



RAVENNA CCS PROJECT

REPORT ON PHASE 1 RESULTS



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1. CCS and its role in industrial decarbonisation



Carbon Capture and Storage (CCS) consists in capturing CO₂ emitted by industrial facilities and permanently and safely storing it underground, with the main purpose of mitigating the increase in atmospheric carbon dioxide concentrations. Carbon dioxide is a greenhouse gas and its accumulation in the atmosphere contributes to global warming. Together with other solutions, CCS supports industrial decarbonisation pathways making production processes more sustainable.

CCS plays an important role in so-called hard-to-abate sectors, namely energy-intensive industrial plants where part of the CO₂ emissions are difficult to eliminate, due to both high energy consumption and intrinsic characteristics of the production processes. In these contexts, CCS represents one of the main available solutions, preventing CO₂ from being released into the atmosphere.

Examples of hard-to-abate sectors include steel, cement, paper, and chemical industries. As mentioned above, the difficulties in

reducing emissions in these industrial sectors are linked to the nature of the production processes involved, and in particular to the chemical and physical transformations that take place within them. The most significant example is the conversion of limestone into lime (calcination), an essential process in clinker production, which releases large amounts of carbon dioxide from the mineral itself and accounts for approximately two-thirds of the emissions generated by cement plants.

A study by the Italian Ministry of the Environment and Energy Security (MASE, 2025)¹ highlights that CCS represents one of the most cost-effective solutions in terms of the cost per tonne of CO₂ avoided, second only to energy efficiency and renewable energy-based electrification. However, these latter options have limited applicability in hard-to-abate sectors due to the presence of process-related emissions, making CCS a pivotal solution. These are some of the

¹ Studio CCUS. Analisi degli aspetti tecnici, economici e normativi funzionali allo sviluppo della filiera CCUS - MASE 2025.

reasons that led the Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) to identify CCS as a crucial technology for achieving the full decarbonisation of industrial activities such as cement and chemical production².

For the same reasons, CCS is attracting increasing interest worldwide. Between 2024 and 2025 the sector experienced significant growth both in the number of projects and in carbon capture capacity, which increased from 416 million tonnes of CO₂ per year (MTPA) to 513 MTPA³. Currently, 77 CCS projects are in operation worldwide and 47 are under construction, but the most notable indicator is the presence of more than 600 projects currently under development³.

The CCS process is structured in stages. The first one involves the capture of carbon dioxide directly from the flue gases emitted by industrial facilities, thereby preventing its release into the atmosphere. CO₂ is separated from the other gases with which it is mixed through technologies which are well-established and that are commercially available since decades, such as amine-based capture technology. Once captured, CO₂ is compressed for transportation through pipelines or, alternatively, by rail, ship, or truck. It is then injected into suitable underground geological formations for permanent storage, where it remains securely trapped. Recent studies⁴ indicate that the probability that part of the stored CO₂ is released back into the atmosphere through leakages from the storage site over timescales of thousands or even tens of thousands of years is negligible.

Geological formations for CO₂ storage are selected through rigorous geological and technical investigations, also leveraging the computational power of modern supercomputers, to ensure safe and permanent CO₂ storage. Among the available storage options, the reuse of depleted gas reservoirs is particularly promising, as these are well-characterized geological formations that have already been extensively studied during natural gas production activities. As a result, the behaviour and migration of carbon dioxide within these structures can be predicted with a high degree of accuracy. Furthermore, these formations have successfully contained large volumes of natural gas for millions of years, thus providing a high degree of confidence when it comes to demonstrate permanent containment of CO₂.

CCS also benefits from the experience and expertise generated by underground natural gas storage activities. In Italy, such activity has been carried out since 1964 to ensure the availability of natural gas throughout the year, thereby contributing to the country's energy security. Underground gas storage plays a key role in balancing seasonal fluctuations in supply and demand, enhancing grid stability, and helping to provide more stable energy prices for end users.

Each stage of the storage project is subject to comprehensive monitoring through an extensive and advanced sensors' network. In the specific case of the Ravenna CCS project, the sensors already operating across the Ravenna area in support of Eni's previous gas production activities have been complemented by newly installed monitoring systems.

In conclusion, CCS is a safe and mature technology since it is based on well-established solutions that have been available on the market for many years and builds upon the experience and expertise developed over recent decades in related fields, supported by dedicated monitoring and control systems.



² "CCS is an option to reduce emissions from large-scale fossil-based energy and industry sources, provided geological storage is available. When CO₂ is captured directly from the atmosphere (DACCS), or from biomass (BECCS), CCS provides the storage component of these CDR methods. CO₂ capture and subsurface injection is a mature technology for gas processing and enhanced oil recovery. In contrast to the oil and gas sector, CCS is less mature in the power sector, as well as in cement and chemicals production, where it is a critical mitigation option. The technical geological CO₂ storage capacity is estimated to be on the order of 1,000 GtCO₂, which is more than the CO₂ storage requirements through 2100 to limit global warming to 1.5°C, although the regional availability of geological storage could be a limiting factor. If the geological storage site is appropriately selected and managed, it is estimated that the CO₂ can be permanently isolated from the atmosphere." Climate Change 2022 Summary for Policy Makers - Mitigation of Climate Change - IPCC 2022.

³ Global Status of CCS 2025 - GCCSI 2025.

⁴ Reviewing the implications of unlikely but potential CO₂ migration to the surface or shallow subsurface - IEAGHG 2025.

2. Ravenna CCS project



The Ravenna CCS Project is Italy's first industrial-scale CO₂ transport and storage project. Developed through a joint venture between Eni and Snam, it aims to provide Italian and European industries a competitive and readily deployable solution for the decarbonisation of industrial activities. The joint venture brings together synergic know-hows and decades of experience: on the one hand, Eni's knowledge and operational experience in reservoir management, and on the other, Snam's expertise in natural gas transportation and storage. The project involves the permanent geological storage of carbon dioxide in the depleted Porto Corsini Mare Ovest (PCMW) and Porto Garibaldi-Agostino (PGA) gas fields, located offshore the Ravenna coast. The storage operation is intended exclusively for environmental and decarbonisation purposes, and the depleted reservoirs involved will permanently cease natural gas production prior to the commencement of CO₂ storage activities. Carbon dioxide captured from Italian and European industrial facilities will be transported via underground pipelines to the Casalborsetti pumping station, in the municipality of Ravenna. Alternatively, CO₂ may be transported by ship to the

Port of Ravenna and subsequently delivered to Casalborsetti through a dedicated pipeline.

The Ravenna CCS project is being developed in phases. Phase 1, which commenced in August 2024, was successfully completed in August 2025. The objective of this phase was to demonstrate, at a small industrial scale, the feasibility of the CCS process, its safety, and the ability to effectively monitor both the facilities and the surrounding environment, while providing the basis for the calibration and development of the following larger scale phases. As this was the first operational CCS project in Italy, it was necessary to implement the entire supply chain, starting from the capture of CO₂. Since no industrial-scale carbon capture facilities were available either in the Ravenna area or elsewhere in Italy, it was decided to install a CO₂ capture unit on one of the two turbo-compressors operating at Eni's Casalborsetti natural gas processing plant. This solution ensured the availability of a quantity of CO₂ adequate for the objectives of Phase 1. From the outset, the use of this capture facility was conceived as a necessary temporary solution,

consistent with the demonstration nature of the project and with the planned evolution of the Casalborsetti plant, which includes the implementation of energy efficiency measures alongside other decarbonisation initiatives. Nevertheless, the experience gained through the operation of the Casalborsetti capture unit proved to be of significant technical value, demonstrating high capture efficiencies even under conditions where CO₂ concentrations in the flue gas were particularly low.

In 2025, Ravenna CCS project started the permitting iter for Phase 2, which aims to reach a storage capacity of up to 4 million tonnes of CO₂ per year by 2030, contributing to the decarbonisation of Italian and European hard-to-abate industries. This phase will include the expansion of the CO₂ transportation infrastructure through an extended pipeline network, as well as the development of a logistic hub at the Ravenna port, capable of receiving liquefied CO₂ transported by ship, rail, or truck.

Beyond 2030, the significant storage potential of the depleted gas reservoirs in the Adriatic Sea, estimated at more than 500 million tonnes of total storage capacity, could enable further expansions of

the project. Depending on the evolution of market demand, storage injection rates could progressively scale up to 16 million tonnes of CO₂ per year, establishing Ravenna as one of Europe's leading carbon storage hubs.

In addition to contributing to achieve Italian and European decarbonisation targets, the Ravenna CCS project has the potential to generate significant economic benefits for the Ravenna industrial district and, more broadly, for the Italian manufacturing sector. Capturing industrial emissions could support the development of a low carbon value chain for products and services, with expected positive impacts on both economic growth and employment⁵. Another important benefit is the reduction of the risk of industrial relocation to non-EU countries with less stringent environmental regulations. This phenomenon, known as carbon leakage, can negatively affect the competitiveness of eurozone industries while undermining global efforts to reduce greenhouse gas emissions. Furthermore, the presence of a CO₂ transportation and storage infrastructure in the Ravenna area could boost the attractiveness of this industrial cluster for both domestic and international investors interested in developing new low-emission industrial initiatives.

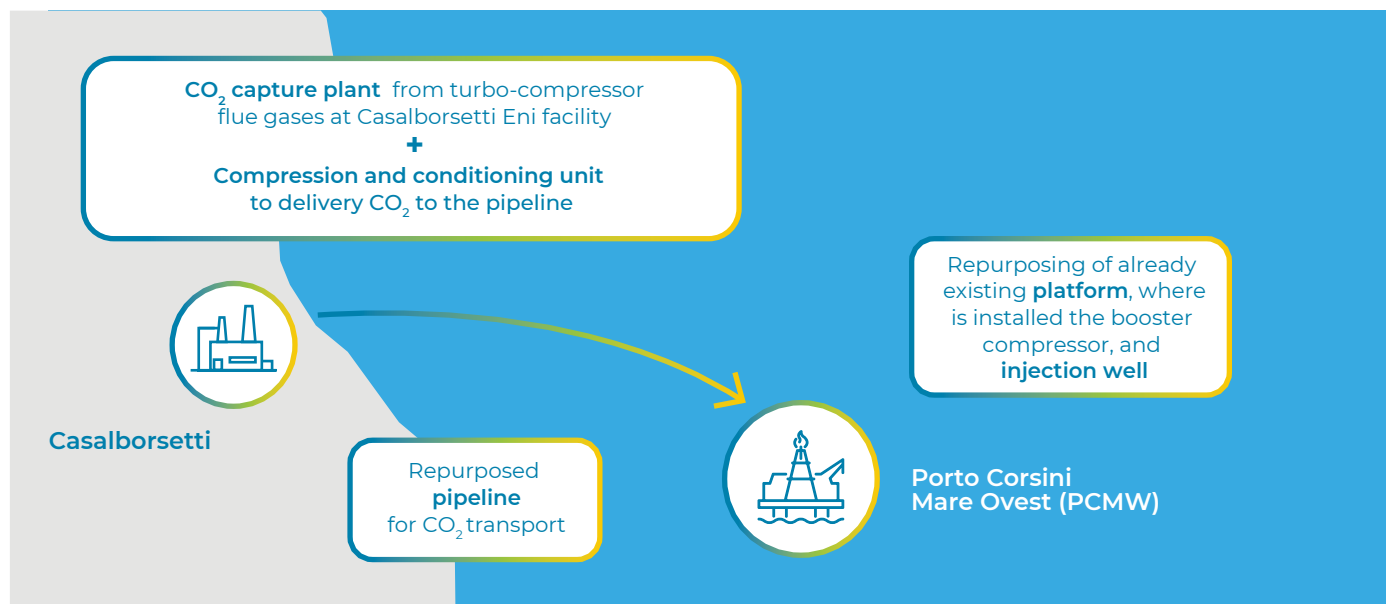


3. Brief technical description



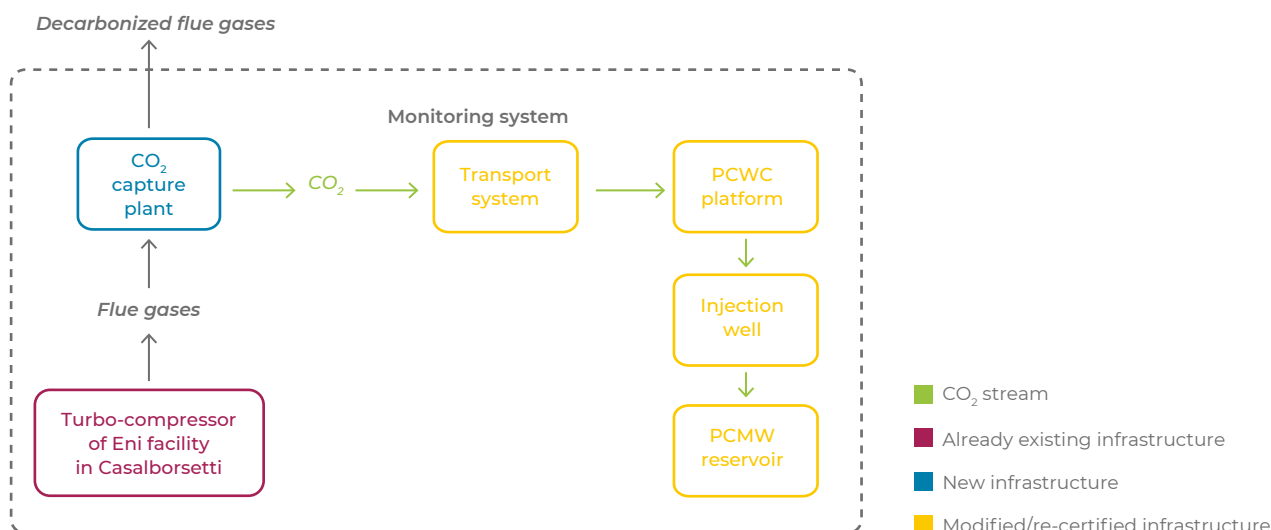
Ravenna CCS Phase 1 involved the construction of new infrastructure alongside the repurposing of existing facilities, as illustrated in Figure 2 and Figure 3 below. Some of the infrastructure developed during Phase 1 will also be reused in Phase 2.

FIGURE 2: DESCRIPTIVE SCHEME OF RAVENNA CCS PHASE 1 PROJECT FACILITIES



The following paragraphs provide a brief description of the main facilities and infrastructures that constitute Ravenna CCS Phase 1 technological process.

FIGURE 3: SUMMARY SCHEME OF THE INFRASTRUCTURE FOR RAVENNA CCS PHASE 1



CASALBORSETTI CAPTURE PLANT

The plant captures CO₂ from the flue gases of one of the two operating turbo-compressors at the Eni gas treatment facility, and it is based on Mitsubishi Heavy Industries (MHI) amine technology. The plant was conceived from the outset as a functional and temporary solution, consistent with the demonstration purpose of the project, and intended to provide up to 25,000 tonnes of carbon dioxide per year for transport and storage. In the meantime, the Casalborsetti compression plant is already implementing other emission reduction measures based on the replacement of the turbo-compressors with more efficient machines.

