CO2_S_COM_Offshore: A Technoeconomic Analysis Tool for Offshore Saline Carbon Storage

NATIONAL ENERGY TECHNOLOGY LABORATORY

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Carbon Transport and Storage Breakout Session 1
Offshore Topics

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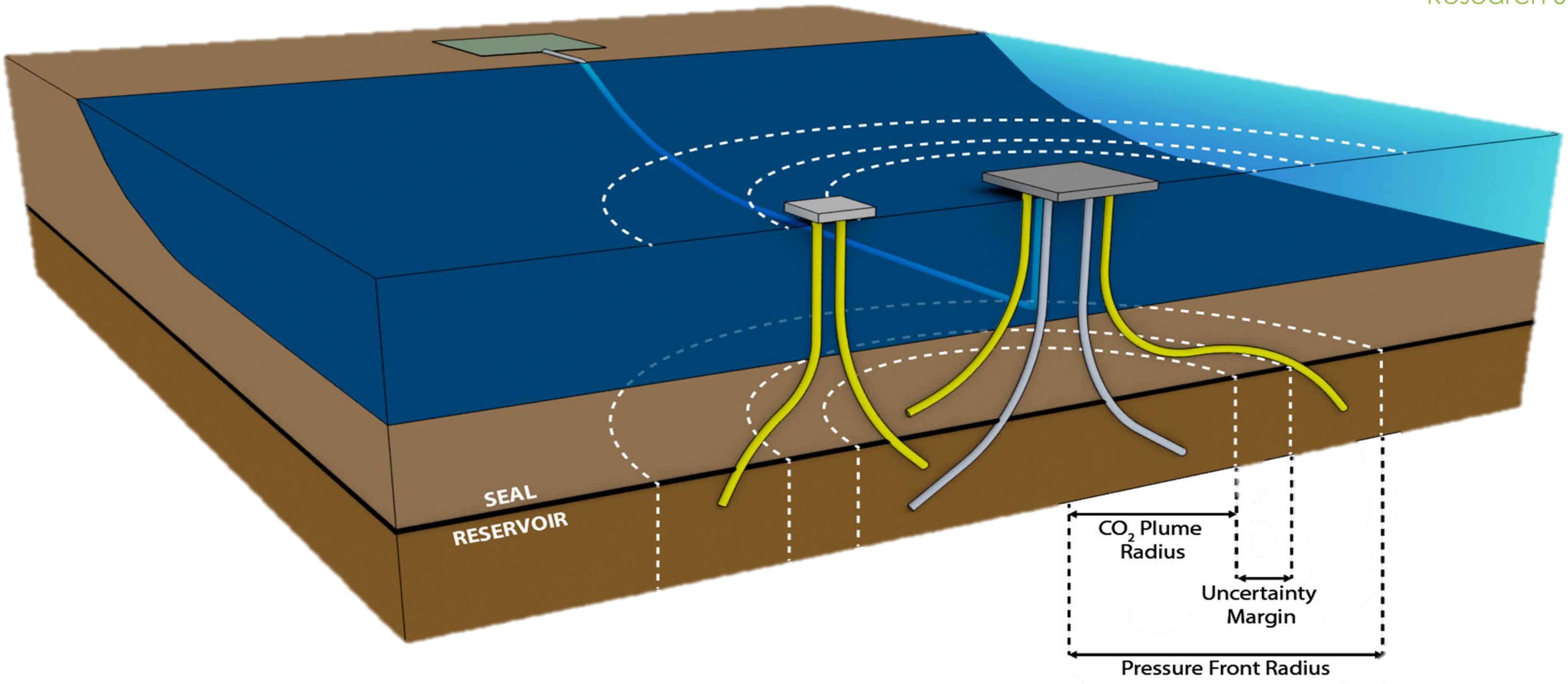

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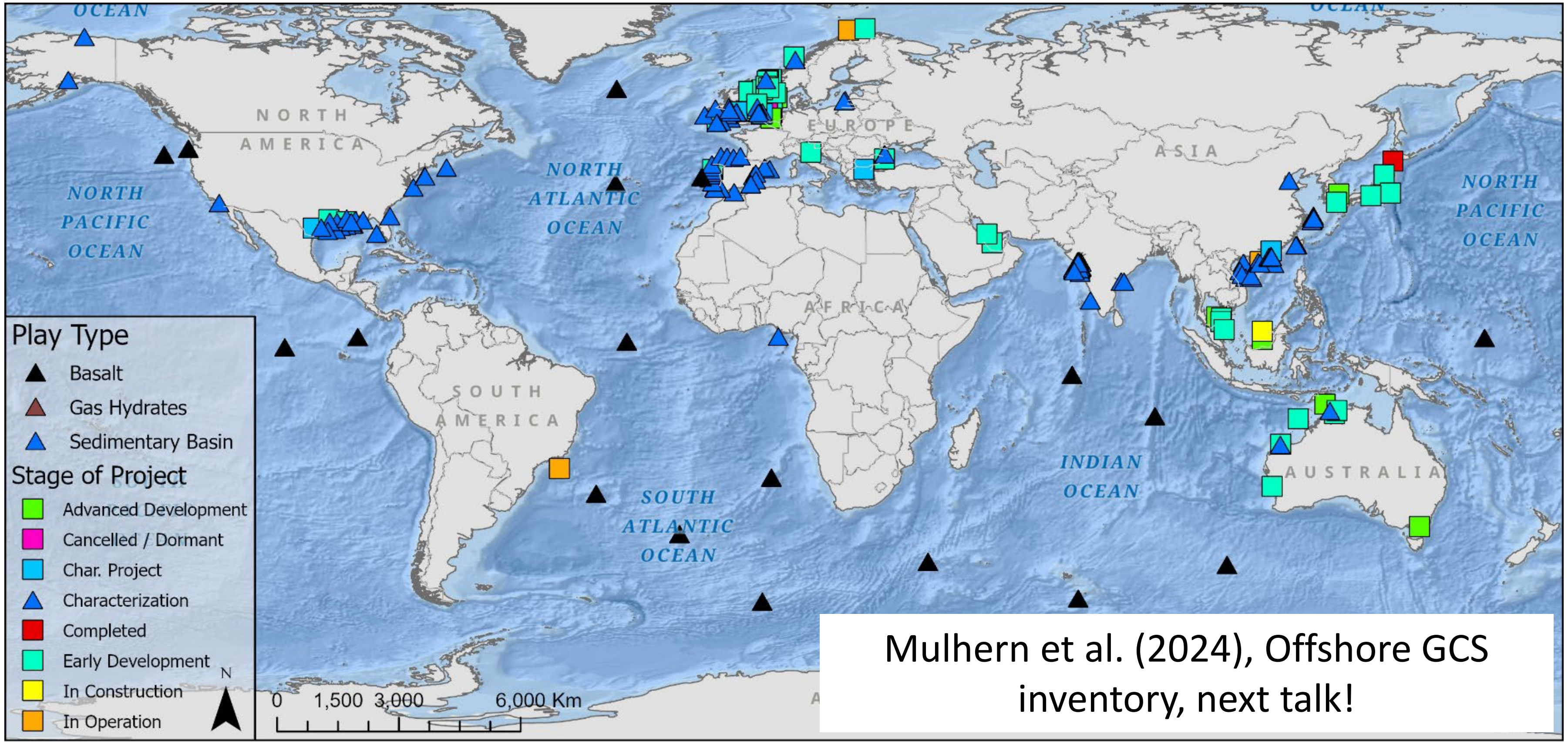
Motivation

CO2_S_COM_Offshore: Cost modeling for carbon storage

- **Offshore CS is accelerating around the world**
- Offshore saline reservoirs provide a significant resource for geologic carbon storage (CS)
- Technical feasibility and viability are the first barriers to pass



Mulhern et al. (2024), Offshore GCS inventory, next talk!

