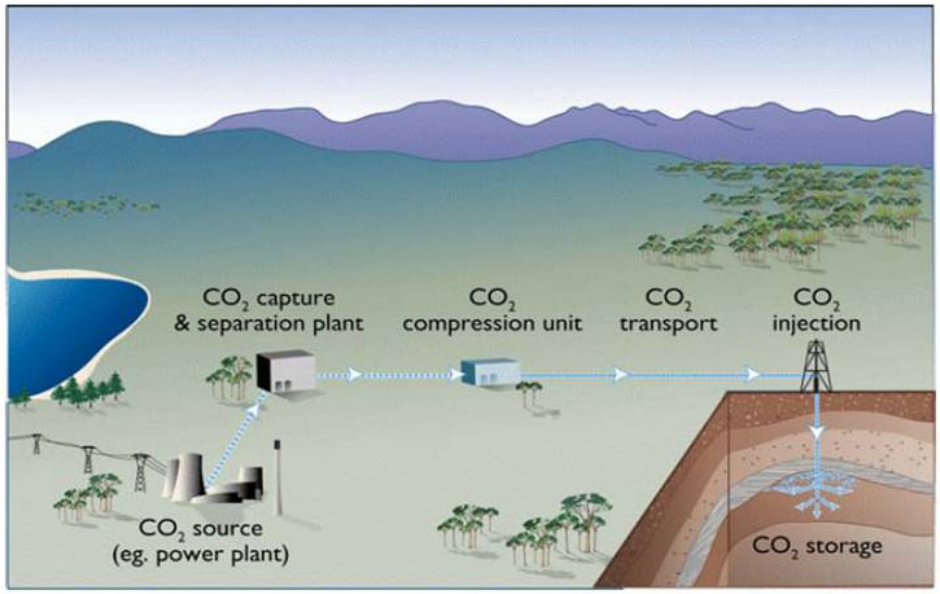


FE/NETL CO_2 Saline Storage Cost Model: Capabilities and Results

Tim Grant, Dave Morgan, Andrea Poe, Jason Valenstein, Richard Lawrence

Carbon Storage R&D Project Review Meeting
August 20-22, 2013

FE/NETL CO_2 Saline Storage Cost Model

Introduction

A look a different analyses:

- **Four Basin Study**
- **Early Test Matrix Results**
- **Financial Responsibility – Trust Fund/Escrow**
- **Financial Parameters - Cost of Equity**
- **Storage Project Cost by Stage**

