Carbon storage cost modeling for the offshore Gulf of America

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University of Houston ROICE Workshop

August 15, 2025

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Emissions and Storage Opportunities

- ~5 $GtCO_2$/year emitted in United States (US EIA)
- **Approx. 0.5 $GtCO_2$/yr emissions from >1,000 industrial sources along the Gulf Coast Corridor** (Grant et al., 2024)
- Significant storage resource exists in federal waters offshore Gulf of America
  - >1700 $GtCO_2$ mean storage resource in saline reservoirs (Romeo et al., 2022)

Grant et al., 2024

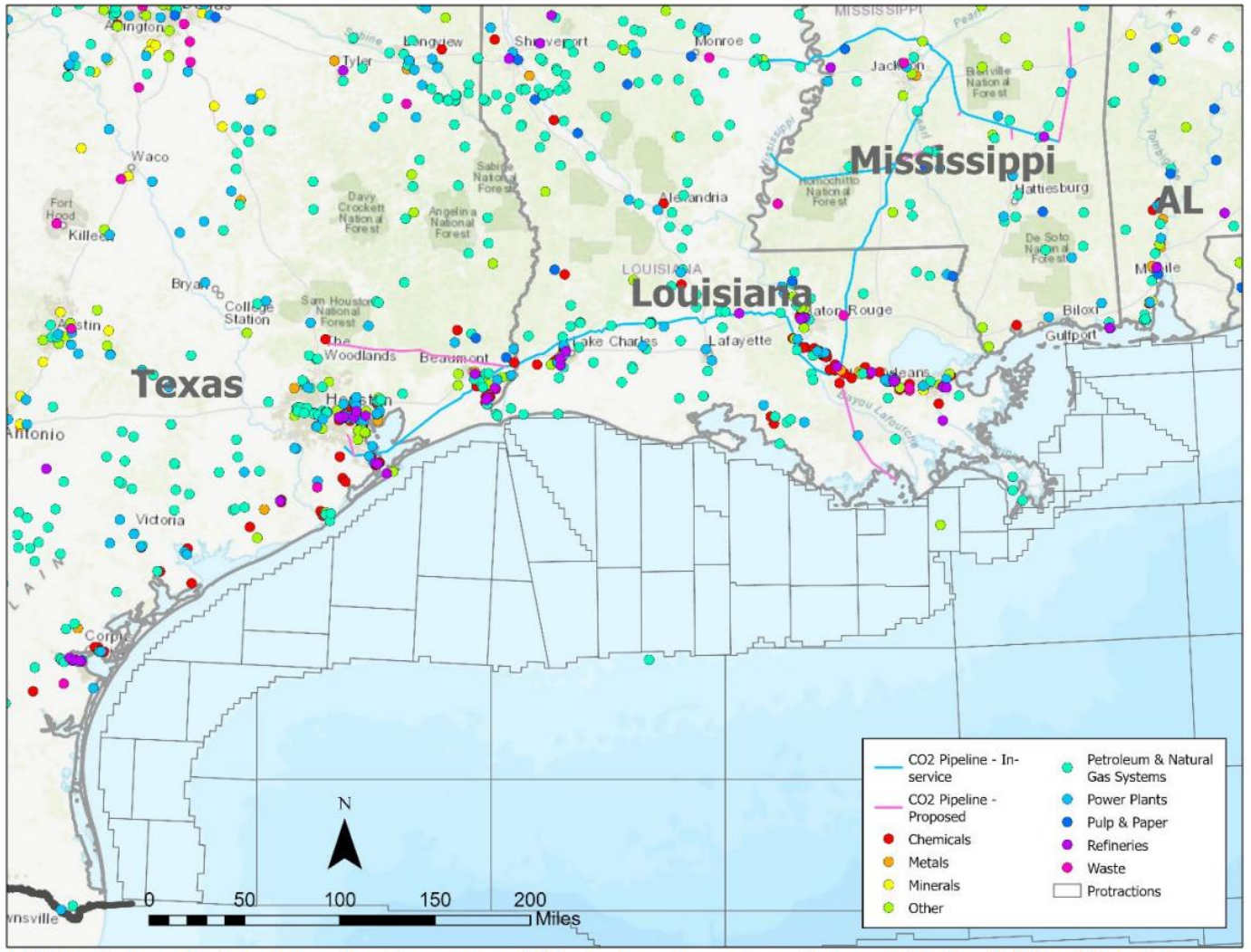
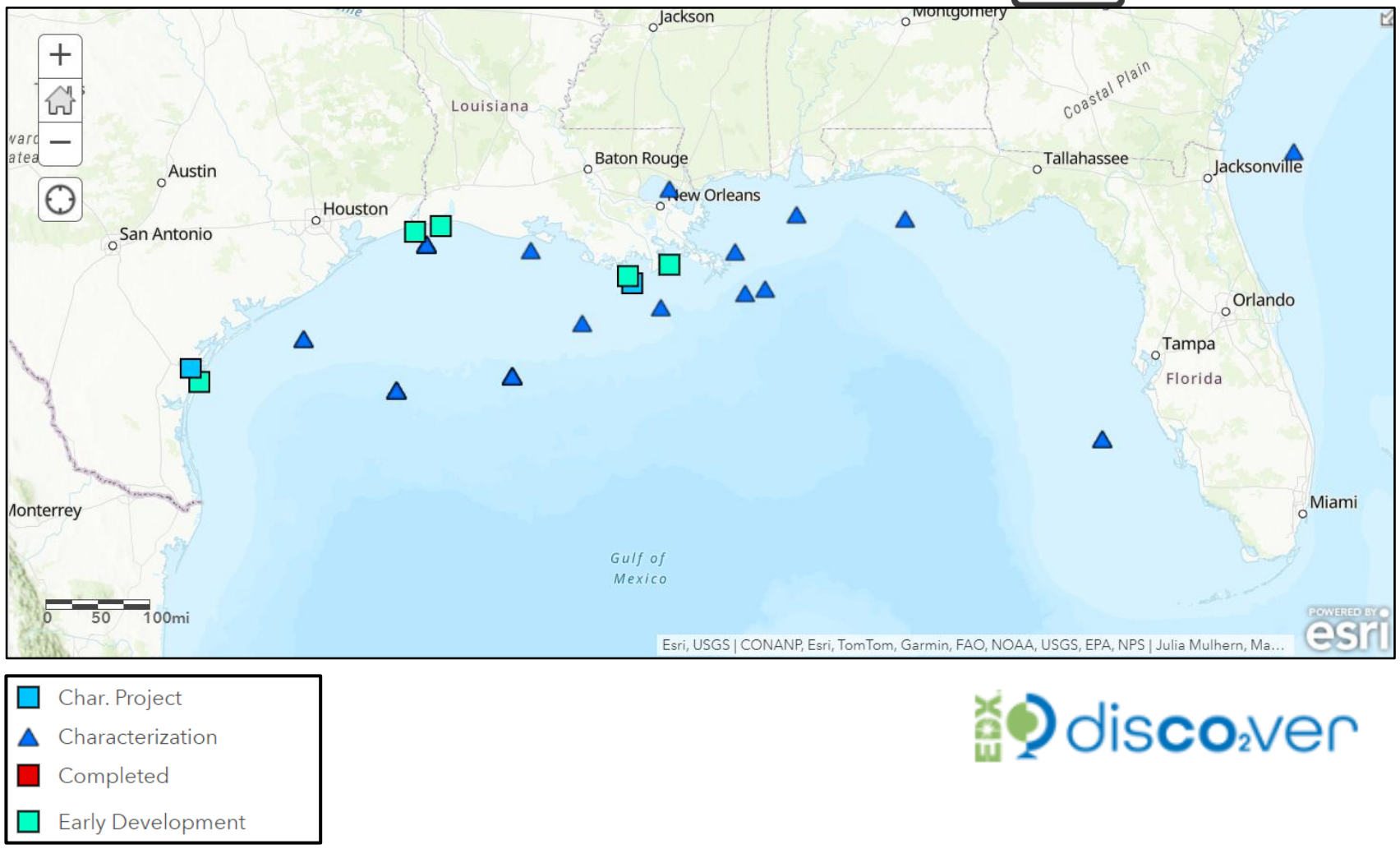


Figure 1. CO_2 emissions point sources colored by sector and CO_2 pipelines, in-service and proposed, in the Gulf Coast Corridor.

