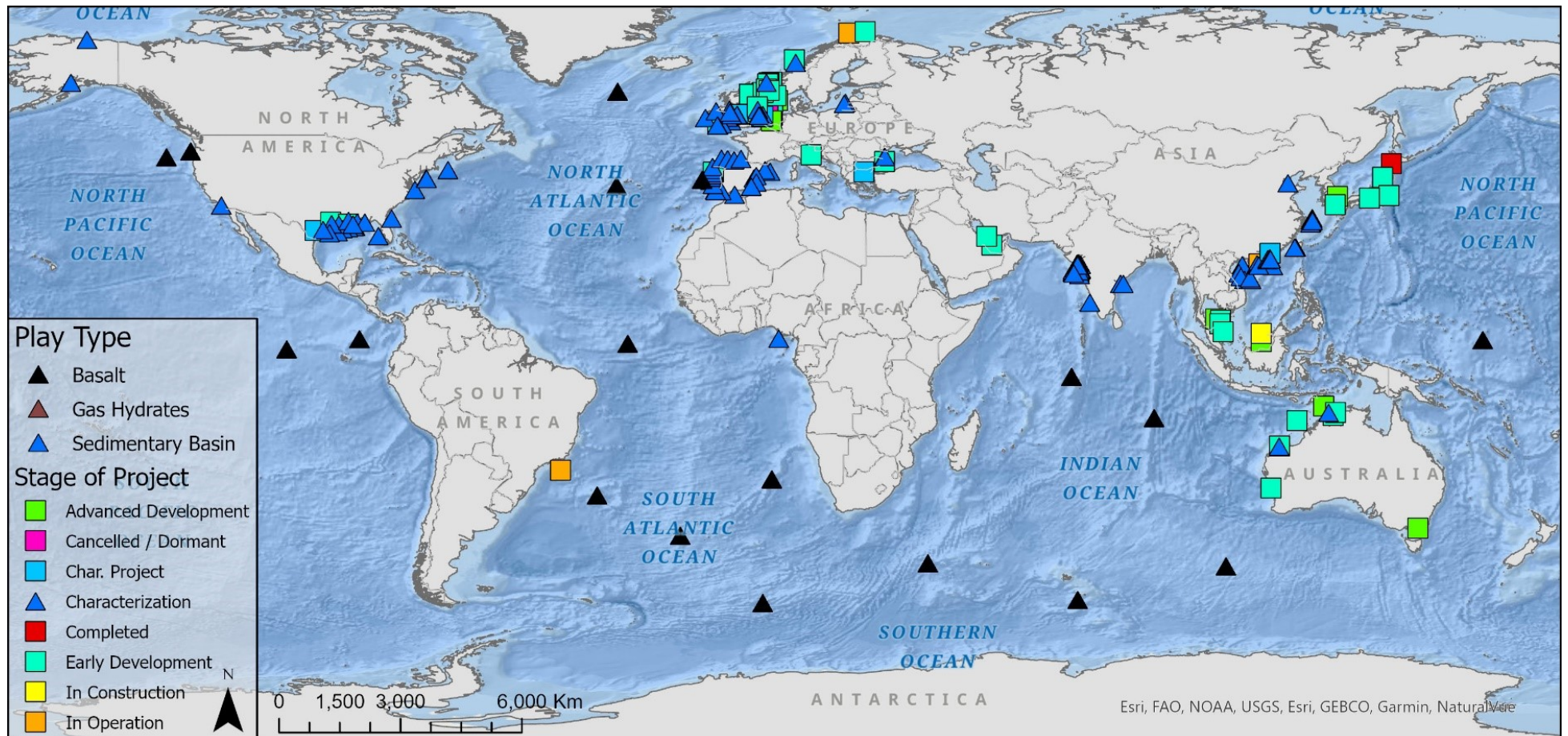


International Offshore Geologic Carbon Storage Project Inventory and Data Collection

Julia Mulhern

National Energy Technology Lab



International Offshore Geologic CO₂ Storage Workshop

Sept. 17, 2024

Disclaimer



This project was funded by the United States Department of Energy, National Energy Technology Laboratory, in part, through a site support contract. Neither the United States Government nor any agency thereof, nor any of their employees, nor the support contractor, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Julia Mulhern^{1,2}; MacKenzie Mark-Moser¹; Kelly Rose¹

*¹National Energy Technology Laboratory, 1450 Queen Avenue SW, Albany, OR
97321, USA*

²NETL Support Contractor, 1450 Queen Avenue SW, Albany, OR 97321, USA

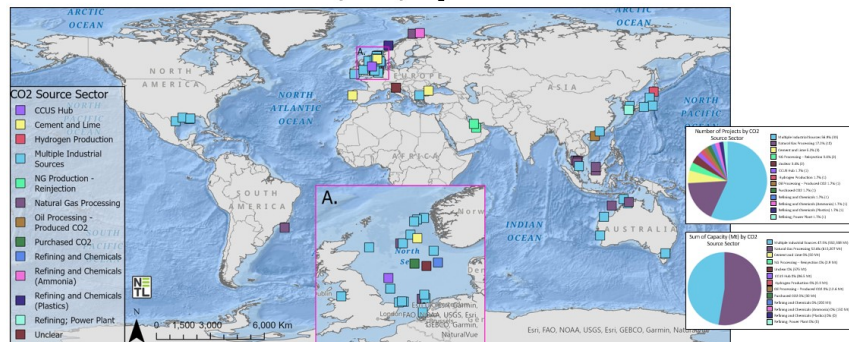
NETL's Offshore Geologic Carbon Storage (GCS) Project Timeline

2022	2023	2024	Value (2022–2024)
------	------	------	-------------------

- Compilation of key data resources on information supporting offshore GCS including geologic setting, infrastructure, policy
- Comprehensive, up-to-date review of international GCS efforts

Inventory

Global Offshore GCS Projects by CO₂ Emission Source Sector



- Updated and integrated available data into U.S. offshore GCS evaluations
- Compiled and released U.S. offshore GCS catalog and inventory

Data Catalog

- Integrated additional data released from ongoing research and release U.S. offshore GCS open resource data collection
- Created web app in lieu of database for greater accessibility
- Shared findings and products with stakeholders

Data Collection Web App

End Product:
Accessible data collections covering both international CCS project products and data for **potential U.S. offshore GCS**, accompanied by web user interfaces and technical reports **summarizing global offshore GCS efforts** to date

