Modeling Cost of Offshore Carbon Storage in Saline Reservoirs

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Research & Innovation Center

NATIONAL ENERGY TECHNOLOGY LABORATORY

Objective and Scope

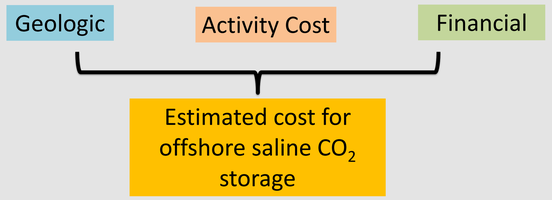
Offshore saline reservoirs provide a significant and accessible resource for geologic carbon storage (CS). The offshore environment requires distinct approaches to site selection, operations, monitoring, and risk that affect the technoeconomic assessment of offshore CS projects. **The National Energy Technology Laboratory (NETL) has developed a CS cost model for offshore saline reservoirs known as CO2_S_COM_Offshore**. Based on NETL's widely used CO2_S_COM cost model for onshore saline CS, CO2_S_COM_Offshore enables technoeconomic analysis of CS in offshore areas. This model comprehensively incorporates multiple facets of offshore CS projects, **from regional evaluation and site selection to permitting, transport, operations, monitoring, site closure, and decommissioning**. Developed to model cost for offshore United States (US) Exclusive Economic Zones, aspects of this model can be adapted to international projects.

Methods

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 configuration falls 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	

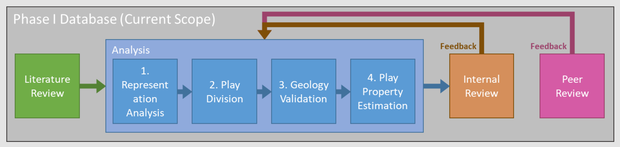
Screenshot of CO2_S_COM_Offshore Key_Input tab

CO2_S_COM_Offshore was developed as a technoeconomic, macro-based spreadsheet that 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**.



Three modules of CO2_S_COM_Offshore

The model incorporated conditions adapted from the onshore CO2_S_COM model in three modules: geologic, activity cost, and financial. **Key inputs include formations, CO_2 volume, injection rate, infrastructure, monitoring intensity, project financing, and post-injection site care duration**. Data were aggregated utilizing S&P Global's QUE$TOR™ cost estimation software and open-source scientific literature.



Iterative process to create underlying geologic database

Development of the underlying geologic database to support CO2_S_COM_Offshore included in iterative analytical process including internal and peer review of the final product (Fig. 3). **Currently, this database supports cost modeling in the U.S. offshore Gulf of Mexico (GoM).**

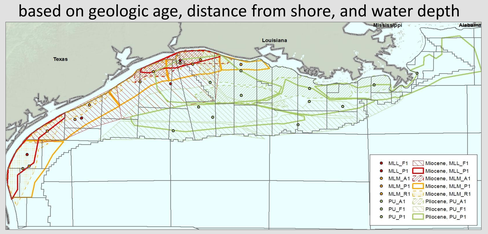
Preliminary sensitivity analyses were performed to show the model's capabilities in handling variable inputs and operational scenarios.

CO2_S_COM_Offshore Model Component Development

Goals:
- ***Calculate revenues and costs for a saline storage project from perspective of the operator of a single saline storage project in the offshore GOM OCS***
- ***Result output from CO2_S_COM_Offshore show potential first-year break-even cost for each tonne of CO_2 stored in a single or multiple reservoir(s)***

Geologic Database

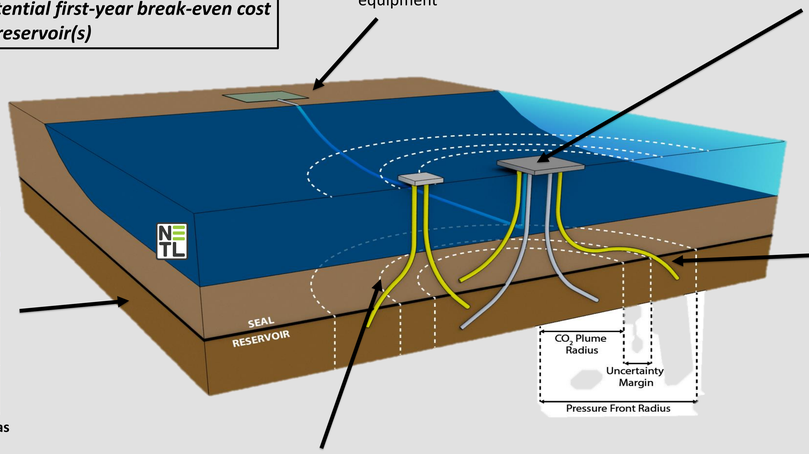
- Outer Continental Shelf (OCS) of the Gulf of Mexico at water depths less than 650 ft
- Based on BOEM sands and Enverus well borehole databases
- Includes a total of 40 plays divided spatially into 117 sub-plays
- Mapping borehole bottom locations to develop sub-areas based on geologic age, distance from shore, and water depth