Conclusions

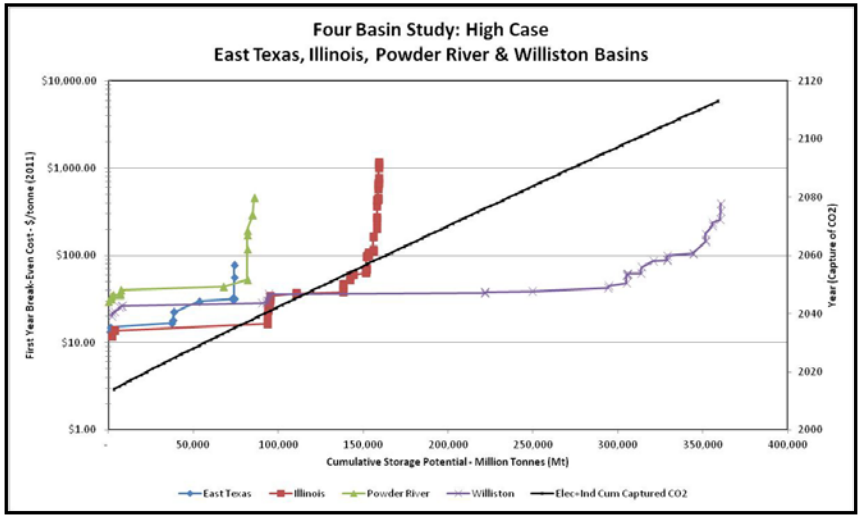
FE/NETL CO_2 Saline Storage Cost Model

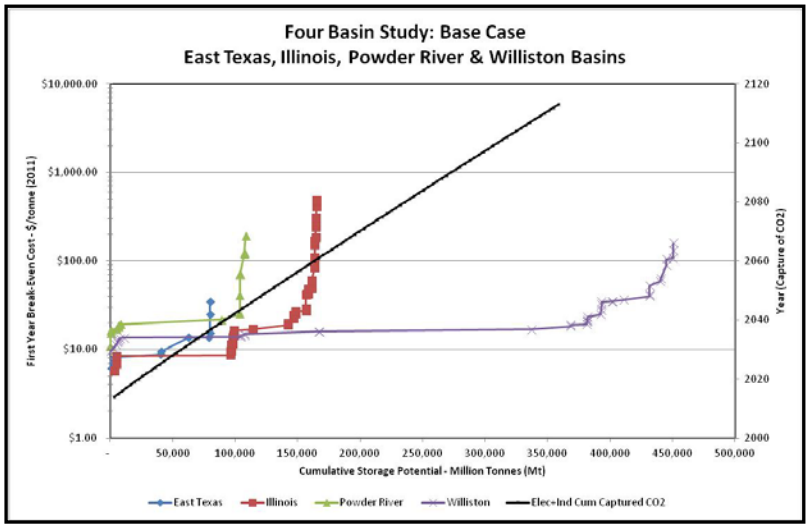
Four Basin Study Test Matrix

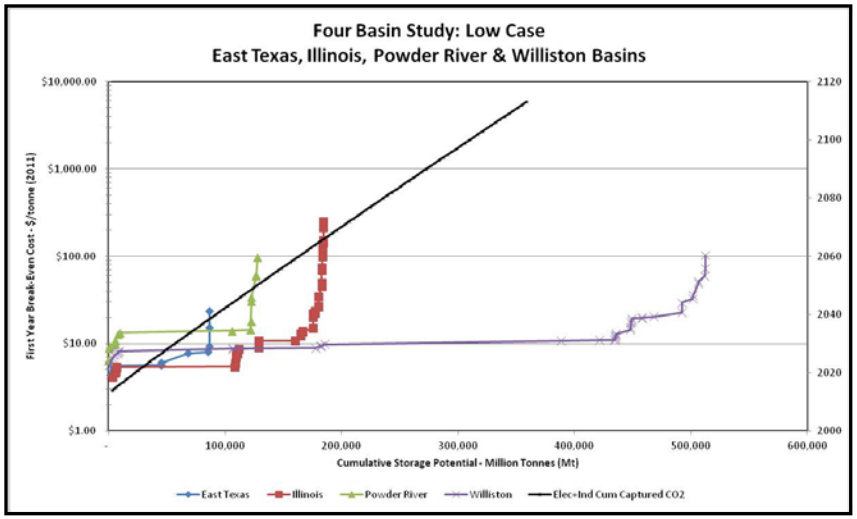
Parameter Modeled	Model Parameters for Baseline CO2 Storage Costs Update - August 2013		
	Low Cost Case	Base Case	High Cost Case
Financial Responsibility	Modified Trust Fund		
Trust Fund Growth Rate	7%	5%	3%
Storage Coefficient	P90	P50	P10
Debt/Equity Ratio	45/55 - based on High Risk scenario for an Investor Owned Utility (IOU)		
Financials	Cost of Debt = 5.5%; Cost of Equity = 12%; Escalation = 3%		
Post-Injection Site Care & Site Closure	25 years	50 years, default period in Class VI regulations	50 years, default period in Class VI regulations
Site Characterization	3 years - 2 sites	3 years - 4 sites	6 years - 4 sites
Permitting	2 years	2 years	4 years
3-D Seismic	$100,000/mi2	$160,000/mi2	$220,000/mi2
Monitoring Wells	In Reservoir: 1 well/8 mi2 Above Seal: 1 well/4 mi2 In reservoir wells dual completed above seal. Pres Front: 1 well/50 mi^2	In Reservoir: 1 well/4 mi2 Above Seal: 1 well/2mi2 In reservoir wells dual completed above seal. Pres Front: 1 well/50 mi^2.	In Reservoir: 1 well/4 mi2 Above Seal: 1 well/2 mi2 No dual completed above seal. Pres Front: 1 well/50 mi^2.
Corrective Action	1 well/8 mi2 requiring corrective action.	1 well/4 mi2 requiring corrective action.	2 wells/mi2 requiring corrective action.