Dashboard and Spatial Data



Recent Offshore GCS Products

Variety of Deliverables Launched and Ready to Use

Offshore GCS Data Collection

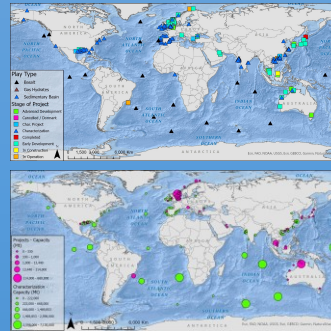
Data Collection Web App



Data Gaps Assessment Report

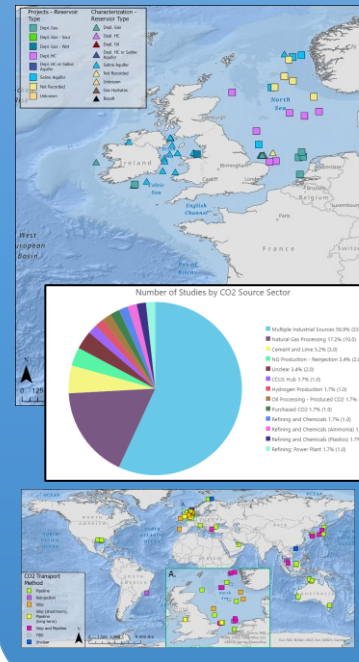


Inventory of Offshore Projects and Studies



International Offshore GCS Inventory

Offshore Meta-Analysis Dashboard



Inventory and Global Project Summary



Inventory Story Map

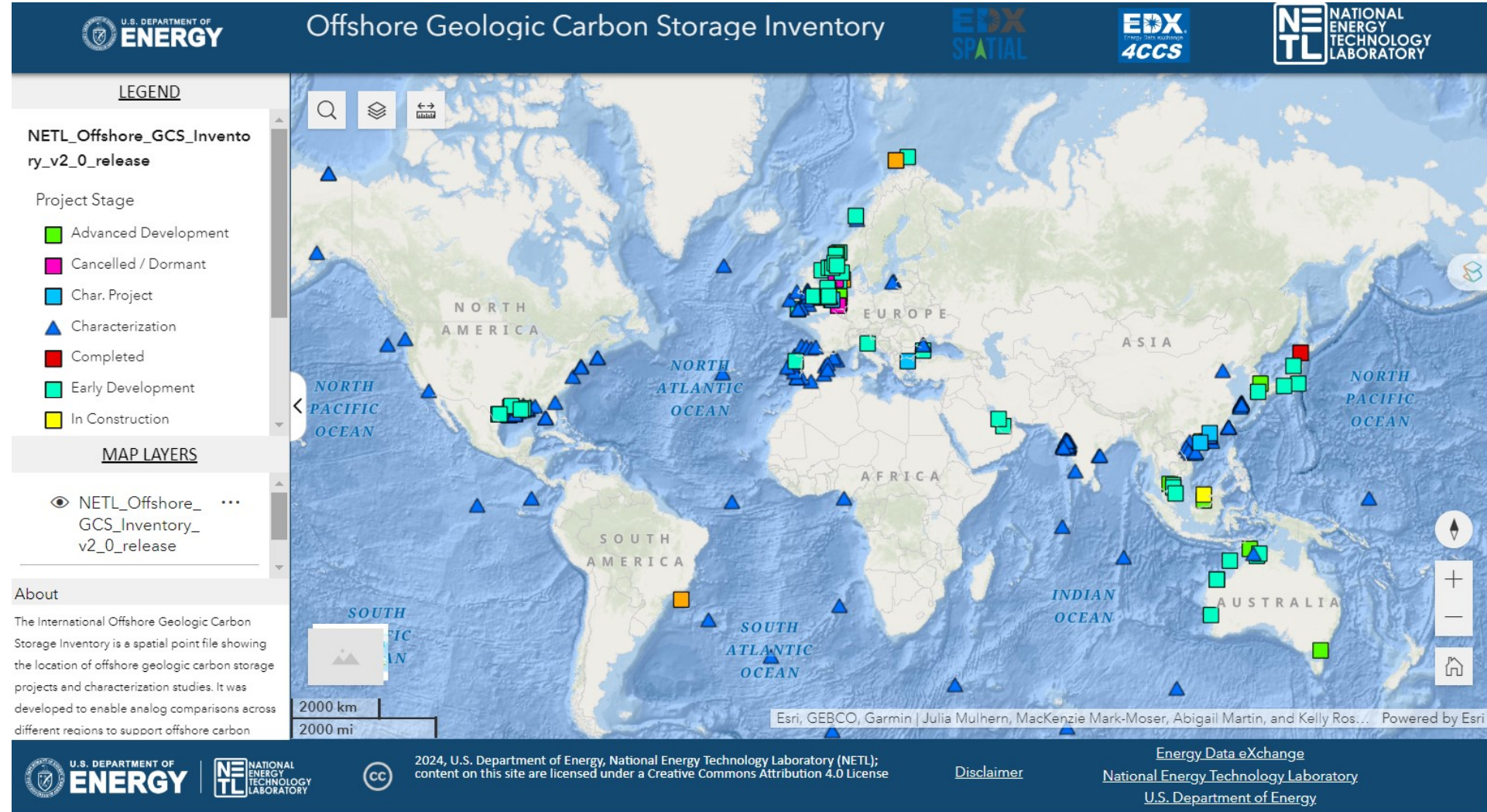
Country	Offshore Projects	Onshore Projects	Total Projects	Advanced Projects	Operational Projects	Completed
United States	20	1	21	1	1	1
Netherlands	3	0	3	0	0	0
Japan	1	0	1	0	0	0
China	4	0	4	0	0	0
India	1	0	1	0	0	0
Malaysia	2	0	2	0	0	0
United Kingdom	3	0	3	0	0	0
Australia	2	1	3	0	0	0
Canada	2	1	3	0	0	0
Thailand	1	0	1	0	0	0
Tanzania	1	0	1	0	0	0
India	1	0	1	0	0	0
China	1	0	1	0	0	0
United Arab Emirates	1	0	1	0	0	0
Spain	1	0	1	0	0	0
Greenhouse of China	1	0	1	0	0	0



NETL Made an Offshore GCS Inventory

Version 2.0 Available Online

- Offshore GCS Inventory has >254 locations globally of both actualized projects and characterization studies
- Additional attributes were added to the inventory to enable meta-analysis and analog comparisons



Inventory Version 2.0 is Published and Available



- Initial inventory v2.0 is **available online** and includes extended set of attributes for all projects and characterization studies.

Dataset Groups Activity Provide Feedback Edit Submission More Options

Offshore Geologic Carbon Storage (GCS) Inventory

doi 10.18141/1963815

License(s):
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Open Data Commons Attribution License

The Offshore Geologic Carbon Storage (GCS) Inventory contains information pertaining to domestic and international development of offshore geologic carbon storage or sequestration gathered in support of the creation of the Offshore Geologic Carbon Storage ArcGIS Story Map (<https://edx.netl.doe.gov/dataset/offshore-geologic-carbon-storage-story-map>).

Followers: 2
+ Follow

Authors
Abigail C. Choisser MacKenzie Mark-Moser Julia Mulhern Kelly Rose

Data and Resources

Download Checked Check All

Filter resources by name... Q

Date: Newest → Oldest

	Web Map Application for NETL's Offshore GCS Inventory Creative Commons Attribution Interactive Web Map Application for NETL's Offshore GCS Inventory to enable users to visualize spatial data.	Read Info or Open Link
	NETL Offshore GCS Inventory Spatial Feature Dataset Creative Commons Attribution Spatial feature dataset of the NETL Offshore GCS Inventory	Read Info or Open Link
<input type="checkbox"/>	NETLOffshoreGCSInventoryVersion2.xlsx Open Data Commons Attribution License Excel version of inventory and references.	Read Info or Download
<input type="checkbox"/>	ReadMeOffshoreCarbonCaptureandStorageInventoryv2.pdf Open Data Commons Attribution License ReadMe describing files within this data set.	Read Info or Download

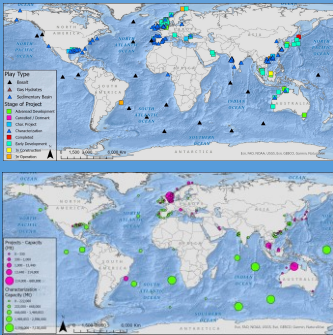


<https://edx.netl.doe.gov/dataset/offshore-gcs-data-inventory>

Version 2.0 Inventory Products

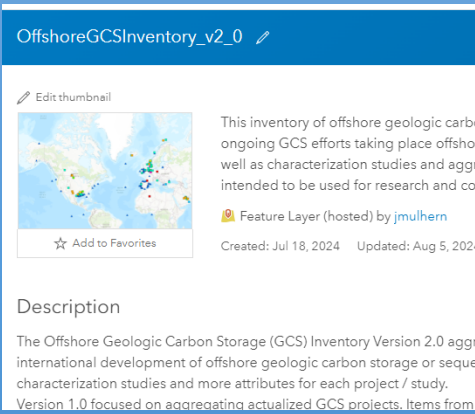
Expanding Published Inventory Products

Inventory of Offshore Projects and Studies



Version 2.0 - Released

Spatial Layer of Full Inventory



OffshoreGCSInventory_v2_0

Edit thumbnail

This inventory of offshore geologic carbon storage (GCS) projects and studies, including ongoing GCS efforts taking place offshore, as well as characterization studies and aggregation studies, is intended to be used for research and communication purposes.

Feature Layer (hosted) by jmulhern

Created: Jul 18, 2024 Updated: Aug 5, 2024

Add to Favorites

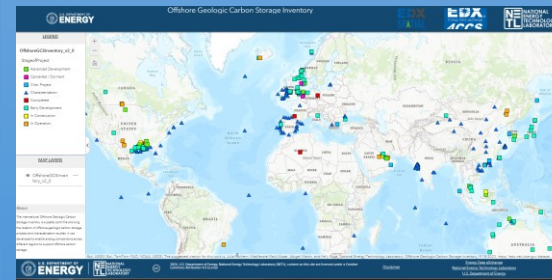
Description

The Offshore Geologic Carbon Storage (GCS) Inventory Version 2.0 aggregates international development of offshore geologic carbon storage or sequence characterization studies and more attributes for each project / study. Version 1.0 focused on aggregating actualized GCS projects. Items from

ArcEnterprise spatial layer to enable public interaction while NETL retains evergreen updating capability

On EDX - Live yesterday!

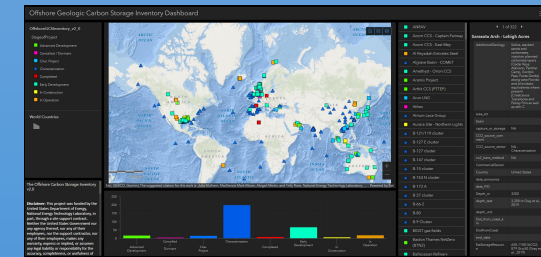
Interactive Web Map



Web map with enabled pop ups to allow users to spatially interact with data without requiring additional software.

On EDX - Live yesterday!

Interactive Dashboard



Dashboard with interactive graphics enabling users to query inventory attributes with live meta-analysis graphics which update based on map display

Publication: January

Spatial Data Layer for Expanded Inventory



- **Spatial layer available**
- Web hosted feature data set (ArcEnterprise) allows spatial data to be publicly available while NETL retains ability to easily update layer to ensure data remain evergreen
- This expanded dataset will include all of the characterization study locations and additional attribute fields.

