NRAP Task 5: Preliminary Evaluation of the Cost of Responding to a Hypothetical Leakage Scenario Using the NRAP/SMART TALES Model and other NRAP Tools

David Morgan[1], Derek Vikara[1,2], Travis Warner[1,2], Kolawole Bello[1,2], Fangning Zheng[3], Bailian Chen[3], Chung Yan Shih[1], Guoxiang (Gavin) Liu[1]

[1]U.S. Department of Energy, National Energy Technology Laboratory (NETL), Pittsburgh, PA; [2]NETL Support Contractor, Pittsburgh, PA; [3]Los Alamos National Laboratory, Los Alamos, NM

National Risk Assessment Partnership

Overview

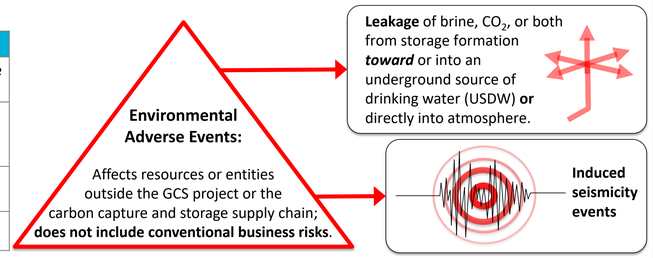
The focus of the National Risk Assessment Partnerships (NRAP) Task 5 is to provide analytical approaches to evaluate and quantify liability associated with responding to potential adverse environmental events at a geologic CO_2 saline storage (GCS) site. The NRAP/SMART Technoeconomic and Liability Evaluation for Storage (TALES) model provides the basis for quantitative liability assessment and cost-based insights to support developers planning GCS projects. This study used the TALES model to evaluate the cost associated with remediating a leakage event at a theoretical CO_2 storage site. TALES was used in tandem with NRAP's Remed-Res model – an analytical model that quantifies optimal production rates for fluid production wells deployed as part of a pressure management strategy to mitigate or safeguard against upward fluid migration at GCS sites. Scenario analysis was conducted to provide a means to compare the cost implications for a potential leakage event requiring remedial response. Two remedial response scenarios were modeled: 1) successful plugging and abandonment of a potentially leaky legacy well, and 2) brine production that successfully manages reservoir pressure to mitigate a potential leak. To quantify liability for each scenario, the scenarios' financial results were compared against results from a baseline business-as-usual scenario where no adverse event occurred.

Task 5 Terminology

Basic Definitions

Term	Definition
Liability	The financial consequence of an **adverse event** relative to a baseline (expected/hopeful) scenario where no adverse event occurs.
Adverse Event	An incident that is **not part of the typical or ordinary activities** of a Geologic Carbon Storage (GCS) project that **adversely affects the operations** of the project.
Remedial Response	A single **remedial action**, or series of remedial actions, that completely address an adverse event, from start to finish.
Remedial Action	A unique action designed to address an aspect of an adverse event.

