

SCREENING FOR CO₂ STORAGE SITES IN CONTINENTAL EUROPE

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E.U. net zero targets and the role CCS must play

In the EU, the Net-Zero Industry Act (NZIA) has set ambitious decarbonization targets for 2030 which further underlines the need for Carbon Capture and Storage (CCS). As part of this policy, the target set for CCS is to reach 50Mtpa (million tonnes of CO₂ captured and permanently stored per annum) within the next 14 years. To reach this objective, deep geological storage of CO₂ is seen as the ultimate solution. Last year, the EU Commission imposed the target on oil and gas exploration/production companies as a way to offset the volume of fossil carbon extracted through their activities. These companies happen to have the experience and resources required for drilling and operating deep wells that is similar to what is required for CO₂ storage. In continental Europe, away from the maturing North Sea storage hubs, industrial CO₂ emitters are faced with a dilemma about where the captured CO₂ should be stored: is it more efficient and cost-effective to transport the CO₂ over long distances for storage at one of the North Sea hubs? Or is there a competitive local solution? Countries in mainland Europe are putting legislation in place to support and regulate onshore storage of CO₂, hence enabling the local storage solution.

Viridien's carbon storage screening studies have been utilized globally to help screen at both the regional and basin scale, including South-East Asia (Shepherd et al. 2024) and more recently over continental Europe. To assess areas for their carbon storage suitability, these subsurface screening workflows rely mainly on a rich legacy digital geological database, built on decades of fieldwork, subsurface studies, data collection and transformation. This database facilitates cross-border screening, limiting any inconsistency arising from country-specific data methods, formats or data vintages. Use of this consistent database to create screening studies ensures they contain quality-controlled data and significantly reduces the time taken by optimizing data harvesting and allowing direct focus on key subsurface risk factors. The approach presented here aims to provide a single workflow across the basins of continental Europe to identify, select, map and rank the best storage plays.

From regional to local scale

Using the legacy digital geological database together with the latest public domain information, a series of regional filters were applied, including water depth, seismicity, volcanicity and sediment thickness. Here are the main principles that were applied:

- **Water depth** – Cut-off at 200m maximum water depth. Anything deeper was considered too deep and out of reach for standard jack-up rigs
- **Seismicity** – Avoid areas where historical earthquakes are clustered
- **Volcanicity** – Avoid areas where historical volcanism is present
- **Sediment thickness** – Regional mapping of basin sediment thicknesses, ensuring a cut-off below 1000m to make sure there is sufficient overburden to maintain CO₂ in supercritical condition (at hydrostatic pressure) and for effective containment

Using country borders and the separation between offshore and onshore domains, these filters were used to map a total of 225 basin sectors across continental Europe, of which 140 were not included due to limiting factors.

Following this initial step, basin-sectors were ranked against an additional set of parameters considered important to maximize carbon storage efficiency (Bachu 2003), including areal extent, leakage risk, geothermal regime, exploration maturity (e.g. wells and hydrocarbon field density), as well as surface accessibility factors such as environmental restrictions, population density, emission site locations, distance to ports (for potential CO₂ import/export) and transport networks. A simple weighted scoring enabled the best basin-sectors to pass through to a subsurface play analysis. By 'play' (i.e. aquifer store) we mean a reservoir rock coupled with cap rock (or top seal) present over the larger part of a sedimentary basin.

