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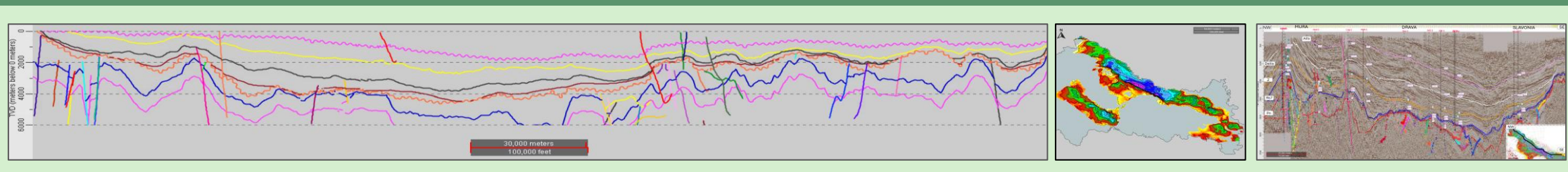
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Croatian Hydrocarbon Agency

# Croatian CO<sub>2</sub> Storage Atlas *Onshore*

## Executive Summary



## 1. Introduction

The Onshore Croatia CO<sub>2</sub> Storage Atlas provides a comprehensive technical evaluation of the country's geological potential for carbon capture and storage (CCS), forming a critical component of Croatia's contribution to regional and European decarbonization efforts. The objective of this evaluation is to assess the feasibility, scalability, and maturity of CO<sub>2</sub> storage opportunities across the Croatian sector of the Pannonian Basin, focusing on both deep saline aquifers and depleted hydrocarbon fields as primary storage targets. The study aligns with broader European Union climate policy frameworks, including the Net-Zero Industry Act and initiatives aimed at industrial decarbonization, where CCS is recognized as an essential solution for hard-to-abate emissions.

The CCS value chain, encompassing capture, transport, storage, and monitoring, is increasingly being deployed at commercial scale across Europe. Croatia is positioned to enter this phase of development, supported by existing subsurface data, legacy hydrocarbon infrastructure, and proximity to industrial CO<sub>2</sub> emitters. The Atlas consolidates decades of geological and geophysical data to provide a consistent framework for identifying and ranking storage opportunities, and for guiding investment and policy decisions in the transition to a low-carbon economy.

## 2. Emissions Profile and CCS Demand

Croatia's CCS potential is strongly influenced by its emissions profile, which is characterized by industrial point sources located predominantly within or near the Pannonian Basin. These include ammonia production, bioethanol facilities, and other industrial operations capable of generating high-purity CO<sub>2</sub> streams suitable for capture. Existing pilot projects at the Petrokemija ammonia plant and the Sisak bioethanol facility together demonstrate capture capacities exceeding 240,000 tonnes of CO<sub>2</sub> per year, highlighting early-stage deployment readiness. In parallel, operational experience from the Molve Gas Treatment Plant, where approximately 0.65 MtCO<sub>2</sub> per year has been successfully injected and retained in subsurface formations, provides robust technical validation for long-term storage.

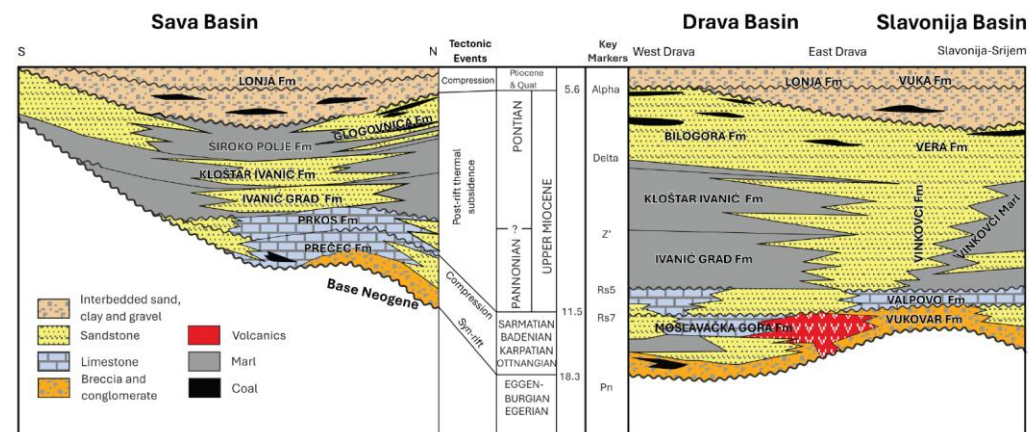
Future CCS development in Croatia is expected to scale significantly, with current and planned projects targeting a combined capacity of approximately 1.9 MtCO<sub>2</sub> per year. A critical advantage is the spatial alignment between emitters and storage sites, with most industrial sources located within 25–30 km of potential geological sinks. This proximity minimizes transport requirements and supports the development of cost-effective cluster-based CCS systems, similar to those implemented in other European regions.