U.S. Offshore Projects Underway

- Offshore Gulf of America has >20 projects (both state and federal waters)
- **Six projects currently in development** in state waters; permits determined by US EPA or state primacy
- **Federal waters regulations to be determined**

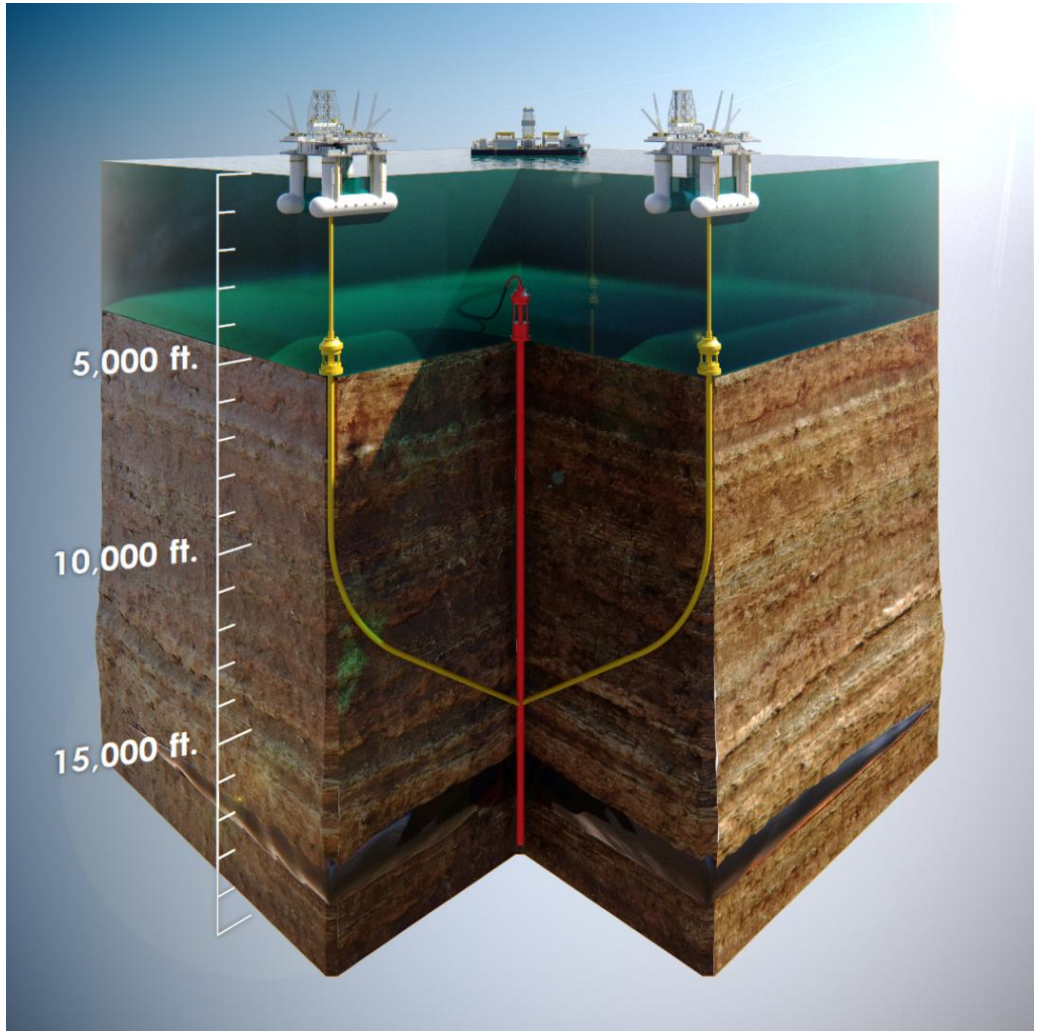


Mulhern, J.S., Mark-Moser, M., Martin, A.C., and Rose, K. Offshore Geologic Carbon Storage Inventory, 9/18/2023, https://edx.netl.doe.gov/dataset/offshore-gcs-data-inventory, DOI: 10.18141/1963815

CO2_S_COM_Offshore Cost Model

- **Screening-level tool** for offshore carbon transport and saline storage cost
- Encompasses the **distinct approaches to the offshore environment**

- **Key value delivery points**:
  - Integrated analytics
  - Customizable specific **project cost evaluation**
  - Informs **supply curve analysis**
  - **Onshore CO_2 source to offshore sink** cost analysis
  - Scenario analysis to **evaluate policy, financial, and technological inputs**



Overview

- Macro-based spreadsheet
- Incorporates **characterization, permitting, transport, operations, monitoring, site closure, and decommissioning**
- Calculates the **first-year break-even cost of offshore CS (2023$/tonne)**
- **Accounts for CAPEX, OPEX and other financing**
  - **Costs calculated via Que$tor and literature review**
- **Reviewed by BOEM/BSEE panels**

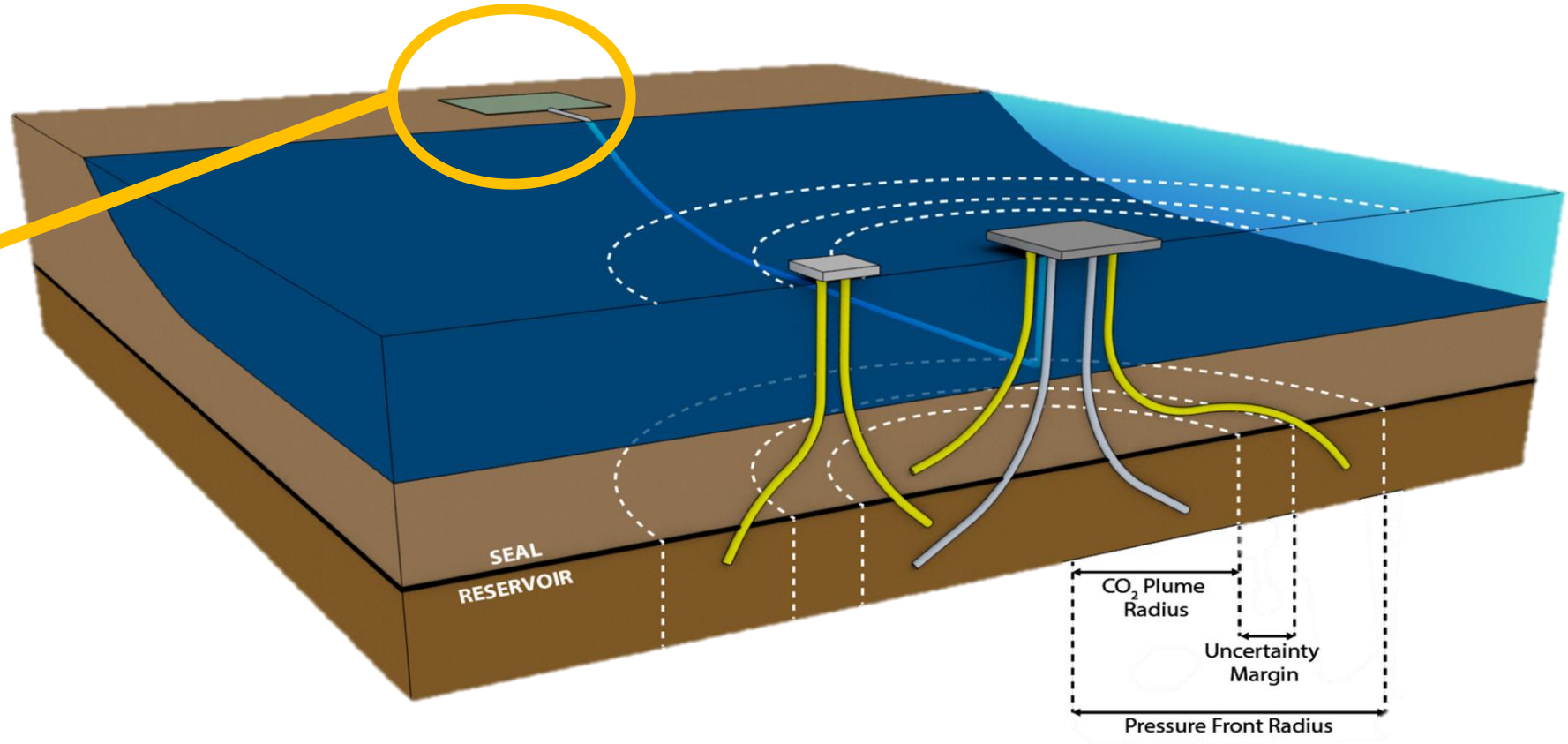
7.0 Offshore Pipeline Inputs for Calculating Capital and O&M Costs		
Item	**Units**	**Value**
Distance to Shore	mi	37.8
Pipeline tortuosity factor	unitless	1.1
Pipeline length	mi	41.6
New or existing pipeline	dropdown	New
Pipeline diameter size calculation settings		
Size objective option	dropdown	Min Diameter
Minimum target pressure exiting pipeline at storage site	psig	1,200
Calculated pipeline diameter size	inch	12
Inputs for pump to boost pressure of CO2		
Onshore pump inlet pressure	psig	1,200
Onshore pump outlet pressure (default)	psig	2,200
Onshore pump outlet pressure override	psig	
Is a pump needed to boost the pressure of CO2?	Yes or No	No
Pipeline pressure drop	psig	416
Accepted pipeline diameter	in	12
Offshore pump inlet pressure	psig	1,784
Offshore pump maximum outlet pressure	psig	2,477
	The pressure drop of this configuration falls within the allowable range.	