Amine-based technology is a consolidated technology since decades and is based on conveying the flue gases through a column where amines, in aqueous solution, chemically capture CO₂ molecules by binding with them, while allowing the remaining gases to pass through and be normally released into the atmosphere at the outlet of the column. The amine solution is then sent to a second column where, upon heating, it releases nearly pure CO₂ and is then recirculated back to the first column to restart the cycle. The captured CO₂ is subsequently compressed by a volumetric compressor and further purified to remove traces of water, oxygen and other impurities, before being sent to storage.

The Casalborsetti capture plant does not generate CO₂ emissions (neither Scope 1 nor Scope 2) because, according to a maximum-efficiency approach, it generates the thermal energy required for its



Figure 4: Capture plant installed in Casalborsetti

operation by recovering residual heat from the flue gases themselves, and the electricity used by the plant is supplied entirely from renewable energy sources. As a result, the capture and compression operations do not generate additional carbon dioxide emissions but exclusively intercept and manage existing emissions.

CO₂ TRANSPORT SYSTEM

The captured and compressed carbon dioxide is subsequently conditioned in compliance with transport specifications and conveyed in gaseous phase from the Casalborsetti plant to the injection platform (PCWC).

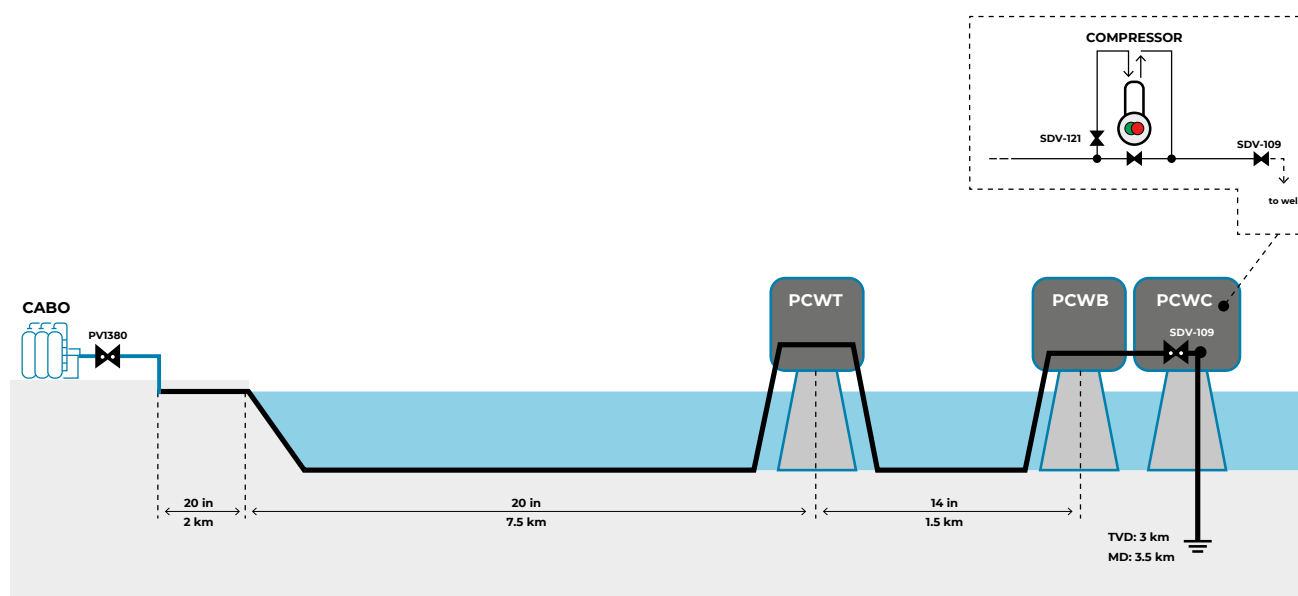
The transport system consists of several elements (Figure 5). From the Casalborsetti plant, CO₂ is injected into an existing 20-inch pipeline (approximately 50 cm in diameter) repurposed for CO₂ transportation, extending for approximately 10 km up to the PCWT transit platform. This pipeline comprises an initial onshore section of approximately 2 km, while the remaining 8 km are offshore.

From the PCWT platform, through specifically designed piping, the CO₂ is routed into a second 14-inch pipeline (approximately 35 cm diameter), also repurposed for CO₂ transportation and extending for 1.5 km up to the PCWB-C platform complex.

Usage of repurposed existing pipelines for CO₂ transportation allowed to limit impacts on the environment and the surrounding area and to reduce project timeline and costs.

To allow the transportation of CO₂ in gaseous phase throughout the entire operational life of the Phase 1 project, a compression unit was installed on the PCWC platform. This system enabled transport operations during the winter months at reduced pressure conditions, thereby preventing the risk of CO₂ condensation within the pipeline. The instrumentation installed at multiple points along the transport system made it possible to accurately monitor the evolution of operating conditions over time and ensure compliance with the requirements for transporting CO₂ in gaseous phase.

FIGURE 5: SCHEME OF CO₂ TRANSPORT INFRASTRUCTURE



PLATFORM AND INJECTION WELLS, AND MONITORING

The PCWC platform accommodates the equipment required to receive CO₂ and convey it to the injection well. To adapt the platform to its new function of supporting CO₂ injection and storage operations, several minor modifications were required, including the installation of a booster compressor used during the winter period. The PCMW 30 Dir B well, a sidetrack of an existing well, was used as injection well. A sidetrack is created by permanently

plugging and abandoning the deepest section of a well, namely the section in contact with the reservoir, and drilling a new branch from the existing upper section. This approach ensures that the materials in contact with the reservoir and with the CO₂ stream are new and suitable for the well's new function, while minimizing new drilling activities. Consequently, the activities required to implement the project, together with their impacts and costs, are significantly reduced. The existing PCMW 09 Dir and PCMW 20 Dir wells were devoted to reservoir monitoring.



Figure 6: PCWC platform

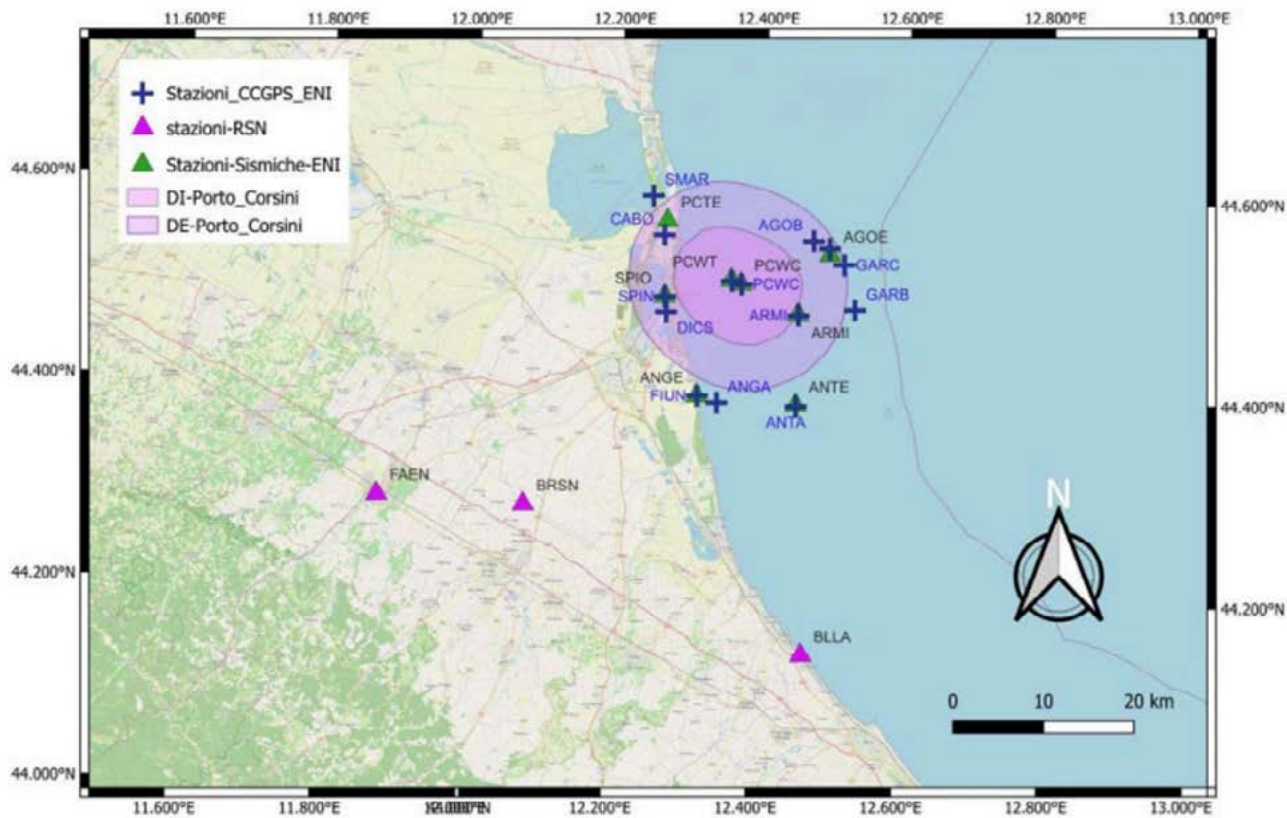
MONITORING SYSTEM

Directive 2009/31/EC on the geological storage of carbon dioxide requires the implementation of an adequate monitoring system for areas devoted to CO₂ storage, in order to confirm safe and permanent geological storage. Ravenna CCS Phase 1 implemented a comprehensive monitoring system including the reservoir, subsurface, and marine environment within the project area, notwithstanding this was not required by the Italian legislation in force at the time of authorization, due to the relatively small quantities of CO₂ injected by the project. The monitoring systems, partly newly installed and partly inherited from the previous gas production activities, confirmed the

safety of the storage operation and the assumptions adopted in the preceding studies and modelling activities. The data collected were useful both in confirming the validity of the techniques employed and in supporting the development of Phase 2. The subsurface monitoring data have been shared with INGV (National Institute of Geophysics and Volcanology) which, in its role of Monitoring Authority appointed by the Ministry and in coordination with the other entities involved, carried out independent analyses⁶, providing an additional level of oversight and transparency. Figure 7 shows the map of the subsurface monitoring system utilized for Ravenna CCS Phase 1 project.

6 Monitoring of CO₂ geological storage experimental program "Ravenna CCS fase 1" - INGV 2025.

FIGURE 7: MAP OF THE MICROSEISMIC MONITORING AND GROUND DEFORMATION MONITORING SYSTEMS BASED ON GPS MEASUREMENTS



The subsurface monitoring plan is structured around two concentric areas, in accordance with the applicable standards. The first area, referred to as the Inner Domain (DI), represents the closest monitoring zone. It extends within a radius of 5 km around the mining concession area and down to a depth of 8 km below sea level. This is the area subject to the most intensive monitoring activities. The second area, known as the Extended Domain (DE), constitutes a broader surveillance zone surrounding the Inner Domain. It extends for an additional 5 km beyond the Inner Domain and reaches a depth of 13 km below sea level. Its purpose is to detect any effects that may propagate beyond the central monitoring area. This two-tiered structure provides a comprehensive understanding of the subsurface system, distinguishing between phenomena occurring in the immediate proximity of the project area and those affecting the wider regional setting. RSN: Rete sismica nazionale (National seismic network).

4. Purpose and rationale of Phase 1



Figure 8: “Project Network 2025” outreach event, organized in Bologna in June 2025 in collaboration with ZEP (now Carbon Management Europe). During the event, the Ravenna CCS Project shared the experience gained during the development and operation of Phase 1 with representatives from industry, local, national and European institutions, as well as international stakeholders from the CCS market.

CCS is a mature and safe process; however, its use for environmental purposes, and therefore as a solution for the decarbonisation of industrial activities, is relatively new. Before 2020, less than 30 CCS projects were in operation worldwide⁷. In recent years, increasing awareness of climate-related issues and the decarbonisation commitments undertaken by various countries and supranational organizations have driven growth in initiatives and investments in transition technologies such as wind and solar power, electrification, biofuels, and others. Due to its effectiveness in reducing industrial emissions, the number of CCS projects has also increased rapidly, rising in 2025 to 77 operational projects and more than 600 projects under development⁸.

Despite this positive signal, CCS market is still at an early stage of development, characterized by a limited number of operators, inhomogeneous knowledge levels among industrial companies regarding the decarbonisation opportunities offered by CCS, and significant differences in the pace at which individual countries are implementing this solution. In Italy, Ravenna CCS Phase 1 was the first industrial-scale project of its kind.

As occurred with many other technologies, from solar panels to electric mobility, the development of a new market must be supported on the one hand by an appropriate regulatory framework and, on the other, stimulated through pilot initiatives that increase understanding of the technology among its end users. This is precisely the role that Ravenna CCS Phase 1 has fulfilled, achieving highly positive results.

Ravenna CCS Phase 1 was approved by the Italian Ministry of the Environment and Energy Security (MASE) in January 2023, with a maximum duration of three years, including both construction and operational activities. The infrastructure was ready in approximately 18 months and began operations in August 2024, concluding injection activities one year later, at the end of August 2025, close to the expiry date of the authorization period. Following the completion of injection operations, the project continues through the planned monitoring activities, aimed at verifying over time the behaviour of the stored CO₂ and the safety and integrity of the storage site. Throughout this period, and continuing to the present day, the Ravenna CCS Phase 1 infrastructure has acted as a catalyst for important steps in the deployment of CCS in Italy.

⁷ Source: Global Status of CCS 2020 - GCCSI.

⁸ Source: Global Status of CCS 2020 - GCCSI.

Among these, it is worth to highlight:

- Inclusion of CCS in Italy's National Integrated Energy and Climate Plan (PNIEC) in 2024.
- Decree-Law No. 181/2023, which updated the national regulatory framework governing carbon dioxide storage and introduced the requirement to further assess and finalize the regulation of the entire CCS value chain.
- The MASE CCS Study, published in August 2025, which introduces:
 - the regulatory framework for CCS and its expected evolution;
 - an analysis of costs and incentive mechanisms;
 - an assessment of the decarbonisation demand of the Italian industrial sector, with particular focus on hard-to-abate industries (cement and lime, refining, chemicals, blue hydrogen, DRI steel and secondary steel production, glass, and ceramics), the thermoelectric sector, and waste-to-energy. The study also highlights the importance of emitter aggregation (clustering) to optimize CCS development.
- The award of European Innovation Fund grants to three Italian industrial companies for the construction of CO₂ capture facilities aimed at decarbonizing their production activities through the transport and storage of CO₂ emissions at the future Ravenna CCS Phase 2 storage site.
- Visits by hundreds of national and international stakeholders to the Casalborsetti site, including representatives from industry, local, national and European institutions, universities and research centres, trade union organizations, and other interested parties.

In addition to the non-technical outcomes mentioned above, the Ravenna CCS Phase 1 infrastructure was also used to achieve various specific technical objectives, including:

- a. Demonstrating the feasibility of transporting carbon dioxide from the Casalborsetti plant and injecting it into the Porto Corsini Mare Ovest reservoir, confirming the accuracy of both the transport and reservoir predictive models.
- b. Field evaluation of the operative performance of a carbon capture plant applied to a natural gas turbo-compressor such as those operating at the Casalborsetti plant, a particularly challenging application due to the low CO₂ concentration (approximately 2.5%) in the exhaust flue gases.
- c. Validating subsurface and environmental monitoring techniques.
- d. Confirming, through the application of monitoring techniques, the safe storage of CO₂ in the reservoir.
- e. More generally, collecting all technical data required to support the optimisation of the future Phase 2 development.