## 3. Geological Framework and Storage Potential

### 3.1 Basin Characteristics

The Croatian sector of the Pannonian Basin represents a mature sedimentary basin with a complex tectonic evolution and significant accumulations of Neogene sediments. The basin is subdivided into the Drava, Sava, Mura, and Slavonia sub-basins, each presenting distinct geological characteristics relevant to CO<sub>2</sub> storage. Structural trends are controlled by regional tectonics, with dominant fault orientations influencing reservoir distribution, connectivity, and potential containment integrity.

Reservoir formations within the basin comprise a combination of sandstones, carbonates, conglomerates, and fractured basement rocks, overlain by sealing lithologies such as marls, shales, and evaporites. The presence of multiple tectonostratigraphic sequences, including pre-rift, syn-rift, and post-rift deposits, creates a vertically stacked system of potential reservoir–seal pairs, enhancing overall storage capacity.



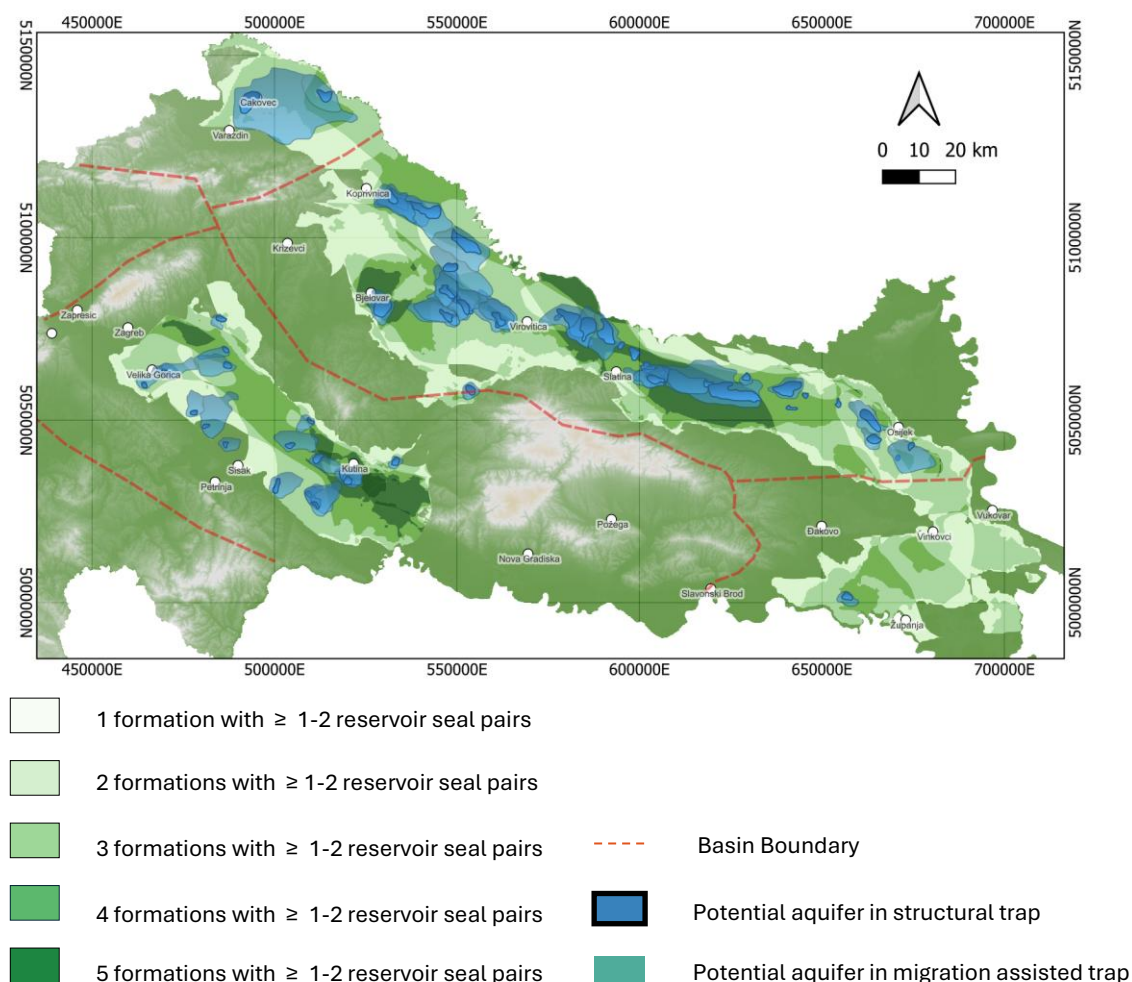
**Figure 1.** Summary lithostratigraphic diagram for the Sava, Drava and Slavonia basins (adapted from Saftić et al. 2003) showing the main formations that have been assessed in this CO<sub>2</sub> Storage Atlas. Saftić, B., Velić, J., Sztanó, O., Juhas, G., and Ivković, Ž. 2003. Tertiary subsurface facies, source rocks and reservoirs in SW Pannonian Basin. *Geologia Croatica* 56: 101–122.

