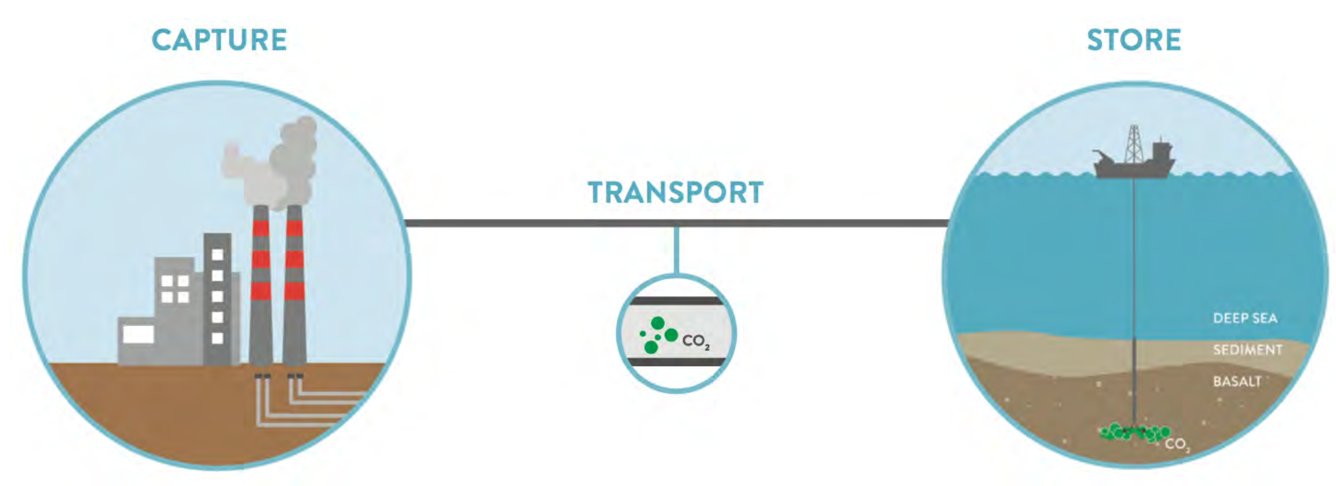
Integrated Pre-Feasibility Study for CO_2 Sequestration in the Cascadia Basin, Offshore of Washington State and British Columbia

CarbonSAFE Cascadia Phase 1 Project Team *

ABSTRACT

The CarbonSAFE Cascadia project is conducting a pre-feasibility study under award from the U.S. Department of Energy (DE-FE0029219) to evaluate technical and nontechnical aspects of collecting and storing 50 MMT of CO_2 in a safe, ocean basalt reservoir offshore from WashingtonState and British Columbia. The primary project goal is to conduct a pre-feasibility assessment for an industrial-scale CO_2 storage project in a subsea basalt reservoir complex in the Cascadia Basin. This involves conducting laboratory and modeling studies to evaluate the potential capacity of this reservoir for CO_2 mineralization and long-term storage, developing potential source/transport scenarios, and completing an economic evaluation of specific source/transport scenarios and a ranked project risk registry. Important accomplishments in the project to date include selection of a potential location for the storage complex area and potential scenarios for sources and transport in USA and in Canada.



Sub-seafloor basalts are very common on Earth and the lessons learned from this study at one offshore location may be transferrable elsewhere around the globe.