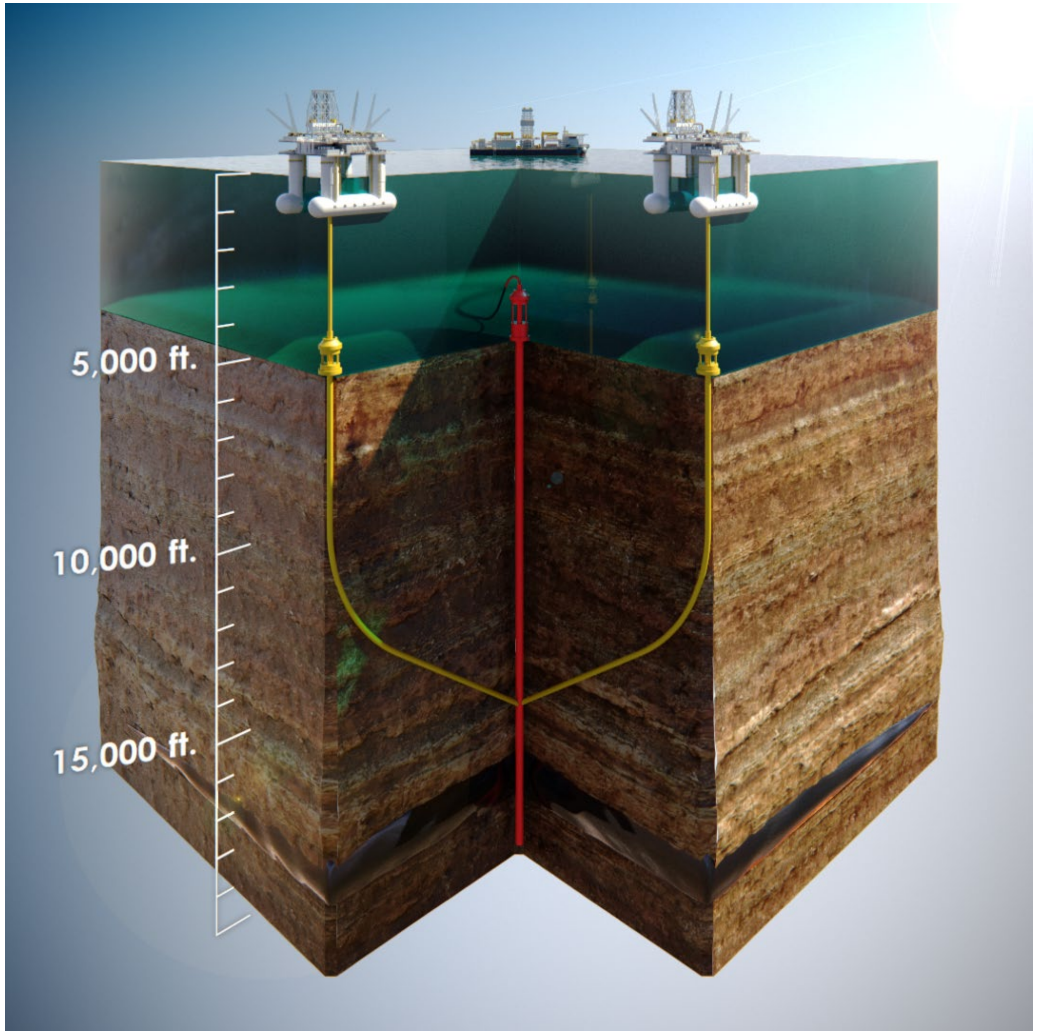
- **Technoeconomic feasibility is another barrier that can be addressed via cost modeling and technoeconomic analysis**

Objective and Scope

CO2_S_COM_Offshore: Cost modeling for carbon storage

- **NETL has developed a CS cost model for offshore saline reservoirs known as CO2_S_COM_Offshore**

- Encompasses the **distinct approaches to the offshore environment**
    - Differing geologic conditions
    - Transport considerations
    - Monitoring
    - Regulation



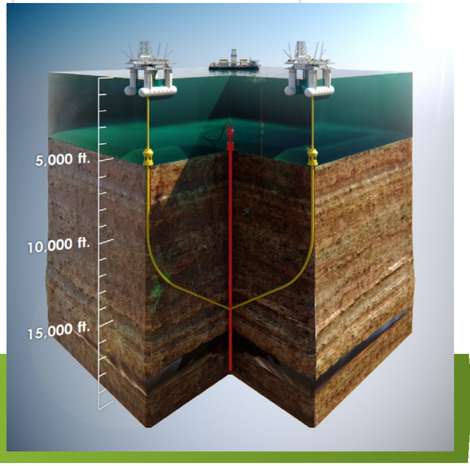
Overview

CO2_S_COM_Offshore: Cost modeling for carbon storage

- CO2_S_COM_Offshore is hosted in a macro-based spreadsheet
- Incorporates **regional evaluation, characterization, permitting, transport, operations, monitoring, site closure, and decommissioning**
- Calculates the **first-year break-even cost of offshore CS (2023$/tonne), accounting for CAPEX, OPEX and other financing costs up to 650 ft water depth to screen potential CS sites**

Offshore Pipeline Inputs for Calculating Capital and O&M Costs				
Inputs for offshore pipeline that transports CO2 from shoreline to the saline storage site				
Distance to Shore	33.7	mi		
Pipeline tortuosity factor	1.1			
Pipeline length	37.1	mi		
New or existing pipeline	New			
Pipeline diameter	Min Diameter	20	inch	
Inputs for pump to boost pressure of CO2				
Onshore pump inlet pressure	1200	psig		
Onshore pump outlet pressure	2200	psig		
Onshore pump outlet pressure override		psig		
Is a pump needed to boost the pressure of CO2? (enter yes or no)			No	
Pipeline pressure drop	191	psig	The pressure drop of this configura within the allowable range.	
Accepted pipeline diameter	20	in		
Offshore pump inlet pressure	2009	psig		
Offshore pump outlet pressure	2200	psig		
Pressure exiting pipeline at storage site	1200	psig		

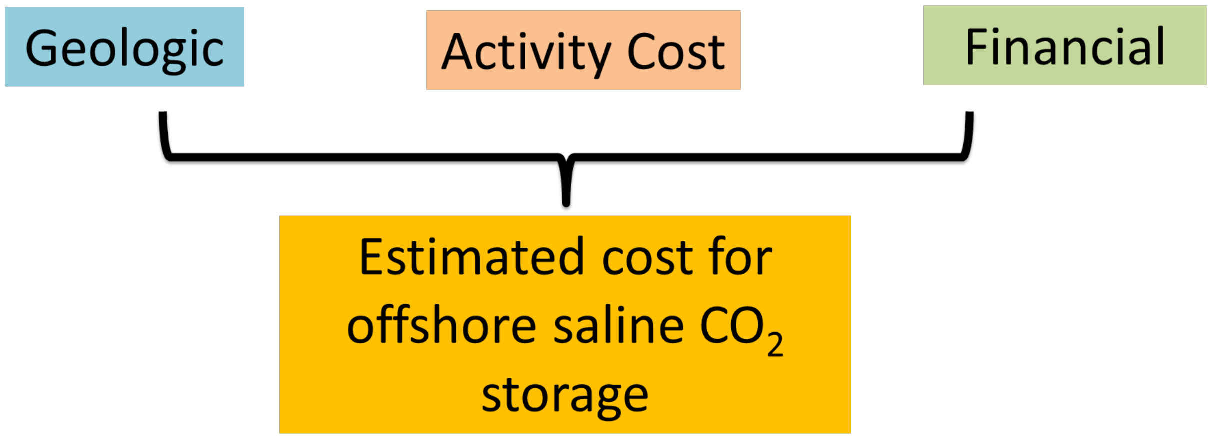
CO2_S_COM_Offshore pipeline inputs



Methods: Overview

CO2_S_COM_Offshore: Cost modeling for carbon storage

- Incorporates conditions adapted from the **onshore saline cost model, CO2_S_COM** in three modules
- **Key inputs:**
  - **formations,**
  - **CO_2 volume,**
  - **injection rate,**
  - **infrastructure,**
  - **monitoring intensity,**
  - **project financing,**
  - **PISC duration**
- Data were aggregated utilizing S&P Global's QUE$TOR™ cost estimation software along with open-source scientific literature review