It should be highlighted that all of the above activities have been carried out in full compliance with the applicable regulations and in collaboration with the authorities responsible for overseeing the implementation of the monitoring plan, including the **Italian Institute for Environmental Protection and Research (ISPRA)** and the **National Institute of Geophysics and Volcanology (INGV)**. In addition, some of the most authoritative national and international institutions were involved, including the **University of Bologna**, **Sapienza University of Rome**, the **Polytechnic University of Turin**, specialists from the **Massachusetts Institute of Technology (MIT)** for the optimization of geological and reservoir models, and the **National Research Council (CNR)** for environmental monitoring campaigns.



Figure 9: Outreach event at the Ravenna CCS project visitor centre (left). Visitors touring the CO₂ capture plant (right).

5. Main results of Phase 1



Ravenna CCS Phase 1 successfully completed its injection operations at the end of August 2025, after 13 months of activity and with all planned objectives fully achieved, as documented in the reports submitted to the authorities and confirmed by the favourable opinion issued by the CCS Committee. The post-operational monitoring activities are currently ongoing.

In particular, the conclusions of the CCS Committee's opinion state that:

- *"The injection and storage, capture and transport activities have enabled the collection of technical data and operational experience that constitute an information basis supporting the development of the industrial phase of the project."*

- *"Advanced monitoring systems were appropriately implemented and managed across the different stages of the pilot program (pre-operational, operational and post-operational) in the environmental, microseismic and ground deformation domains. The results recorded and documented by the operator, also through the support of the authorities responsible for monitoring activities, do not indicate any anomalies or issues relating to significant CO₂ leakage, microseismic events or ground deformation phenomena referable to the storage activities carried out."*

These results are in addition to the positive non-technical outcomes already described in Chapter 4. The following sections of this document present the individual components of the project and the corresponding results achieved.

6. Capture and compression plant's performance



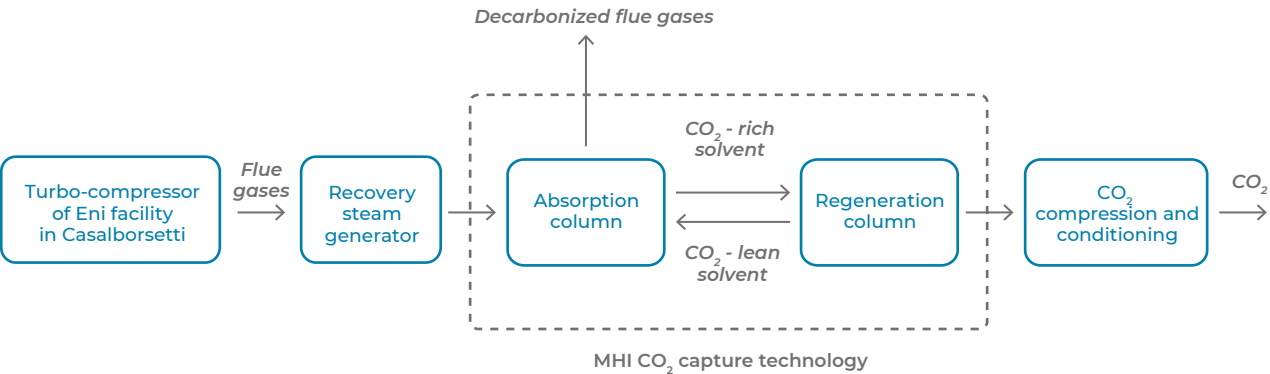
The carbon dioxide used in the project is captured from the exhaust gases of the TK-04 turbine, which drives one of the two PGT-5 turbo-compressors at the gas compression plant located in the municipality of Casalborgsetti, a few kilometers north of Ravenna. The plant receives and processes natural gas produced from offshore fields located off the Ravenna coast and then delivers it to the national gas transmission network operated by Snam. For this purpose, the natural gas must be compressed to the pressure of the transmission network, a process carried out by the plant's turbo-compressors. These compressors are powered by methane-fuelled

turbines which, due to the combustion of natural gas, generate CO₂ emissions.

The CO₂ concentration in the turbine exhaust gases is approximately 2.5% at atmospheric pressure, representing one of the most challenging conditions for carbon capture technologies, whose performance generally improves as CO₂ concentrations increase. The technology used at the Casalborgsetti plant is based on a proprietary amine solvent developed by Mitsubishi Heavy Industries (MHI).

A block flow diagram of the plant is shown in the figure below.

FIGURE 10: BLOCK-FLOW DIAGRAM FOR CO₂ CAPTURE PLANT



A distinctive feature of the Ravenna CCS Phase 1 capture plant is the presence of a heat recovery steam generator (HRSG), which produces all the steam required for the operation of the capture facility by recovering residual heat from the exhaust gases of the turbo-compressor. These gases leave the turbine at high temperature (approximately 500°C). As a result, the net thermal energy consumption of the capture plant is virtually zero, increasing the efficiency of the capture process. Furthermore, considering that 100% of the electricity used by the capture plant is sourced from certified renewable energy, the Casalborsetti capture facility does not generate any additional direct CO₂ emissions or emissions associated with electricity supply (technically referred to as Scope 1 and Scope 2 emissions).

CAPTURE PROCESS DETAILS

The exhaust gases from the TK-04 turbine pass through the heat recovery steam generator, leaving it at a temperature of approximately 200°C, and are then conveyed to a cylindrical cooling tower. There, through contact with water, their temperature is further reduced to approximately 35°C. Decreasing flue gases temperature helps improving the efficiency of the CO₂ absorption process. After cooling, the flue gases are sent to the base of the absorption column. As they rise through the column, they get in contact with the amine solvent flowing downwards. It is during this stage that more than 90% by volume of the CO₂ contained in the exhaust gases is absorbed by the solvent.

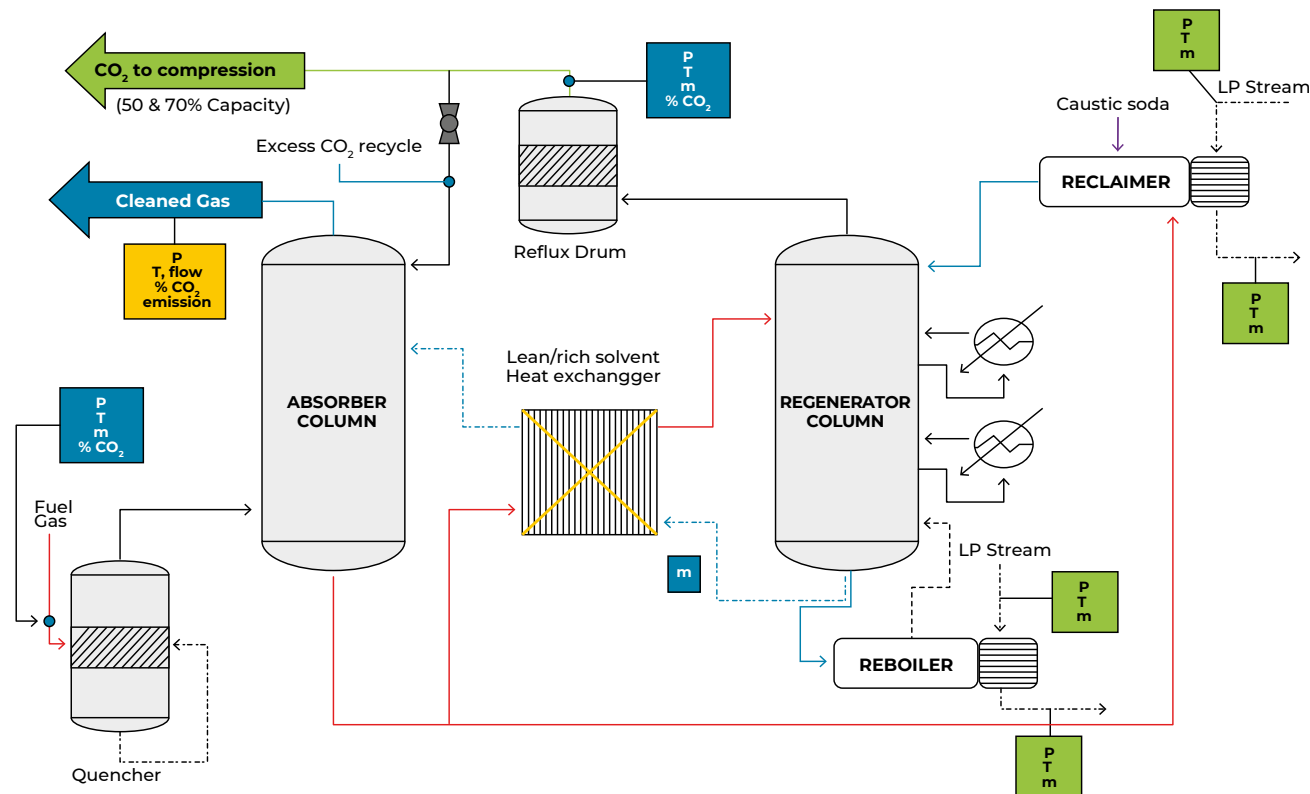
Figure 11: Capture plant in Casalborsetti



The flue gases pass through a washing section to prevent amine carryover and to be further cooled down. Having thus been relieved from most of their carbon dioxide content, they are discharged into the atmosphere from the top of the column, where continuous monitoring systems are installed to control the composition of the emitted exhaust gases.

From the bottom of the absorption column, the CO₂-rich solvent is sent to the regeneration column, where it is heated by the steam

previously produced by the heat recovery steam generator, thus releasing the absorbed CO₂. The solvent, once regenerated, is then returned to the absorption column to be reused in the process. The recovered CO₂ is instead routed to the compression and conditioning system. The plant is also equipped with a series of intermediate heat exchangers to improve its energy efficiency, as well as a system designed to reduce amine consumption, since the solvent must be periodically replenished to replace the portion that degrades over time.

FIGURE 12: OPERATING DIAGRAM OF THE CO₂ CAPTURE PLANT

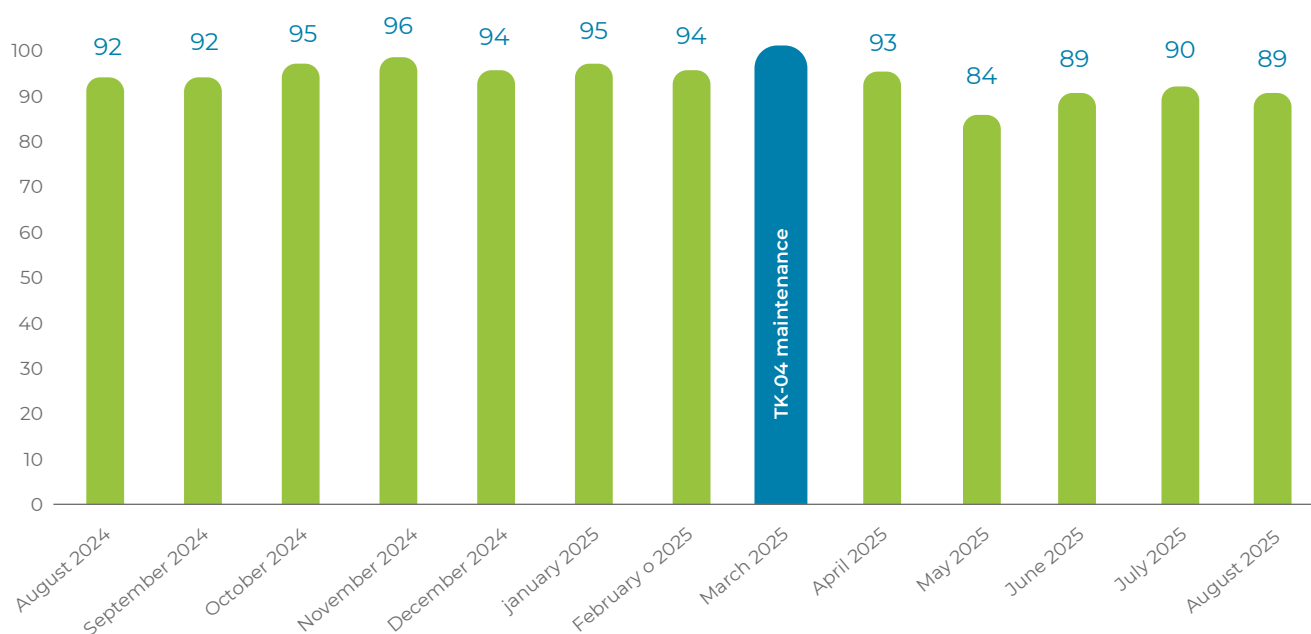
The green and blue boxes indicate sensors used to measure selected process parameters, including pressure (P), temperature (T), mass flow rate (m) and CO₂ concentration (% CO₂).

CAPTURE EFFICIENCY

Capture efficiency measures the ability of a capture plant to remove carbon dioxide from the flue gases. It is expressed as the ratio between the amount of CO₂ captured and the amount originally present in the flue gas. The benchmark value generally considered to be the industry standard is 90%, meaning that 90% of the CO₂ originally contained in the flue gas is captured by the system, while the remaining 10% remains in the gas stream and is released into the atmosphere. As noted previously, the capture process becomes easier as the concentration of CO₂ in the exhaust gas increases. As a practical example, achieving a 90% capture efficiency is easier for the flue gases of a cement plant, where the initial CO₂ concentration exceeds 15%, than for those of a gas-fired power plant, where the initial CO₂ concentration is below 5%. For this reason, the Ravenna CCS Phase 1 capture plant proved to be a state-of-the-art application, as it demonstrated the ability to capture carbon dioxide with efficiencies well above 90% during much of its operational period, starting from a particularly dilute CO₂ concentration of approximately 2.5%. The chart below shows the average monthly capture efficiency over the entire operational period.

It can be observed that capture efficiency reached **peaks of 96%** and remained consistently above 90% until February 2025. **The average efficiency over the entire year of operation was 91.9%.** In March 2025, the plant was shut down to allow for the scheduled and mandatory maintenance of the turbo-compressor at the Casalborsetti plant. When the operations restarted, the TK-04 turbine performed with improved combustion efficiency because of the maintenance activities, and thus with a lower concentration of carbon dioxide in its exhaust gases. Consequently, the CO₂ concentration, already very low at approximately 2.5%, decreased further to around 2.3-2.4%.

This reduction in the CO₂ concentration of the flue gases required adjustments to the capture plant's operating parameters, which maintained a capture efficiency of 93% also in April 2025. At the same time, however, the new operating conditions led to a faster degradation of the solvent, causing a decline in efficiency during May. This issue was addressed through the addition of fresh amine solvent and subsequently through an extraordinary replacement of the degraded solvent. These actions enabled the

FIGURE 13: CO₂ CAPTURE EFFICIENCY AT THE CASALBORSETTI PLANT OVER THE OPERATIONAL PERIOD (%)

In March 2025, the TK-04 turbo-compressor was temporarily shut down for scheduled maintenance.

plant to restore capture efficiency to approximately 90% during the final months of operation.