Home Gallery Map Scene Groups Content Organization

Julia Mulhern
jmulhern

OffshoreGCSInventory_v2_0

Overview Data Visualization Settings

Edit thumbnail

Add to Favorites

This inventory of offshore geologic carbon storage (GCS) projects and studies begins to summarize ongoing GCS efforts taking place offshore globally. This inventory includes both actualized projects as well as characterization studies and aggregates a variety of attribute fields for each project / study. It is intended to be used for research and comparison purposes, see full disclaimer and credits.

Feature Layer (hosted) by jmulhern

Created: Jul 18, 2024 Updated: Aug 5, 2024 View Count: 69

Description

The Offshore Geologic Carbon Storage (GCS) Inventory Version 2.0 aggregates publicly available information pertaining to domestic and international development of offshore geologic carbon storage or sequestration. Version 2.0 expands on Version 1.0 to include more characterization studies and more attributes for each project / study.

Version 1.0 focused on aggregating actualized GCS projects. Items from Version 1.0 are discussed in the Offshore Geologic Carbon Storage Story Map: <https://edx.netl.doe.gov/dataset/offshore-geologic-carbon-storage-story-map> Every effort was made to create a comprehensive inventory at the time of release with an emphasis on collecting information on more active projects. However, some significant cancelled/dormant projects that had significant history or useful information were included. Characterization projects were added as time allowed, however, authors acknowledge that the dataset is not comprehensive.

Version 1.2 provides updates to existing offshore geologic carbon storage sites, logs additional sites found since the first release, and provides additional information on geology, project stage, and storage resource.

Version 2.0 expands the data set to include myriad additional attribute fields as well as a non-comprehensive selection of characterization studies in addition to actualized projects.

The suggested citation for this work is: Julia Mulhern, MacKenzie Mark-Moser, Abigail Martin, and Kelly Rose, National Energy Technology Laboratory, Offshore Geologic Carbon Storage Inventory, 9/18/2023, <https://edx.netl.doe.gov/dataset/offshore-gcs-data-inventory>, DOI: 10.18141/1963815

This inventory is included as part of a broader Offshore GCS Data Collection which can be found here: Julia Mulhern, MacKenzie Mark-Moser, Kelly Rose, Offshore Geologic Carbon Storage (GCS) Data Collection Web Application, 5/28/2024, <https://edx.netl.doe.gov/dataset/offshore-geologic-carbon-storage-gcs-data-collection-web-application> DOI: 10.18141/2367369

Open in Map Viewer Classic

Open in Scene Viewer

Open in ArcGIS Desktop

Publish

Create View Layer

Export Data

Update Data

Share

Metadata

Item Information

Low High

Details

Source: Feature Service

Created from: OffshoreGCSInventory_v2_0

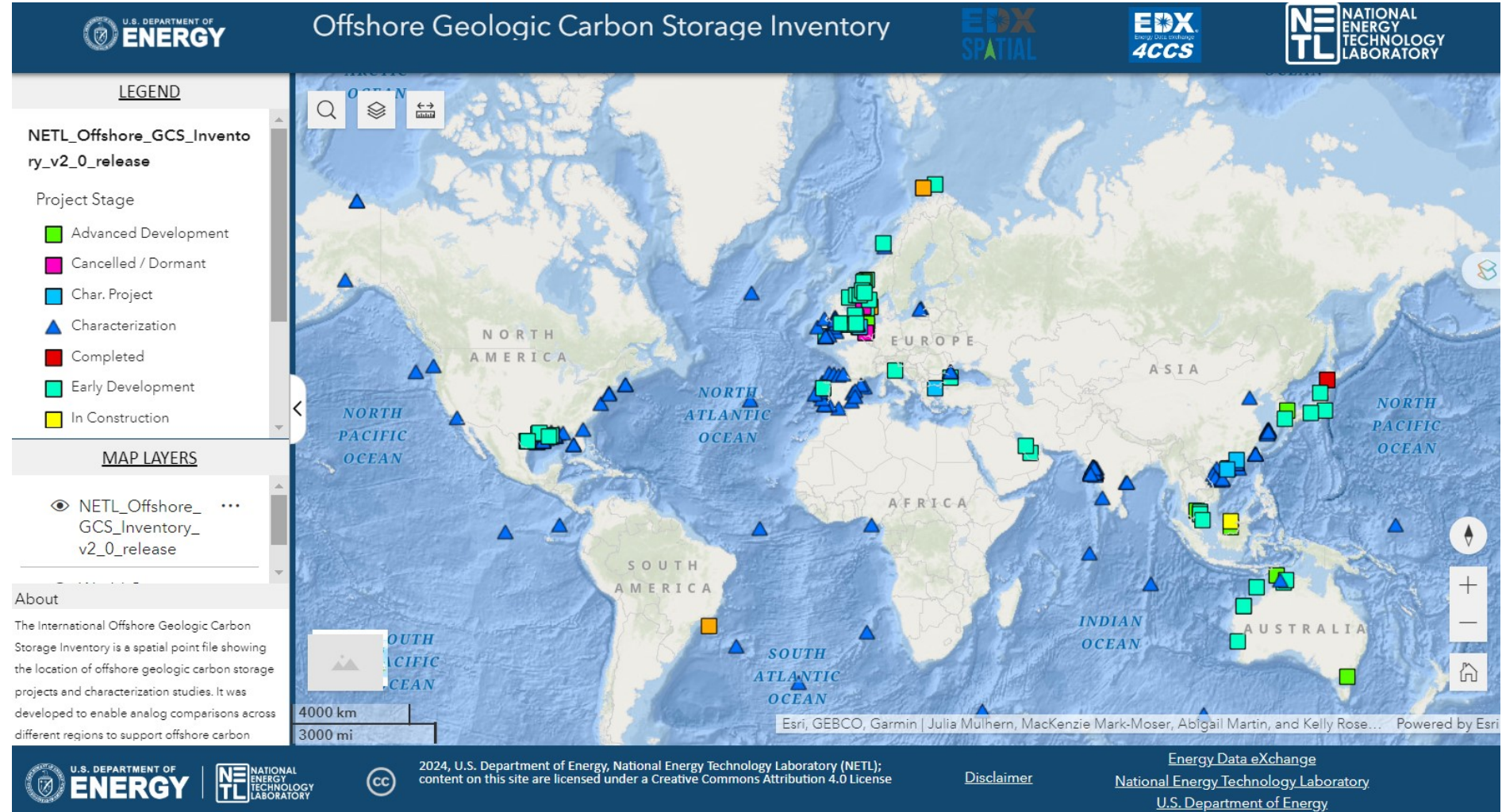
Service Definition

Other Views:

Interactive Web Map –Public Product

Web Map will Enable Public Interaction and Feedback

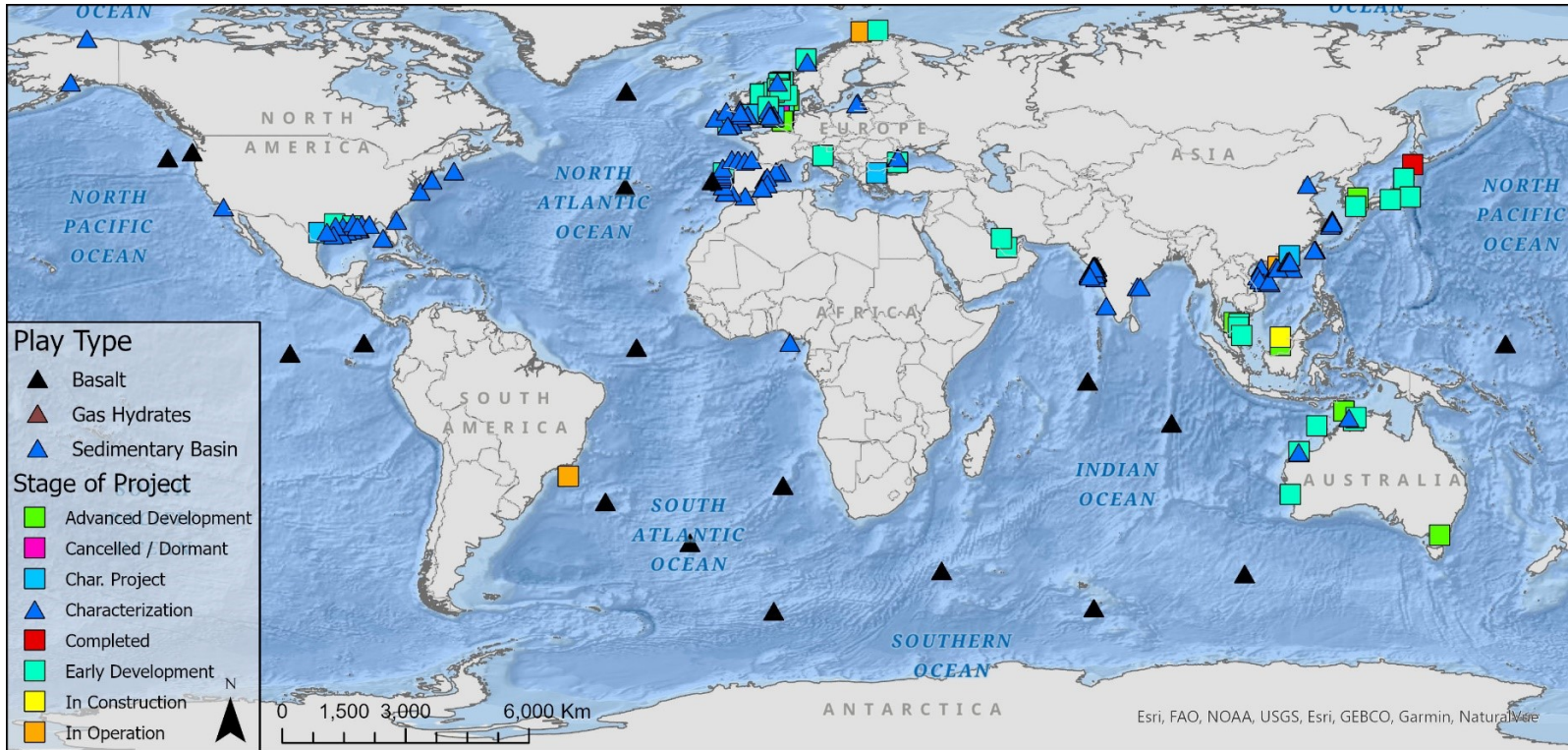
- Web map is live
- Web map showing the inventory as an interim product to enable public interaction and feedback while comprehensive dashboard is under development



