Assessment of Geological Carbon Storage Potential in Western Ukraine and potential connection with Southern Poland emitters

Introduction

Carbon capture and storage (CCS) is a key technological pathway to achieve decarbonization targets across Europe, particularly for hard-to-abate industrial sectors (Bachu, [2003]). Western Ukraine, located within the Carpathian petroleum province, represents a promising yet underexplored region for geological CO_2 storage, offering a combination of depleted hydrocarbon fields and deep saline aquifers.

This study was conducted within the framework of the COREu – CO_2 Routes Across Europe project and aims to identify and evaluate favorable geological storage sites suitable for integration into a regional CO_2 transport and storage network. The screening criteria included reservoir depth (>800 m), storage capacity (porosity and permeability), seal integrity, structural trapping conditions, and availability of geological and geophysical data.

Two priority candidates were selected for detailed investigation: the Solotvyno gas field (Transcarpathian Basin) and the Rudky Jurassic aquifer (Carpathian Foredeep). These represent contrasting storage concepts, namely depleted gas reservoirs with potential for combined production–injection strategies and large-scale saline aquifers intended for long-term storage. There is further development of previously recognized favorable zones for storages (Virshylo et al., [2024]). This study includes some conclusions and considerations from COREu Western Ukraine and Poland regional scenarios and propose some foresights to scale-up the project outputs.

Domestic Western Ukraine scenario includes known potential emitters from cement and gas industries with total capacity up to 2Mta with two transport options: pipelines and railroads. This study is proposing to expand this scenario to include of Southern Poland emitters, using international railway transportation, which can add up to 3.3Mta into the system.

Method and Approach

The assessment workflow integrates geological analysis, numerical modelling and dynamic simulation. Geological interpretation involved analysis of 2D/3D seismic data, well logs and historical production data. Structural frameworks and reservoir architectures were constructed using Petrel software, while dynamic behaviour of CO_2 injection and migration was simulated using ECLIPSE 300.

Petrophysical properties were derived from well data and laboratory measurements, supplemented by empirical relationships between porosity and permeability. In the absence of complete datasets, deterministic and stochastic approaches were applied to represent spatial variability.

For both case studies, CO_2 injection simulations considered:

- supercritical CO_2 conditions,
- reservoir pressure constraints below fracture limits,
- multi-well injection configurations,
- long-term plume migration and trapping mechanisms.

A key modelling assumption is permeability anisotropy, with vertical permeability taken as one order of magnitude lower than horizontal permeability, reflecting layered sedimentary structures.

Storage assessment results

Solotvyno Gas Field. The Solotvyno field is characterized by a salt dome structure with a caprock thickness exceeding 1 km, ensuring high sealing capacity. Reservoir rocks are represented by volcaniclastics and clastic sediments with porosity ranging from 6% to 15%. A sector reservoir model was developed, covering four wells and multiple productive horizons. The total pore volume was estimated at approximately 8.89 million m³.

Dynamic simulations considered several scenarios combining depletion and CO_2 injection. The results indicate that total injected CO_2 volumes vary from 1.2 to 1.55 Mt depending on operational strategy.

Table 1. Summary of injection scenarios for Solotvyno field

Scenario	Description	Recovery factor (%)	Total CO_2 stored (Mt)
1.1	Depletion to pressure limit then injection	40	1.2
1.2	Depletion to economic limit then injection	55	1.53
1.3	Scenario 1.2 + additional injector	55	1.55

The results demonstrate that integrated production–injection strategies improve both gas recovery and storage efficiency. However, pressure depletion below supercritical conditions may reduce CO_2 storage effectiveness and increase migration risks.

Rudky Jurassic Aquifer. The Rudky site represents a deep saline aquifer system with reservoir depths between 1.2 and 3.7 km and total thickness up to 900 m. Porosity values range between 8% and 14%, with effective sealing provided by thick clay formations. A regional-scale geological model (~13 × 17 km) was constructed. Due to limited well control, stochastic methods were applied to generate reservoir property distributions.

Dynamic simulations assumed a multi-well injection system consisting of 10 injectors with individual injection rates. The total injection capacity is approximately 1 Mt CO_2 per year. Over a simulation period of 50 years, the total stored CO_2 volume is estimated at approximately 41 Mt. Injection rates decrease after ~30 years due to pressure limitations approaching fracture thresholds. Long-term simulations indicate progressive stabilization of the CO_2 plume, with increasing importance of dissolved trapping mechanisms.

Transportation

In domestic Western Ukraine scenarios transportation with gas pipelines make sense due to well-developed transport system in Ukraine and expected high performance with good control of pressure and temperature. However, there is expensive capital investments, which is very sensitive to business and legislation environments,

For international scenario, authors assumes a railroad transportation as main element flexible enough to manage potential rapid changes in system capacity supply and demand due to market mechanisms and normative constraints, Therefore, we construct a potential routes between emitters and storages, using existing railroad network (figure 1). Logistical network propose enough alternatives for flexible physical transportation and main risks would be assigned to economical and normative factors.

There are some additional emitters could be included in Southern Poland and Central Ukraine in future to scale up the project and develop conception of “open network” in the region.