Database example showing lower Miocene to upper Pliocene reservoir areas

Onshore Facilities

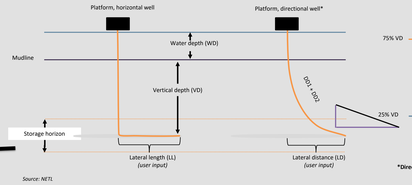
- Entry gate to offshore CO_2 storage operations
- Custody transfer meter, power generation, boost line pressure, and other support equipment



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
- Annual O&M costs can be adjusted to include operating personnel cost; power demand is driven by compression power requirements

Well Drilling Costs



DD for a directional well

$$\sqrt{(0.75 * VD)2 + (0.25 * LD)2} + \sqrt{(0.25 * VD)2 + (0.75 * LD)2} + \text{depth below mudline}$$

- 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

Offshore Pipeline Modeling

- Enter 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

Offshore Satellite Structure

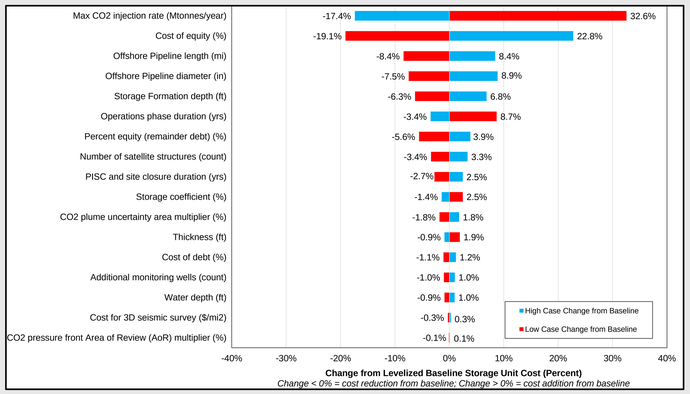
- Pressure front monitoring and water production estimates for projects with up to four satellite structures
- May include three deep monitoring wells; vertical or directional
- Accounts for above-seal well(s), located at the injection site

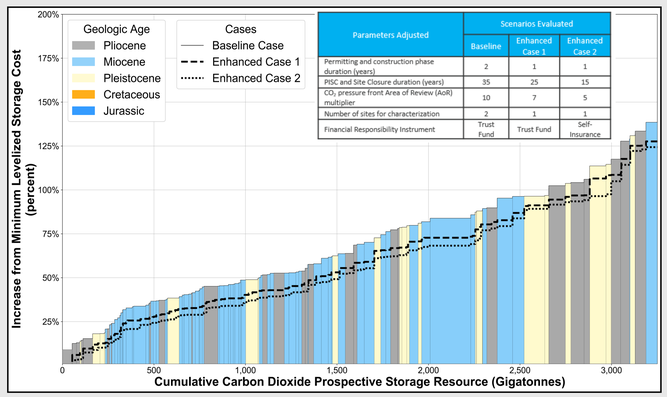
Integrated Analytics

- Supply curve analysis (region to basin-level)
- Customizable specific project cost evaluation
- Onshore CO_2 source to offshore sink cost analysis
- Scenario analysis to evaluate policy, financial, or technological factors

Results and Observations

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





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

- The one-at-a-time method used explore how the output of the cost model can be apportioned to the variability in its inputs
- Baseline values for parameters of interest were incorporated into the model and a single formation analysis was completed
- Parameters were then modified relative to their baseline levels while maintaining the baseline values for all other parameters to obtain the relative change in cost from the baseline value
- **Preliminary results from CO2_S_COM_Offshore indicate that maximum CO2 injection rate, cost of equity, pipeline length, pipeline diameter, storage formation depth have the greatest impact on per unit CS costs**

- Offshore CS cost and associated prospective storage resource result data at the reservoir-level was generated to gain insight to the scale at which the GoM OCS may support saline CS
- Model was run upon the GoM database using three distinct modeling scenarios that reflect different CS-related policy or operational conditions
- Potential variability in the cost of storage due to different scenarios was then evaluated for each of the 117 sub-plays in the CO2_S_COM_Offshore
- **Results show variability of CS levelized cost increase, with each enhanced case showing lower costs than the baseline case**

Conclusions and Future Work

- First-of-a-kind analytical resource for evaluating CS in offshore settings
- **Adaptable as the CS industry advances and regulations are enacted**, with plans to include reduced order costs and reflect energy market models
- Adaptable to **work with integrated toolkits** (e.g. NRAP), visualization platforms, and AI/ML solutions
- Currently a working protype that will be **finalized mid-2024** after external peer review
- Will join **NETL's suite of technoeconomic energy analysis tools** (below)

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

Access released tools from NETL's Energy Analysis Website

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