Inventory of Offshore GCS Projects and Characterizations



- Offshore GCS Inventory has >254 locations globally of both actualized projects and characterization studies
- Additional attributes were added to the inventory to enable meta-analysis and analog comparisons



Version 2 Attributes

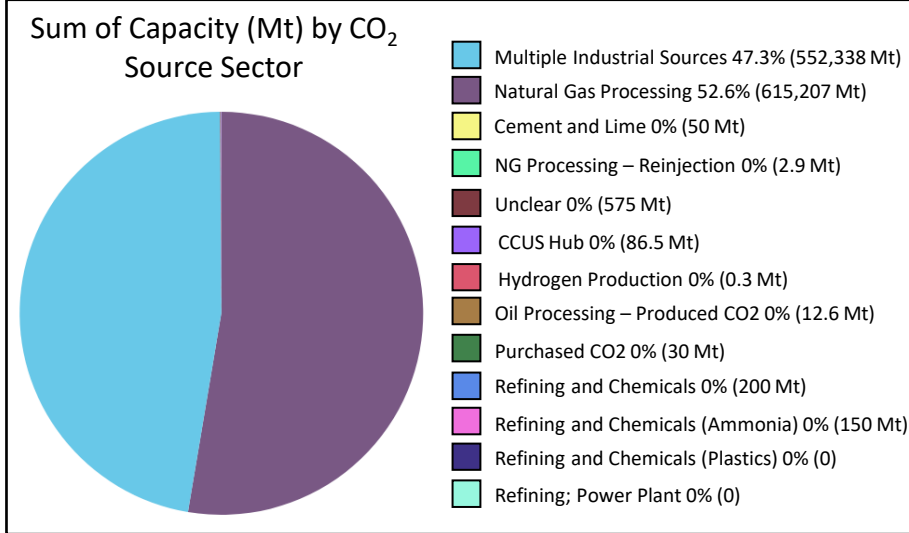
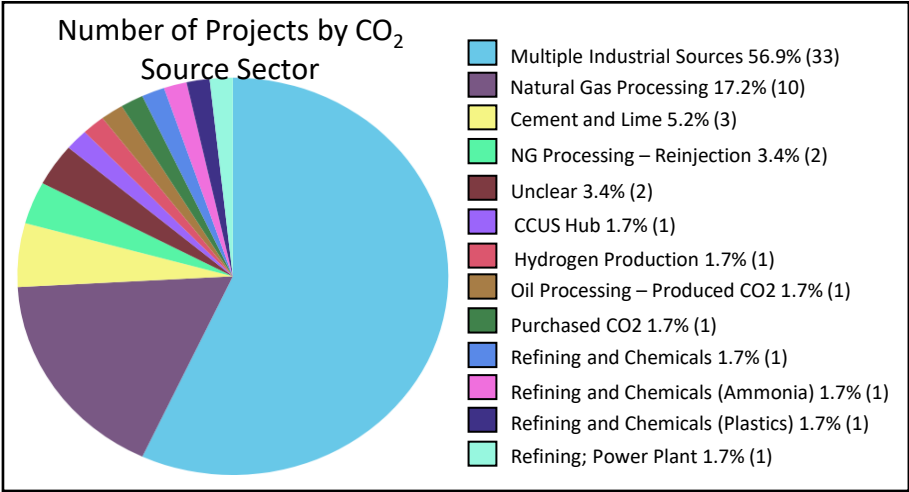
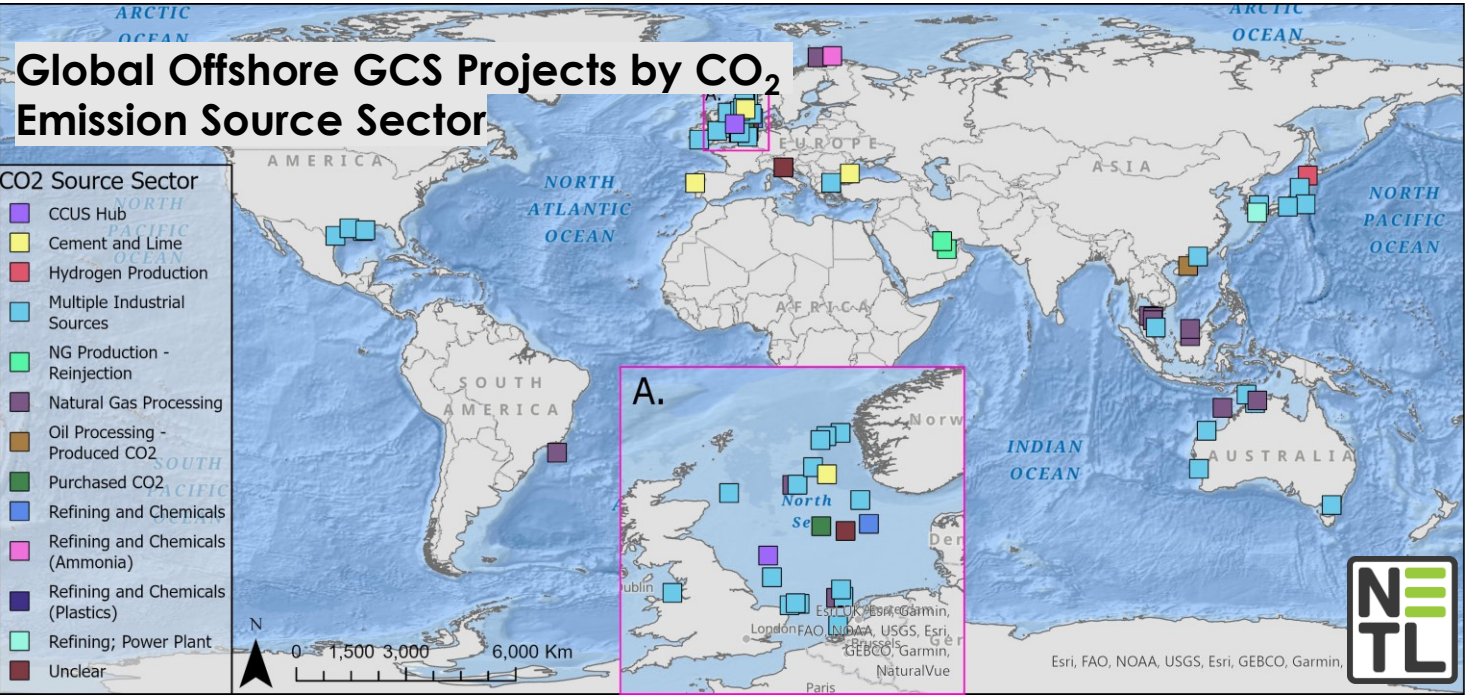
Project Name	Reservoir Depth Comment
Region	Reservoir Depth (m)
Sub-Region	Units of Reservoir Depth
Country	Estimated Storage Resource
State	Min. Est. Storage Resource (Mt)
Location	Max. Est. Storage Resource (Mt)
Location Description	Rate of Injection Description
Location Certainty	Rate of Injection (Mt/yr)
Basin	Companies
Project Stage	References
Project Stage Number Code	Distance from Coast Description
Project Type	Distance from Coast (km)
Study Type	Reservoir Depositional Environment
Play Type	Reservoir Age
CO2 Transport Method	Reservoir Formation
CO2 Source Sector	Porosity Description
Description	Porosity (%)
Inventory Version	Permeability Description
Longitude	Permeability (mD)
Latitude	Reservoir Thickness Description
Water Depth Description	Reservoir Thickness (m)
Water Depth (m)	Reservoir Characteristics References
Date Announced	Reservoir Characteristics Comments
Date FID	Onshore vs. Offshore Location
Expected Operational Year	Seal Formation
End Date	Seal Thickness Description
Reservoir Lithology	Seal Thickness (m)
Reservoir Fluid	Percent CO2 in Gas
Seal Lithology	IEA Name