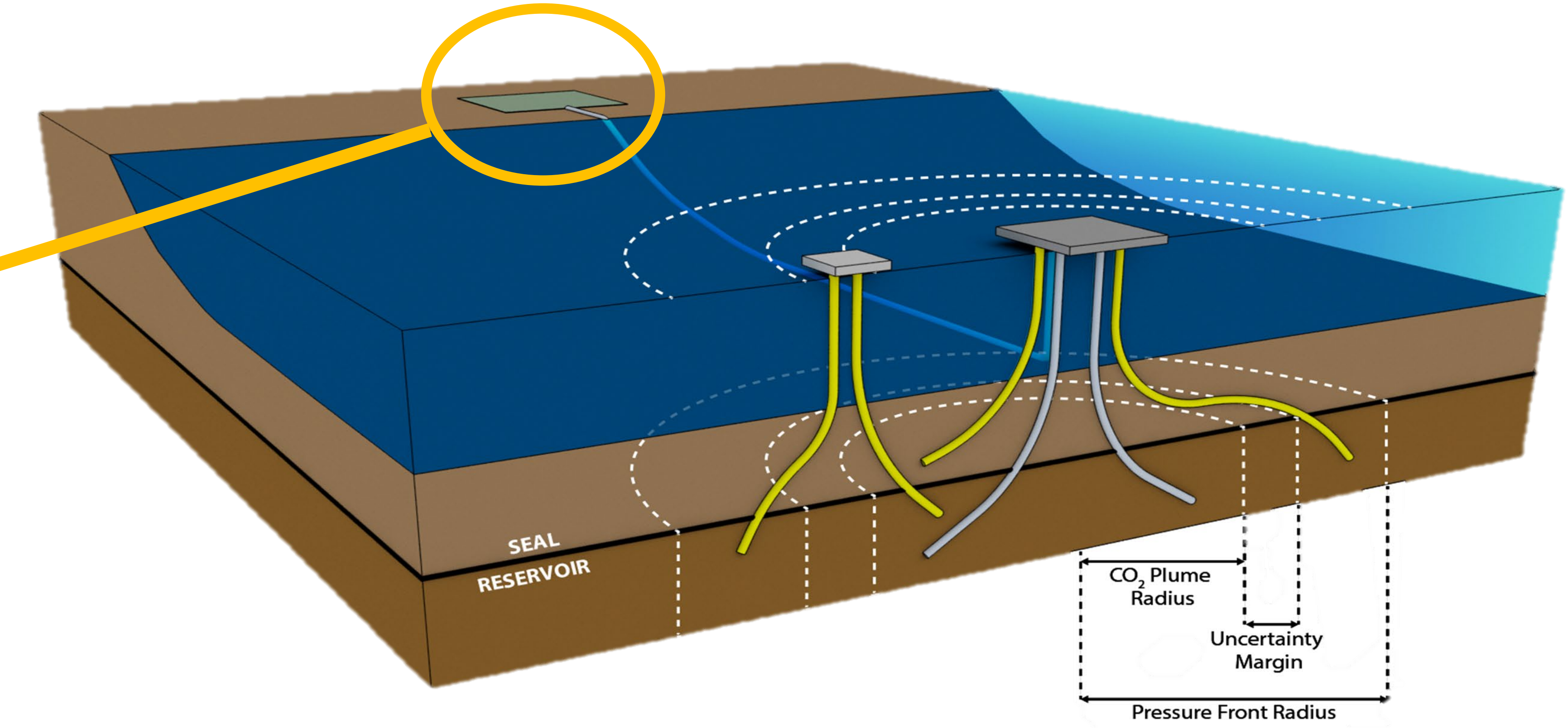


Cost Model Component Development

CO2_S_COM_Offshore: Cost modeling for carbon storage

Onshore Facilities

- Entry gate to offshore CO_2 storage operations
- Custody transfer meter, power generation, boost line pressure, and other support equipment

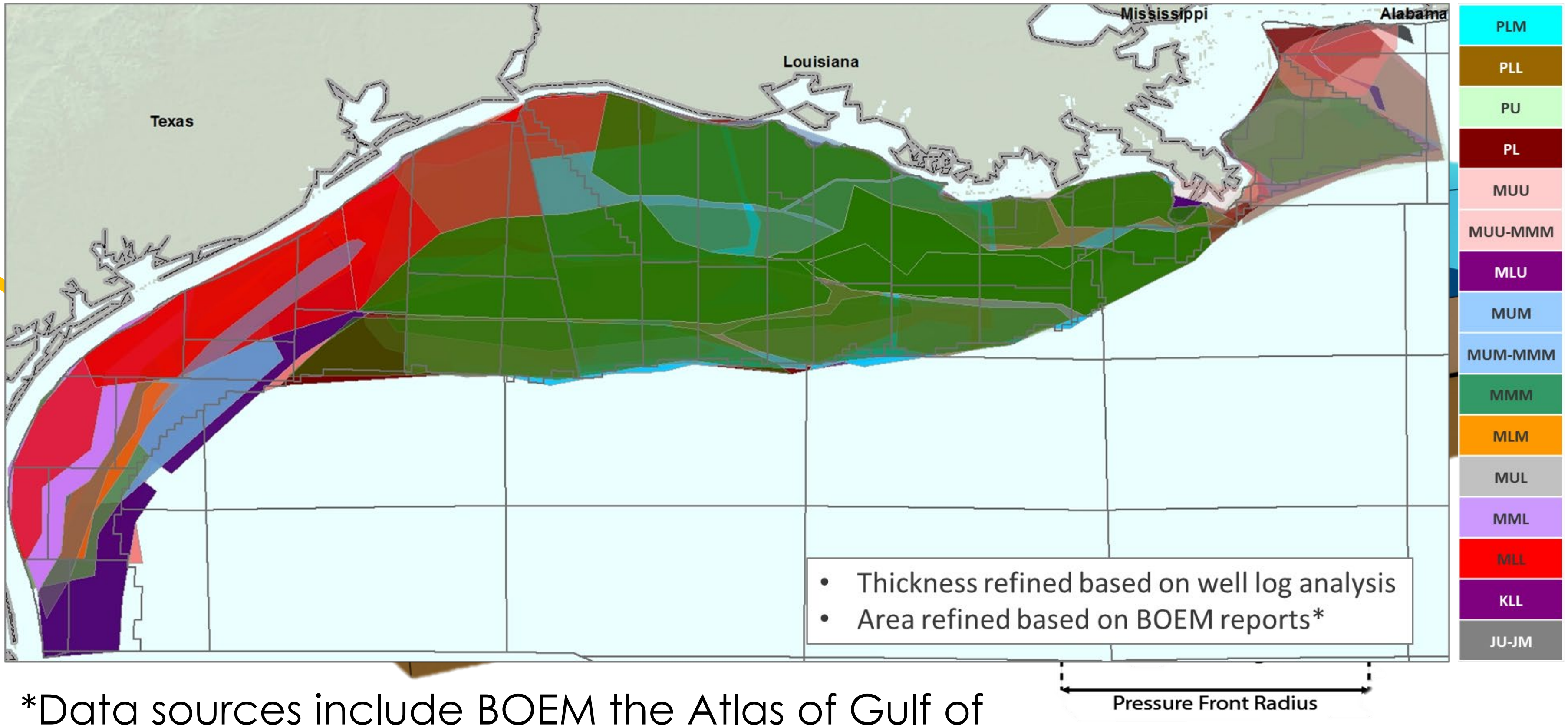


Cost Model Component Development

CO2_S_COM_Offshore: Cost modeling for carbon storage

Geologic Database

- **Outer Continental Shelf (OCS) of the Gulf of Mexico at water depths less than 650 ft**
- 40 plays divided spatially into 117 sub-plays
- Mapping borehole bottom locations to develop 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