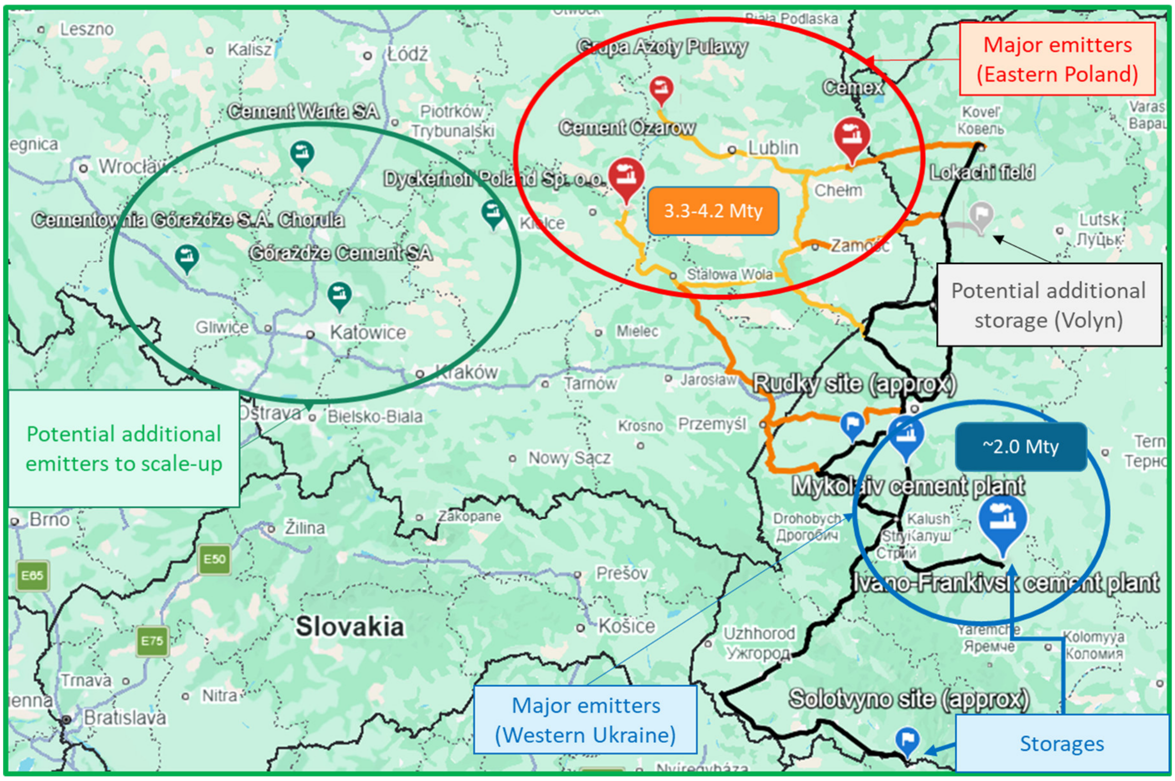

Figure 1 *Conceptual CO_2 source–sink network in Western Ukraine and adjacent regions showing major emitter clusters, prospective storage sites (Rudky and Solotvyno), and potential transport corridors..*

Discussion

The comparative evaluation highlights two complementary storage strategies. The Solotvyno field offers relatively low-risk storage due to existing production data and well-constrained geological conditions, but its storage capacity is limited (~1–1.5 Mt CO_2). In contrast, the Rudky aquifer provides large-scale storage potential (~41 Mt CO_2), but is associated with higher geological uncertainty due to limited data availability.

Key uncertainties affecting both sites include:

- limited core and petrophysical data,
- uncertainty in permeability distribution and anisotropy,
- lack of geomechanical constraints,
- incomplete characterization of sealing integrity.

These uncertainties directly impact predictions of injectivity, storage capacity and long-term containment. However, numerous advantages of uncertain aquifers versus well known depleted fields (Warden, [2024]), such as higher capacity and less risk of leakage are key factors for further investigations of deep horizons in this case.

Including international component into scenario increase project uncertainty due to legislation bottlenecks (Tkachenko et al., [2024]). In case of Ukraine and Poland connection, we expect for reducing some of these risks during Ukraine accession to European Union negotiations and corresponding harmonization of normative framework in horizon on the project timeline.

Conclusions

Two priority geological storage candidates in Western Ukraine were identified and assessed. The Solotvyno gas field demonstrates moderate storage capacity (1.2–1.55 Mt CO_2) with relatively low geological risk, making it suitable for early-stage CCS deployment. The Rudky Jurassic aquifer represents a large-scale storage target with a capacity of approximately 41 Mt CO_2 but requires further data acquisition and uncertainty reduction.

The combined use of depleted fields and saline aquifers supports a balanced regional CCS strategy, integrating short-term deployment with long-term storage capacity. Further work should focus on:

- acquisition of core and laboratory data,
- detailed geomechanical modelling,
- refinement of reservoir properties,
- assessment of leakage pathways and sealing integrity.

Acknowledgements (Optional)

This study was carried out within the Horizon Europe project COREu – CO_2 Routes Across Europe, coordinated by SINTEF. The authors acknowledge contributions from international project partners and supporting institutions.

References

Bachu, S. [2003]. Screening and ranking of sedimentary basins for CO_2 sequestration. *Environmental Geology*, 44, 277–289.

Worden, R.H. [2024]. CCS in saline aquifers versus depleted gas fields. *Geosciences*, 14(6).

Virshylo I., Bratakh M., Kurylo M., Shabatura O., Caccamo Ch., Wojnicki M. [2024]. Onshore CCS in Western Ukraine – exploration challenge for depleted fields, *AAPG European Regional Conference 2024 "Energy Transition. Is European Approach different?". Krakow, Poland, 28-29 May, 2024*

Tkachenko Yu., Virshylo I., Clarkson Ch., Ghanizadeh A., Kurylo M. [2024]. Carbon Capture, Utilization, and Storage legislation and technical framework – leveraging the Canadian experience for Ukraine. *AAPG European Regional Conference 2024 "Energy Transition. Is European Approach different?". Krakow, Poland, 28-29 May, 2024*