Displaying Projects by Attribute for Analog Comparisons



Expanded attribute fields within inventory enables meta-analysis

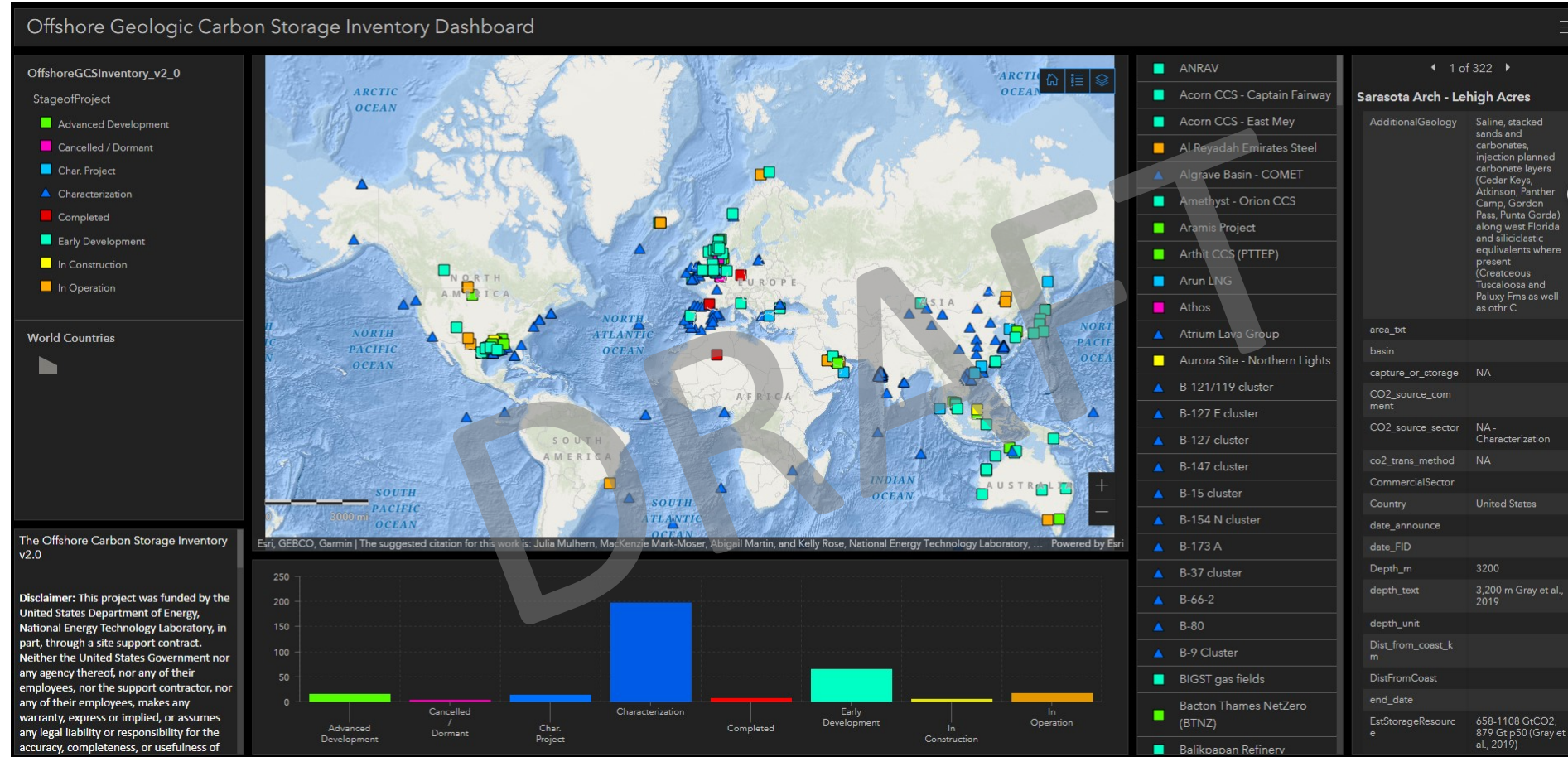
- Symbolizing and summarizing projects by characteristics shows the spatial distribution by various attributes
- New attributes include: Study Type, Project Type, CO₂ Transport Method, CO₂ Source Sector, Basin Type



Upcoming Interactive Dashboard for Inventory

Dashboard will Enable Exploration of Inventory Using a Variety of Attributes

- Inventory will be published as an ArcGIS Enterprise layer with a REST API service link to allow access to an evergreen inventory version (September release)
- Attribute fields will be used to generate graphics with scale with map display to enable scalable comparisons and analysis on the fly (January release)
- Updates and additional information are welcome to ensure accuracy
- Creating an email list to announce additional product releases



Offshore GCS StoryMap and Scoping Review Report

- **Story Map** provides review of global offshore GCS characterizations and operations, communicating progress, stages, locations
- **Report** summarizes global scoping and includes project descriptions and extensive references



ENERGY | NETL | International Offshore Geologic Carbon Storage

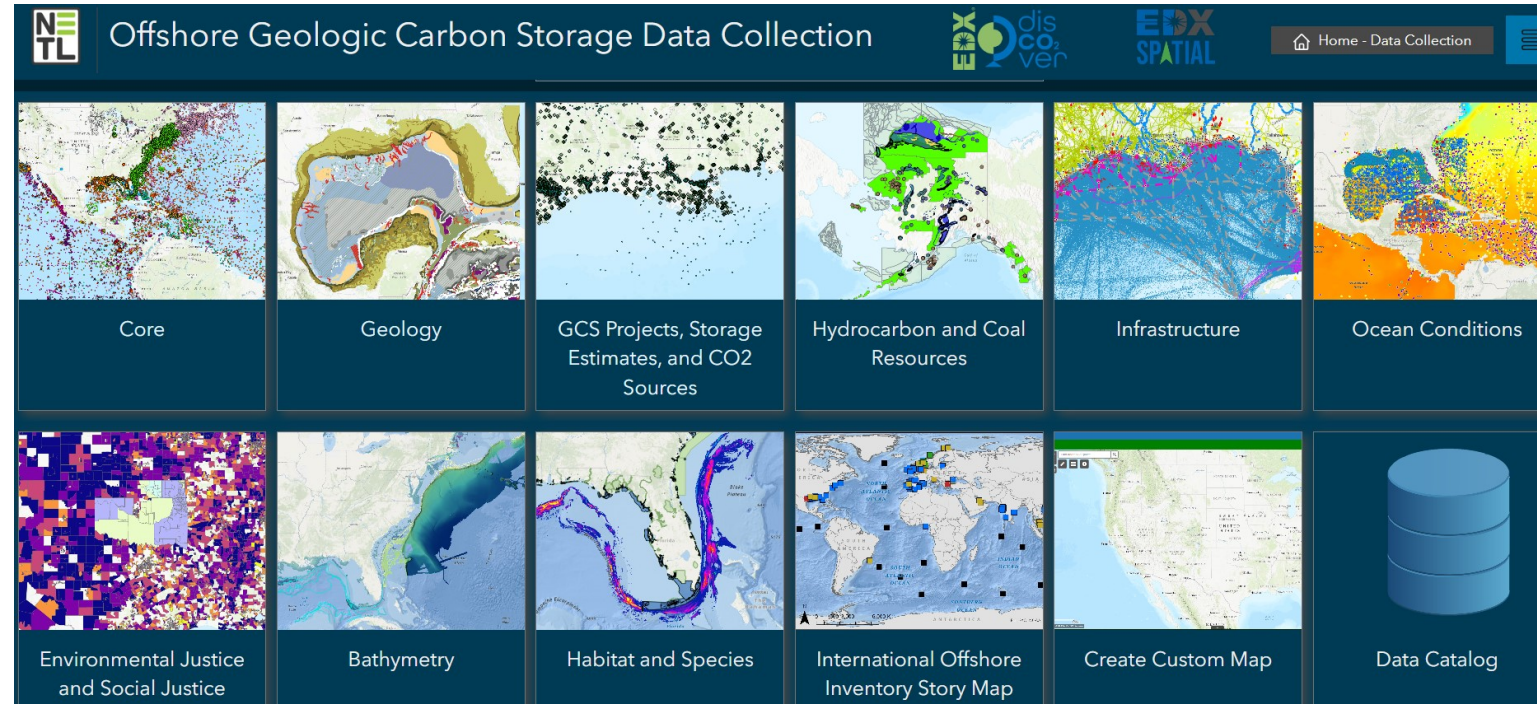


Abigail C. Choisser, MacKenzie Mark-Moser, Julia Mulhern, Kelly Rose, International Offshore Geologic Carbon Storage Story Map, 9/22/2023, <https://edx.netl.doe.gov/dataset/offshore-geologic-carbon-storage-story-map>, DOI: 10.18141/1995986