FE/NETL CO_2 Saline Storage Cost Model

Four Basin Study







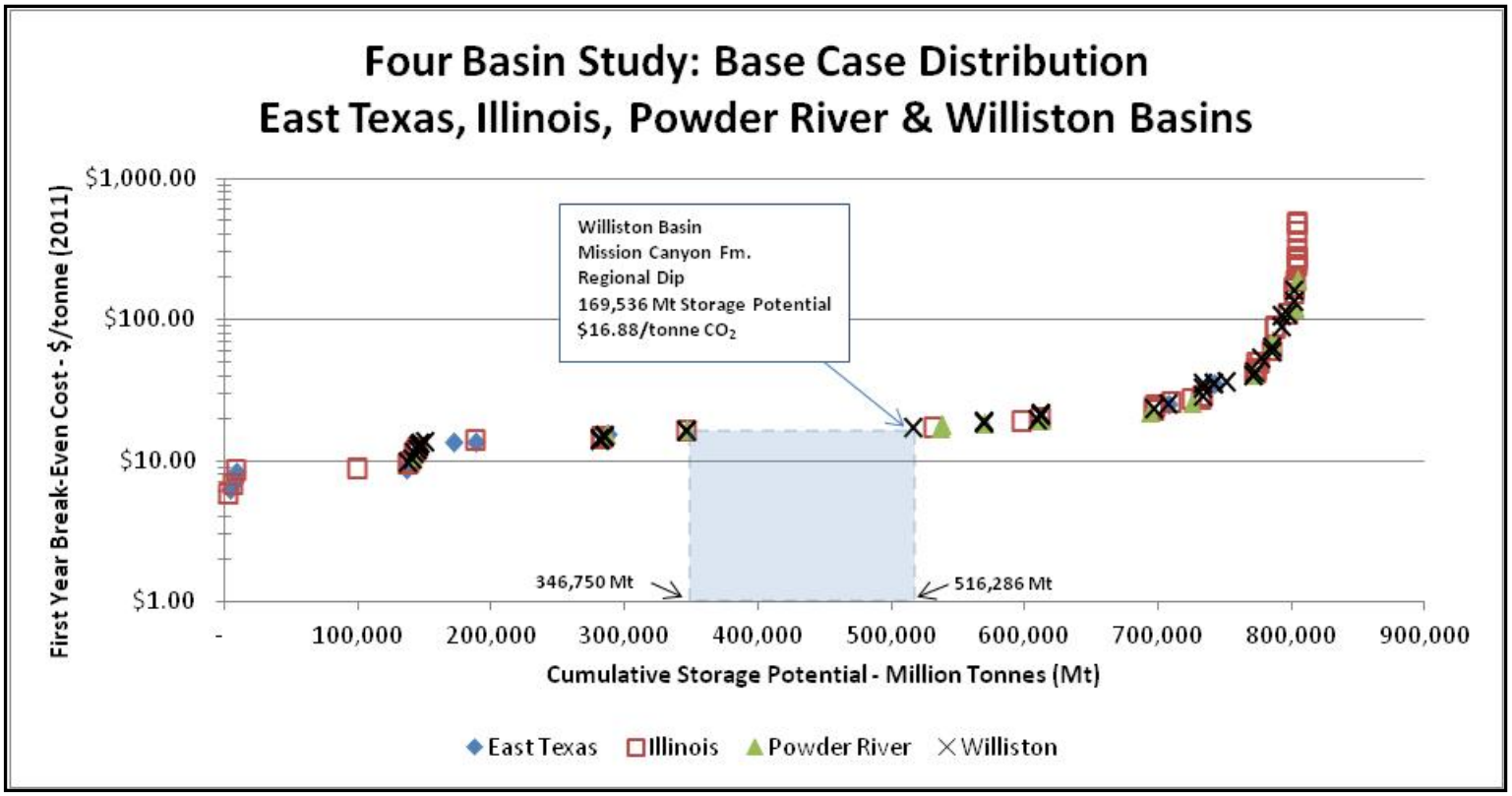
Formations modeled by Basin:

- **Illinois (Red): Mt. Simon, St. Peter & Knox**
- **East Texas (Blue): Woodbine & Paluxy**
- **Williston (Purple): Red River, Mission Canyon (Madison), & Basal Cambrian Sandstone**
- **Powder River (Green): Minnelusa, Madison, Muddy**

Electric & Industry Sector CO_2 Captured

- **A reference relating storage needs to capture**
- **Does not imply level of successful efforts**

FE/NETL CO_2 Saline Storage Cost Model



- Occurrence of storage potential along cost supply curve.
- Formation divided into three structural divisions: Dome, Anticline & Regional Dip
- Regional Dip – 97.5% of formation volume