Methods: Geologic Database Recent Updates

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CO2_S_COM_Offshore: Cost modeling for carbon storage

Addressing hard overpressure

- **Formations with hard overpressuring (>0.7 psi/ft) were flagged**
- **Not likely to be suitable for injection**
- Due to overpressuring in some prospective formations, fracture pressure calculations were included
- Frac pressure calculated in relation to pore pressure (& other parameters) by a user selected method, resulting in more realistic injectivity restrictions & calculated injection well counts per reservoir
  - Eaton (1969): Minimum fracture pressure
  - Zhang (2011): Average fracture pressure
  - Zhang (2011): Maximum fracture pressure

Relationship between pressure and CO_2 compression

Depth (ft)	Pressure gradient (psi/ft)	Bottom hole pressure (MPa)	Well head pressure (MPa)	Extra pumping power for 1MT/yr injection (kW)
9,000	0.52	32	9	350
9,000	0.70	43	17	190,000
10,000	0.52	35	12	1,000
10,000	0.70	48	18	210,000
13,000	0.60	54	20	270,000
13,000	0.70	62	26	404,000
13,000	0.80	72	35	600,000

same base assumed for all scenarios

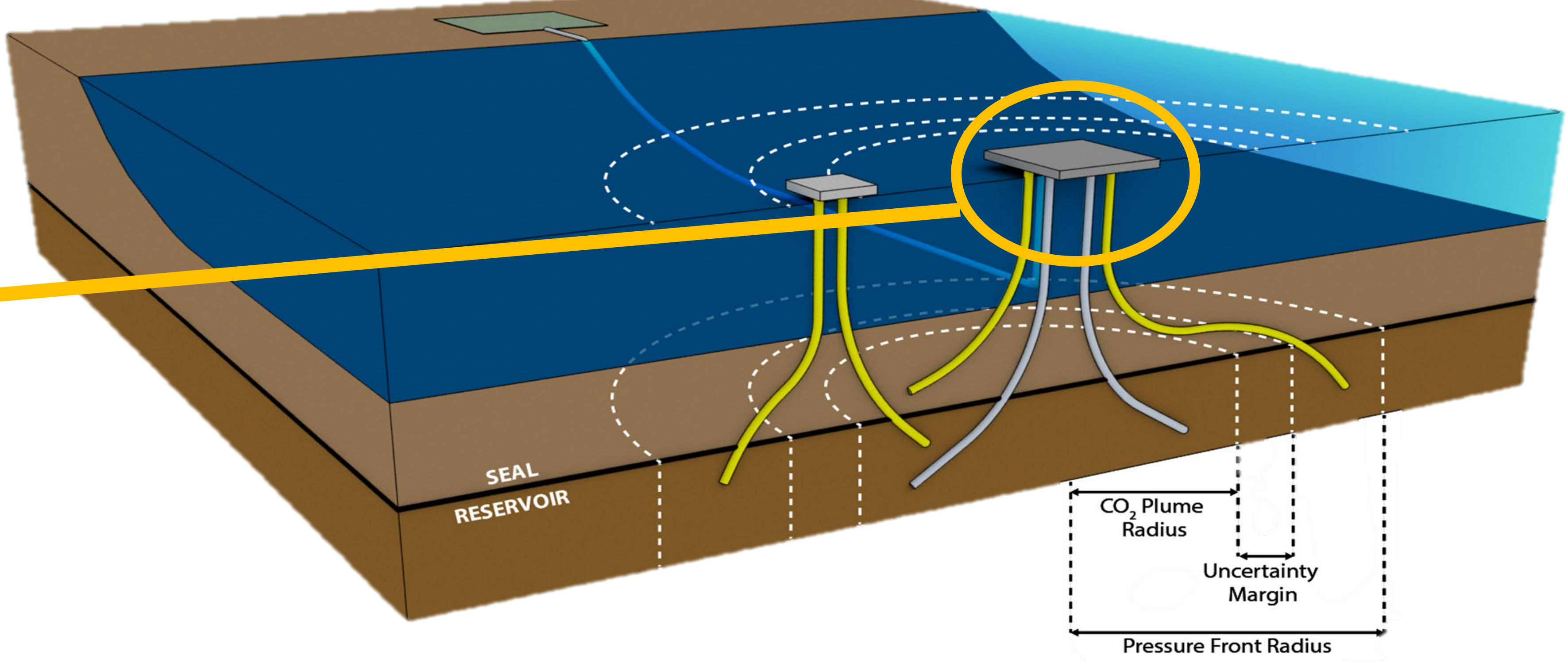
Source: Texas Bureau of Economic Geology, 2022

Cost Model Component Development

CO2_S_COM_Offshore: Cost modeling for carbon storage

Primary Offshore Structure

- All injection wells located on primary platform structure (jacket or caisson)
- Accounts for water depth, injection rate, and well count
- Structure refurbishment estimated to be 25%-50% of new structure cost
- Booster pump logic was improved to reflect cost changes associated with increasing reservoir pressure
- Annual O&M costs can be adjusted to include operating personnel cost; power demand is driven by compression power requirements