CO2_S_COM_Offshore pipeline inputs

Cost Model Component Development

Onshore Facilities

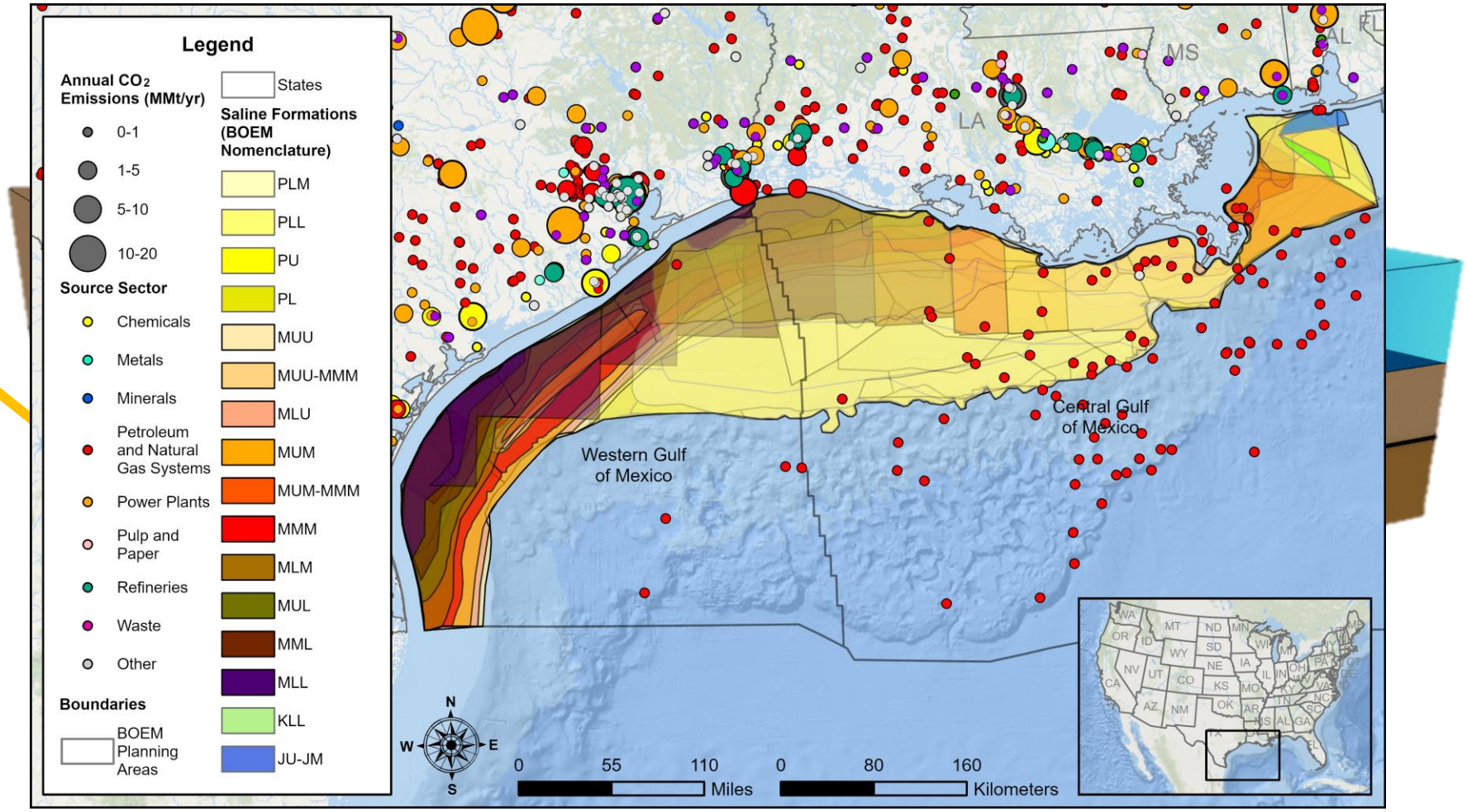
- Custody transfer meter, power generation, boost line pressure, and other support equipment



Cost Model Component Development

Geologic Database

- Outer Continental Shelf (OCS) of the Gulf of America at water depths less than 650 ft
- Sub-plays based on geologic age, distance from shore, and water depth

