Integrated Pre-Feasibility Study for CO$_2$ Geological Storage in the Cascadia Basin, offshore Washington State and British Columbia

DE-FOA-0001584
CarbonSAFE: Phase 1

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U.S. Department of Energy
National Energy Technology Laboratory
Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting
August 1-3, 2017
Objective:

Integrated pre-feasibility study to characterize an ocean basalt reservoir for safe and permanent storage of 50 MMT of CO₂ in the Cascadia Basin, offshore Washington State and British Columbia
CarbonSAFE Project Goals

Goal 1: Technical assessment of offshore basalt reservoirs for safe and permanent CO$_2$ storage (e.g., reservoir characterization, CO$_2$ sourcing, transport, and monitoring at offshore site)

Goal 2: Non-technical assessment of offshore CO$_2$ storage site (e.g., regulatory framework, stakeholder engagement, risk assessment, financial needs and long-term liability)
CO$_2$ storage security and permanence in basalt

*prevailing view in 2005*

$\text{CO}_2$ injected into water reservoirs below the surface may be stored through structural, residual solubility and mineral trapping

*current view in 2016*

In situ mineralization via CO$_2$-fluid-basalt reactions occurs quickly (a few years)

*Snaebjornsdottir et al., IJGGC, 2017*
Wallula, WA Basalt Pilot Project

• Injected 1000 tons CO$_2$ (liquid) into permeable, layered basalt flow tops

• After 2 years, isotopic analysis of sidewall cores chemically distinguishes post-injection ankerite nodules from ambient carbonate

• Progressive enrichment in Fe & Mn over time indicates mineralization of host basalt, not re-precipitated calcite

McGrail et al., ES&TL, 2016
Upscaling questions: in situ mineral carbonation in basalt

- Do other adequate basalt reservoir sites exist?

- What are anticipated in situ reaction rates? Will \( \text{scCO}_2 \) injection rapidly precipitate carbonates, other minerals?

- What is best injection strategy for \( \text{CO}_2 \) with seawater for large volumes? To optimize mineralization?

- What large potential industrial sources of \( \text{CO}_2 \) could be delivered to the site?

- What are best monitoring and volume assessment methods?
CO\textsubscript{2} storage in the Cascadia Basin

CO\textsubscript{2} injected below sediments may be stored through physical, solubility, and mineral trapping mechanisms – CarbFIX and Wallula projects show mineralization occurs quickly (a few years)

(after Goldberg et al., 2008)
Existing physical data in Cascadia Basin

- Several existing well completions and instrumentation at IODP sites along buried basement ridge

- Multi-year tracer experiments through basalt ocean crust indicate focused northward fluid flow

- Extensive core and measurement data in public archives

- Active cabled network (NEPTUNE) for observation and monitoring
Injection approaches for mineralization: Synergies with Wallula and CarbFix projects

(from Gislason and Oelkers, Science, 2014)
Preliminary accomplishments

• Developed flyer describing the project and contacted potential industry-sourced CO₂ streams in the region

• Began laboratory analysis and injection modeling studies to optimize mineralization in basalt

• Compiled inventory of existing petrophysical, hydrological, and regional data in vicinity of the offshore reservoir

• Reviewed framework for offshore storage regulations in US and Canada

• Constructed initial risk registry for project-related risks and related NRAP modeling
Potential CO$_2$ sources near Cascadia area

(from M. Scherwath, Ocean Networks Canada, 2016)
Laboratory results in seafloor samples: 
CO$_2$ reaction rates in basalt

Differential Bed Reactor (DBR) Reactivity Experiments (1 bar @ 30°C, far from equilibrium)

**Low pH ~3**  Samples: 11.7% CaO, 7.4% MgO, 10.8% FeO

**High pH ~6**  Samples: 11.7% CaO, 7.4% MgO, 10.8% FeO

Results show differing behaviors in glassy and non-glassy basalt, especially under low pH conditions

→ 76% Ca extraction from non-glassy basalt at low pH
Water Alternating Gas (WAG) miscible flooding for CO$_2$ mineralization in basalt

Initial 3-cycle model using STOMP-CO2 with ECKEChem to optimize for CO$_2$ solubility in seawater and mineralization in basalt

(see poster Thursday – Demirkanli, et al.)
## Physical data categories, subtasks and status in inventory

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Bathymetry</th>
<th>Chemistry</th>
<th>CO₂ Source and Transport</th>
<th>Heat Flow, Temperature and Pressure</th>
<th>Geologic Model</th>
<th>Physical Properties</th>
<th>Seisms</th>
<th>Seismicity</th>
<th>Site/Hole Info</th>
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*(as of 24 July 2017)*
Natural Seismicity: Juan de Fuca tectonic plate

Data sources: IRIS Interactive Earthquake Browser; USGS Earthquake Catalog; Natural Resources Canada Earthquake Database; Ocean Networks Canada Cascadia Basin
## Preliminary Project Risk Registry

**Tally of identified project risks from the comprehensiveness analysis**

(As of 5 July 2017)

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<th>Responsible Actor</th>
<th>R Tally</th>
<th>Component</th>
<th>C Tally</th>
<th>Time/Phase</th>
<th>T Tally</th>
<th>Location</th>
<th>L Tally</th>
<th>Goal</th>
<th>G Tally</th>
<th>Activity</th>
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<td>7</td>
<td>T01 pre-FEED</td>
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<td>L01</td>
<td>G01</td>
<td>A01 Mission &amp; Scoping</td>
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<td>C07</td>
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<td>T07 Post-Closure/PISC</td>
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<td>G07 Prove injectivity</td>
<td>4 A07 Communications</td>
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Lessons Learned to date

- Large potential sources of anthropogenic $CO_2$ exist in the region.
- Existing regulations appear to restrict $CO_2$ transport across national boundaries (e.g., between US and Canada).
- Compiled hydrological data indicate basalt injectivity is high but likely anisotropic.
- Laboratory studies of $CO_2$–basalt–water mixtures indicate large variability in reaction rates.
- Real-time injection monitoring is feasible using NEPTUNE.
Project Summary

• **Objective**: Integrated pre-feasibility study to characterize an ocean basalt reservoir for safe and permanent storage of 50 MMT of CO$_2$ in the Cascadia Basin, offshore Washington State and British Columbia

• **Accomplishments**: Technical and non-technical tasks for assessment of this storage option are on track for the anticipated project schedule

• **Next steps**: Project workshop, 3-5 October 2017
Thank you