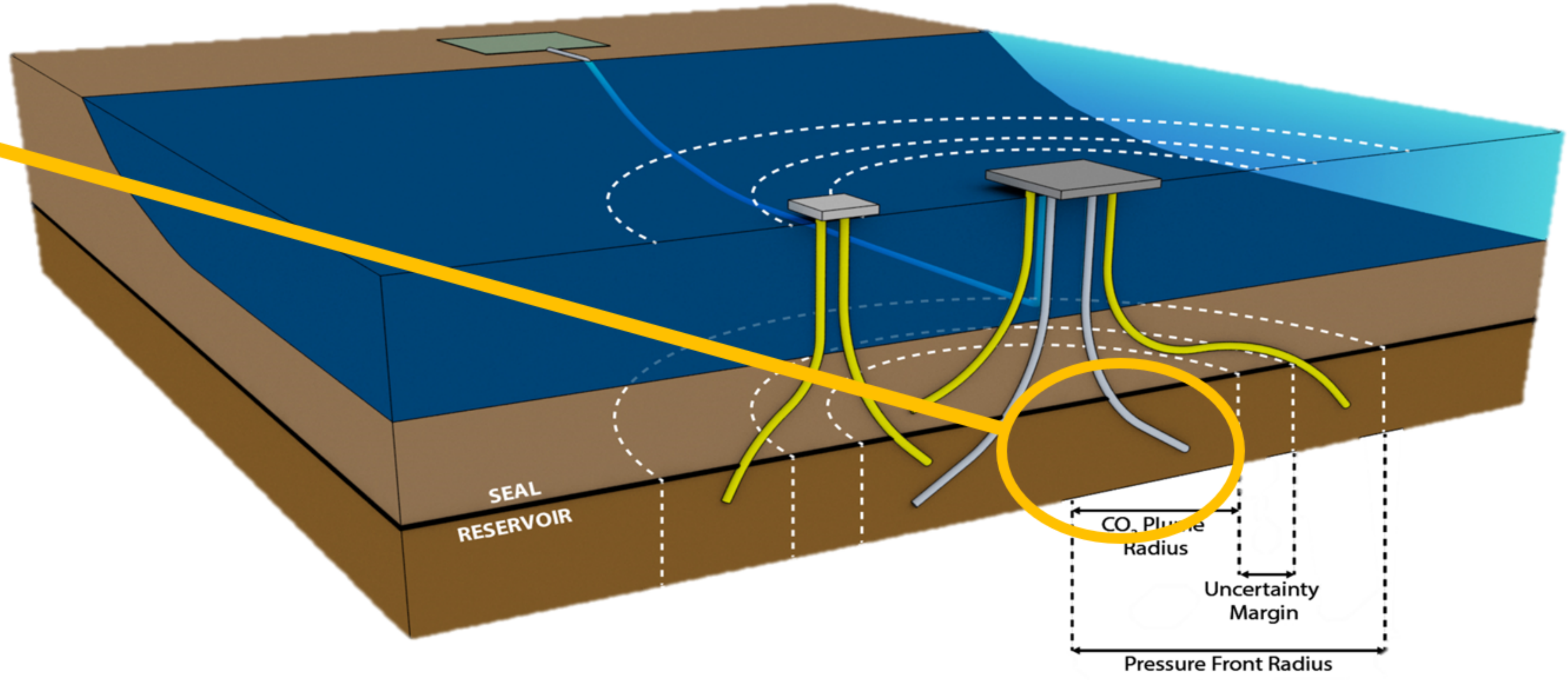


Cost Model Component Development

CO2_S_COM_Offshore: Cost modeling for carbon storage

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
- Annual O&M accounts for routine and non-routine maintenance



Cost Model Component Development

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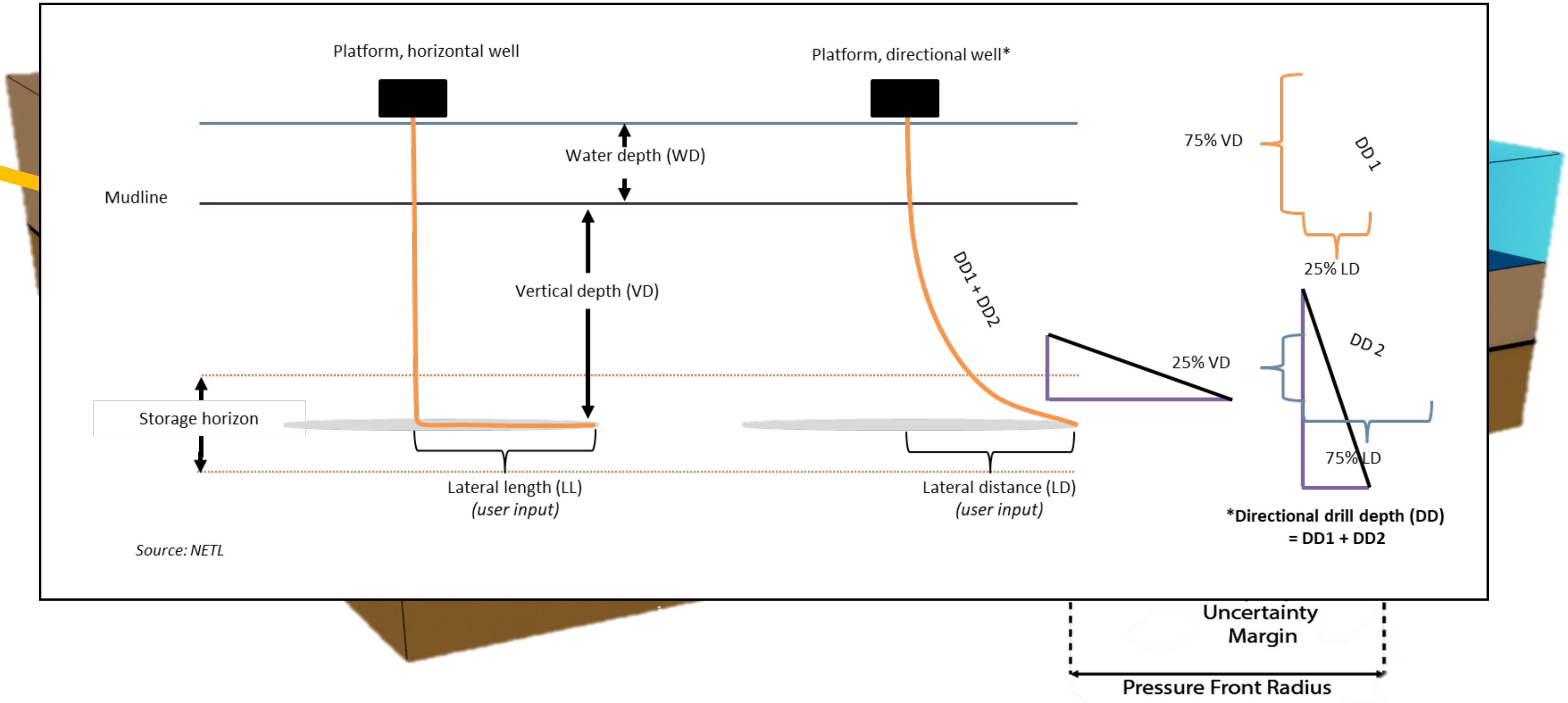
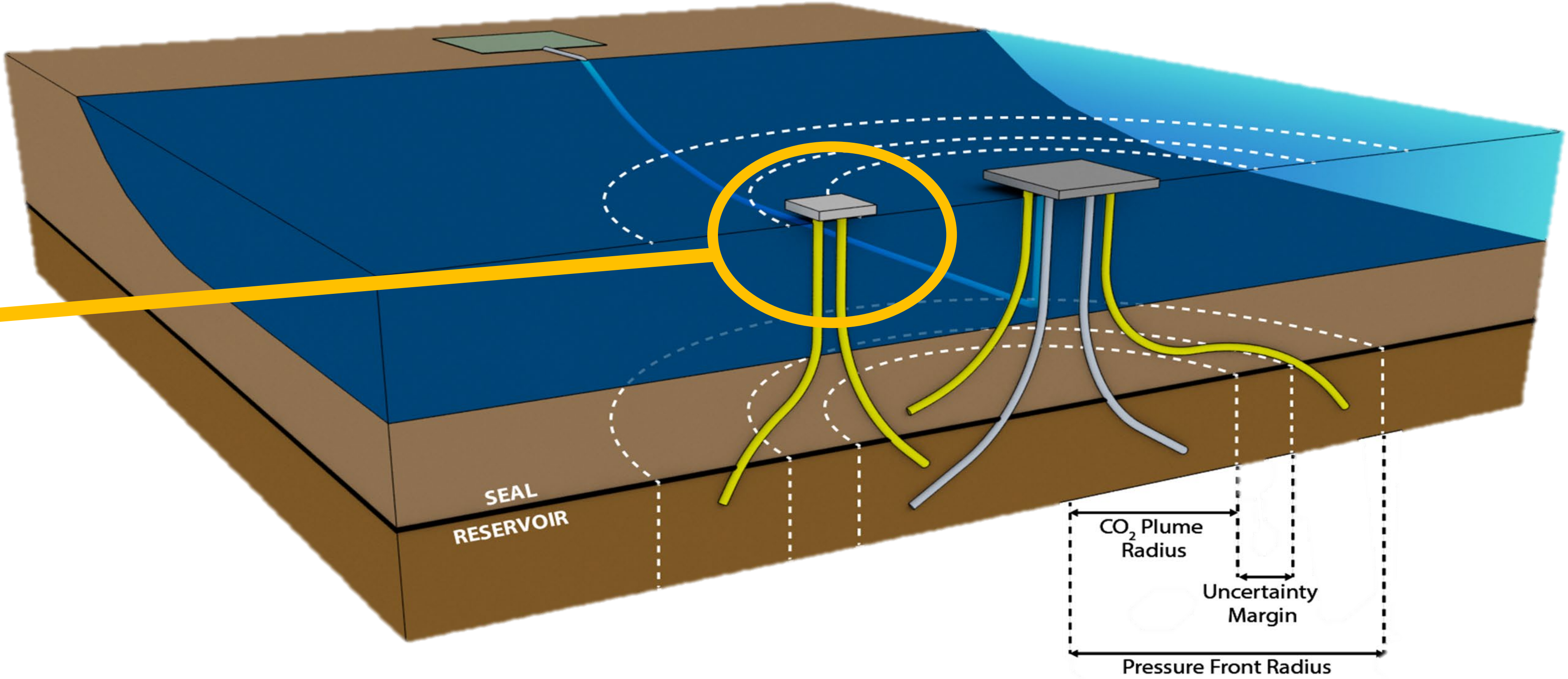