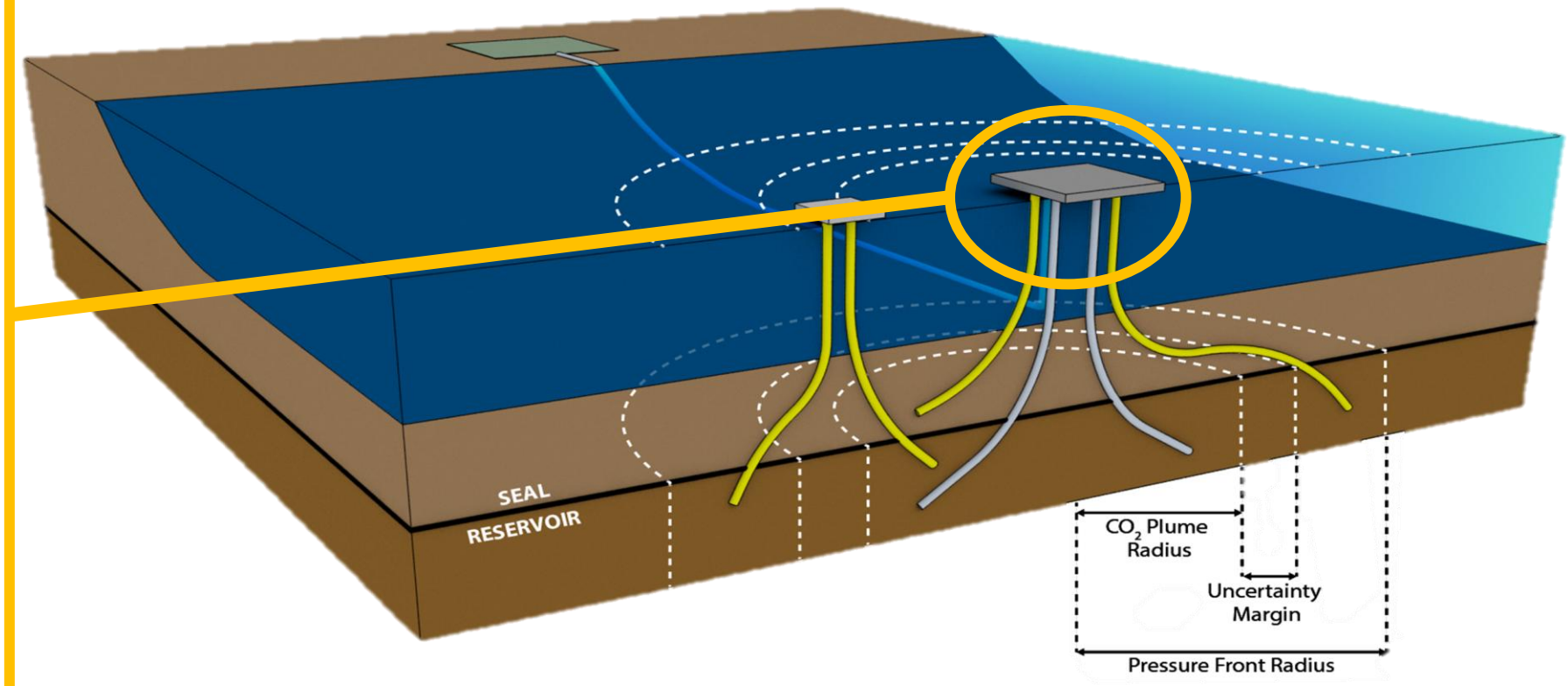


*Data sources include BOEM the Atlas of Gulf of Mexico Gas & Oil Sands, BOEM borehole and play boundary data, Enverus geophysical well logs

Cost Model Component Development

Primary Offshore Structure

- Water depth, injection rate, and well count, structure type
- **Booster pump logic includes cost changes associated with increasing reservoir pressure during injection**
- **Power demand is driven by compression power requirements**
- Annual O&M costs can be adjusted to include operating personnel cost