SOURCES AND TRANSPORT

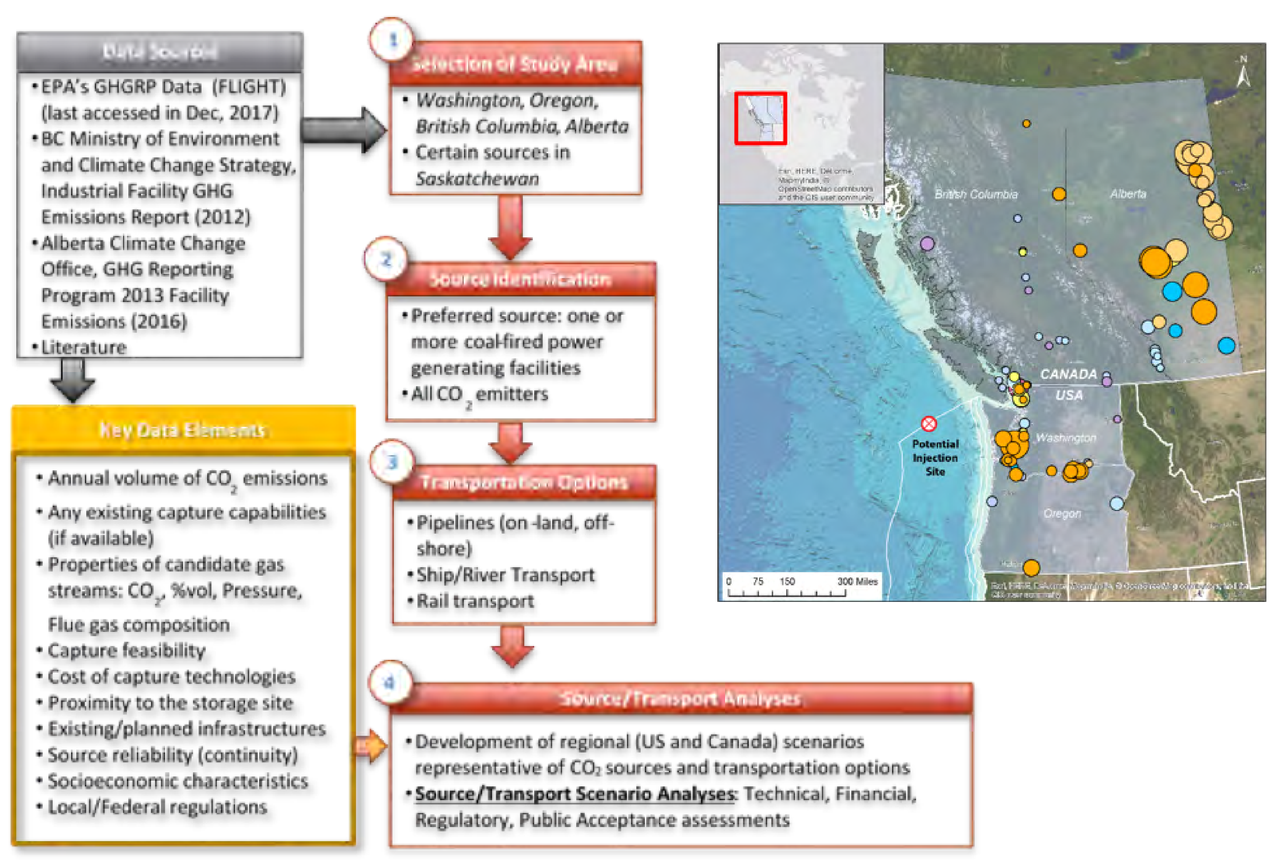


Fig. 1. CO_2 source and transportation technical, financial, public acceptance, and regulatory assessment workflow for the CarbonSAFE Cascadia project showing the study area and large (>100,000 MT/year) emitters.Color and diameter of circles indicate power (orange) and manufacturing (purple–yellow) plants and relative annual emission volumes, respectively.

Workflow

Technical, financial, public acceptance, and regulatory assessment in the project is evaluating large (>100,000 MT/yr) emitters in the region. More than half of these emissions are associated with power plants, primarily fueled by natural gas (e.g., 52% of WA and 86% of OR emissions). The remainder is from other industrial sources, such as refineries, ammonia production operations, and mineral processing plants. We highlight one scenario below that is representative of the region, with potentially available transportation options. Although no dedicated CO_2 pipelines exist in the region, offshore transportation options are common for all scenarios, using either offshore pipeline or shipping vessels.

Example Source/Transport Scenario

Two representative source options are shown, collecting CO_2 from Shell's Puget Sound refinery and/or from Alcoa's aluminium production facility. The transportation component considers two alternatives - via ship and via pipeline. With pipeline, a 80 km-long line would connect the Alcoa Intalco Works facility to a pumping station located near the Shell Puget Sound refinery. An offshore pipeline of ~2.5 MMT/yr capacity would be required to connect the pumping station to the injection site located ~250 km offshore. For shipping, a tanker collecting CO_2 from each source facility, with a multi-source design concept, would transport CO_2 to the offshore injection site. Different combinations of these transport options are also considered.