Cost Model Component Development

CO2_S_COM_Offshore: Cost modeling for carbon storage

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
- Accounts for above-seal well(s), located at the injection site

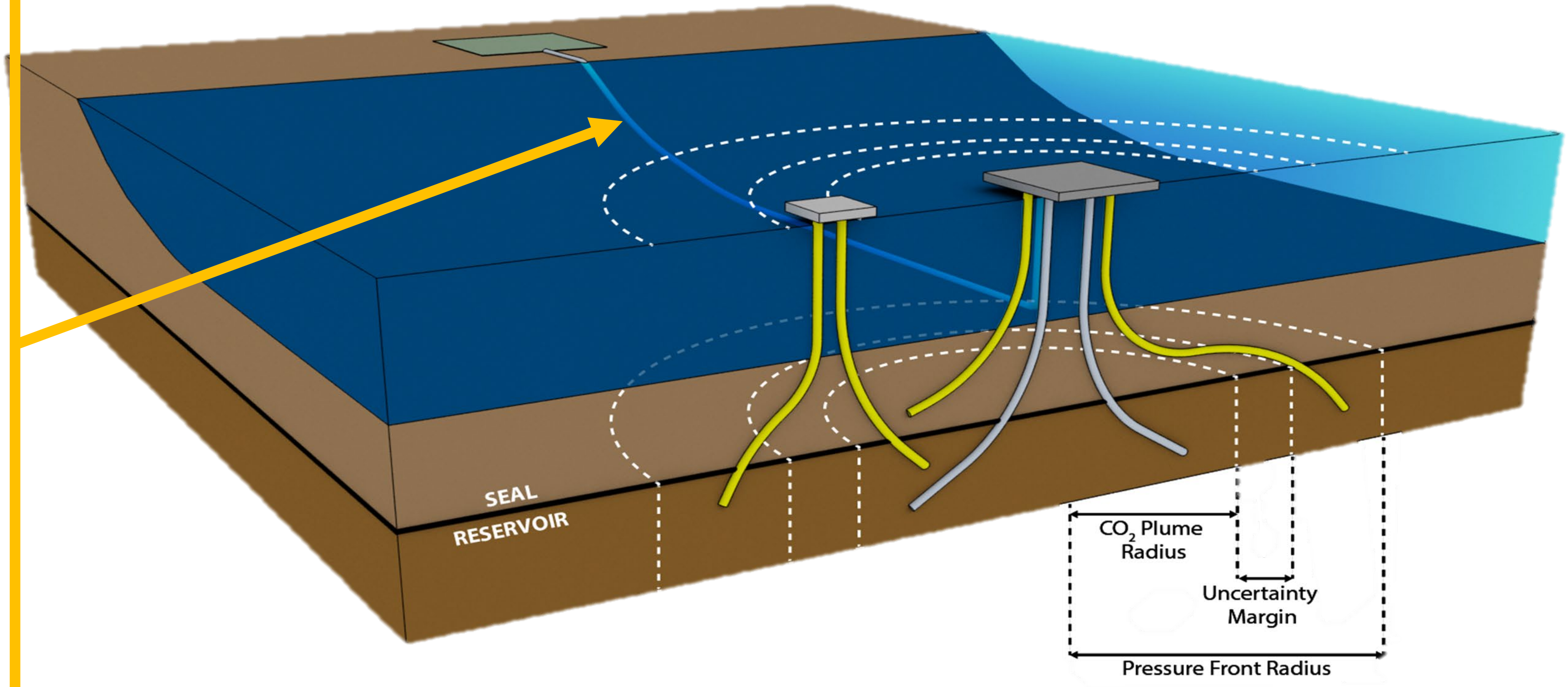


Cost Model Component Development

CO2_S_COM_Offshore: Cost modeling for carbon storage

Offshore Pipeline Modeling

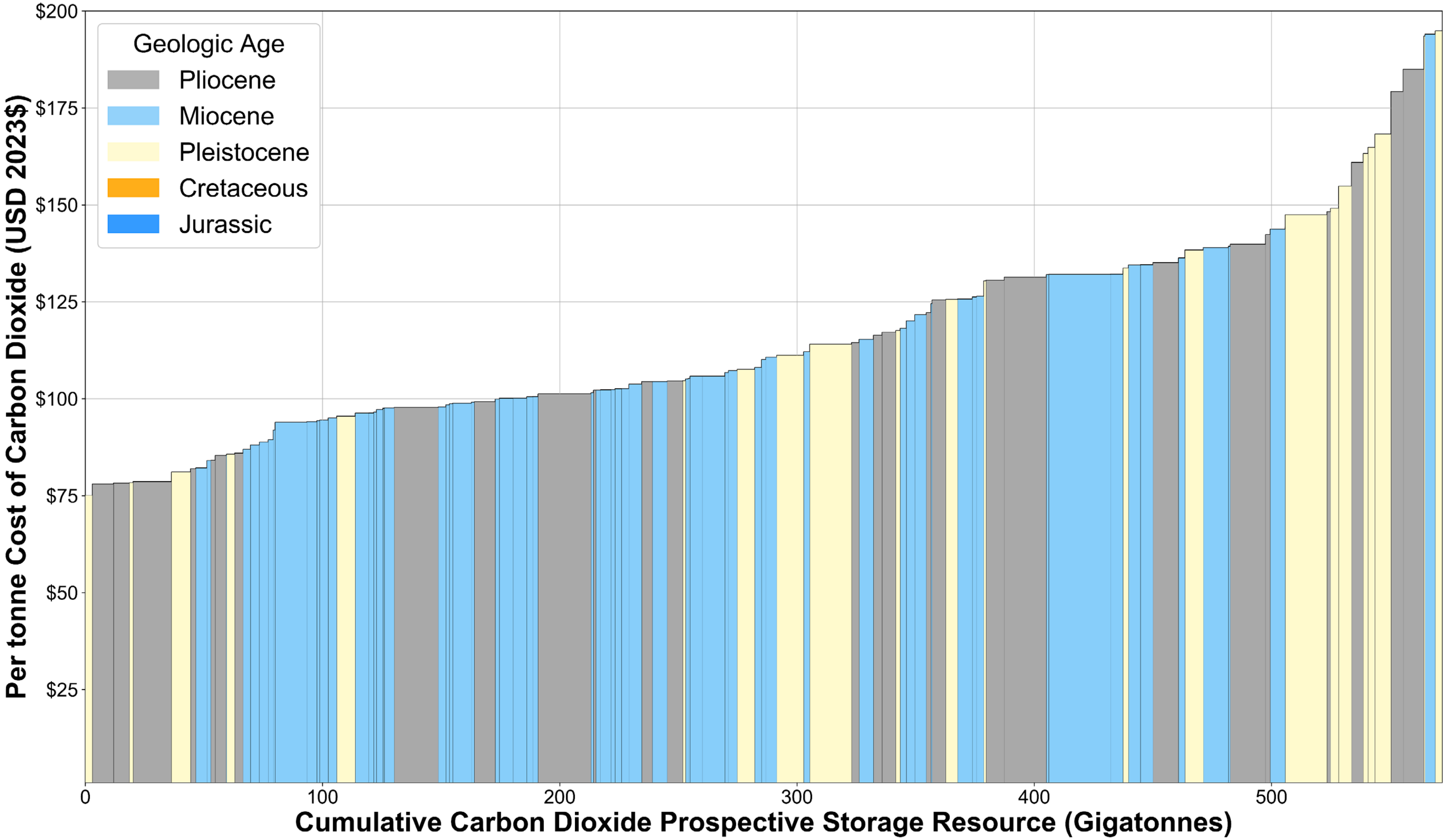
- Length of pipeline, onshore pump inlet/outlet pressure, offshore pump outlet pressure
- Select new or existing, option to manually select diameter or use model-calculated minimum diameter
- Outputs pressure drop, acceptable diameter