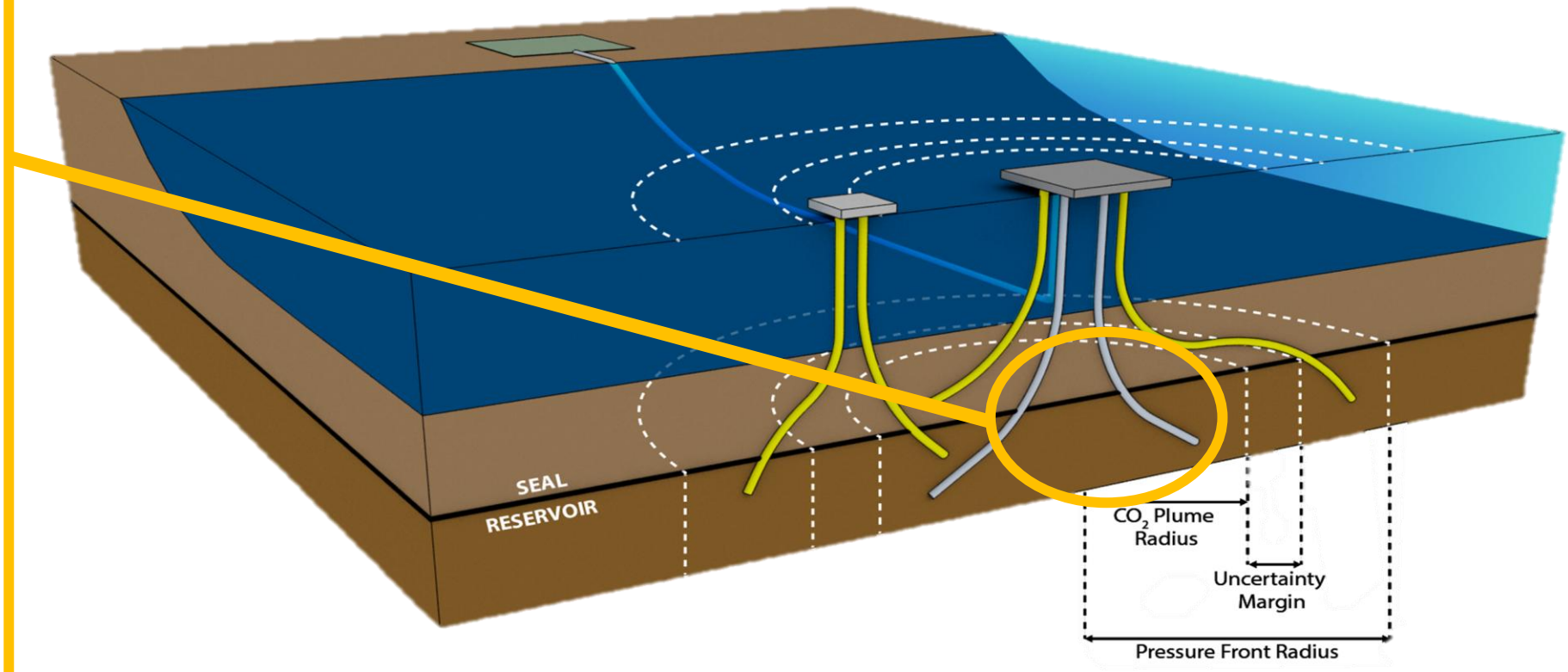


Cost Model Component Development

NATIONAL ENERGY TECHNOLOGY LABORATORY

Well Drilling Costs

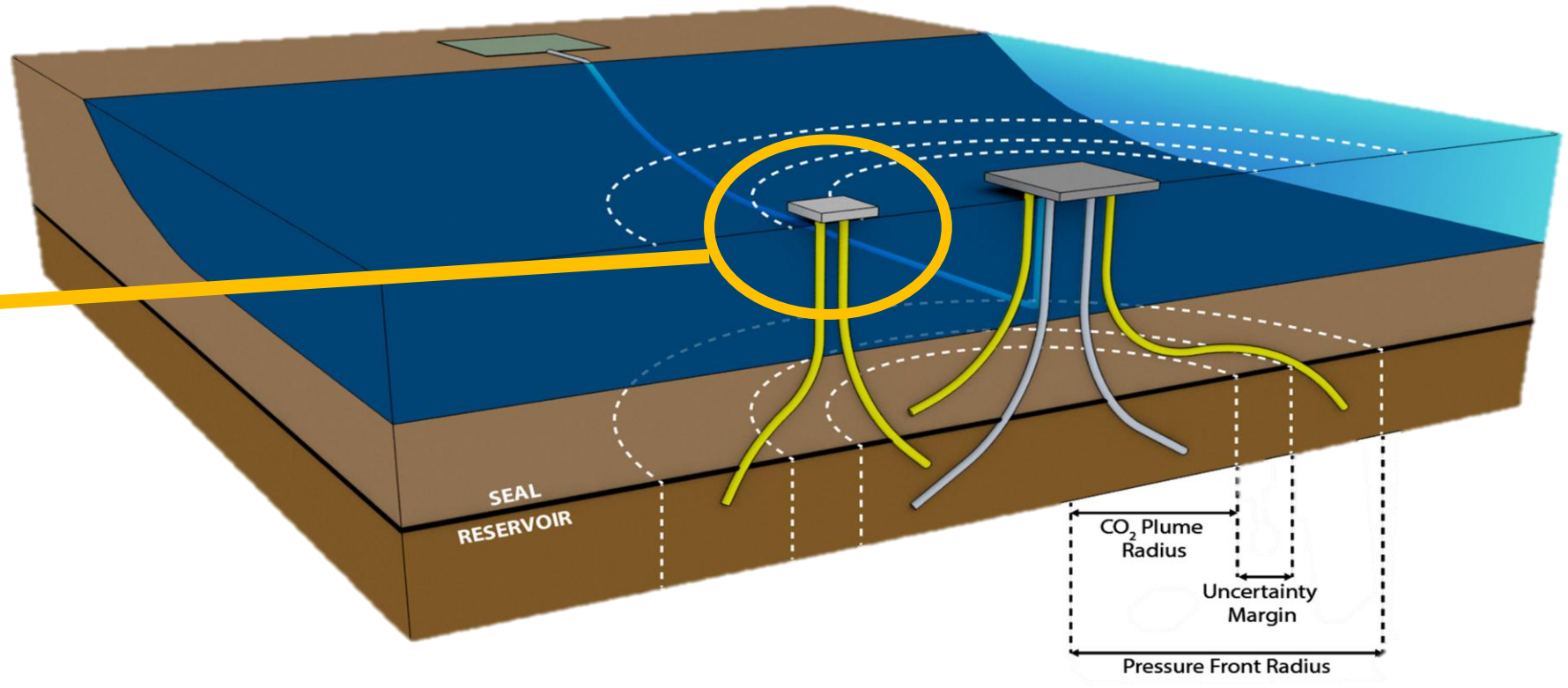
- Key inputs include well type (horizontal or directional), drilling rig type (mobile or fixed rig), and drill depth
- Monitoring well can be customized for dual/multi-completion, above seal completion, or in-zone completion



Cost Model Component Development

Offshore satellite structures

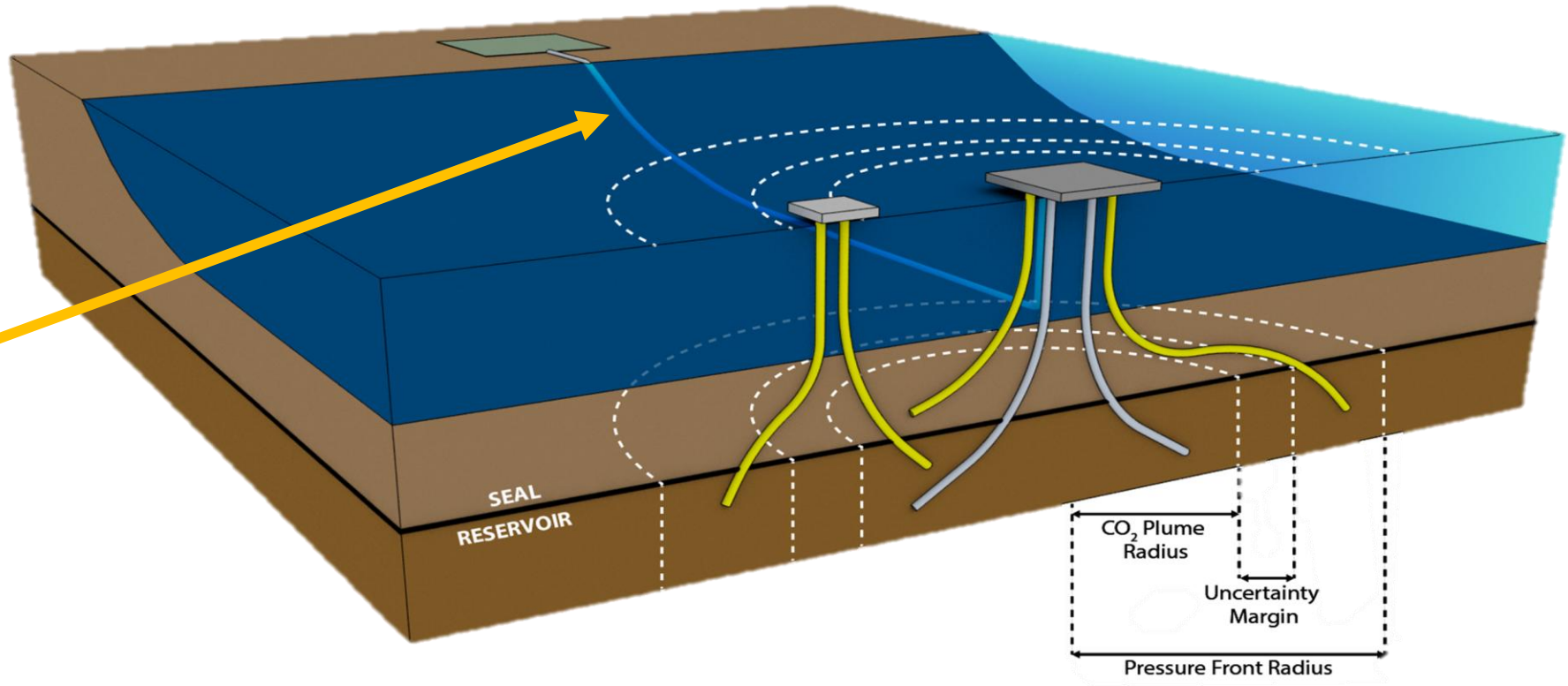
- Pressure front monitoring and water production estimates for projects with up to four satellite structures
- May include three deep monitoring wells; vertical or directional



Cost Model Component Development

Offshore Pipeline Modeling

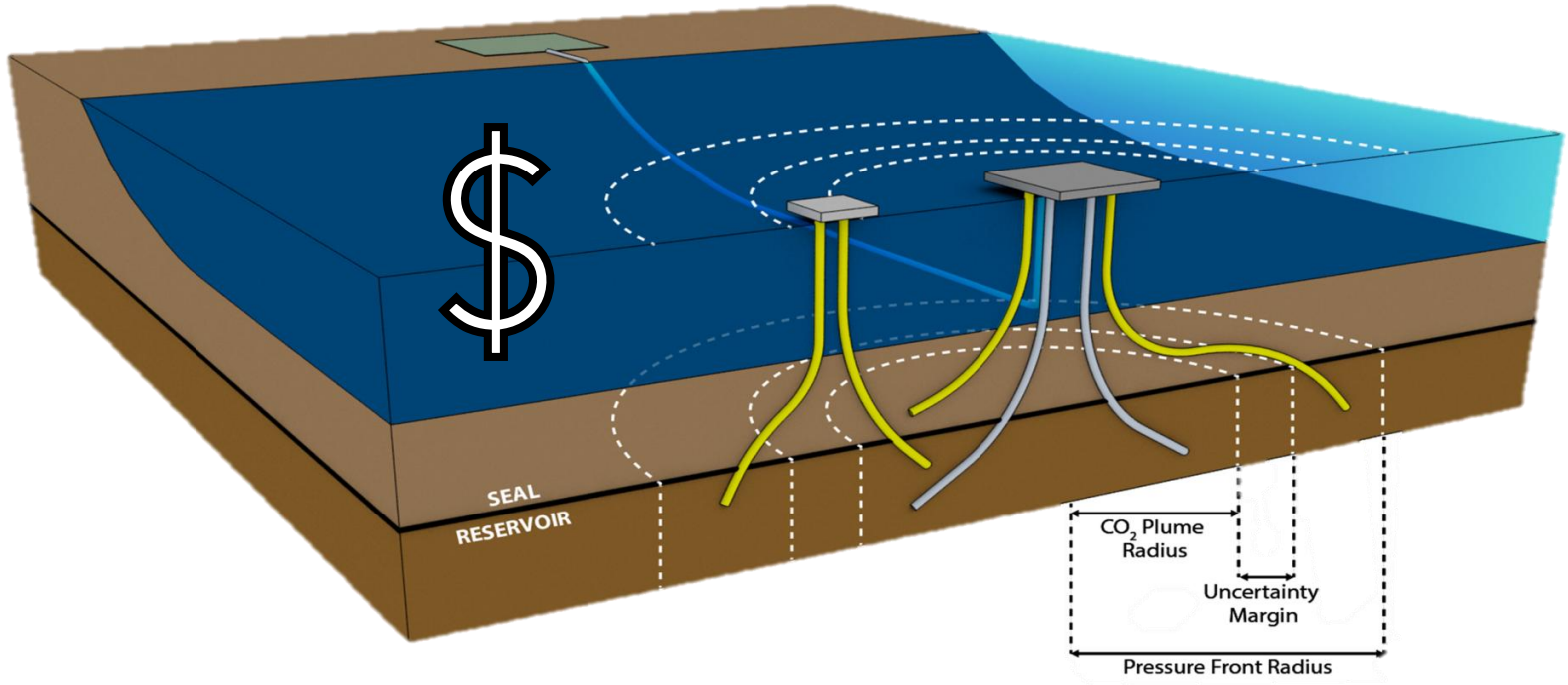
- Length of pipeline, onshore/offshore pump pressures
- Select new or existing, option to manually select diameter or use model-calculated minimum diameter
- Outputs pressure drop, acceptable diameter