### 3.2 Storage Types and Resources

The evaluation focuses on two principal storage options: deep saline aquifers and depleted oil and gas fields. Saline aquifers offer large theoretical storage capacities but are comparatively less well characterized, whereas EPU provide higher confidence due to extensive production data and proven containment of hydrocarbons over geological timescales.

Among the evaluated basins, the Drava Basin demonstrates the most favourable conditions, characterized by significant sediment thickness, high-quality reservoir-seal pairs, and extensive data coverage (Figure 2). The Sava Basin presents moderate potential with relatively good distribution of storage opportunities, while the Mura Basin offers localized but promising targets, particularly within deeper stratigraphic intervals. The Slavonia Basin is comparatively constrained by limited data and reduced reservoir continuity.

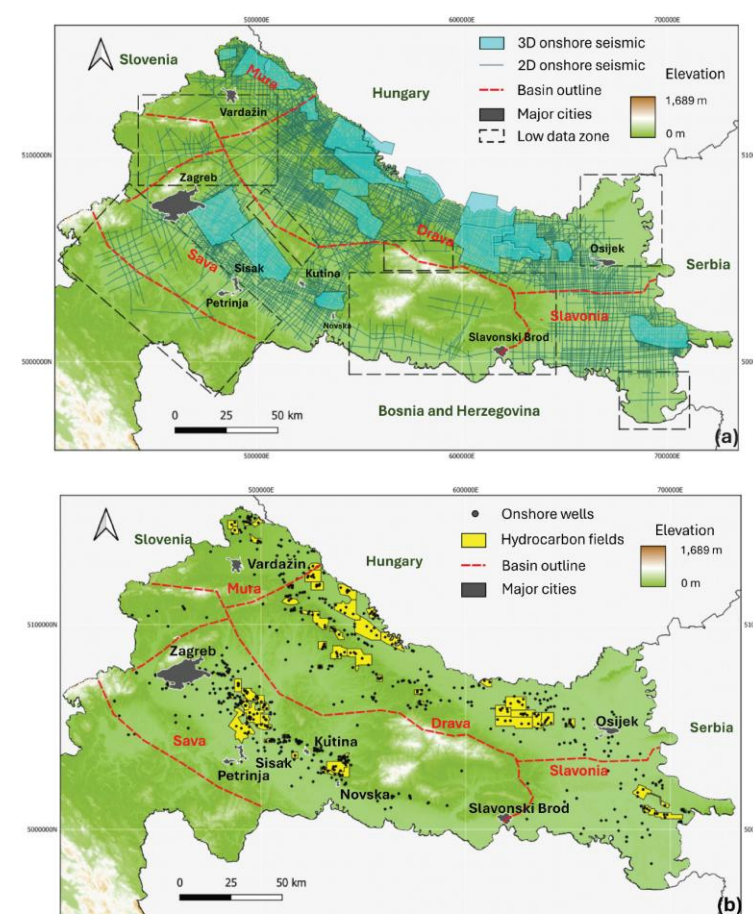
Reservoir properties typically include porosity values ranging from approximately 6% to over 20%, thicknesses between 60 and 177 metres, and many formations reach a sufficient depth threshold for maintaining supercritical CO<sub>2</sub> conditions. Storage capacity estimates indicate that key intervals, particularly within the Drava Basin have significant potential. The total capacity of the evaluated geological formations in all four basins has a theoretical resource estimate of 346 Mt of which 222 Mt is from the Drava Basin. This estimate assumes injection into all parts of formations which meet the criteria for injection and is therefore theoretical. The total resource found in structural and associated migration-assisted traps equates to 132 Mt distributed over 6 opportunities in the Drava and Mura basins. These traps reach the 10 Mt threshold considered as commercially attractive.



## 4. CCS Value Chain Readiness

Croatia benefits from a well-established oil and gas industry infrastructure, which significantly enhances the feasibility of CCS deployment. The subsurface dataset includes approximately 950 exploration wells, 3,000 development wells, and extensive seismic coverage exceeding 30,000 km of 2D data and over 3,300 km<sup>2</sup> of 3D seismic surveys (Figure3). This dataset provides a strong foundation for accurate geological interpretation and reduces exploration risk associated with storage site development.