NRAP Task 5 Focus: Environmental Adverse Events



Remedial Action Types

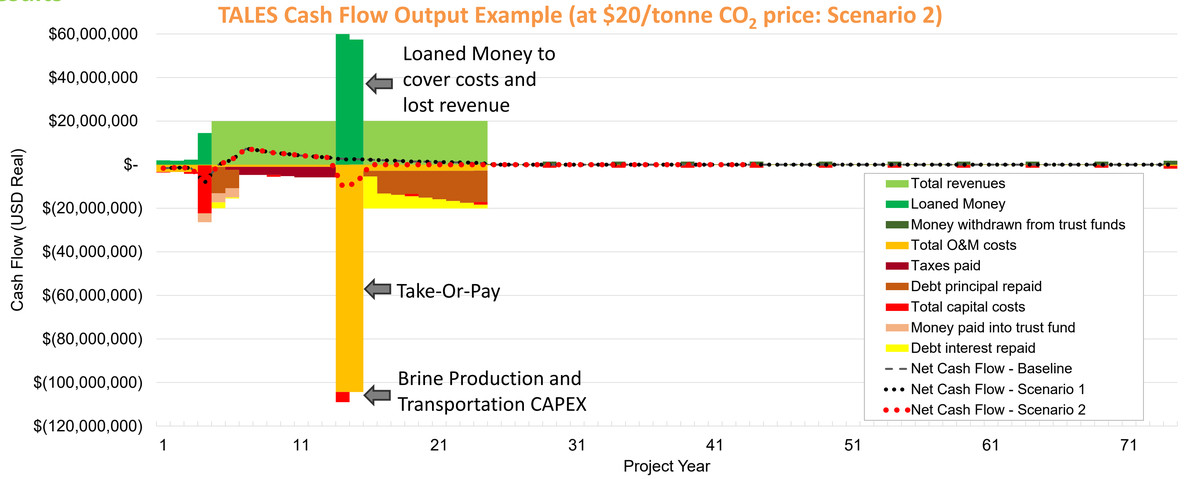
Remedial Action Type	Remedial Action Description	Remedial Action(s) Example	Inclusion in ERR Plan Cost Estimates
Operational	"Baseline" or "normal" operation of the GCS project is altered.	Injection of CO_2 is reduced or halted for a specified period due to leakage.	Yes (possibly)
Extrinsic	Action taken outside of "normal" operation of a GCS project; likely the major elements of the Emergency and Remedial Response (ERR) Plan.	Source of leak investigated with monitoring technologies; found to be a leaky legacy well, which is located and plugged.	Yes (definitely)
Penalty	Fine or contractual fee associated with an adverse event.	If a leak forces a GCS project to cease injection, the GCS project may have to pay a take-or-pay fee to the CO_2 source that can no longer claim 45Q tax credits.	No

Case Study Scenario Matrix

Scenario	Scenario Description	CO_2 Injection Rate (Mtpa)			Cumulative CO_2 Injected (Mt) over 20 years	Extrinsic Cost Items				Lost CO_2 Storage Revenue	Penalty Cost Item	Extrinsic Cost Items	Gained Treated Water Revenue
		Op. Years 1-10	Op. Years 11-12	Op. Years 13-20		Op. Year 11				Op. Years 11-12		Op. Years 11-20	
Baseline	Baseline Case; no environmental adverse event	1	1	1	20	N/A							
Scenario 1	Potentially leaky legacy well found at end of Op. Year 10; successfully plugged and abandoned	1	1	1	20	USDW endangerment actions: labor to locate and assess leak and determine appropriate ERR	Plug and abandon potentially leaky legacy well	N/A					
Scenario 2	Leak identified by monitoring at end of Op. Year 10, source of leak confirmed but cannot be located; CO_2 injection ceases for 2 years while production well and brine pipeline to treatment plant installed, and 1 year of brine produced to mitigate leakage risk.	1	0	1	18	USDW endangerment actions: labor to locate and assess leak and determine appropriate ERR	N/A	Drill brine production well outside the CO_2 plume	Install brine pipeline to treatment facility	No CO_2 storage revenues	Pay Take-Or-Pay penalties to CO_2 source	Operate brine production well	Pay brine treatment costs	Receive treated water sales revenue

Results

TALES Cash Flow Output Example (at $20/tonne CO_2 price: Scenario 2)



Case Study Results: Liability

Scenario	FYBE ($2023/t)	NPV @ $20/t ($2023M)	Total ERR Take-or-pay Penalty ($2023M)	Total ERR Extrinsic Costs ($2023M)	Total Treated Water Sales Revenues ($2023M)	Total CO_2 Storage Revenues ($2023M)	Liability (Total ERR costs and Revenues, Relative the Baseline Scenario)
Baseline	7.86	43.1	0	0	0	400	0.0
Scenario 1	7.97	42.7	0	-2.9	0	400	-2.9
Scenario 2	17.49	6.6	-204	-23.6	1.1	360	-266