Cost Model Component Development

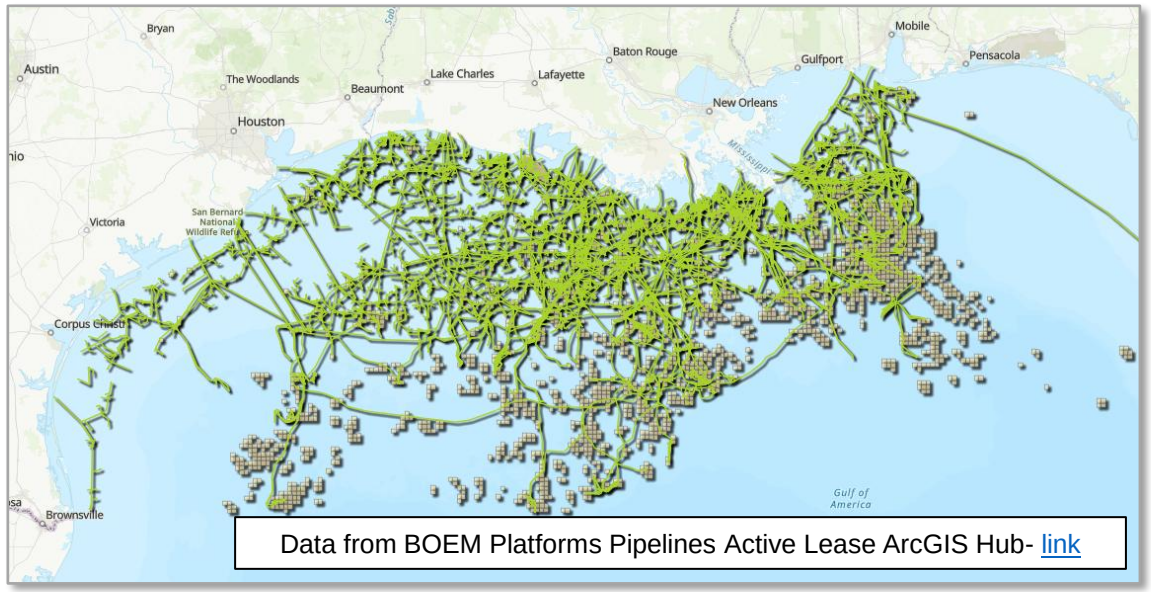
Financial Modeling

- Base financial modeling set to 2008 (EPA's CS economic data), augmented with lit. review and Que$tor
- Regulatory assumptions made while regulations are prepared
- Include financial responsibility instrument (e.g. trust fund), letter of credit, escrow, surety bond and insurance methods, post-injection site care, debt-equity ratio
- Inflation accounted for via US Bureau of Statistics CPI. Cost escalated to year specified by user via Handy-Whitman index



Infrastructure re-use in CO2_S_COM_Offshore

Users able to evaluate cost impacts from reuse of pipeline or primary platform infrastructure



Data from BOEM Platforms Pipelines Active Lease ArcGIS Hub- link

Figure from BSEE Website - link

Pipeline Reuse Logic

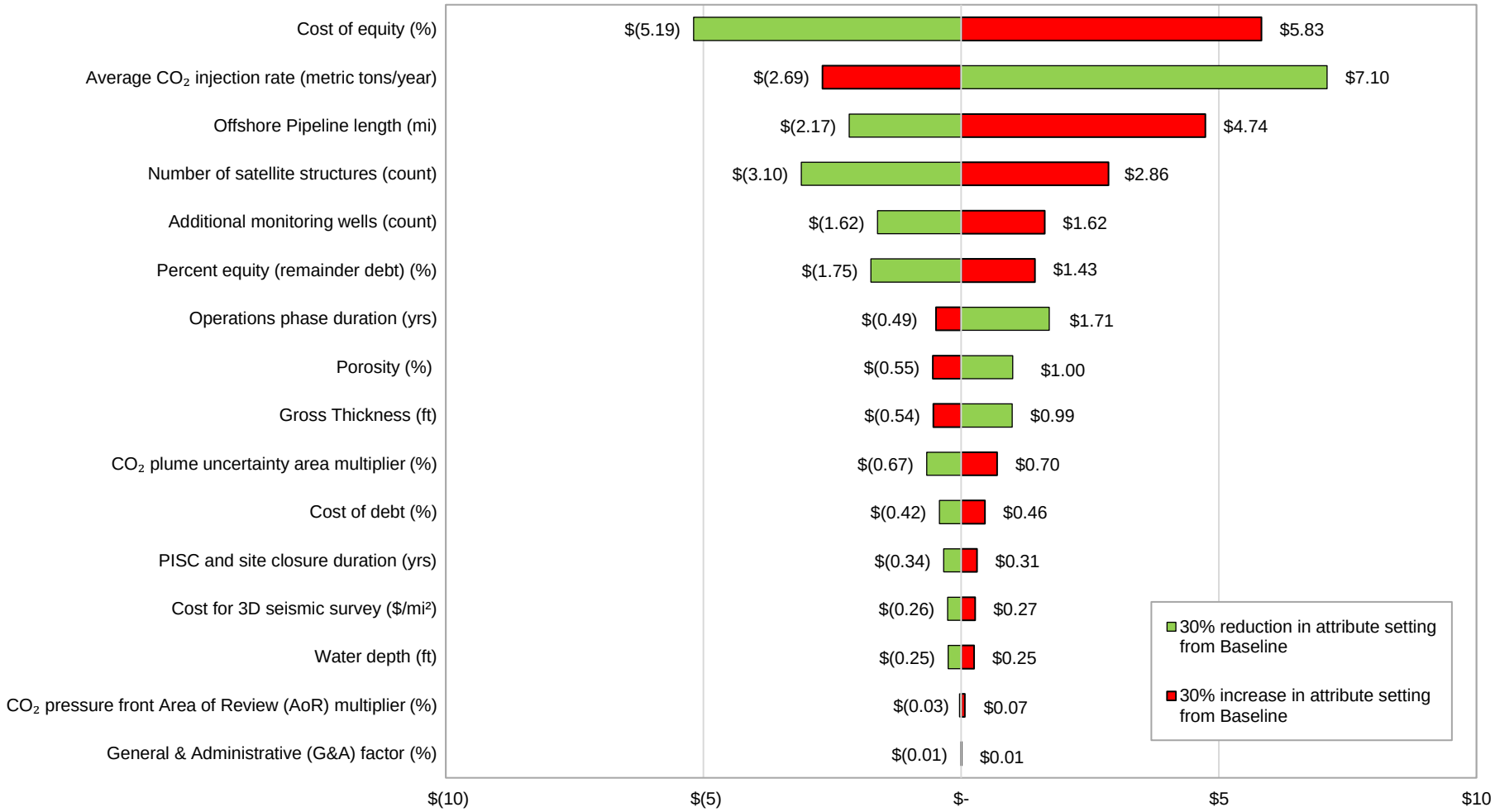
- Pipeline operating pressure assumed reduced by ~30%
- No CAPEX required / included
- OPEX calculated for each year of operation
- Does not consider any refurbishment efforts