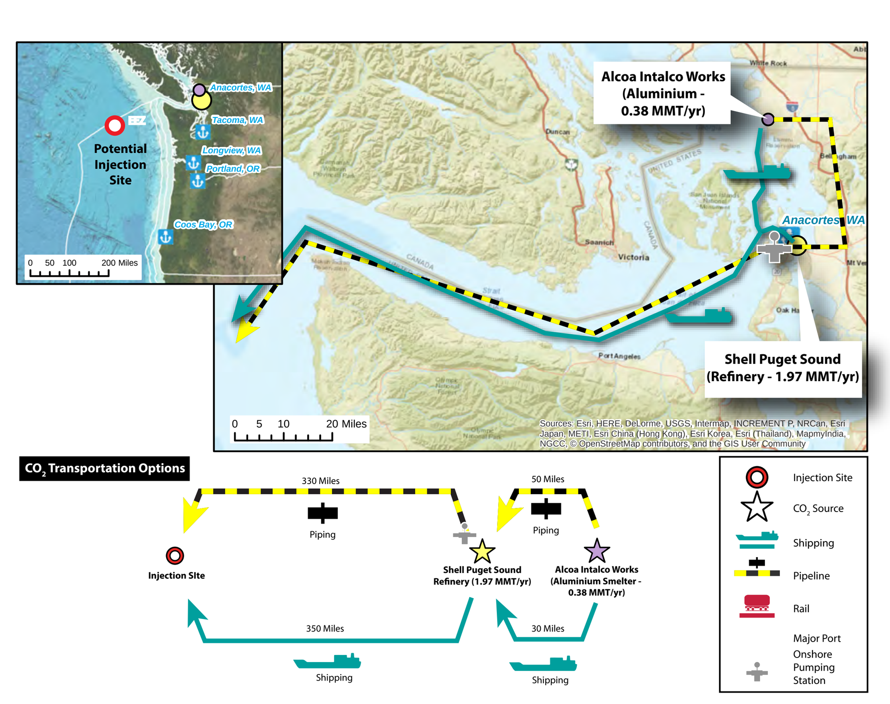


Fig. 2. Representative CO_2 source and transportation options in Washington State for the CarbonSAFE Cascadia project. Inset map: location of potential offshore injection site (red circle). Existing scientific research wells and nearby survey areas are shown in greater detail in Fig. 3.

RESERVOIR AND MONITORING

Target Basalt Reservoir

Targeted injection formations for the project are sub-ocean basalt layers below the Cascadia Basin on the Juan de Fuca plate.The reservoir is comprised of both pillow lavas, fractured and massive flows containing plagioclase, olivine, and clinopyroxene, which are geochemically reactive (see Laboratory Studies **below**).