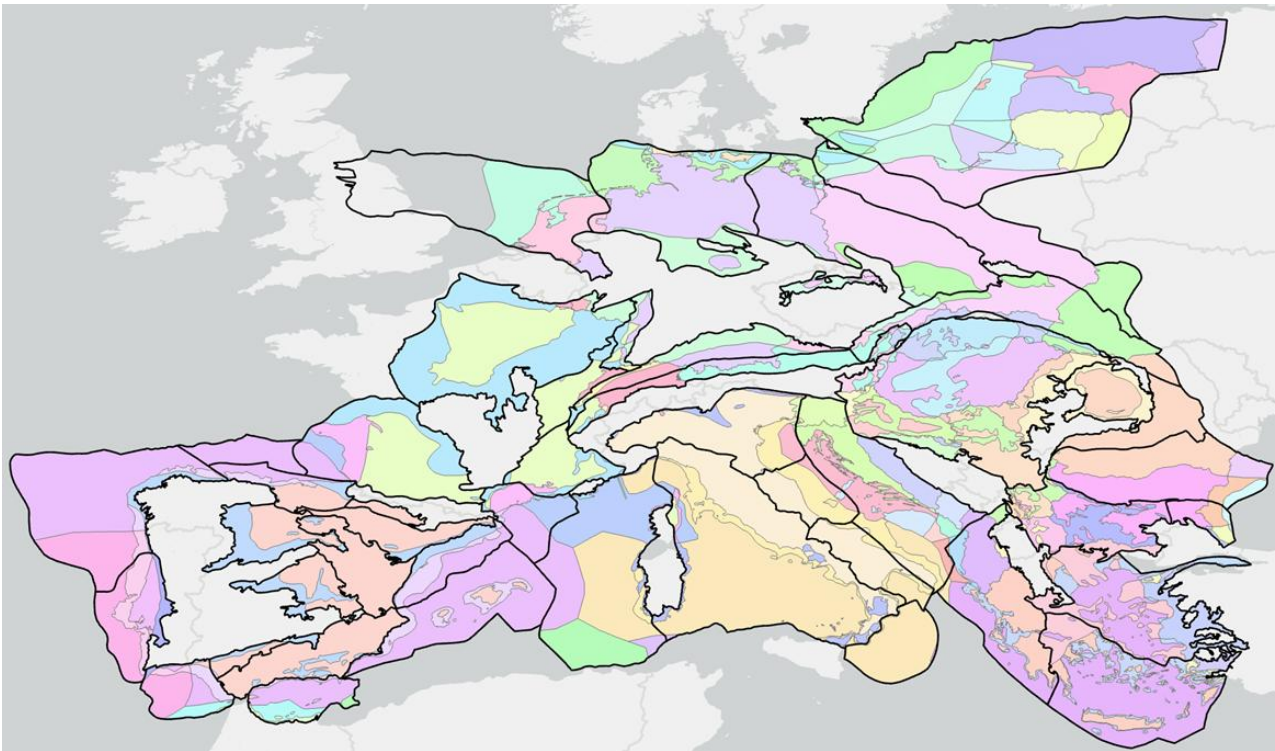


Figure 1 – Basin sectors across continental Europe assessed in the study. Sectors are divided by country, onshore/shelf and sediment thickness >1000m. (Image courtesy of Viridien).

Looking more closely at one of the key subsurface factors, Figure 2 shows an example of the mapping carried out for the geothermal regime factor. We generally prefer cool geothermal regimes over warm ones for CO₂ storage because temperature directly affects CO₂ density, phase behavior, storage efficiency, and containment security. Here is a breakdown of the reasons why:

- 1- **More storage capacity** - At lower temperatures, CO₂ is denser, which means more mass of CO₂ can be stored in the same pore volume and better storage efficiency can be achieved
- 2- **Lower pressure requirements** - For optimal storage behavior, CO₂ must be kept in supercritical phase (>31°C and >7.38MPa). In cooler geothermal conditions, reaching and maintaining this state requires less extreme pressure conditions compared to hotter systems, which makes storage site engineering and operations easier
- 3- **Improved caprock integrity** – Higher temperatures can increase chemical reactions between CO₂, brine and rock, and potentially weaken caprock through mineral alteration or dissolution. However, cooler subsurface conditions slow down these reactions and help preserve geological seal integrity, which reduces the risk of leakage
- 4- **Greater trapping through greater CO₂ viscosity** – In cooler conditions, CO₂ tends to have higher viscosity, which reduces its mobility. This leads to more efficient residual trapping and less risk of CO₂ migrating rapidly through the formation
- 5- **Reduced buoyancy effects** – Warmer CO₂ is less dense, more buoyant and rises faster, whilst cooler CO₂ is denser and less buoyant relative to formation fluids. This means there is a lower tendency for CO₂ to migrate upwards towards (and/or through) the caprock
- 6- **Better control on injectivity rates** – High temperature accelerates mineral dissolution and precipitation reactions. This can change permeability and create uncertainty around injectivity rates and storage performance overall. Cooler systems are more stable and offer more predictable behaviour in the long term
- 7- **Thermal stress and mechanical stability** – Injecting CO₂ into a warmer reservoir can create strong temperature gradients. This may induce fractures and affect wellbore or formation integrity. Cooler geological formations offer reduced thermal stress risks

For all those reasons, time was spent on extraction of all useful data points to produce a map of geothermal regimes across continental Europe, as seen in Figure 2. The same level of work was carried out on the other parameters cited earlier and combined to rank the basin sectors.