Primary Platform Reuse Logic

- Assumes substructure and topside are refurbished to support injection operations
- User setting in Offshore_Eq tab sets refurbishment cost (default is 25% of new structure cost)
- OPEX calculated for each year of operation

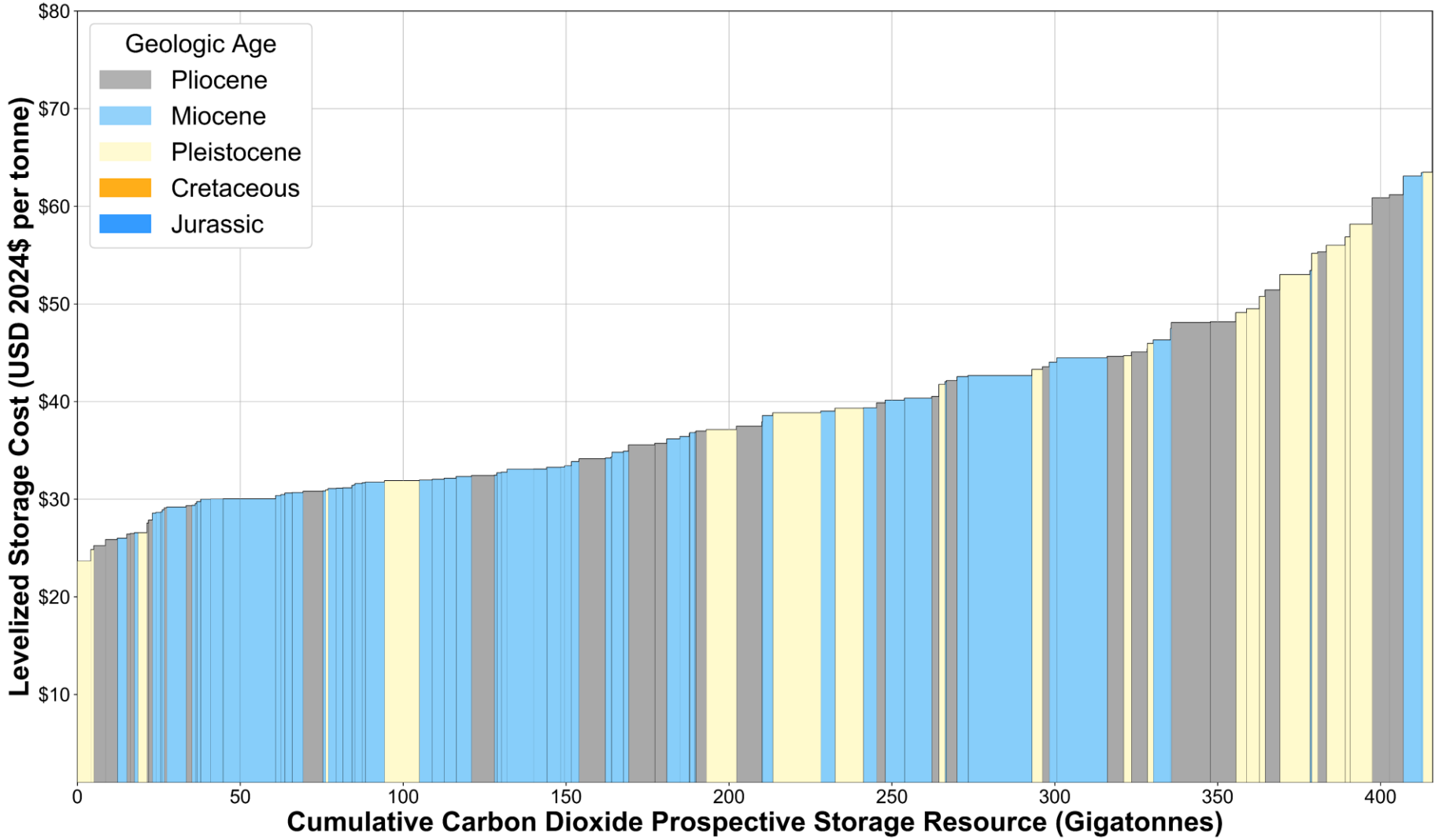
Model Performance: Input Variability

- Outputs apportioned to the variability in its inputs
- **Preliminary results from CO2_S_COM_Offshore indicate that cost of equity, CO2 injection rate, pipeline length, number of satellite structures, and monitoring well count have the greatest impact on per unit CS costs**



Model Performance: Standard Injection Scenario

- Evaluation of per tonne cost to store CO_2 against cumulative CO_2 storage resource in GOM sub-plays
- Scenario: Input of **4 million tonnes per year for 30 years** – relatively small project
- Lower cost formations are **typically shallower, thicker, more porous, closer to shore, and have lower water depth**