COMPRESSION AND CONDITIONING

The carbon dioxide leaving the regenerator column of the capture plant must be purified and compressed before it can be sent into the pipelines. This was achieved through a multi-stage positive displacement compressor which, during the periods before November 2024 and after April 2025, compressed the gas to approximately 50 bar. During the winter period, in order to prevent the risk of CO₂ condensation within the offshore pipeline, the gas was compressed onshore up to 30 bar only, while a small booster compressor installed on the offshore platform provided additional compression to reach 50 bar before injection into the well. In this way, the pipeline was operated under pressure and temperature conditions that ensured the CO₂ remained entirely in the gaseous phase. Following onshore compression, and partly during the compression process itself, the oxygen content of the carbon dioxide stream was reduced to below 10 ppm (parts per million) and the water content to below 50 ppm, in compliance with the

specifications established for pipeline transportation aimed at preventing potential corrosion phenomena.

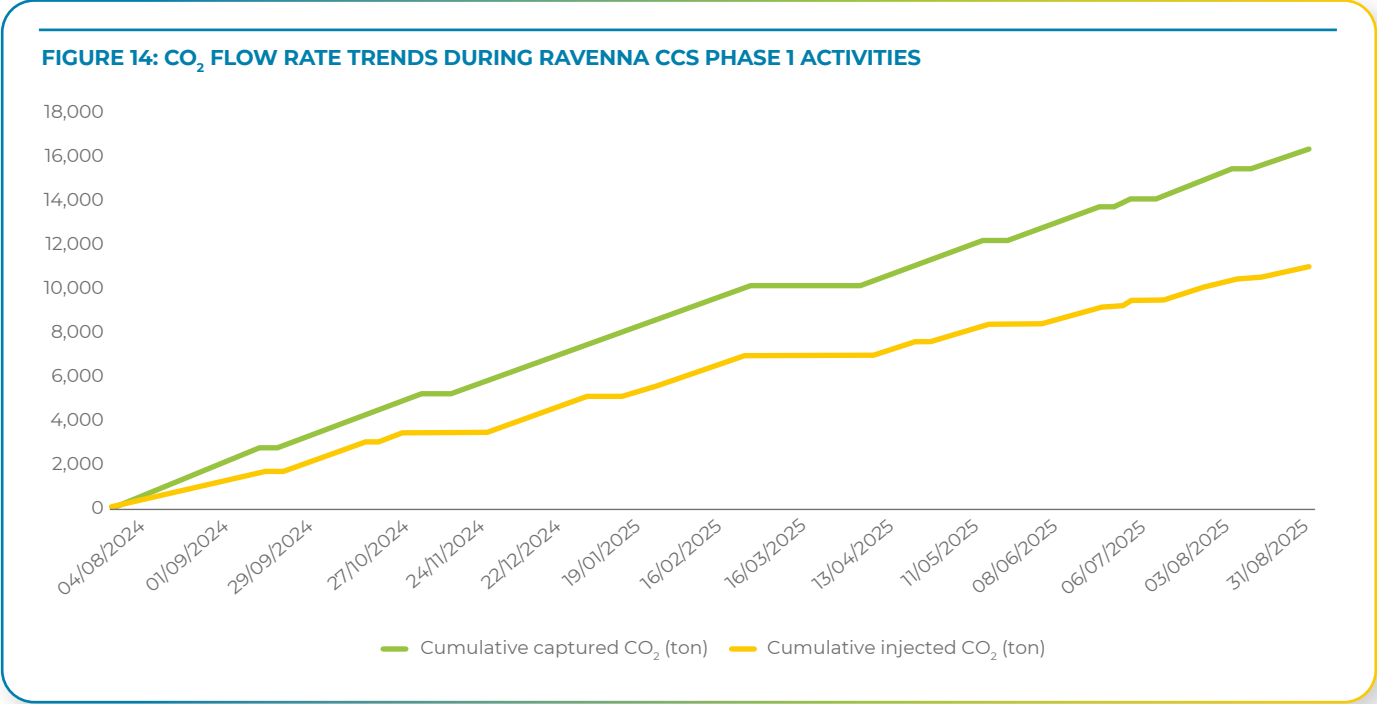
Impurities in the CO₂ stream sent to the reservoir were continuously monitored both through online analysers installed at the outlet of the capture plant and through periodic sampling and analyses carried out by specialized laboratories. **The impurity levels were consistently well below the limits established by the transportation specification. The purity of the CO₂ increased progressively throughout operations and remained above 99% by volume at all times.**

PLANT AVAILABILITY

The Ravenna CCS Phase 1 capture plant operated successfully from August 2024 to August 2025. During the operational period, the plant supplied the carbon dioxide required to achieve all the objectives of Phase 1, operating with continuity despite some planned shutdowns took place to allow maintenance, other activities at the Casalborsetti plant, and other unplanned events none of them however attributable to CO₂ injection, storage, or leakage issues.

CAPTURED AND INJECTED CO₂ VOLUMES

The subsequent chart shows the cumulative volume trends for CO₂ captured at the onshore plant, and for CO₂ injected into the well over the entire operating period.



During the operational period, the capture plant separated 16,139 tonnes of carbon dioxide. Of this amount, approximately 11,000 tonnes were injected into PCMW 30 Dir B well. The quantity captured exceeded the quantity injected into the reservoir for three main reasons:

1. during some of the shutdown events that occurred throughout the year (see the previous section), the capture plant continued operations whenever possible in order to maximize the collection of operational data. During these periods, the entire stream of CO₂ separated from the flue gases was released into the atmosphere;
2. given the temporary nature of Ravenna CCS Phase 1, the multi-stage positive displacement compressor installed at the Casalborsetti plant and the injection compressor installed on the PCWC platform were not equipped with Variable Speed Drives (VSD). Instead, they could operate only at fixed speed settings, and therefore at fixed flow rates (e.g. 50%, 75%, or 100% of maximum capacity). This configuration was consistent with the objectives of the project phase and aligned with engineering choices based on technical reasons, proportionality, and safety. Positive displacement compressors cannot operate at flow regimes higher than the available flow rate, as this would create conditions potentially damaging to both the equipment and the pipelines. Hence, the compressor flow regime was set at the first available fixed value lower than the CO₂ capture rate of the plant. The captured CO₂ exceeding the compressor capacity was therefore routed back to the stack and released into the atmosphere.

3. the pipeline connecting Casalborsetti to the PCWC platform contains approximately 400 tonnes of CO₂ which, at the end of the injection campaign, were captured by the plant but did not reach the injection well.

The approximately 11,000 tonnes of carbon dioxide injected are fully consistent with the objectives of Ravenna CCS Phase 1, which was conceived as a demonstration project aimed at validating the operations of the entire CCS value chain.

Phase 2 will be developed on a different scale and within a different operational context, and the project is specifically designed to serve multiple industrial emitters. Under this configuration, the compression station will be equipped with multiple compression trains equipped with Variable Speed Drives (VSD), to provide the necessary operational flexibility to manage the variable flow rates delivered to the CO₂ gathering network. For these reasons it is expected that the entire CO₂ volume supplied by industrial emitters will be injected during Phase 2.

Finally, it should be noted that Phase 1 was not intended to decarbonize the Casalborsetti plant, which is already undergoing an independent and substantial energy-efficiency improvement program. This program includes the replacement of the existing PGT-5 turbo-compressors with new-generation machines characterized by significantly higher efficiency levels and lower footprint.

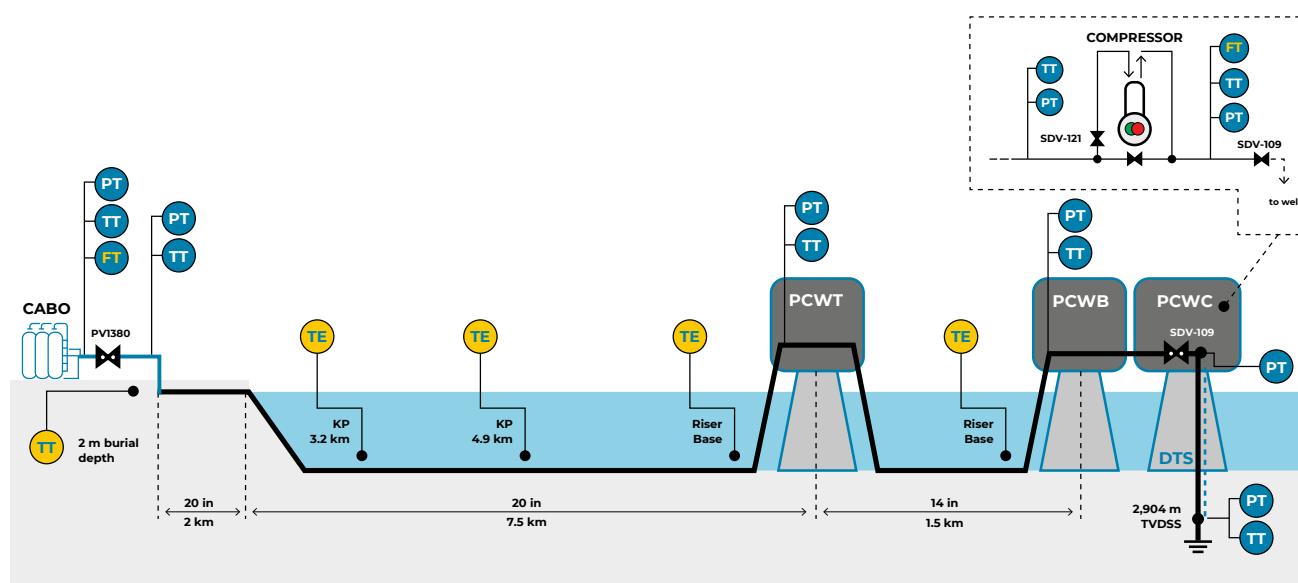
7. CO₂ transport infrastructure performance



As described in Section 3, the captured, compressed and specification-compliant CO₂ stream is transported to the PCWC injection platform through a repurposed pipeline system approximately 11 km in length, laying on the Adriatic Sea seabed at a depth of approximately 14 m. At PCWC, the carbon dioxide

enters the injection well through a 3.5-inch nominal diameter injection tubing (approximately 90 mm) and reaches the reservoir injection level located at a depth of approximately 3 km. A schematic representation of the transport infrastructure is provided in Figure 15.

FIGURE 15: CO₂ TRANSPORT INFRASTRUCTURE LAYOUT, FROM CASALBORSETTI TO PCWC PLATFORM AND INJECTION WELL.



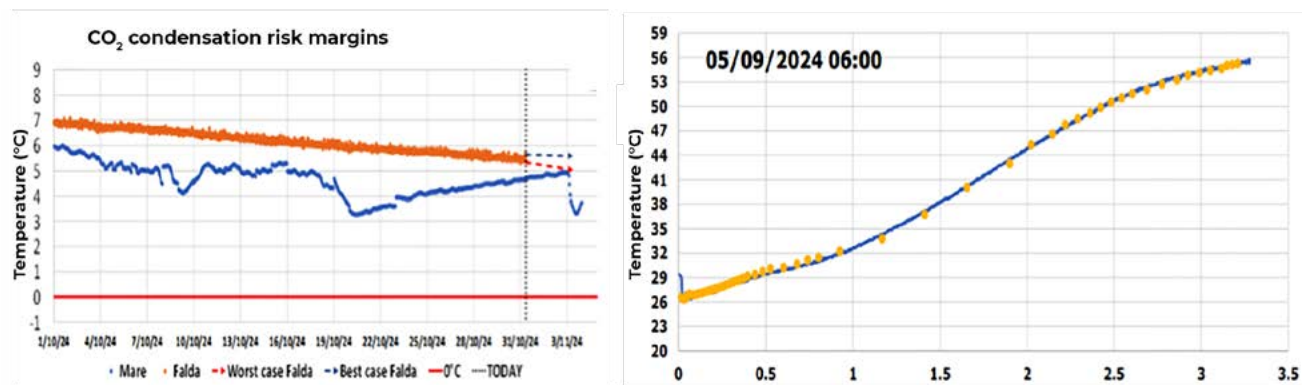
The main pipelines (20-inch and 14-inch diameters) were recertified for CO₂ transportation, under the condition that the CO₂ remained in gaseous phase throughout the transport system. Since the wellhead injection pressure at the PCWC platform was approximately 50 bar, during the colder months of the year the pressure and temperature conditions within the transport pipeline would have led to the condensation of liquid CO₂ in the line. For this reason, a second compressor was installed on the PCWC platform, making it possible during the winter months to decouple the operating pressure of the transport system (maintained at 30 bar to prevent the formation of liquid CO₂ in the pipeline) from the wellhead injection pressure (increased to 50 bar by the offshore compressor). This operative configuration started on 2 December 2024 with the expected seasonal temperature decrease, and remained in operation until ambient temperatures increased again in April 2025.

The entire transport and injection system was equipped with several flowmeters, temperature and pressure sensors, distributed from the outlet of the capture and compression plant at Casalborsetti to the bottom of the PCMW 30 Dir B well. In addition, the entire pipeline was monitored through Eni's e-vpms® vibro-acoustic technology, which

is capable of detecting a pipeline leakage in real time. The injection tubing was equipped with a Distributed Temperature Sensing (DTS) system based on fibre-optic technology, installed along the tubing itself and providing distributed temperature measurements down to the bottom of the well.

In addition to process measurements (flow rates, temperatures and pressures), CO₂ samplings were collected periodically. This measurement campaign had different objective: first, to determine the concentration of all impurities present in the CO₂ stream and verify compliance with the required transportation specification; second, to analyse in laboratory the physical behaviour of the CO₂ within the transport system in order to assess the potential formation of reaction products resulting from interactions between impurities. This latter objective was achieved using dedicated Eni laboratory equipment and expertise developed over many years in the Oil & Gas sector and subsequently applied to less conventional contexts such as CO₂ transportation. The results of the composition monitoring campaign confirmed both compliance with the transportation specifications and the reliability of the predictive models adopted during the design phase.

FIGURE 16: MONITORING OF OPERATING PARAMETERS FOR CO₂ TRANSPORT INFRASTRUCTURE



Trend over time of the minimum CO₂ temperature in the onshore pipeline (orange) and offshore pipeline (blue). The distance from the horizontal red line at 0°C indicates the safety margin with respect to CO₂ condensation within the pipeline. At the end of October, this margin was still approximately 4-5°C, but it was progressively decreasing, making it necessary to bring the offshore compression system into operation (left). Comparison between the temperature measured along the well and their predictions made by the simulation models (blue: model prediction; yellow: observed data) (right).

Overall, throughout the operational period, **the transport and injection system operated without any anomalies** compared with the expected behaviour. The compositional analyses described above, the measurements collected, the analytical and predictive models of CO₂ behaviour within the pipelines and the monitoring of ambient temperature conditions led to the following conclusions:

- The pipelines constantly transported CO₂ in the gaseous phase, in accordance with the pipeline reuse certification, and any risk of CO₂ condensation within the transport system was successfully avoided.