Progressing Offshore GCS Understanding

Utilizing Offshore GCS Data Collection and Inventory:

- Data availability and data gathering
- Offshore cost modeling
- Analog comparisons to leverage understanding
- Offshore transport analysis
- Input data for risk assessments
- Leveraging global learnings



Next Steps for this Project:

- Dashboard development with attributes (anticipated Q1 2025 release)

Recent Offshore GCS Products

Variety of Deliverables Launched and Ready to Use

Offshore GCS Data Collection

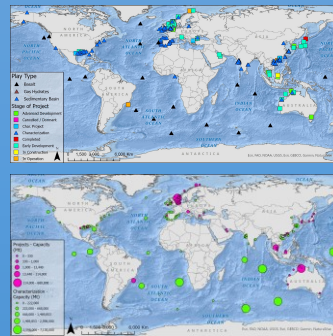
Data Collection Web App



Data Gaps Assessment Report

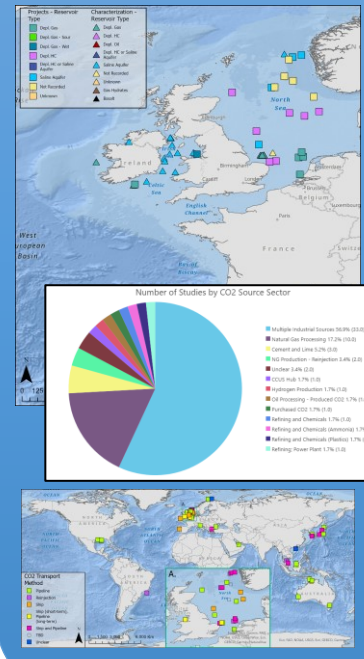


Inventory of Offshore Projects and Studies



International Offshore GCS Inventory

Offshore Meta-Analysis Dashboard



Inventory and Global Project Summary



Inventory Story Map



Offshore GCS Data Collection

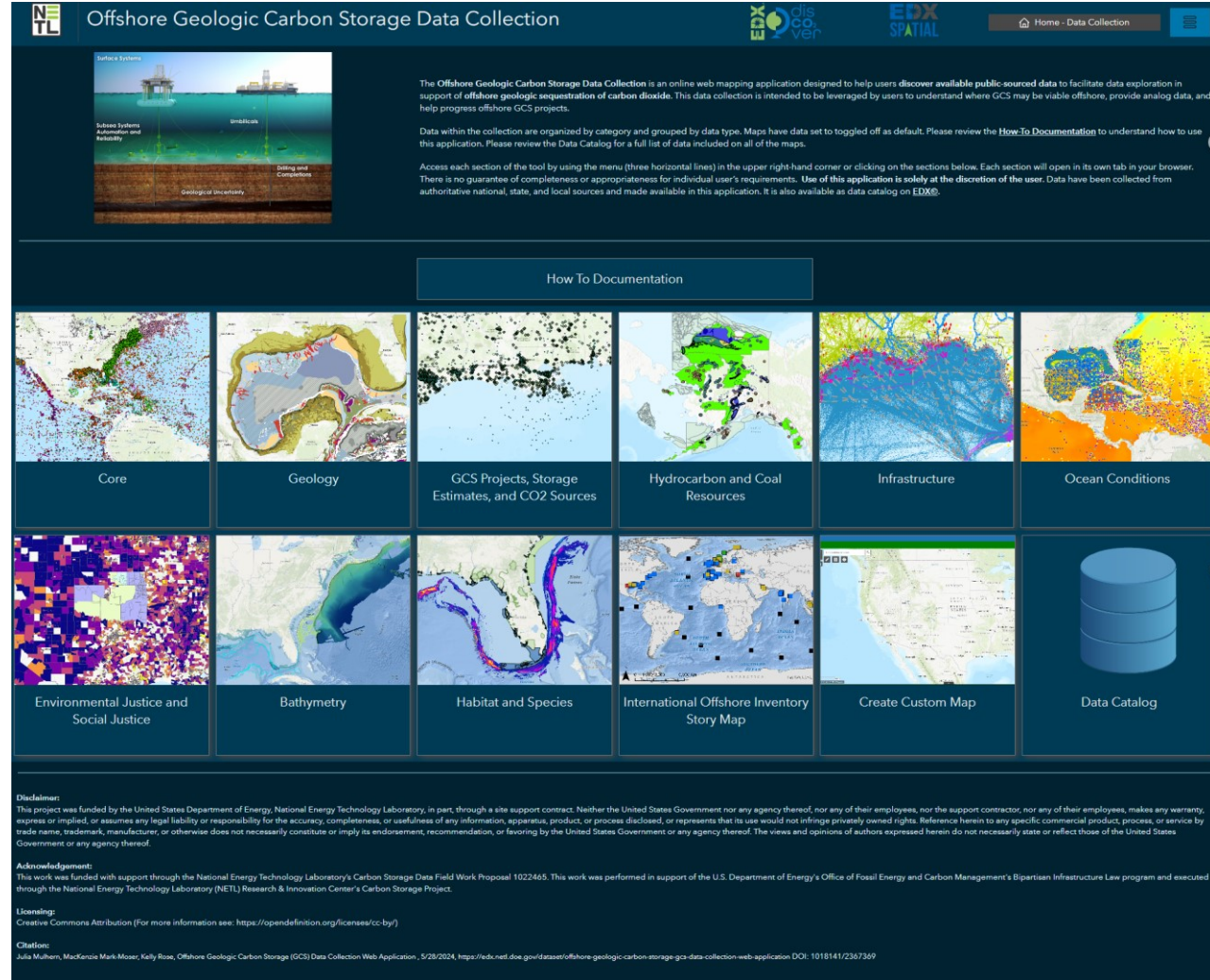
Interactive Web Application to Visualize Data Collection

Nine interactive maps with categorized data

- Data collection aggregates publicly available, authoritative data into one location
- Data collection can be used to:
 - Compare between datasets
 - Quickly visualize data
 - Support a variety of analysis



Data Collection
QR Code

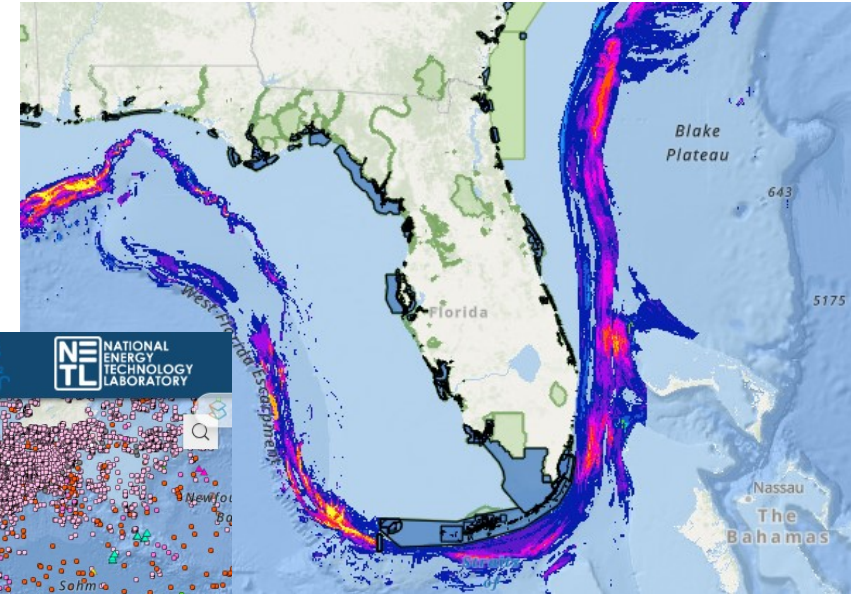
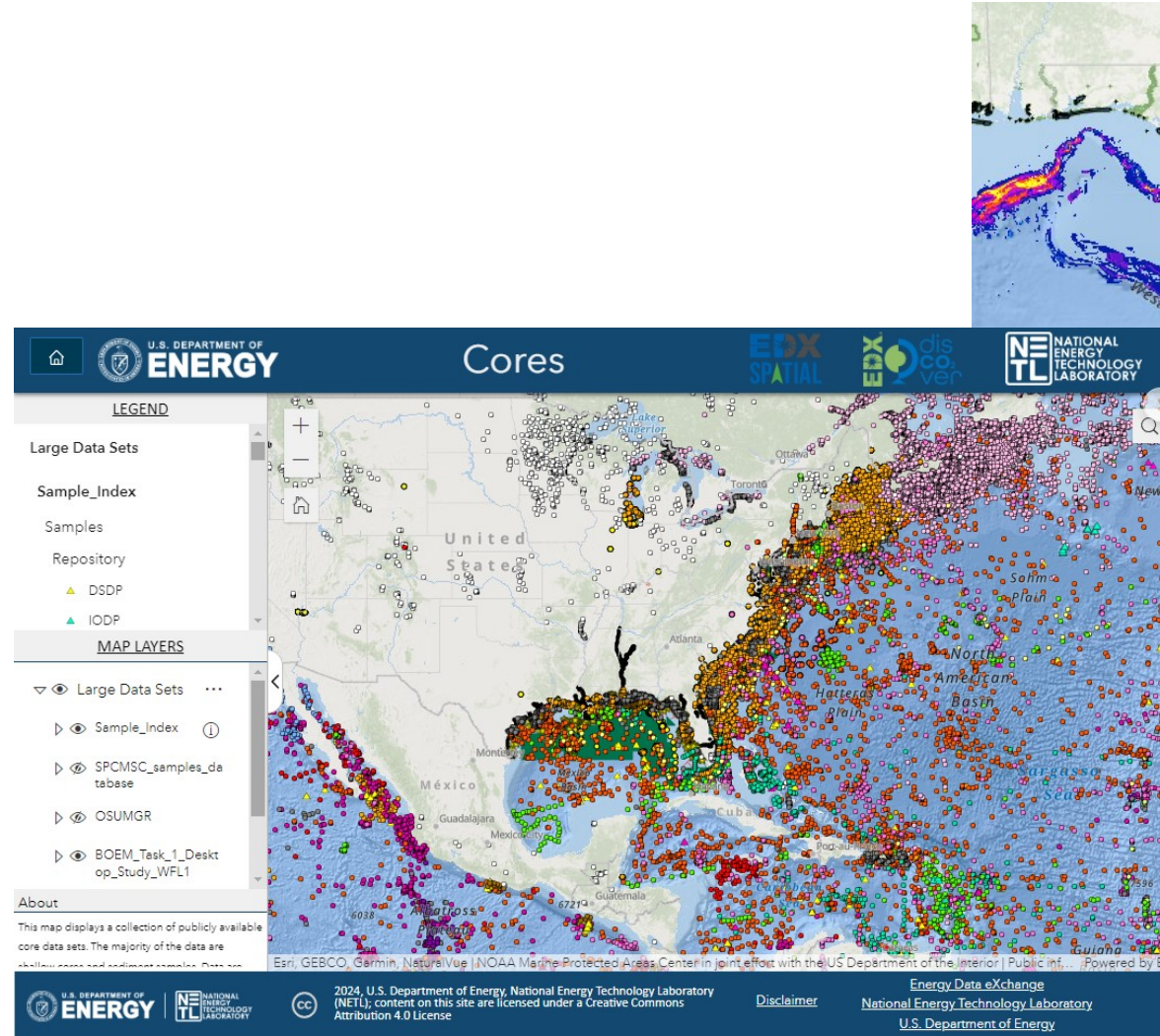