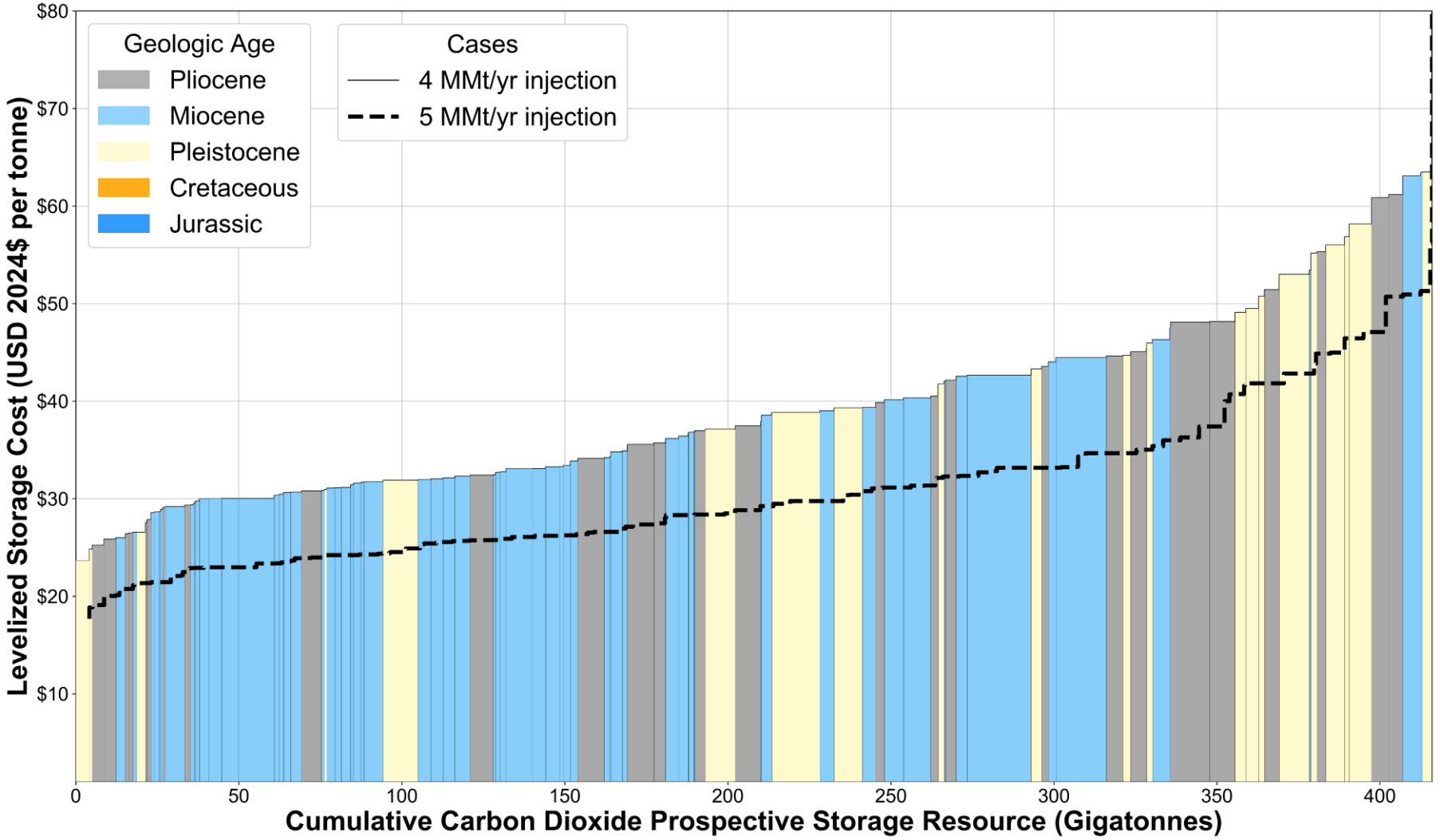


Model Performance: Multiple injection rates

Changed in levelized cost evaluated under different injection rates per year:

- 4 MMt/yr case
- 5 MMt/yr case

Results show variability of CS levelized cost and economics-of-scale savings with larger injection rate projects



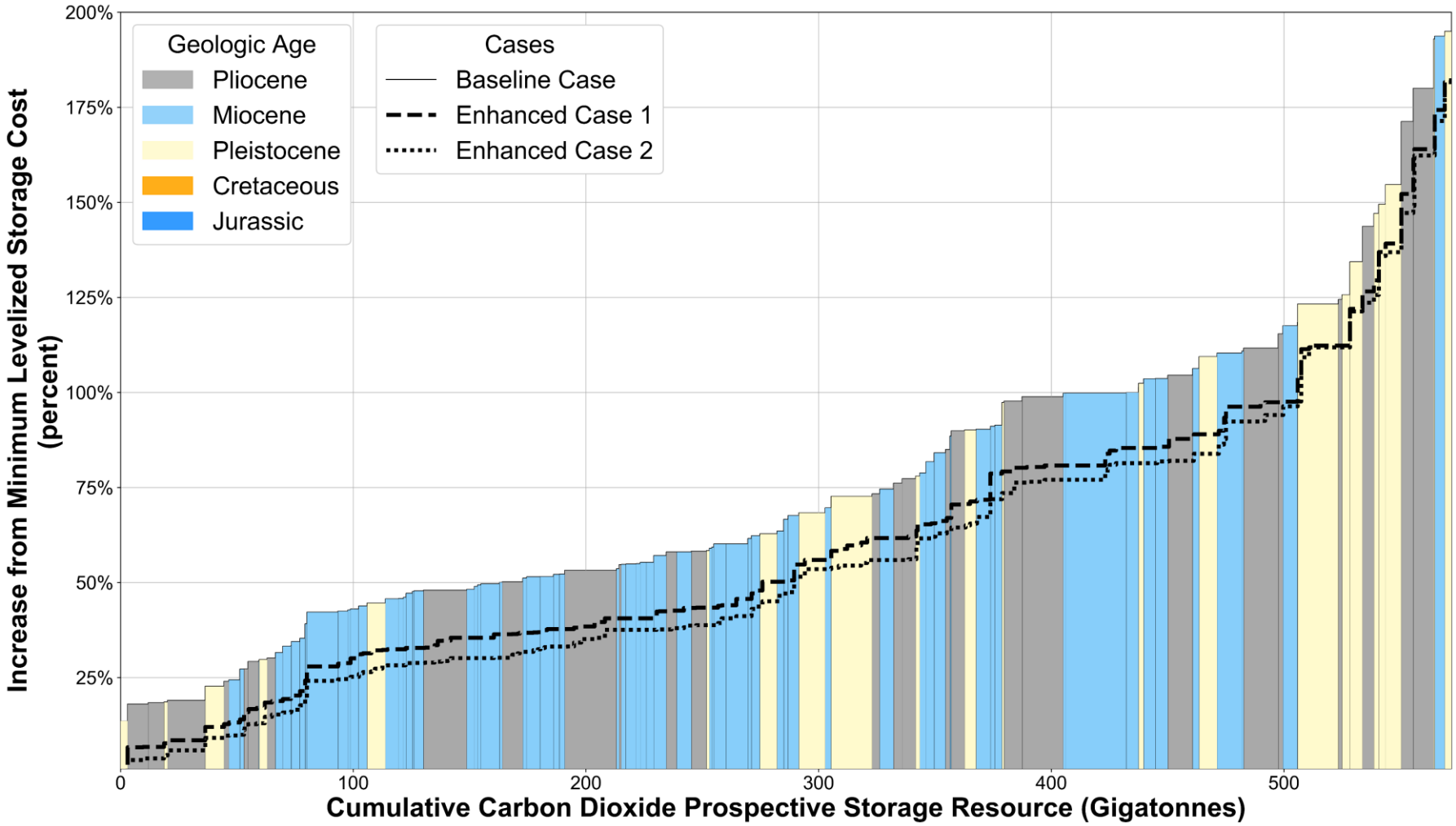
Scenario Sensitivity Analysis

Parameters Adjusted	Scenarios Evaluated		
	Baseline	Enhanced Case 1	Enhanced Case 2
Permitting and construction phase duration (years)	2	1	1
PISC and Site Closure duration (years)	35	25	15
CO_2 pressure front Area of Review (AoR) multiplier	10	7	5
Number of sites for characterization	2	1	1
Financial Responsibility Instrument	Trust Fund	Trust Fund	Self-Insurance

- Sensitivity analyses indicate **the ability of the model to capture variability on cost based on altering inputs that reflect different policy/operational scenarios**
- **Scenario cases here are based on construction/operation and financial options**

Results - Scenario Sensitivity Analysis

Results show variability of levelized CS cost increase, with each enhanced case showing lower costs than the baseline case



Takeaways

- First-of-a-kind analytical resource for evaluating CS costs in offshore settings for screening potential sites based on the **first-year break-even cost of offshore CS per tonne**
- **Adaptable as the CS industry advances and regulations are enacted**, with plans to include reduced order costs and reflect energy market models
- Supports decarbonization value chain evaluations
- **Member of NETL's suite of technoeconomic energy analysis tools**
- **Released March 2025**

FECM/NETL Carbon Transport and Storage (CTS) Screening Tool
FECM/NETL CO_2 Transport Cost Model (CO2_T_COM)
FECM/NETL CO_2 Saline Storage Cost Model System
- CO_2 Saline Storage Cost Model, Onshore (CO2_S_COM)
- Offshore CO_2 Saline Storage Cost Model (CO2_S_COM_Offshore)
FECM/NETL Onshore CO_2 EOR Evaluation System
- CO_2 Prophet Model (CO2_Prophet)
- CO_2 EOR Cost Model (CO2_E_COM)
- Onshore CO_2 EOR Evaluation Tool (CO2_E_EvTool) [*in development*]
FECM/NETL Hydrogen Evaluation System
- Hydrogen Pipeline Cost Model (H2_P_COM)
- Natural Gas with Hydrogen Pipeline Cost Model

Next steps

Incorporating user feedback – let us know what you think!

Planning for annual updates

- User interface
- Regulations

Manuscript discussing model theory (In Prep)

https://edx.netl.doe.gov/dataset/fecm-netl-offshore-co2-saline-storage-cost-model-version-1

References

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