- The transport operating mode (i.e. operation with or without the offshore compressor) was adjusted at the appropriate season, maintaining adequate safety margins with respect to condensation risk.
- The predictive calculation models were reliable not only in estimating performance under normal operating conditions, but also in describing the physical behaviour of the system under transient conditions, including along the injection tubing with the DTS technology.
- The models and tools adopted for Phase 1 are considered suitable for application in Phase 2 as well.

8. Reservoir monitoring

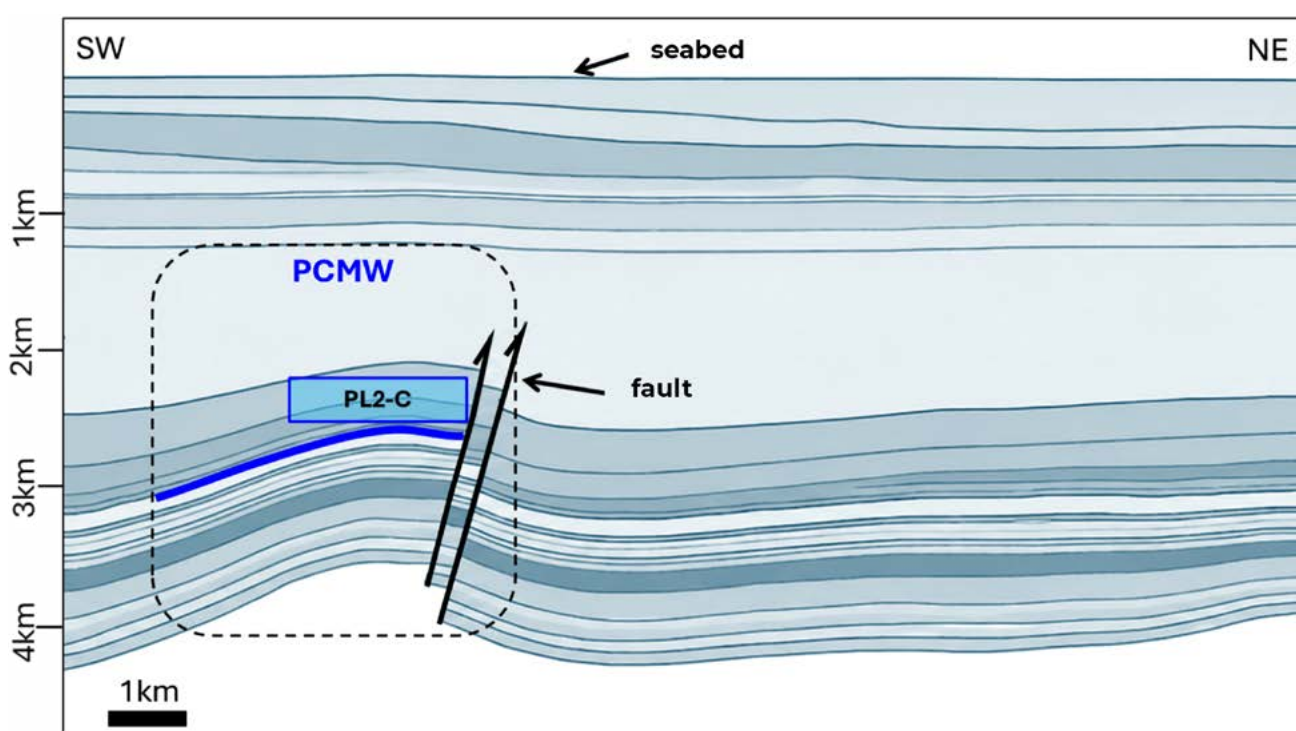
STORAGE SITE CHARACTERISTICS

Storage took place in the PL2-C geological layer, selected among all the layers constituting the depleted PCMW reservoir as the most suitable for CO₂ injection, thanks to a combination of petrophysical, stratigraphic, structural and fluid-dynamic characteristics.

From a structural standpoint, the reservoir is characterized by an asymmetrical anticlinal geometry, namely a subsurface fold with a

convex-upward shape, comparable to an elongated dome. This type of configuration represents one of the main natural mechanisms for hydrocarbon trapping. In this specific case, the structure is buried beneath a thick sequence of undeformed sediments and is bounded by inactive faults, which contribute to ensuring the lateral confinement of the system.

FIGURE 17: SIMPLIFIED GEOLOGICAL CROSS-SECTION OF THE PORTO CORSINI MARE OVEST (PCMW) RESERVOIR, ORIENTED FROM SOUTH-WEST (SW) TO NORTH-EAST (NE),



Illustrating in a simplified and representative manner the stratigraphic and structural setting of the subsurface down to the seabed. The different shades of grey represent distinct stratigraphic layers within the subsurface. The PL2-C layer, highlighted in blue in the proximity of the PCMW reservoir, corresponds to the depleted gas reservoir used for CO₂ storage in Ravenna CCS Phase 1 project. This layer is confined by overlying low-permeability sedimentary sequences, which act as a natural barrier to fluid migration. The geometry of the reservoir is controlled by inactive faults, visible in the central part of the cross-section, which border the PCMW structural compartment (dashed area). The distribution and orientation of the stratigraphic layers reflect the geological evolution of the basin and contribute to defining the containment and storage capacity of the site.

The origin of this geometry is linked to the tectonic evolution of the Northern Apennines. During the compressional phases that affected the Adriatic region over the last several million years (from approximately 7 million to 1 million years ago), the sedimentary succession was deformed by tectonic stresses directed predominantly towards the north-east. This process generated numerous similar structural traps, many of which subsequently became natural gas reservoirs exploited for hydrocarbon production.

One of the key factors that makes the PCMW reservoir suitable for carbon dioxide storage is its stratigraphic architecture. The reservoir consists of multiple layers of porous and permeable sandstone alternating with low-permeability clay-rich layers, which therefore act as a cap rock.

This multilayer configuration enables effective fluid trapping. Above the selected injection interval, several additional

impermeable layers are present, acting as barriers that prevent the upward migration of CO₂. Furthermore, throughout its geological history, the reservoir has successfully accumulated natural gas within many of these reservoir intervals, demonstrating the excellent sealing capacity of the cap rock. The proven integrity of the system represents a fundamental element in the assessment of its suitability for permanent CO₂ storage and has been further confirmed by the detailed geological, geomechanical and geochemical studies carried out as part of the rigorous site-selection process.

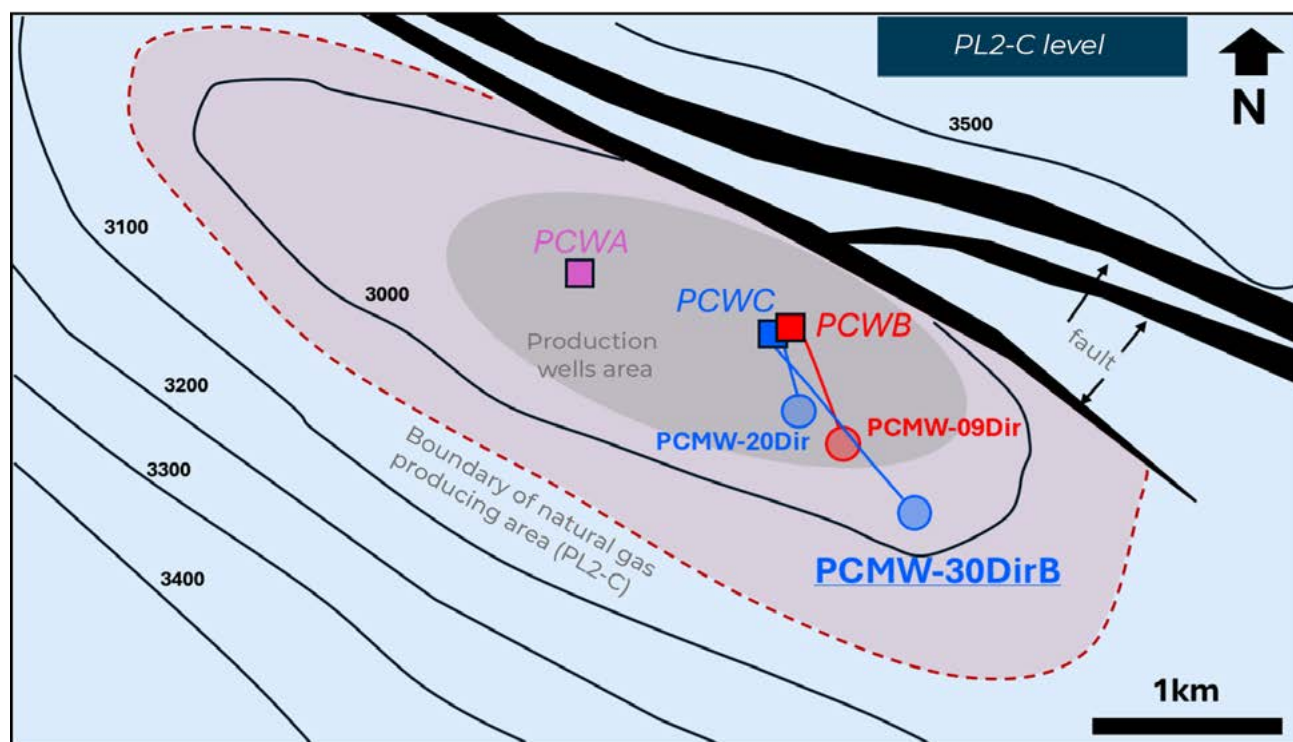
The PCMW reservoir is part of the wider group of Adriatic gas fields that have been exploited for natural gas production for several decades. As a result, it has reached depleted conditions, meaning that the pressure within the rock pores is lower than its original value. From an operational perspective, the use of an exploited reservoir offers additional advantages, as the extensive knowledge

of reservoir geometry, rock properties and system behaviour resulting from the data acquired during the production phase.

Injection took place at a depth of approximately 3,000 metres, at temperatures of around 55°C. Above the injection point lies a clay-rich cap rock that provides effective hydraulic isolation of the reservoir. Prior to the beginning of natural gas production, reservoir pressure was approximately 335 bar, while it currently ranges between 110 and 160 bar. This pressure reduction, resulting from natural gas production, indicates the availability of accessible pore volume which can now be re-occupied by the injected CO₂.

In geological carbon dioxide storage projects, pressure is one of the key parameters for ensuring effective, safe and well-controlled injection operations, without compromising the mechanical integrity of either the reservoir or the cap rock. In this respect, the PCMW reservoir offers a substantial operational margin, as the

FIGURE 18: SIMPLIFIED MAP OF THE DEPLETED PORTO CORSINI MARE OVEST (PCMW)



Simplified map of the depleted Porto Corsini Mare Ovest (PCMW) gas reservoir, showing the PL2-C geological layer, which is currently used for CO₂ injection as part of the Ravenna CCS Phase 1 project. CO₂ is injected through the PCMW 30 Dir B well, located in the south-eastern portion of the area, while the PCMW 09 Dir and PCMW 20 Dir wells are dedicated to site monitoring activities. The coloured squares represent the offshore platforms from which the wells previously used for natural gas production were drilled, within the reservoir area outlined by the grey ellipse. The original extent of the gas accumulation area within the PL2-C layer is shown in semi-transparent red (dashed outline). This layer is now fully depleted and is no longer in production. The thin black lines describe the geometry and depth of the layer in the subsurface, while the black polygons indicate the projections of the inactive faults that bound the reservoir towards the north-east.

pressures reached during injection remain significantly below the original reservoir pressure, which the geological formation has already demonstrated to sustain under natural conditions.

Current reservoir pressure and temperature conditions are such that CO₂ is naturally maintained in a supercritical state⁹, namely conditions which are intermediate between those of a liquid and an ideal gas. This state is particularly well suited for efficient storage, as it combines a high density similar to that of a liquid with a low viscosity characteristic of a gas, thereby facilitating both injection and distribution within the porous medium.

INJECTION WELL, OPERATIONS AND DATA COLLECTION

Injection took place through the Porto Corsini Mare Ovest 30 Dir B (PCMW 30 Dir B) well, a sidetrack specifically drilled to reach the PL2-C layer, targeted for CO₂ injection. During drilling operations all the information required to characterize the geological formations intersected by the well were collected. In addition to the acquisition of specific well measurements aimed at verifying the integrity of the cap rock and the safety of the well itself, several cores (rock samples) were collected to characterize in laboratory both the reservoir rock and the cap rock, the latter responsible for the permanent confinement of CO₂ in the subsurface. Samples of the reservoir fluids were also collected to support operational monitoring activities. Additional data on the mechanical behaviour of the rock formations, which are essential for ensuring safety throughout all phases of operation, were also collected.

The data acquisition program allowed the development of a detailed characterization of the reservoir, the reservoir rock and the cap rock, which acts as a natural barrier ensuring the permanent containment of CO₂.

The PCMW 30 Dir B well is a sidetrack, meaning that it was drilled from a section of an existing well that had previously been abandoned and plugged using CO₂-resistant materials. Once the drilling phase was over and the safety and performance of the well had been verified, the well was completed using materials suitable for being in contact with carbon dioxide and equipped with continuous monitoring systems, including electrical sensors for pressure and temperature measurements and a fibre-optic cable to verify well integrity during and after injection operations.

The well was drilled between January and April 2024.

INJECTION WELL MONITORING

The PCMW 30 Dir B injection well (Figure 18) was equipped with electrical sensors and a fibre-optic cable to allow continuous monitoring of pressure and temperature during and after injection operations. The analysis of these data was complemented by specific periodic surveys that enabled a detailed characterization

of the behaviour of both the well and the surrounding reservoir area. These surveys included acquisitions known as logs, namely measurements describing how a given parameter varies along the well trajectory. These logs were repeated over time to accurately monitor the evolution of the phenomena associated with the injection process.

The integrated evaluation of all these data highlighted the absence of CO₂ outside the geological layer designated for storage, confirming the effectiveness and safety of the injection operations, as well as the integrity of both the injection well and the cap rock. The data collected also made it possible to verify the consistency of the reservoir model predictions with the observed results, confirming the predictive capability and robustness of the model itself.

DEDICATED MONITORING WELLS (PCMW 09 DIR AND PCMW 20 DIR)

In addition to the PCMW 30 Dir B injection well, two already existing wells were selected for monitoring purposes for Ravenna CCS Phase 1. In line with the objectives of the monitoring plan established under the European directive about CCS projects, these wells were used to acquire subsurface data aimed at verifying the containment of CO₂ within the storage site ensured by the cap rock, and at calibrating the predictive models describing fluid migration within the reservoir (conformance assessment).

The first monitoring well (PCMW 09 Dir) was used to acquire field data on the behaviour of CO₂ in the reservoir and on the formation reaction during injection. Repeated measurements of pressure and temperature were collected over time, together with samples of reservoir fluids present in the well and saturation logs (i.e. logs used to identify the type of fluid present in the area surrounding the well).

The measurements acquired showed no increase in pressure in the area surrounding the well, indicating that the carbon dioxide plume had not reached the monitoring well. This evidence is consistent with, and further supported by, the results of integrated laboratory analyses performed on the reservoir fluid samples collected from the well, which showed no presence of CO₂. These findings are aligned with the three-dimensional reservoir models used to describe CO₂ migration in the subsurface and the pressure increase that may result from injection activities, thereby confirming the reliability and robustness of the models.