FE/NETL CO_2 Saline Storage Cost Model

- Four Basin Study
- **Early Test Matrix Results**
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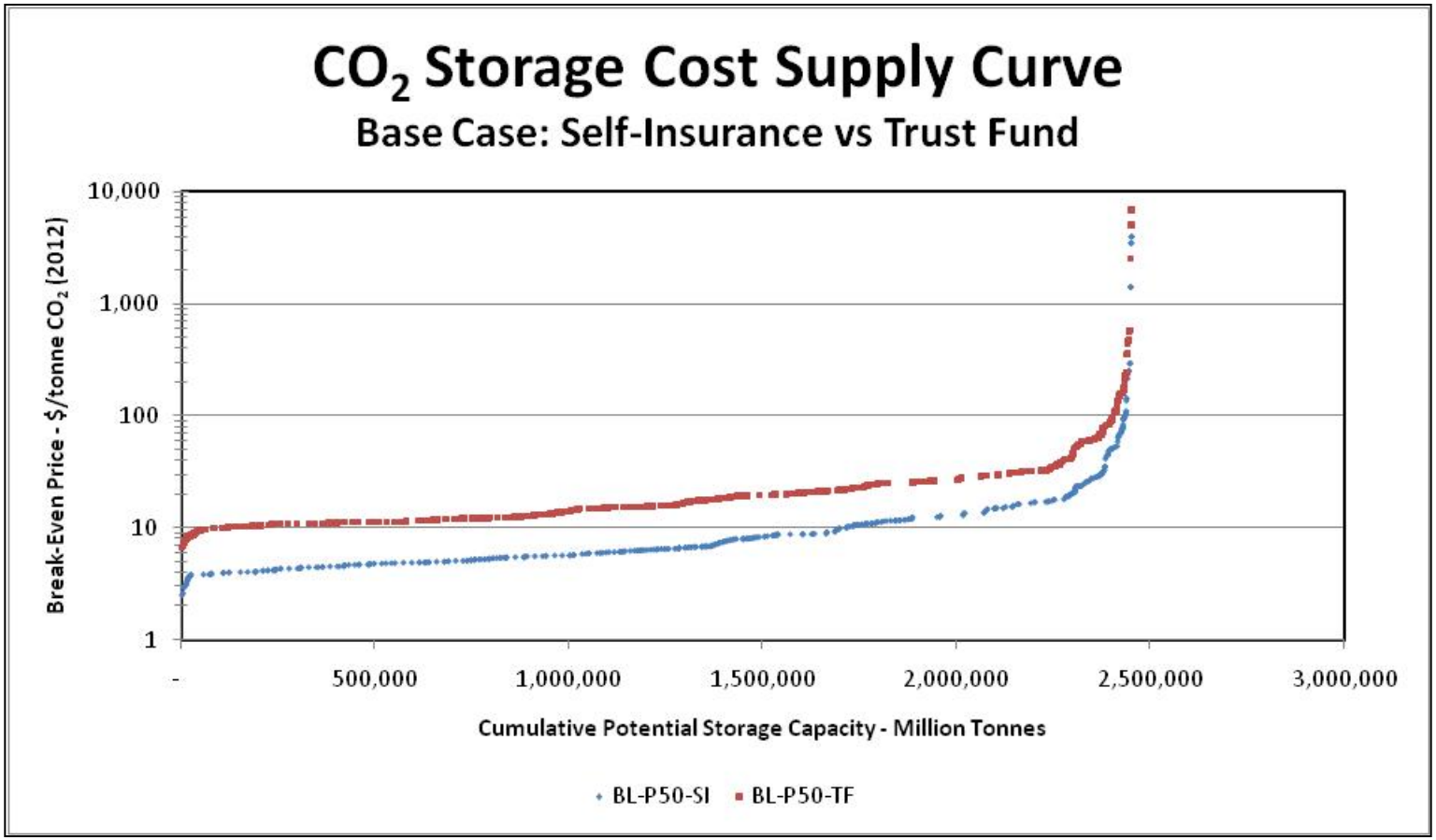
FE/NETL CO_2 Saline Storage Cost Model

First Test Matrix (2012) Parameters

Parameter Modeled	Base Case	Change in Parameter
Financial Responsibility	Self-Insurance & Trust Fund	
Storage Coefficient	P50	P10 or P90
Debt/Equity Ratio	45/55 - based on High Risk scenario for an Investor Owned Utility (IOU)	15/85 or 70/30
Financials	Cost of Debt = 5.5% Cost of Equity = 12% Escalation = 3%	No Change
Post-Injection Site Care & Site Closure	50 years, default period in Class VI regulations	25 years or 10 years (minimum time period required by some states)
Site Characterization	3 years	6 years or 9 years
Permitting	2 years	4 years or 6 years
3-D Seismic	$160,000/mi^2	$70,000/mi^2 or $260,000/mi^2
Monitoring Wells	In Reservoir: 1 well/4 mi^2 Above Seal: 1 well/2 mi^2 In reservoir wells dual completed above seal.	In Reservoir: 1 well/4 mi^2; Above Seal: 1 well/2 mi^2 and No dual completions in above seal zone. or In Reservoir: 1 well/8mi^2; Above Seal 1 well /4mi^2 with In Reservoir wells dual completed above seal.
Corrective Action	1 well/4 mi^2 requiring corrective action.	1 well/10 mi^2 or 2 wells/mi^2 requiring corrective action.