Model Performance

CO2_S_COM_Offshore: Cost modeling for carbon storage

- Evaluation of per tonne cost to store CO_2 against cumulative CO_2 storage resource in GOM sub-plays
- Input of **1 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**

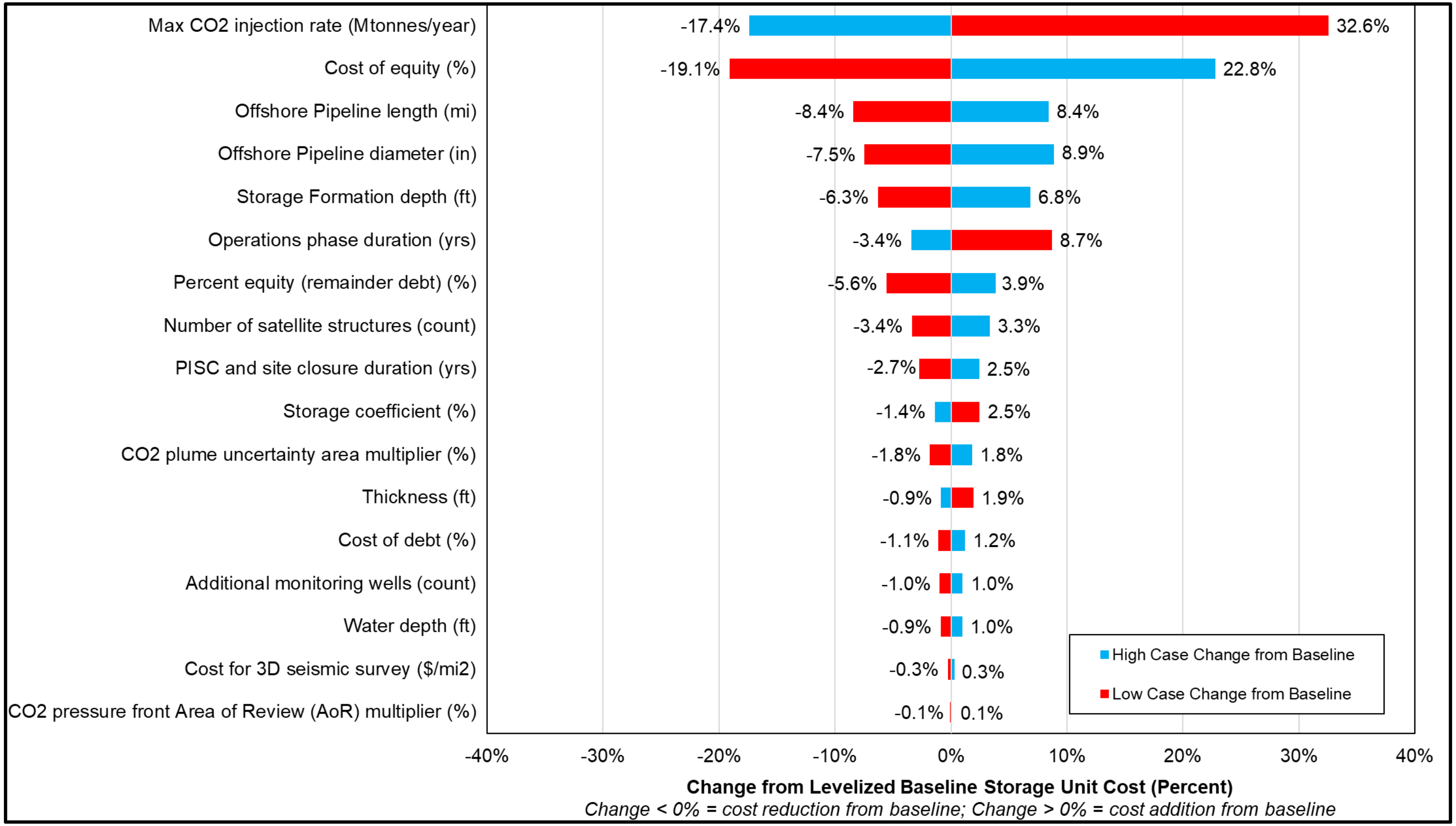


Model Performance: Input Variability

CO2_S_COM_Offshore: Cost modeling for carbon storage

- Explore how the output of the cost model can be apportioned to the variability in its inputs

- **Preliminary results from CO2_S_COM_Offshore indicate that maximum <u>CO_2 injection rate, cost of equity, pipeline length, pipeline diameter, storage formation depth have the greatest impact</u> on per unit CS costs**