Logs also confirmed the absence of CO₂ within the sedimentary succession above the PL2-C layer, thus providing further evidence of the safety of the storage operation and the containment capacity of the cap rock.

The second monitoring well (PCMW 20 Dir) will instead be used during 2026 to acquire saturation logs (similarly to the activities carried out in PCMW 09 Dir). Once compared with equivalent logs

⁹ Carbon dioxide is in the supercritical (or dense) phase when both its critical temperature of 31.1°C and its critical pressure of 73.8 bar are exceeded simultaneously.

acquired before the start of injection operations, these logs will provide additional data to further confirm the predictive capability and robustness of the reservoir models.

INJECTION WELL PERFORMANCES

During Phase 1, approximately 11,000 tonnes of CO₂ were injected, at injection rates ranging between 35 and 50 tonnes per day, over a total injection period of approximately 13 months. The data collected during this period enabled a positive assessment of the achievement of project objectives. In particular:

1. During injection operations, bottomhole pressure always remained well below the 240 bar safety limit established by the authorities, showing stable behaviour with no significant increase over time. This indicates that the geological formation accommodated the injected CO₂ as predicted by the reservoir models, without exhibiting resistance to injection. Temperature also remained stable throughout the injection period. These results confirm both the safety and effectiveness of the injection process. Measurements acquired in the monitoring well showed no pressure variations within the surrounding area, in line with pre-injection forecasts and consistent with expectations.
2. Analysis of the pressure data acquired during project execution allowed the assessment of injectivity (namely the ability of the well to accept the injected CO₂), permeability (the capability of the reservoir rock targeted for injection to allow CO₂ to flow through it), and any potential deterioration in the well's capacity

to inject CO₂ into the reservoir. The results were positive. The analyses confirmed the main reservoir properties, which had already been characterized through decades of production history from the field, as well as the performance of the well, both of which were found to be consistent with expectations and suitable for supporting the planned injection activities. Furthermore, as anticipated, no decline in well performance was observed over time, and the well consistently maintained a high capacity to inject carbon dioxide.

3. Well integrity monitoring was carried out continuously through the fibre-optic cable installed in the well, capable of measuring along the entire well the temperature and tracking its variations over time. The data collected showed no anomalies and confirmed both the safety of the site and the effective containment of the CO₂. Temperature was monitored throughout all project phases (before, during and after injection) and consistently displayed values coherent with the operations. The absence of anomalous variations indicates that no leakage occurred and further confirms the safety of the injection operations.

In conclusion, all the elements evaluated produced positive results, confirming the success of Phase 1 of the project. The findings demonstrate that the injection process operated within the defined limits, that effective monitoring can be successfully implemented, and that the PCMW 30 Dir B injection well delivered excellent performance throughout the project.



9. Monitoring of the subsurface and of site area



Since many years the Ravenna area, due to the presence of industrial activities and its role as an energy hub, is surveyed by continuous monitoring systems both onshore and offshore. More specifically, monitoring activities focus on ground deformations, micro seismicity and environmental parameters. Data are continuously collected by onshore and offshore sensor networks, some already in place and others newly installed. These networks allow constant monitoring of the area, verifying over time the safety of the operations and the conditions of the surrounding environment.

MICROSEISMICITY

In many areas, natural microseismic activity occurs because of normal subsurface adjustments. These phenomena are generally characterized by very low energy levels and, in most cases, are not perceived by the population and can be detected only through dedicated and very accurate instruments.

Microseismic monitoring is a fundamental tool for the real-time observation of natural subsurface seismic activity and to detect potential variations over time. Detailed temporal and spatial analyses allow to distinguish between natural events and seismicity induced by human activities, thereby supporting the management of operations.

To achieve a more comprehensive understanding of the area and to adopt a proactive monitoring approach, Ravenna CCS Phase 1 included a dedicated microseismic monitoring program aimed at demonstrating the safety of CO₂ storage, although this was not expressly required by the regulations in force at the time of authorization due to the limited scale of the project.

The main challenges of the Ravenna CCS project microseismic monitoring program were in the offshore nature of the storage site and in the absence of a pre-existing monitoring network. The area to be monitored presented accessibility limitations both offshore, for obvious reasons, and onshore, where the area overlapped with the city of Ravenna and its port district, as well as the Po river delta, characterized by water-saturated soils.

A dedicated microseismic monitoring network was therefore established, consisting of eight stations, five offshore and three onshore (Figure 12). The system began operating as early as January 2022, with the activation of the first two onshore stations. From December 2022, following the addition of the third onshore station, continuous monitoring and the localization of potential seismic events became possible. In March 2023, the network was completed with the

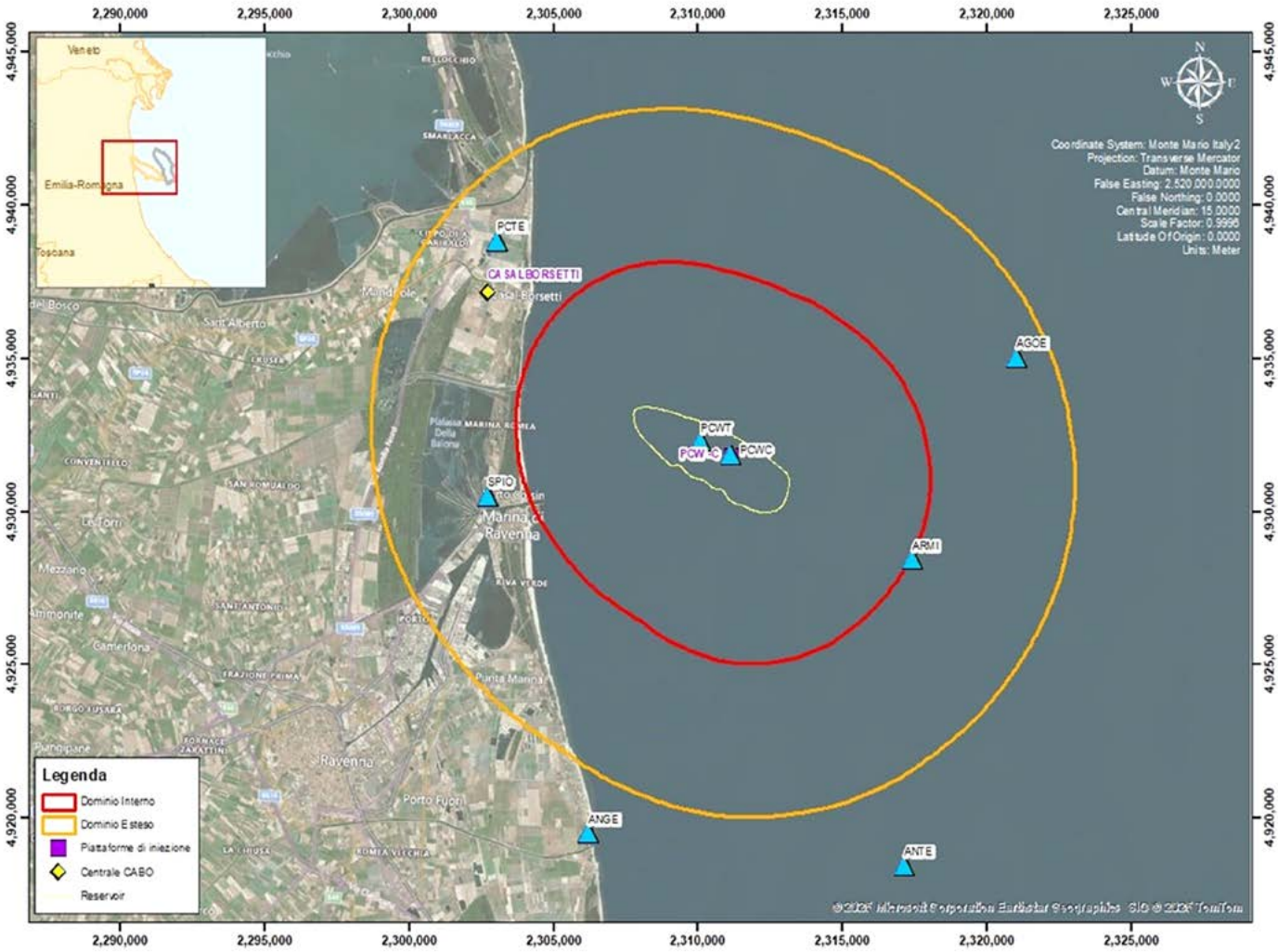
installation of the offshore stations, becoming fully operational more than one year before the start of CO₂ injection and thereby ensuring the acquisition of an adequate baseline dataset.

The design of the monitoring network, including the selection of sensors, station locations and installation procedures, was developed in accordance with the document “Guidelines and Recommendations for the Monitoring of Seismicity, Ground Deformation and Pore Pressure in Relation to Anthropogenic Activities” (ILG), issued by the Italian Ministry of Economic Development on 24 November 2014. The ministerial decree authorizing Phase 1 also explicitly required

the adoption of these guidelines for the design and implementation of the monitoring system.

The continuous data acquired by each stations are transmitted in real time to Eni’s offices in San Donato Milanese and, at the same time, to the INGV Monitoring Centre, where they are processed by INGV in its role of monitoring authority (SPM) designated by the competent authorities in accordance with ILG requirements. Data processing is performed automatically, followed by a manual review by part of a seismologist to confirm and reprocess only those signals identified as potential seismic events.

FIGURE 19: MAP SHOWING THE SEISMOLOGICAL STATIONS OF THE PORTO CORSINI MONITORING NETWORK



Monitoring activities covered the period from 2022 to 2025, including both the pre-injection phase and the CO₂ injection operational phase. The data were also independently analysed by

the Monitoring Authority (SPM - INGV), guaranteeing an additional level of oversight and transparency.

During the monitoring period, **20 local natural seismic events**¹⁰ were recorded, with magnitudes ranging from -0.3 to 2.5, values consistent with the natural microseismic activity of the area.

The monitoring results relevant to **the period before start of injection** operations confirm that **the area identified for the storage activities is characterized by low seismicity**. In fact, the municipality of Ravenna is classified as Seismic Zone 3 (D.G.R.E-R No. 1164/2018).

The monitoring results collected **during the injection period** indicate that **there was no increase in seismicity** compared with the pre-injection phase. Detailed analyses, both in terms of temporal evolution and spatial distribution, showed that the recorded events fall within the range of the **area's natural microseismic activity and are not imputable to CO₂ storage operations**.

Monitoring activities will continue until August 2026, one year after the completion of injection operations. Phase 2 of the Ravenna CCS project will be subject to a new microseismic monitoring program, whose design will also benefit from the evidence and experience gained during Phase 1.

SOIL DEFORMATION

Ground deformation monitoring is another fundamental activity whenever subsurface operations are concerned, such as the extraction or storage of fluids. In such cases, the ground may be subject to small movements: down lifts (subsidence) or uplifts. These phenomena are generally very gradual and difficult to perceive directly, but their monitoring is essential to ensure safety, sustainability of operations and protection of the environment.

The main objective of monitoring is therefore to measure ground movements over time, identify any anomalous variations and understand their causes. To achieve this, multiple technologies are used in combination, each providing complementary capabilities. In this case, the main techniques employed are:

- Continuous GNSS (permanent GPS stations);
- Satellite interferometry (InSAR);
- High-precision geometric levelling.

The combined use of these methodologies allows to obtain a comprehensive and reliable understanding of ground deformation phenomena, both at regional and local scale.

Continuous GNSS monitoring: point-based observation

GNSS (Global Navigation Satellite System) stations are instruments installed at specific locations that continuously record their position with respect to satellites. Each station can measure its elevation and position with a high degree of accuracy over time, generating time series, i.e. sequences of data showing how the position changes from day to day.

This type of monitoring has several important characteristics:

- it is continuous, enabling the trend analysis over time;
- it is highly accurate, with a sensitivity of a few millimeters;
- it provides three-dimensional information (vertical and horizontal movements).

Time series analysis allows to calculate the average ground movement rate (e.g. millimeters per year), a key parameter for assessing whether the observed behaviour is stable or evolving over time.

The main limitation of this technique is that measurements are point-based, as they only refer to the locations where stations have been installed. For this reason, it is necessary to complement GNSS monitoring with other methodologies capable of observing larger areas.

InSAR: observing ground movements from space

InSAR (Interferometric Synthetic Aperture Radar) is a satellite-based remote sensing technique that uses radar images acquired by orbiting satellites to measure ground surface displacements.

The technique is based on the comparison of satellite images acquired at different times, making it possible to measure ground displacement time series with millimetre-level precision.

This methodology offers several important advantages:

- It provides coverage over very large areas (tens or hundreds of square kilometres).
- It enables the measurement of ground displacements with millimetric accuracy.
- It allows the analysis of long time periods, spanning years or even decades, using satellite data archives.

InSAR measurements are most reliable over stable features that provide strong radar backscatter, such as buildings, infrastructure and other man-made structures. These features act as persistent radar targets, enabling highly accurate displacement measurements.

Levelling: maximum accuracy at control points

Geometric levelling is a traditional technique that remains highly important today. It consists of measuring elevation differences between points along a network of benchmarks distributed across the area using optical/digital instruments.

This methodology has several distinctive characteristics:

- it provides very high vertical accuracy;
- it is especially reliable to compare repeated measurements over time;
- it allows to establish a highly robust baseline.

¹⁰ Local events are defined as those occurring within the monitoring network or at a distance not exceeding 10 km from the nearest monitoring station.

Measurements are carried out through periodic survey campaigns, for example at multi-year intervals. By repeating the same measurements at the same locations over time, it is possible to calculate the rate of ground subsidence or uplift.

The main limitation of levelling is that it requires field operations and therefore covers smaller areas with respect to satellite-based techniques. However, owing to its high accuracy, it plays a fundamental role in validating and complementing data obtained from other monitoring methods.

Objectives of ground deformation monitoring

The objective of ground deformation monitoring is the interpretation of the observed phenomena, enabling verification that ground movements are consistent with expectations,

identifying any anomalies, and providing information to support operational and safety decisions.

Results for Ravenna CCS Phase 1

Ground deformation monitoring within the Ravenna CCS Phase 1 project involved the analysis of data collected from a Continuous GNSS network consisting of 14 stations (9 installed on offshore platforms and 5 located onshore), InSAR satellite interferometry covering the area of interest and high-precision levelling surveys conducted along a network extending for approximately 250 km.

The main results indicate **ground deformation patterns consistent with the natural dynamics** of the area, with **no variations imputable to the injection of CO₂ into the subsurface**.