Methods

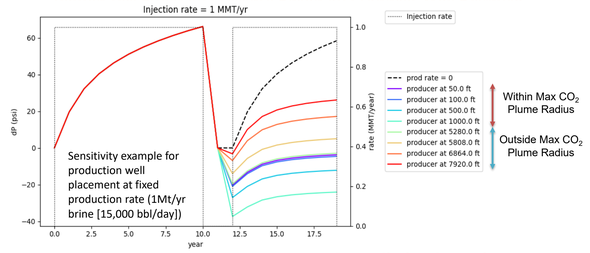
Integrated scenario-specific timing of remedial response activities based on **Remed-Res** and a **Commercial Case Basis Study** into **TALES** to assess a baseline case and the liability associated with two remedial response option scenarios.

- **Remed-Res:** analytical model based on Theis's equation; assesses the placement (location) and production rate of production well(s) in the storage formation to optimally manage reservoir pressure (i.e., keeping reservoir pressure at the leaking source location below the critical pressure) to mitigate potential leakage events.
- **Commercial Case Basis Study:** TALES model with activity inputs designed for a theoretical commercial-scale GSC project located in Illinois.
- **TALES:** technoeconomic model that generates GSC project costs using cash flow calculations. TALES accounts for the costs of discrete activities and the timing for when those costs occur. Activities, their costs, and their timing, are provided by the user into the TALES input sheet.

Reservoir Property Assumptions

Reservoir Depth (ft)	5,454
Reservoir Thickness (ft)	1,956
Porosity (%)	16.8
Permeability (mD)	33
Hydrostatic Pressure (psi)	3,206
Temperature (°F)	125
Salinity (mg/l TDS)	190,000

Remed-Res Effect on Pressure Based on Producer Well Distance



Process for Calculating Liability

Determine Costs of Baseline Situation:

- Evaluate revenues, costs, and financial performance of GCS Project in TALES ***assuming no environmental adverse events occur***.
- TALES calculates key financial metrics for baseline situation (e.g., net present value [NPV] for project, first-year break-even [FYBE] CO_2 price), and cash flows.

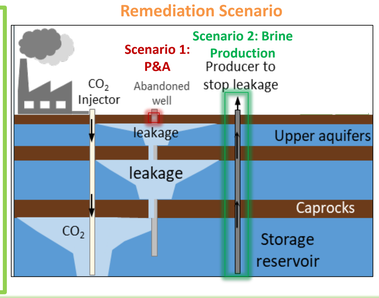
Determine Costs of Remedial Response Actions Needed to Respond to a Potential Environmental Adverse Event:

- Generate a list of remedial response options and associated remedial actions.
- Input into TALES activity costs, operational and physical variables, and scheduling parameters (e.g., start time, duration, recurrence) for each remedial action.

Estimate Overall Liability of each Remedial Response Option:

1. Evaluate revenues, costs, and financial performance of GCS project in TALES assuming the remedial response option is implemented.
2. TALES calculates key financial metrics for the remedial response option.
3. Compare key financial metrics for the remedial response option with those for the baseline situation.
4. **The difference in these financial metrics represents the overall liability of responding to the environmental adverse event.**

Remediation Scenario



Conclusions

- This study demonstrated potential data flows between TALES and other NRAP tools (i.e. Remed-Res) needed to quantify the liability of responding to an environmental adverse event. These types of inter-NRAP-tool data flows are planned to be automated in future iterations of TALES as it continues to be improved.
- Take-or-pay penalties assumed in this study ($85/t CO_2 undelivered in first 12 years of operations, based on 45Q tax credit value lost to a CO_2 source if their 3rd party storage provider temporarily shuts down storage services) are a significant source of liability (-$204M in Scenario 2).
- This study demonstrated TALES is capable of nuanced comparative scenario analysis, by having the ability to incorporate user-inputs for specific project design and specific remedial actions (both cost and timing) which are needed to quantify the liability associated with relatively simple (Scenario 1), and more complex (Scenario 2) remedial response options.

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