliminary de-risking and testing have already been performed. In case of lower performance of the heat pump the demonstration could still be operated .	Low

Table 5. Risks description and mitigations categorized by severity levels.

8. Conclusion and Next Steps

The primary focus of Task 1 in Work Package 5, carried out during the first year of the project, was to analyse all relevant data from the Riva del Garda Demo site. This involved conducting a comprehensive review of the local area, including its geological and hydrogeological framework, analysing current energy flows within the district heating network, and establishing a baseline for project development.

All technical requirements and non-technical specifics necessary for project progress have been documented, and a detailed timeline of future activities has been established. Additionally, a risk assessment was conducted, accompanied by proposed mitigation strategies. This deliverable serves as a reference for project development under Tasks 5.2 and 5.3 and provides critical guidance for other work packages (WP2/3) to ensure the correct deployment of project activities.

Additional technical information related to the development of USES4HEAT technologies at the Riva del Garda Demo site will be collected and reported, with contributions from all partners involved in this work package, in Deliverable D5.2, to be finalized by the end of November 2025.