FIGURE 20: DISTRIBUTION OF THE CONTINUOUS GNSS MONITORING STATIONS WITHIN THE PROJECT AREA (left) LOCATION OF THE BENCHMARKS OF THE HIGH-PRECISION LEVELLING NETWORK (right)

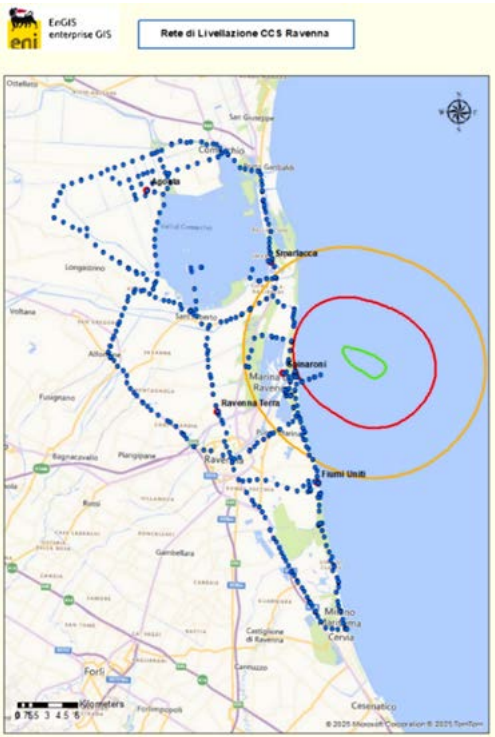
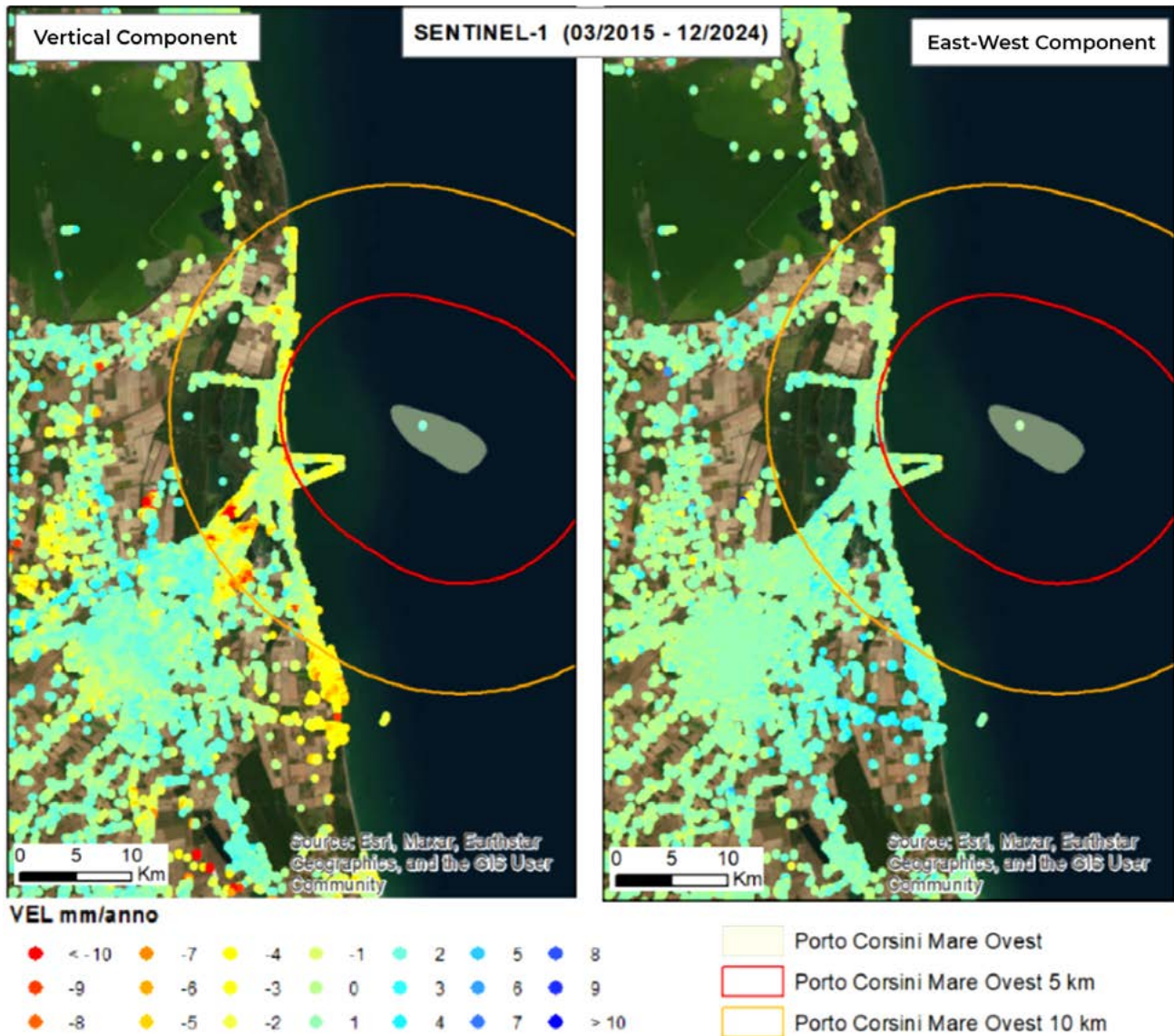


FIGURE 21: INSAR-DERIVED GROUND DEFORMATION MAP OF THE AREA OF INTEREST



10. Environmental monitoring



The Environmental Monitoring Plan (Piano di Monitoraggio Ambientale - PMA) for Ravenna CCS Phase 1 enabled the investigation of all environmental factors, both onshore and offshore, including air, water, soil, and marine biota (i.e. local animal, plant, and microbial communities). The monitoring activities were designed to analyse the main physicochemical and biogeochemical environment characteristics and assess their evolution over time, with the aim of ensuring proper execution of CO₂ injection operations.

Onshore environmental monitoring primarily focused on the accurate measurement of atmospheric emissions, through both continuous and periodic monitoring programs, some of which were already in place as part of the routine operation of the Casalborgorsetti gas processing plant. To ensure the monitoring of all parameters required according to the project authorization, additional instruments to measure both the flow rate and composition of the injected CO₂ were installed across the entire CCS value chain. Furthermore, for the capture plant specifically, continuous monitoring of the most

significant operating parameters was implemented through a Continuous Emissions Monitoring System (CEMS). This monitoring system was installed at the top of the column constituting the new emission point (CCS stack), from which the flue gases, after being relieved of most of their CO₂ content, were released into the atmosphere. During operation of the capture plant, this stack replaced the emission stack normally used for the exhaust gases from the TK-04 turbo-compressor.

Offshore environmental monitoring is carried out through a combination of multidisciplinary studies that include:

- geophysical surveys of the seabed and water column;
- acoustic measurement campaigns to monitor and quantify bubble seepages from the seabed, a phenomenon that naturally occurs in the Adriatic Sea as a result of the decomposition of organic matter on the seafloor;
- chemical and biological analyses of the water column, sediments, and biota;
- environmental risk modelling and assessment.

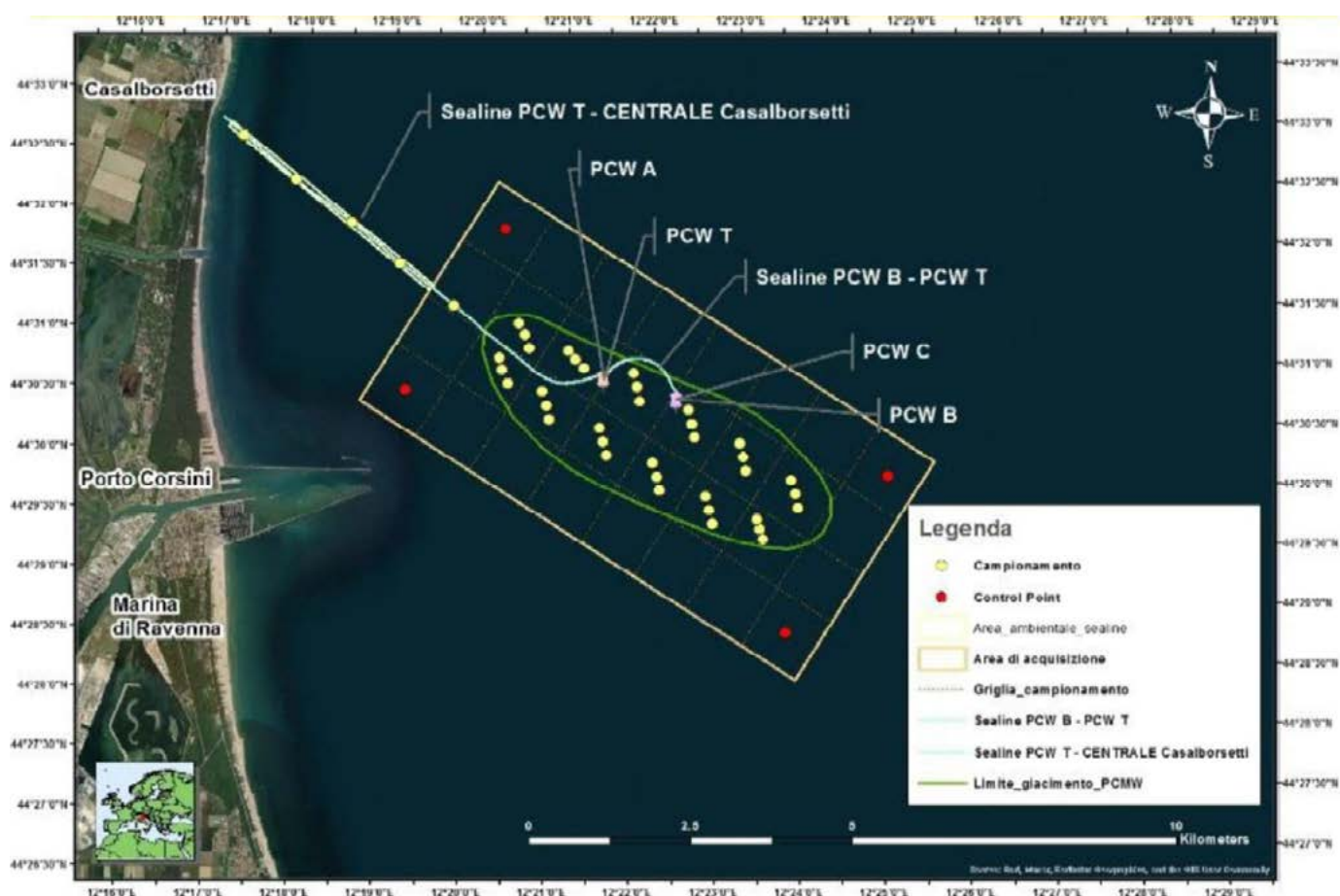
The preparation and implementation of the Marine Environmental Monitoring Plan benefited from the collaboration and specialist expertise of several inter-university scientific and technical departments, as well as the National Research Council (CNR).

The Marine Environmental Monitoring Plan was designed to cover the whole duration of Ravenna CCS Phase 1 (before, during, and after CO₂ injection operations) and was scheduled to measure the natural seasonal variability of the monitored parameters. The monitored area

is not limited to the reservoir itself but extends beyond the storage site boundaries, including the entire CO₂ transport pipeline route. Totally, 49 monitoring campaigns have already been carried out (on the 2023-2025 period), and post-injection monitoring activities are planned to continue until August 2026.

Phase 2 of the Ravenna CCS project will be supported by a dedicated monitoring plan, which will leverage the evidence and experience gained during Phase 1.

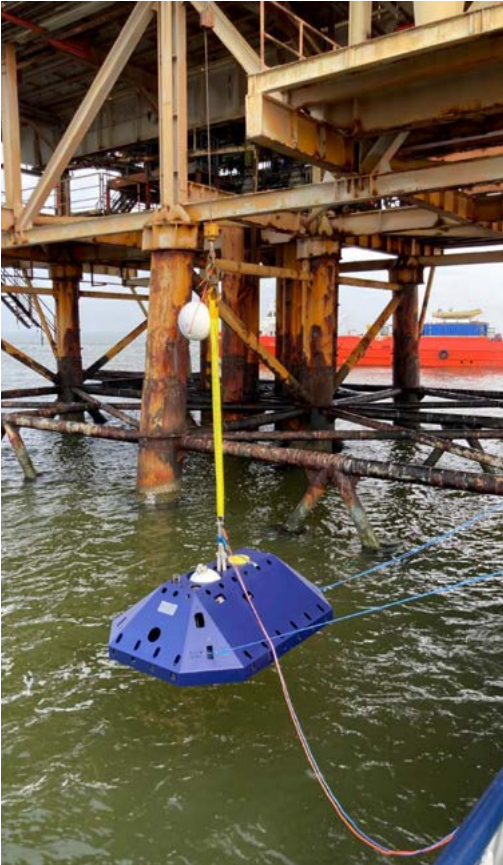
FIGURE 22: MAP OF THE OFFSHORE SAMPLING LOCATIONS



Sampling activities are carried out at regular intervals by meshing the area into elements within which sampling stations were identified. The layout shown in Figure 22 was designed to monitor the physicochemical characteristics of the water column, sediments, and marine biota, with particular attention to areas where previously abandoned wells are present. This integrated approach allows to directly correlate the different parameters and, at the same time, to analyse their variability across different periods of the year.

In addition to the periodic sampling campaigns, a fixed monitoring station known as the “CCS Lander” was installed. This system was specifically designed to continuously monitor the main oceanographic, acoustic, and physicochemical parameters of the water column, aiming to detect periodic fluctuations of the data acquired. The instrument was installed near the connection point between the CO₂ transport pipeline and the platform, in proximity to the injection well.