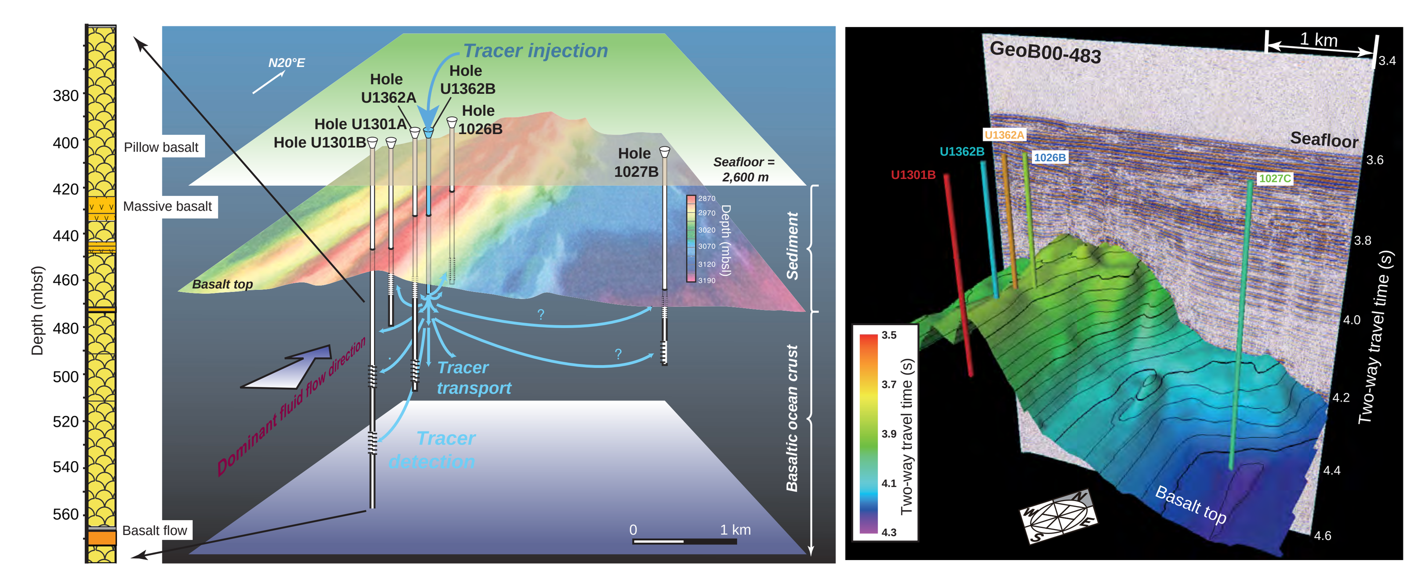


Fig. 3. The proposed storage reservoir is located in permeable pillow lavas, fractured and massive flows along a buried basement ridge in the Cascadia Basin (left, colored surface; modified from Fisher et al. IODP (2011)). Several well completions penetrate these basalt layers, illustrated over a 200-m depth interval (left, lithology column). Tracer injections tests indicate focused northward flow in basement that is sealed by impermeable fine-grained sediments to the seafloor (left, green surface). A seismic image of the basement-sediment contact shows well locations on the basement ridge with an exaggerated vertical scale (right; colored surface).

The subseafloor basalt reservoir is:

- Located along a buried basement ridge (colored surface) and drilled at several existing IODP sites;
- Highly fractured, channelized, and porous (10-15%);
- Sealed to the seafloor above (green) by impermeable fine-grained turbidites and hemipelagic clay sediments; and
- Permeable with focused northward fluid flow indicated by multi-year tracer experiments in existing well completion.

Monitoring CO_2 Transport and Injection

An active cabled network (NEPTUNE) is in place from Victoria BC to the Cascadia Basin. In situ instrumentation could enable real-time monitoring for:

- Pipeline leakage (pressure, temperature, acoustic)
- Injection pressure changes
- Well pipe and head corrosion
- Reservoir pore water, and rock matrix chemistry (e.g., mass spectroscopy, titration)
- Fracturing and induced seismicity (seismometers, hydrophones, borehole strain)
- Seafloor deformation and compliance (pressure, tilt, broadband seismometer, gravimeter)

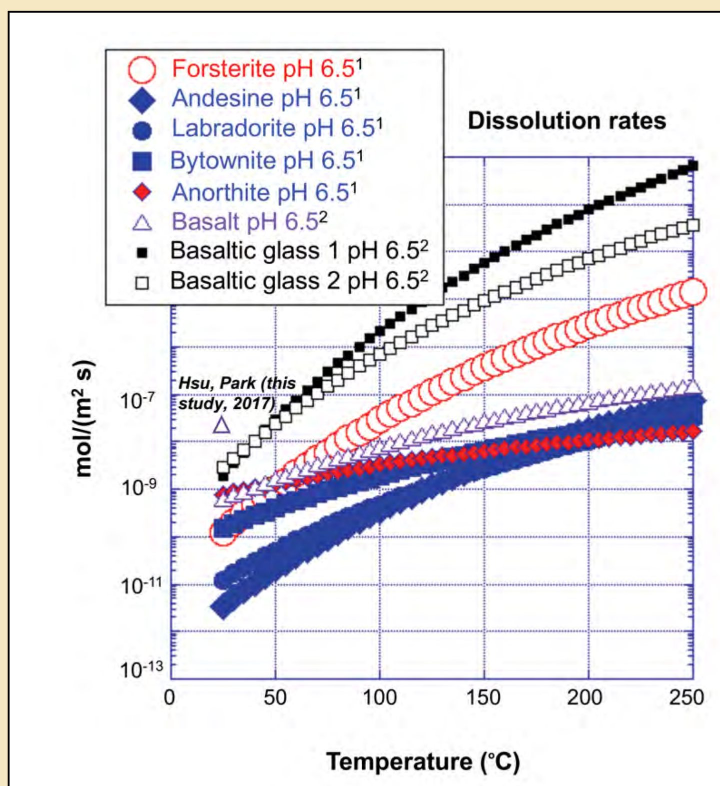


Fig. 4. Ca dissolution rates of basaltic rocks. Data from this study, Palandri, J.L., Kharaka, Y., USGS (2004); Schaef, T.H., McGrail, P. B., Appl. Geochem. (2009).

Laboratory Studies

Laboratory experiments are underway using representative ocean basalt samples from the Cascadia Basin and other locations.

- Measured dissolution rates of basalt indicate that flow channels are much more reactive than the massive basalts, with Ca ion extraction efficiencies reaching ~11-12% at low pH.
- Compared with kinetic data in basalts from the literature, preliminary tests indicate more rapid dissolution in shallow ocean basalts.

PHASE 1 ACCOMPLISHMENTS TO DATE

- **Contacted potential industry-sourced CO_2 streams in the region and developed different source/transport scenarios in the USA and Canada**
- **Conducted 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**
- **Evaluated cost variables and potential economic incentives to optimize for this offshore storage location**

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