Existing pipelines and processing facilities offer opportunities for repurposing as part of the CO<sub>2</sub> transport network, while the proximity of emitters to storage sites minimizes the need for extensive new infrastructure. The integration of CCS with emerging industrial projects, such as the KODECO near-zero-emission cement initiative and geothermal-based CCS concepts, further enhances the potential for developing integrated low-carbon industrial hubs.



**Figure 3.** (a) 2D and 3D seismic legacy data through the Pannonian Basin. (b) Hydrocarbon wells and fields in the Pannonian Basin

**Figure 2.** Map showing potential saline aquifers at a formation level that present potential areas for storage of CO<sub>2</sub> in the Croatian Pannonia Basin. Polygons only show those areas where suitable reservoir-seal pairs exist. Also shown are the location of potential saline aquifer traps. The most favorable traps are studied in detail in the Atlas.

## 5. Methodology and Evaluation Framework

The Atlas applies a structured, multi-phase methodology to ensure consistent identification and ranking of potential storage sites. For saline aquifers, a six-phase workflow is implemented, encompassing area of interest definition, site qualification based on fundamental geological criteria, screening for reservoir–seal pairing, detailed characterisation of properties, location-based risk assessment, and final ranking using a heatmap scoring system.

A parallel five-phase workflow is applied to EPU (hydrocarbon fields), incorporating additional data-driven evaluation and also dynamic modelling of injection scenarios for a representative field in each basin. Screening criteria for both saline aquifers and EPU include depth constraints between 800 and 3,500 metres, CO<sub>2</sub> density thresholds exceeding 300 kg/m<sup>3</sup>, reservoir thickness and permeability, seal integrity, and proximity to infrastructure and emission sources.

The Storage Resource Management System (SRMS) is used to classify storage resources according to their maturity and commercial readiness. This system distinguishes between discovered, prospective, and contingent resources, thereby enabling standardized reporting and facilitating comparison across projects and investment decisions.

## 6. Risks and Constraints

Several technical and environmental risks must be addressed to ensure safe and effective CCS deployment. Geological uncertainties, including variability in reservoir properties, heterogeneity, and seal continuity, represent key challenges in accurately defining storage capacity and containment integrity. Fault systems may act as potential leakage pathways or could be reactivated under increased pressure conditions during CO<sub>2</sub> injection.

Seismicity is a significant consideration in Croatia, with certain regions exhibiting moderate to high seismic activity. Buffer zones are applied around earthquake epicentres and active faults to reduce the risk of induced seismicity and ensure long-term storage security. Additionally, legacy wells present a potential risk for leakage if not properly abandoned, requiring detailed assessment and remediation strategies prior to injection.

Surface constraints, including restricted zones such as protected areas and challenging topography, may limit site accessibility and increase development costs. Furthermore, data gaps in certain regions, particularly in the Slavonia Basin, introduce additional uncertainty that must be addressed through further data acquisition and analysis.

## 7. Opportunities and Strategic Outlook

Croatia presents opportunities for CCS development at regional scales. The presence of multiple reservoir–seal pairs, stacked storage intervals and close proximity of potential structural traps indicates that certain areas could hold development for potential CO<sub>2</sub> storage in saline aquifers and associated migration-assisted trapping mechanisms further enhance effective storage capacity beyond structural closures. In addition several hydrocarbon fields may hold opportunities for storage once production has ceased. The more favorable ones are located in the Drava and Mura basins.

The country's strategic advantages include proven subsurface performance, extensive infrastructure, and alignment with EU climate policy and funding mechanisms. These factors collectively position Croatia as a potential CCS hub for Central and Eastern Europe, with opportunities for cross-border CO<sub>2</sub> transport and storage. Integration with industrial decarbonization initiatives, including cement production and geothermal energy, further strengthens this potential.

## 8. Conclusions

The evaluation demonstrates that Croatia possesses a technically viable and strategically valuable CCS resource base, particularly within the Drava and Mura basins. These regions combine favourable geological conditions, extensive data coverage, and proximity to CO<sub>2</sub> emitters, making them prime candidates for near-term development.

Future efforts should prioritize the detailed appraisal of high-potential sites, including further data acquisition to reduce uncertainty and enhance confidence in reservoir and seal properties. The development of cluster-based CCS systems, leveraging existing infrastructure and minimizing transport distances, should be a central component of the implementation strategy.

Risk mitigation measures, including comprehensive assessment of legacy wells, seismic monitoring, and validation of seal integrity, are essential to ensure long-term storage security. At the same time, leveraging EU funding mechanisms and aligning with regulatory frameworks will be critical to enabling investment and accelerating project timelines.