FIGURE 23: CCS LANDER USED FOR CONTINUOUS SEABED MONITORING



RESULTS FOR PHASE 1 MONITORING

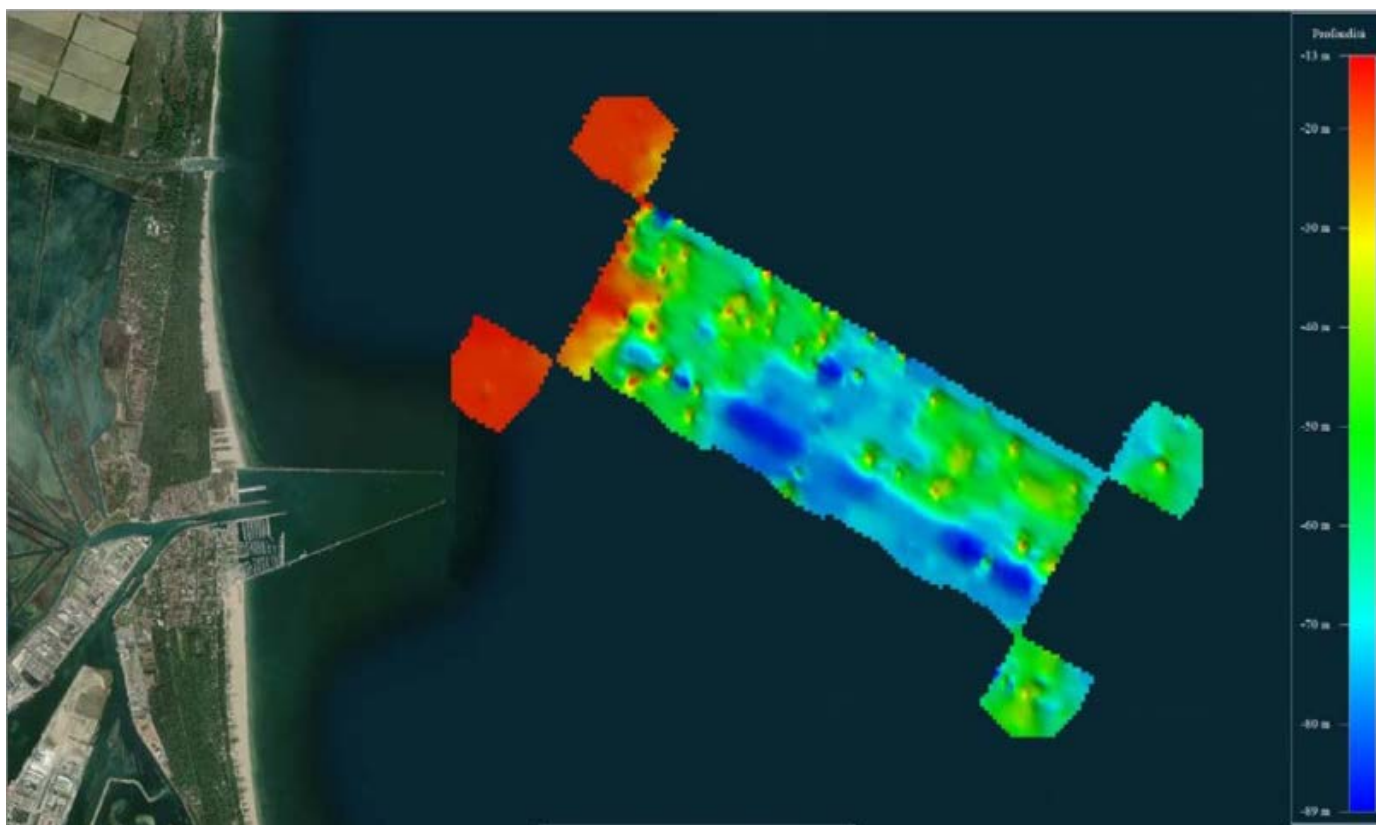
Geophysical and acoustic surveys of the water column and seabed

Periodic surveys were carried out across the entire offshore area covered by the project using geophysical and acoustic instrumentation capable of reconstructing seabed morphology and of detecting, within the water column, signals associated with low-level gaseous emissions naturally released from the superficial sediments. This is a natural phenomenon related to the decomposition of organic matter part of it transported by rivers, deposited on the seabed. Before being released from the

sediments into the water column, these gases accumulate within the pore spaces of the most superficial layers of sediment (Figure 24). These biogenic emissions, which naturally vary over time and across different locations, were monitored periodically to identify any increase potentially associated with fluid migration from the PCMW reservoir.

The analysis of the data acquired through acoustic surveys of the seabed geomorphology indicates that no alterations imputable to the CO₂ injection operations have occurred. The results also confirm that the monitoring methodologies adopted constitute an effective monitoring technique.

FIGURE 24: REPRESENTATION OF THE MORPHOLOGY OF THE UPPER SURFACE OF BIOGENIC GAS ACCUMULATIONS WITHIN THE SEABED SEDIMENTS



The colour scale indicates the depth of the upper boundary of these gas accumulations.

Physicochemical and biogeochemical investigations of the water column and sediments

The results of the physicochemical analyses carried out on the water and sediment samples showed no significant variations other than those associated with seasonal cycles

and the variability of discharge regimes of rivers whose outlets are located along the coastal area in proximity to the project site. The results obtained also demonstrate the capability of monitoring techniques to detect local variations in the observed parameters.

FIGURE 25: WATER COLUMN SAMPLING OPERATIONS – COURTESY OF THE NATIONAL RESEARCH COUNCIL (CNR)

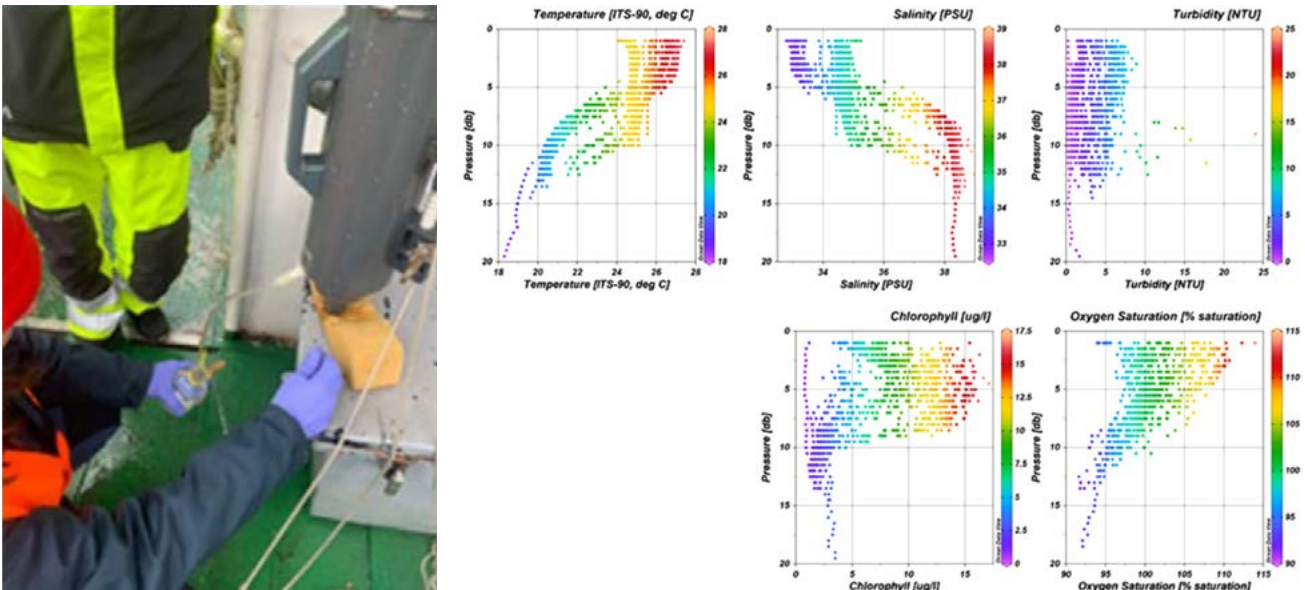
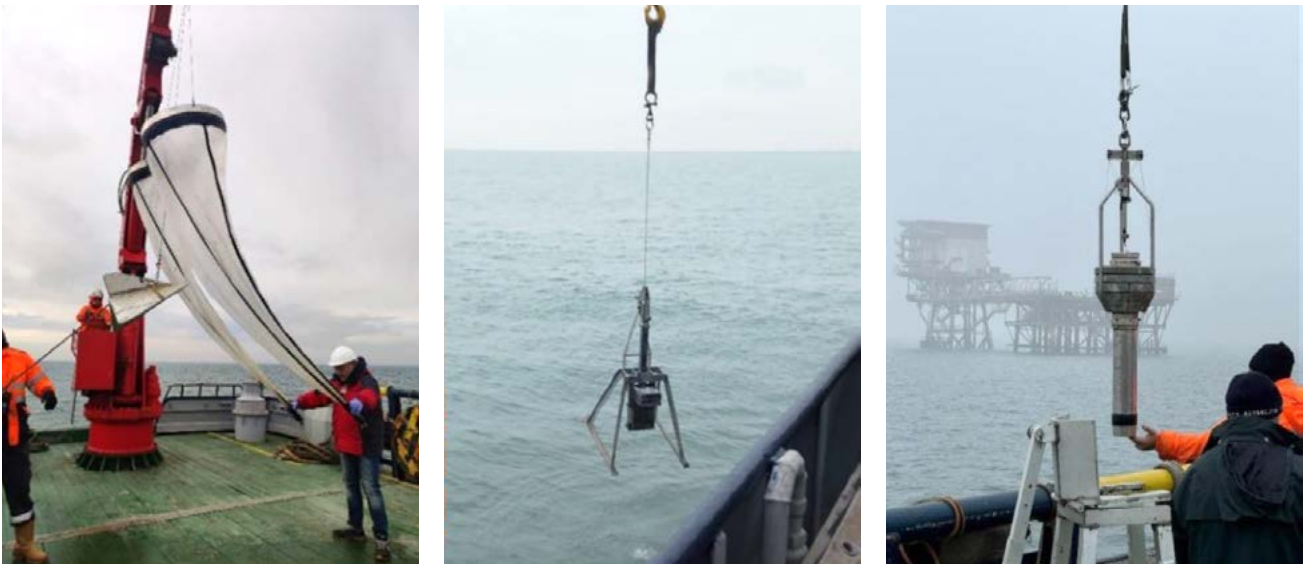


FIGURE 26: WATER AND SEDIMENT SAMPLING OPERATIONS USING A BONGO NET, A BOX CORER, AND A SW104 SHORT GRAVITY CORER



Marine biota investigations

Regarding the marine biota status, no significant variations were observed other than those associated with seasonal cycles and the natural adaptation dynamics of microflora, microfauna, and fish communities, whose overall structure remained consistent with the typical dynamics of Adriatic coastal environments. The final Environmental Risk Assessment Report, which analyses the findings of the marine biota surveys conducted before and during the CO₂ injection activities, states the following:

“In the overall assessment, it should be considered that the entire study area is located within a coastal environment characterized by substantial variability in environmental conditions, influenced by both anthropogenic pressures (e.g. maritime traffic) and natural factors (e.g. shallow water depths, river inputs, storm events, etc.). Overall, the variations observed in the metrics analysed during the operational phase fall within the natural seasonal dynamics of coastal fish communities and cannot be attributed to the CO₂ injection activities.”

FIGURE 27: DEPLOYMENT OF THE BENTHIC CHAMBER AND CHARACTERIZATION OF THE BENTHIC COMMUNITY.
Image courtesy of the National Research Council (CNR)



Environmental risk assessment and monitoring effectiveness evaluation

All the collected evidence leads to the conclusion that the monitoring activities carried out are effective in assessing the environmental footprint of CO₂ injection and storage operations. The monitoring results do not indicate any CO₂ leakage, nor any significant alterations to biological communities, and the observed variations are due to natural processes or to local anthropogenic activities different from CO₂ injection. In its final Environmental Risk Assessment Report, which analyses the results of all marine environmental monitoring campaigns conducted before

and during the CO₂ injection period, the following conclusion is reported:

“In conclusion, the analysis of the monitoring activities carried out, together with the reprocessing and comparison of the related results, has fully demonstrated the effectiveness of the sampling methodologies, the instrumental approach, and the monitoring schedule. This leads to the conclusion that the monitoring activities performed are effective in assessing the environmental footprint of injection and storage operations [...] and that such footprint is currently negligible or non-existent.”

11. Conclusions



Ravenna CCS project is Italy's first industrial-scale CCS project, developed through an equally own joint venture between Eni and Snam to provide Italian and European industries a competitive and readily deployable solution for the decarbonisation of industrial activities. The project involves the permanent geological storage of carbon dioxide in the depleted Porto Corsini Mare Ovest (PCMW) and Porto Garibaldi-Agostino (PGA) reservoirs, located offshore the Ravenna coast. The stored carbon dioxide will primarily come from third-party industrial emitters in Italy and across Europe. Storage activities are intended exclusively for emissions mitigation purposes and will not be associated with any natural gas production activities.

Phase 1 of the project started in August 2024, and CO₂ injection operations were completed in August 2025, with all planned objectives successfully achieved. The purpose of this phase was to demonstrate, at the small industrial scale and thanks to the acquisition of operational data and experience, the feasibility of the CCS process, its safety, and the capability to effectively monitor both the facilities involved and the surrounding environment. Ravenna CCS Phase 1 also played a key role in promoting awareness and understanding of CCS among its future users, an

essential factor for the development of a new market dedicated to the decarbonisation of industrial activities.

Looking in deeper detail at the infrastructure involved in Phase 1, **the main results achieved** can be summarized as follows.

More than 16,000 tonnes of carbon dioxide were captured from the flue gases of one of the turbo-compressors at the Casalborsetti natural gas processing plant. Despite the challenging capture conditions, with low CO₂ concentration in the flue gas (2.3-2.5%), the plant delivered excellent performance: **the average capture efficiency reached 91.9%, with peaks of up to 96%**. Impurity levels in the CO₂ stream remained consistently well below the limits established by the transportation specification, while CO₂ **purity** was always **above 99%** by volume. The plant operated with continuity, considering the need for some scheduled maintenance shutdowns, activities at the Casalborsetti facility, and other causes unrelated to injection, storage, or CO₂ leakage issues.

The transportation of CO₂ from Casalborsetti to the injection well through an approximately 11 km long repurposed pipeline was carried out regularly and in accordance with the planned operating

conditions. The modelling tools applied were proved capable of accurately predicting the behaviour of the transported gas and of forecasting pressure and temperature conditions that, during the winter season, could have resulted in CO₂ condensation within the pipeline. This made it possible to implement, in a timely manner, the appropriate operational strategies that had been defined during the design phase.

Storage operations were successfully carried out in the depleted Porto Corsini Mare Ovest reservoir (PL2-C layer), which was selected following detailed geological, structural and fluid-dynamic studies. Continuous reservoir monitoring through pressure and temperature sensors, together with the fibre-optic cable installed along the entire wellbore and complemented by periodic well surveys (well logs), **confirmed the effectiveness and safety of the injection, as well as the integrity of both the injection well and the cap rock. This was further demonstrated by the substantial margin maintained between the injection pressure and the maximum pressure limit established by the authorities (240 bar).** The data collected in the field also made it possible to validate the accuracy of the reservoir predictive models. Ravenna CCS Phase 1 has been, and continues to be, subject to a comprehensive **program of environmental, subsurface and reservoir monitoring activities**, both during operations and throughout the pre-operational and post-operational phases, to demonstrate the safety of CO₂ storage operations. These monitoring activities have been carried out in collaboration with the competent authorities, including the Italian Institute for Environmental Protection and Research (ISPRA) and the National Institute of Geophysics and Volcanology (INGV), and with the support and expertise of the National Research Council (CNR), and scientific and technical

departments of several universities. The monitoring program **confirmed the proper execution of operations and the effective containment of CO₂ within the reservoir. At the same time, no impacts due to the injection activities were detected in the surrounding environment.** Monitoring activities will continue until August 2026.

The subsurface was monitored through a **microseismic network** composed of eight stations, which **confirmed that the storage area is characterized by low seismicity** and that **injection activities did not result in any microseismic activity increase** compared with the pre-injection period. The events recorded by the monitoring network fall within the range of the area's natural microseismic activity (generally below the threshold of human perception) and are not imputable to CO₂ storage operations.

Ground deformation monitoring also confirmed that the combined analysis of data from the GNSS network (14 stations), InSAR satellite interferometry, and the approximately 250 km high-precision levelling network revealed **ground movement patterns consistent with the natural dynamics of the area, with no variations due to CO₂ injection into the reservoir.**

Finally, the **marine environmental monitoring program** combined different techniques, including geophysical surveys of the seabed and water column, acoustic measurement campaigns, and chemical and biological analyses of water, sediments, and marine biota. **The activities carried out during Phase 1 demonstrated** the effectiveness of the monitoring techniques employed and **did not identify any impacts on the marine environment related to CO₂ injection operations.**