The screenshot shows the 'Offshore Geologic Carbon Storage Data Collection' web application. At the top, there is a header with the NETL logo, the title, and navigation links for EDX, CO2 Connect, and EDX SPATIAL. A 'Home - Data Collection' button is also present. Below the header is a descriptive text block explaining the application's purpose and how to use it. A central grid of 11 interactive map thumbnails is displayed, each with a title: 'Core', 'Geology', 'GCS Projects, Storage Estimates, and CO2 Sources', 'Hydrocarbon and Coal Resources', 'Infrastructure', 'Ocean Conditions', 'Environmental Justice and Social Justice', 'Bathymetry', 'Habitat and Species', 'International Offshore Inventory Story Map', and 'Create Custom Map'. A 'Data Catalog' icon is also visible. At the bottom, there is a 'Disclaimer' section, an 'Acknowledgement' section, a 'Licensing' section (Creative Commons Attribution), and a 'Citation' section.

Interactive Maps Enable Quick Data Visualization

Web Hosted Maps Facilitate Data Access

- Each of the nine web maps have datasets aggregated by topic which can be toggled on and off
- The corresponding database can be used to sort and filter data for all nine maps



Coral Reefs and Fish Habitats.

Sediment Cores.

Interactive Web Maps Enable Data Visualization

Example showing layer groupings

MAP LAYERS

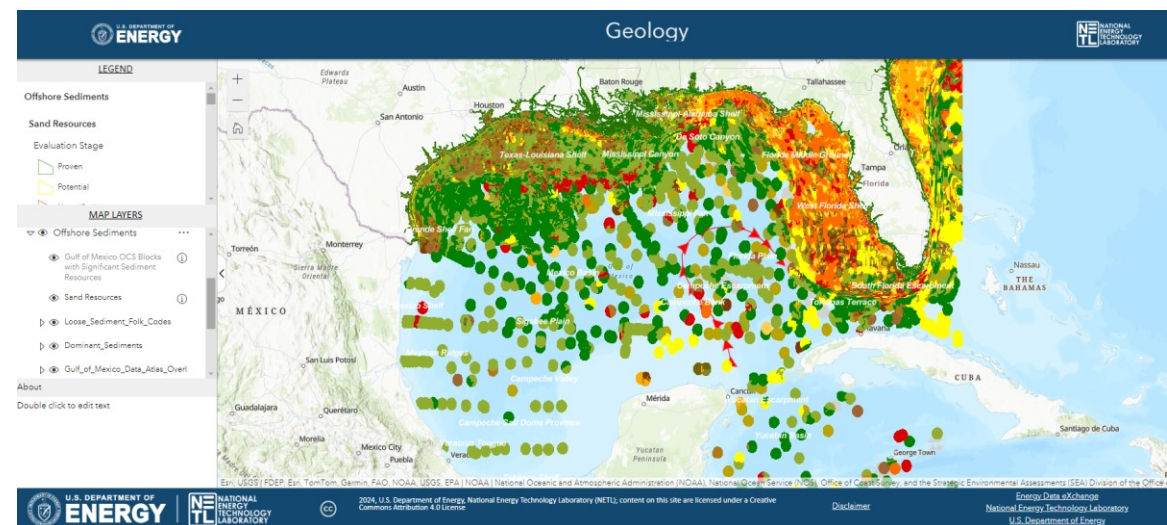
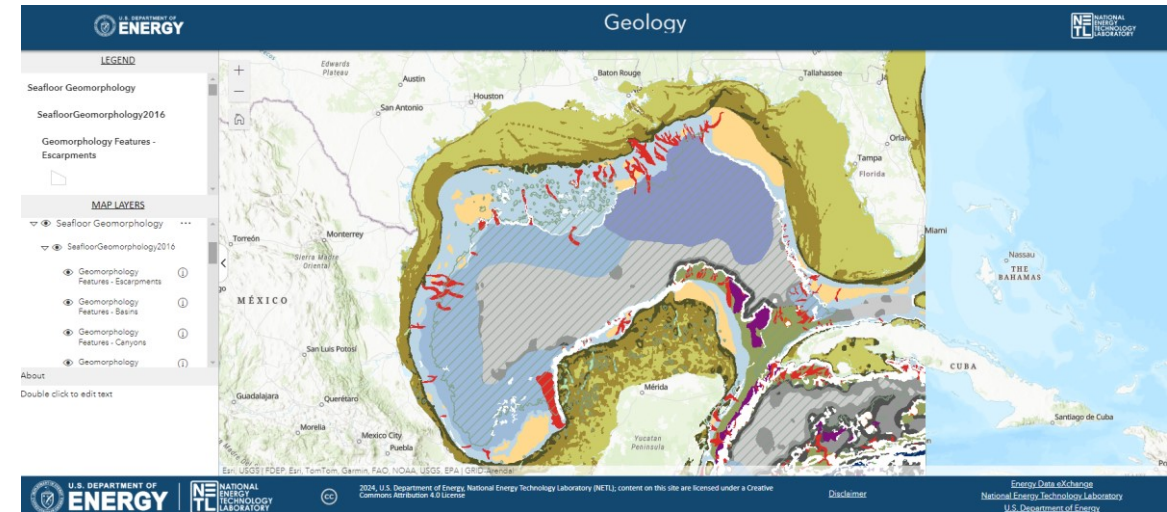
- ▶ Seismic Surveys
- ▶ Subsurface Geology
- ▶ Seafloor Geomorphology
- ▶ Offshore Sediments
- ▶ World Lithology
- ▶ Alaska Geology

MAP LAYERS

- ▼ Seafloor Geomorphology
 - ▼ SeafloorGeomorphology2016
 - ▶ Geomorphology Features - Escarpments
 - ▶ Geomorphology Features - Basins
 - ▶ Geomorphology Features - Canyons
 - ▶ Geomorphology

MAP LAYERS

- ▼ Offshore Sediments
 - ▶ Gulf of Mexico OCS Blocks with Significant Sediment Resources
 - ▶ Sand Resources
 - ▶ Loose_Sediment_Folk_Codes
 - ▶ Dominant_Sediments
 - ▶ Gulf_of_Mexico_Data_Atlas_Ov



Offshore GCS Data Catalog of Web Links

Web Hosted Data Expedites Visualization and Utilization

- Excel sheet catalog for the data collection is easily searchable and allows users to link back to original data sources via REST Service landing pages and links
- This enables quick and easy visualization of evergreen data sources



The **Offshore Geologic Carbon Storage Data Collection** is an online web mapping application designed to help users **discover available public-sourced data** to facilitate data exploration in support of **offshore geologic sequestration of carbon dioxide**. This data collection is intended to be leveraged by users to understand where GCS may be viable offshore, provide analog data, and help progress offshore GCS projects.