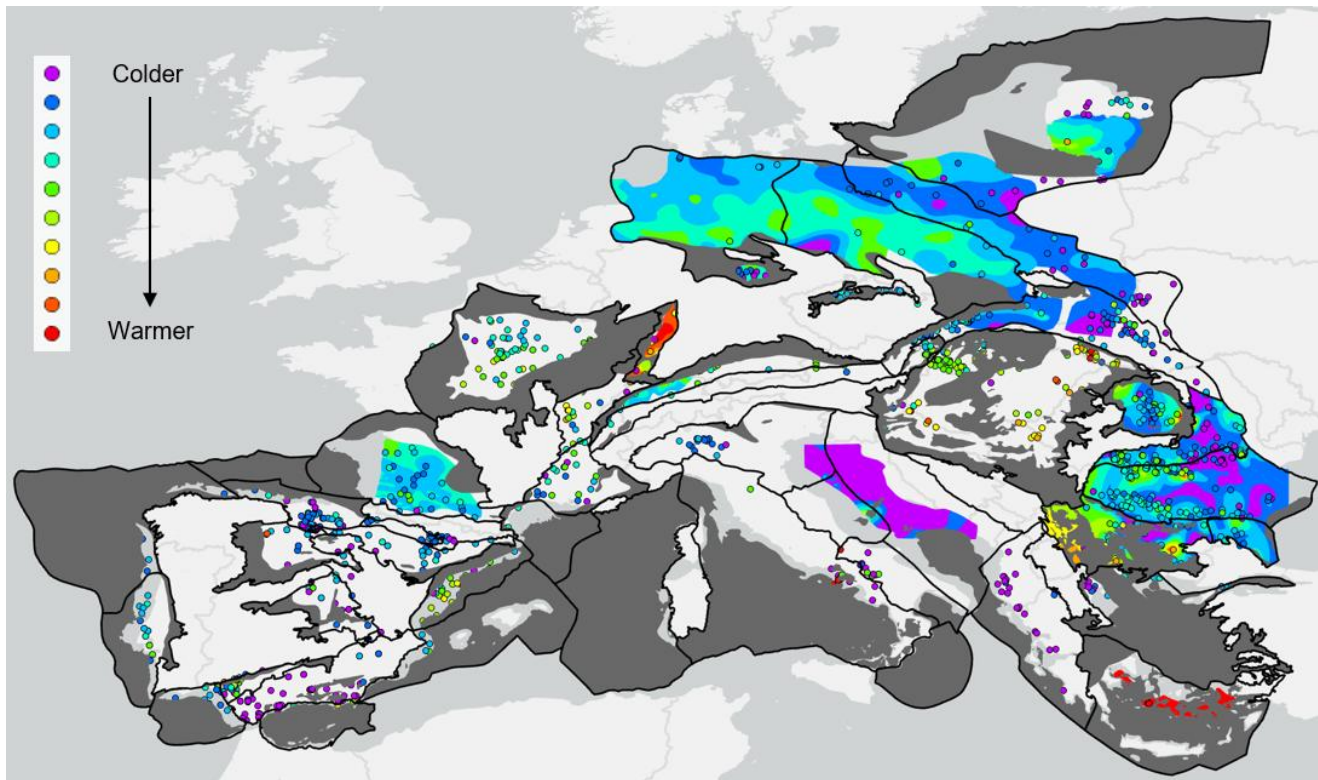


Figure 2 – Map compiled from Viridien's digital geological database showing variations in geothermal regimes across Europe. (Image courtesy of Viridien).

With the mapping and ranking of basin sectors completed, the best candidates were put through the final phase of the regional screening workflow, which meant identifying, inventorying and ranking individual aquifer opportunities. Each of these was assessed and scored on lithology, reservoir facies, depth, area, reservoir properties and seal thickness, using internally developed cut-offs and scores.

The final screening outputs identified subsurface aquifers with storage potential, which can now be used to prioritize CO₂ emission sites in an industrial sites portfolio for CCUS investment, or to focus in on an individual emission location to narrow down potential areas for further investigation.