Results – Senstivity Analysis

CO2_S_COM_Offshore: Cost modeling for carbon storage

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

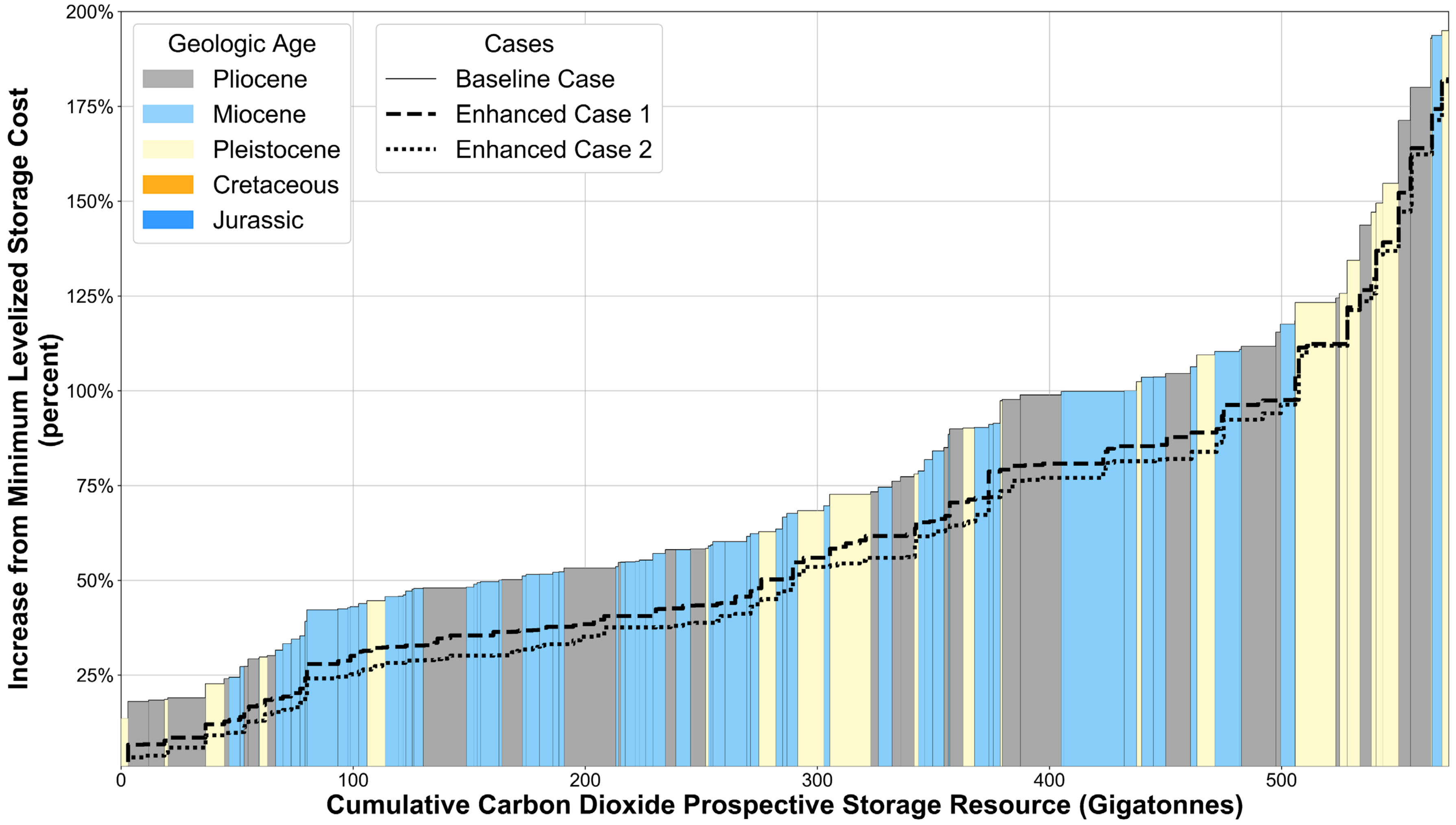
Sensitivity analyses indicate **the ability of the model to capture variability on cost based on altering inputs that reflect different policy/operational scenarios**

Scenario cases here are based on construction/operation and financial options

Results – Scenario Modeling

CO2_S_COM_Offshore: Cost modeling for carbon storage

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

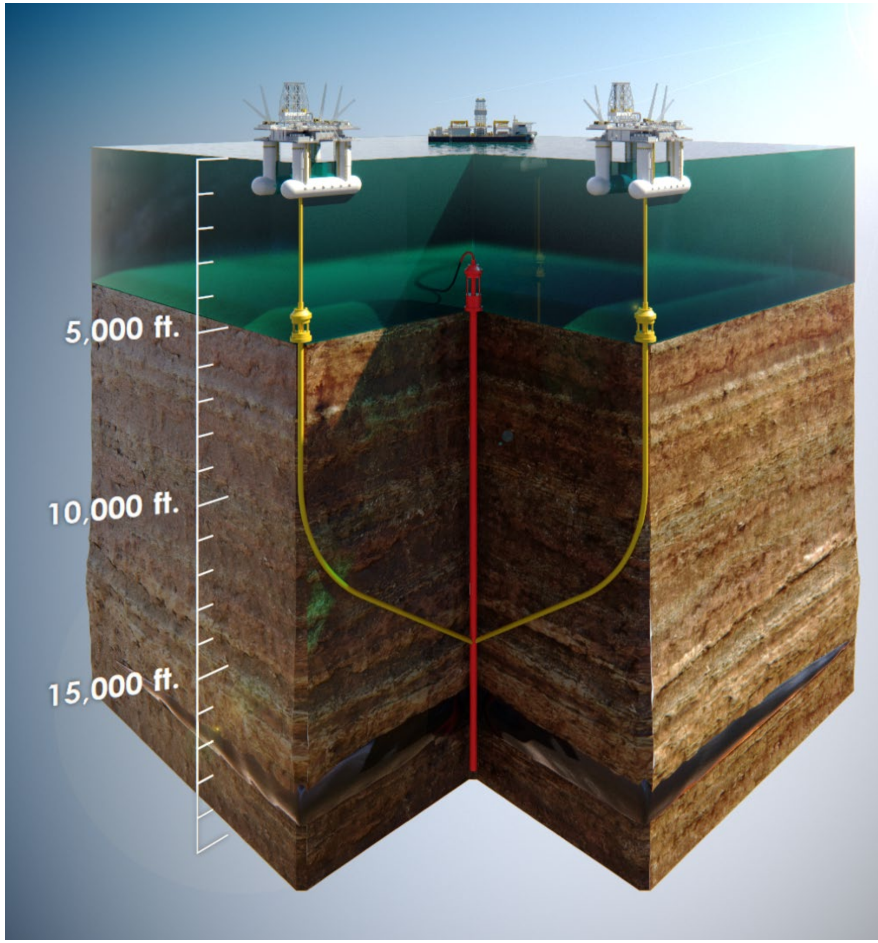


Summary of Updates EY23-EY24 Q1

CO2_S_COM_Offshore: Cost modeling for carbon storage

- **Updated financial module and activities with onshore CO2_S_COM latest version**
- Improved pipeline calculations for length, tortuosity, with automated pipeline diameter calculation
- Well injection rate logic added based on lit. review
- Various cost updates including **regression logic for major cost items** and 2D/3D seismic costs
- **Added relevant activities, fees, permits, approvals, and reporting required by 30 CFR Chapters II and V for an offshore operation**
- **Major additions to decommissioning to align with BOEM/BSEE requirements**
- **Discussion with BOEM/BSEE as stakeholders to align cost model**
- Updates to geologic database
- **Organization, streamlining, cleanup, overhauled Key_Inputs tab layout**

In Review; Release expected September 2024



Ongoing and Future Work

CO2_S_COM_Offshore: Cost modeling for carbon storage

- Conversion **to Python to increase interoperability**, potential for web-hosting and integration with additional data and tools
- Will incorporate simplified algorithm for **pressure interference**
- **Incorporation of offshore CS regulations** as they are released by Dept. of Interior, BOEM/BSEE
- Publication on model; reports on case studies, scenario analyses

Mulhern et al. (2024), Offshore GCS inventory, next talk!

Python coded cost models increase potential for integration with other tools, data

Takeaways

CO2_S_COM_Offshore: Cost modeling for carbon storage

- First-of-a-kind analytical resource for evaluating CS costs in offshore settings for the purposes of screening potential sites
- **Adaptable as the CS industry advances and regulations are enacted**, with plans to include reduced order costs and reflect energy market models
- Also, potentially adaptable to other regions
- Will join **NETL's suite of technoeconomic energy analysis tools**

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) [*dev*]
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 [*in development*]
- Hydrogen Pipeline Cost Model (H2_P_COM)
- Natural Gas with Hydrogen Pipeline Cost Model

Thank You!

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CONTACT

Get in touch! We're interested in your thoughts and potential collaboration.

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