Data within the collection are organized by category and grouped by data type. Maps have data set to toggled off as default. Please review the [How-To Documentation](#) to understand how to use this application. Please review the Data Catalog for a full list of data included on all of the maps.

Access each section of the tool by using the menu (three horizontal lines) in the upper right-hand corner or clicking on the sections below. Each section will open in its own tab in your browser. There is no guarantee of completeness or appropriateness for individual user's requirements. **Use of this application is solely at the discretion of the user.** Data have been collected from authoritative national, state, and local sources and made available in this application. It is also available as data catalog on [EDX®](#).

Julia Mulhern, MacKenzie Mark-Moser, Kelly Rose, Offshore Geologic Carbon Storage (GCS) Data Collection Web Application , 5/28/2024, <https://edx.netl.doe.gov/dataset/offshore-geologic-carbon-storage-gcs-data-collection-web-application>, DOI: 10.18141/2367369

Data Collection and Data Availability Report



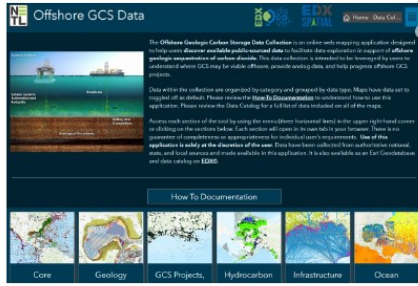
Technical report which leverages Carbon Storage Technical Viability Approach Matrix as a framework for data gaps assessment by region

- Report documents how the web application was developed, detailing development process

Report QR Code







Offshore Geologic Carbon Storage Data Collection and Data Gaps Analysis

30 June 2024




Office of Fossil Energy and Carbon Management

DOE/NETL-2024/4804

Retention and Geomechanical Risk					
Sub-Cat	Components	Gulf of Mexico	Atlantic	Pacific	Alaska
Seals and Pressure	Proven/Demonstrated Effectiveness of Top Seal	Some aggregated well data and regional geologic interpolations of seal properties exist. Included in some interpretations of nationwide datasets.	Understanding of seals limited by sparse drilling and seismic data for the region.		Seals mapped in regions where oil and gas exploration has taken place.
	Top Seal Thickness and Spatial Variability				
	Top Seal Viability, Fracture Pressure, Lithology, Porosity, and Permeability				
	Secondary Confining Unit Presence and Viability				
	Bottom Seal, Downward Flow, and Induced Seismicity				
	Pressure Communication with Reservoir				
Trap	Geological Trap Type and Certainty	Aggregated data on traps available. Some information can be garnered from existing hydrocarbon field information.	Limited data on traps for the region based on limited subsurface mapping.		Some information can be garnered from existing hydrocarbon field information.
	Trap Viability and Previously Demonstrated Integrity				
Faulting	Fault Presence, Depth, Spacing, Magnitude, Status (Active vs. Inactive)	Mapped faults from USGS. Some earthquake occurrence data aggregated.	Mapped faults from USGS. Some earthquake occurrence data aggregated.	Mapped faults from USGS. Some earthquake occurrence data aggregated.	Mapped faults from USGS. Faults mapped for Alaska included in dataset.
	Fracture Type and Density				
	Fault Reactivation Likelihood with Increased Pressure				
	Fault Gouge and Cementation/Fault Seal Viability				
	Earthquake Prevalence and Likelihood				

Data Gaps Assessment by Region Using CS TVA Matrix



Siting, Regulatory, and Jurisdictional Feasibility					
Sub-Cat	Components	Gulf of Mexico	Atlantic	Pacific	Alaska
Land Rights/ Use	Surface - Land Ownership and Access	Leases and boundaries included in dataset.			
	Subsurface Pore Space Rights				
Population and Habitats	Protected Areas and Sensitive Habitats	Lots of species and habitat data included. Census data available.	Some species and habitat data available. Census data available.		
	Population Density				
Jurisdiction	Jurisdictional Boundaries, Support, and Stability	Maps of tax credit eligibility distribution. County maps by various eligibility labels.			
	Governmental Policies and Incentives				
Regulatory	Maturity of Regulatory Framework	Class VI permit locations and status. Ongoing and historic GCS projects.			
	Maturity of CCS Activity in Area				

Reservoir Suitability					
Sub-Cat	Components	Gulf of Mexico	Atlantic	Pacific	Alaska
Reservoir Quality	Reservoir Porosity	Some aggregated well data and regional geologic interpolations for reservoir properties exist, primarily for the Gulf of Mexico.	A limited number of wells (~30) were drilled in the late 1970s and no drilling has taken place since then. Core data available for seafloor sediments.	Drilling data and information for coastal California are limited. Core data available for seafloor sediments.	Extensive well data for oil and gas regions is available. Core data available for seafloor sediments.
	Reservoir Permeability				
	Depositional Environment, Lithology, Grainsize, and Sorting				
	Diagenesis, Grain Scale Deformation, Secondary Alteration, Reservoir Fractures				
Reservoir Geometry	Reservoir Thickness Distribution, Spatial Extent, and Lateral Variability	Some mapped extent layers and interpreted well data exist with limited coverage. Seismic datasets are available. Some depth to reservoir top layers included.	Limited to no information available.	Data status uncertain but no data included in current collections.	Data likely exist are not currently included in collection.
	Reservoir Internal Variability, Geobody Architecture, and Net-to-Gross				
	Depth to Top of Formation				
Reservoir Conditions	Reservoir Temperature	Some aggregated well data and regional geologic interpolations for reservoir properties exist, primarily for the Gulf of Mexico.	Limited to no information available.	Data status uncertain but no data included in current collections.	Data likely exist are not currently included in collection.
	Reservoir Pressure				
	In-situ Fluids, Salinity, and CO ₂ Density				

Data Gaps Assessment by Region Using CS TVA Matrix



Environmental Justice, Social Justice, and Community Impacts					
Sub-Cat	Components	Gulf of Mexico	Atlantic	Pacific	Alaska
Community Sentiment	Community Familiarity with Drilling Process	Social well-being and vulnerability data available. Maps of county types. Some information within publications available.	Nationwide Environmental Justice and Social Justice census datasets available; localized data on carbon storage impacts unknown.		
	Community Attitude Toward Industrial Development				
	Community Attitude Toward Climate Change and Net Zero Ambitions				
	Community Cohesiveness and Jurisdiction Authority				
Impact on Community	Environmental Impact of Operations	Existing infrastructure data available.	Nationwide Environmental Justice and Social Justice and census datasets available; localized data on carbon storage impacts unknown.		
	Infrastructure and Resource Impacts	Some pollution datasets available.			
	Workforce Development and Job Creation	Economics and trade data available.			

Hazards					
Sub-Cat	Components	Gulf of Mexico	Atlantic	Pacific	Alaska
Subsurface Hazards	Overburden Drilling Hazards	Some geologic layers are mapped and included. Overburden hazards can be interpreted from seismic.	Limited drilling has taken place in the region therefore subsurface hazards are relatively unconstrained.	Subsurface hazards are understood where drilling has taken place but more information is needed for unexplored areas.	Some geologic layers are mapped and included. Overburden hazards can be interpreted from seismic.
	Pre-existing Well Density, Depths, and Ages				
Surface Hazards	Depth and Certainty of Drinking Water Aquifers in Overburden	Hurricane paths available for the Gulf of Mexico. Wind speed data are included. Seafloor geomorphology and offshore sediments data available. Multiple types of infrastructure layers are available.	Multiple types of infrastructure layers are available.		
	Water Depth (if offshore)				
	Topography or Location Risks				
	Climate, Weather, and Met-ocean				
	Natural Hazards - Land Surface or Seafloor Hazards				
Infrastructure Hazards					

	Data are available
	Insufficient data available
	Limited or no data available within current collection.

List of References Related to this Project



Data Collection:

Mulhern, J.S., Mark-Moser, M., and Rose, K. Offshore Geologic Carbon Storage (GCS) Data Collection

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Recent Talks and Posters:

Mulhern, J.S., Mark-Moser, M., and Rose, K. International Offshore Geologic Carbon Storage Project Inventory and Data Collection. 7th International Workshop on Offshore Geologic Carbon Storage, Port Arthur, TX. September 17-19, 2024. *Invited Oral Presentation*.

Mulhern, J.S., Mark-Moser, M., and Rose, K. International Offshore Geologic Carbon Storage Data Collection, Web Application, Inventory, and Meta-analysis. 2024 FECM / NETL Carbon Management Research Project Review Meeting. Pittsburgh, PA. August 5-9, 2024. *Oral presentation*

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