Screening for local storage opportunities

Once an area with potential for a storage hub has been identified or when an isolated capture site requires a nearby storage solution (e.g. within a radius of 20-40km), the next step usually requires additional, detailed subsurface data (seismic and well data) to refine the subsurface analysis and delineate an area for potential storage license application. This example looks at the Bohemian Basin in the Czech Republic, where historic exploration efforts have focused on coal mining on the basin margins. Interpretation of well log and sparse 2D seismic data from the Czech Geological Survey, integrated with information derived from public domain references enabled the construction of individual property maps for the identified aquifer of interest, comprising:

- Aquifer Gross Depositional Environment (GDE) and lithology
- Top depth-structure
- Aquifer porosity, permeability and net thickness
- Aquifer temperature
- Seal GDE and lithology



- Seal thickness

These maps use categories defined by Duval et al. (2022) and Callas et al. (2024) and were then combined into storage potential maps with associated first-pass capacity estimates.

Note that this workflow focuses on subsurface static parameters, whilst the final modeling phase (not presented here) focuses on a preliminary 3D dynamic CO₂ plume model to support a future storage permit application and delineate its extent. This is also used to define a suitable subsurface work programme and storage site monitoring plan (likely including 3D seismic data acquisition) recently covered by Duval and Kent (2026) in a separate white paper.

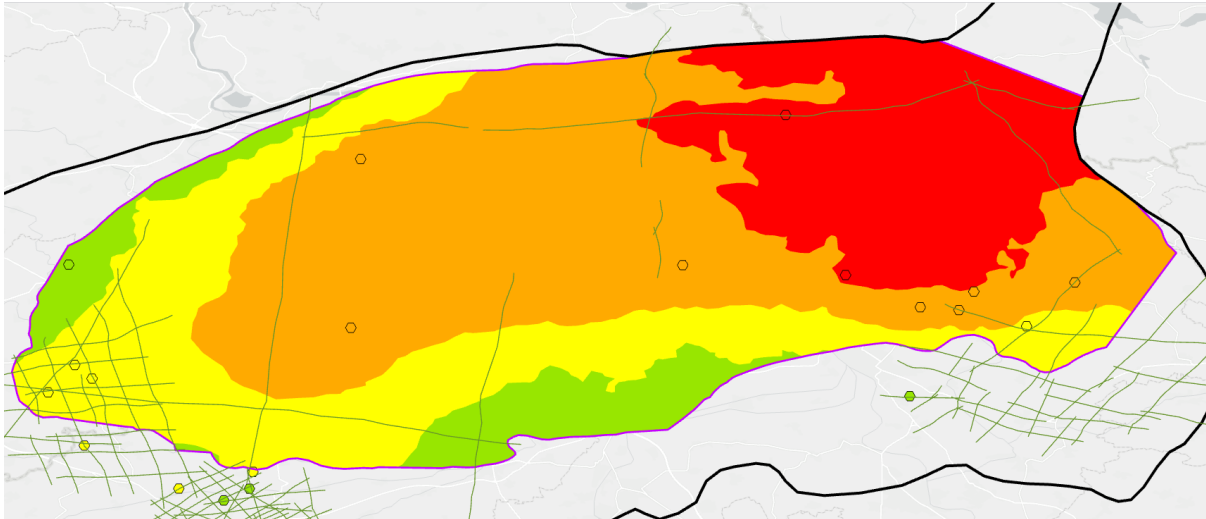


Figure 3 – Interpreted categories for aquifer permeability covering part of the Bohemian Basin, showing an increase from red (poor) to green (good) strongly correlated to porosity and depth changes. The map also shows available seismic lines (green) for subsurface calibration and well data (hexagons). (Image courtesy of Viridien).

Accelerating the development of onshore CCS projects in Europe

A sound screening methodology, from regional scale to local scale, built on a rich, robust and globally consistent geological database helps storage developers and CO₂ emitters quickly focus on the analysis of key storage parameters for rapid and sound business decisions and prioritization of opportunities in a CCS investment portfolio. It enables the rapid and cost-effective identification of areas of high potential for suitable storage sites. It aims to support, accelerate and increase CO₂ storage permit applications in continental Europe and around the world, ensuring CCS project lead times are decreased and that it plays its expected role in achieving net-zero 2050, including the NZIA 2030 milestone targets.