Test matrix run for entire geologic database – 151 reservoirs.

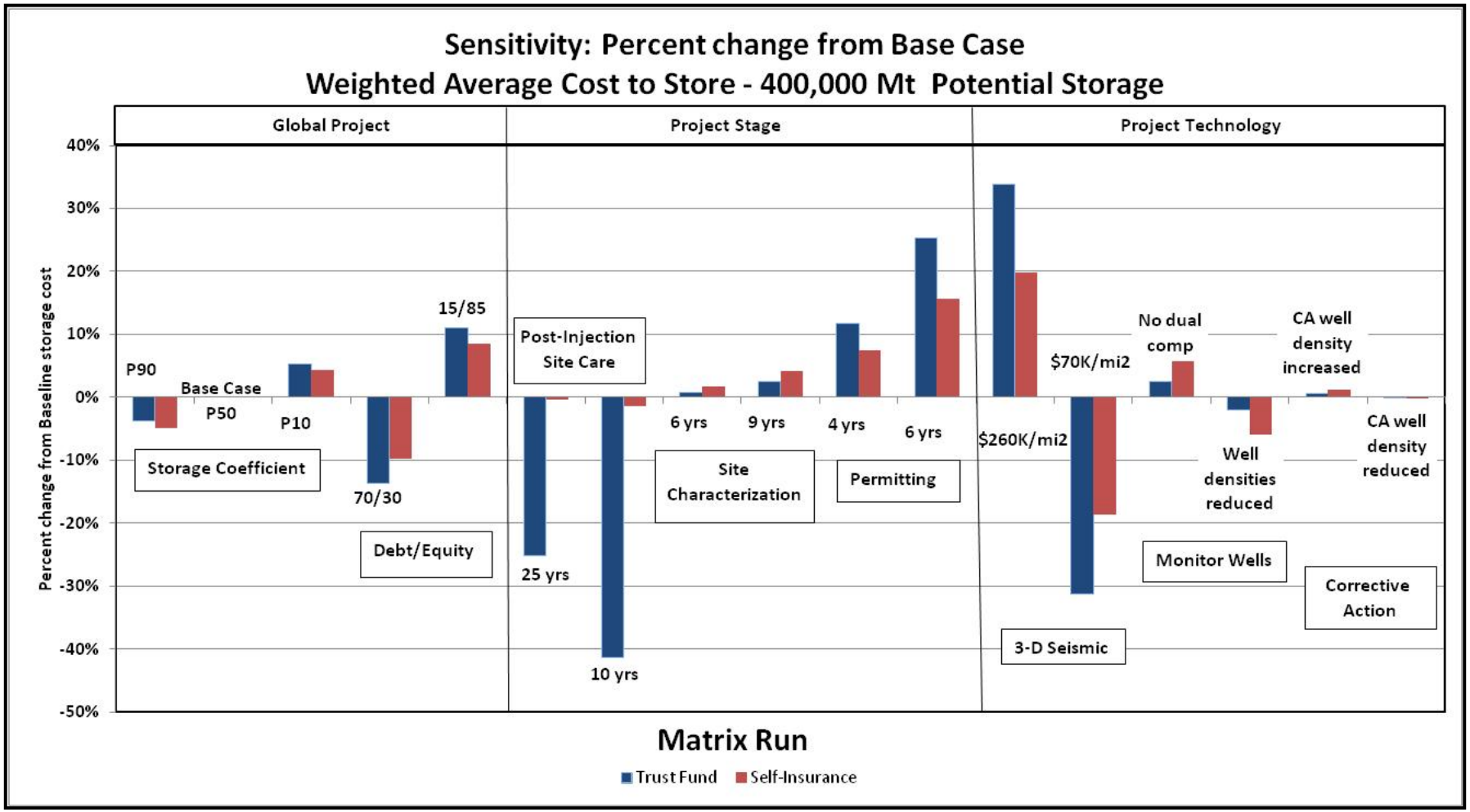
FE/NETL CO_2 Saline Storage Cost Model



- **Further analysis done on the first 400,000 million metric tonnes of storage potential**

FE/NETL CO_2 Saline Storage Cost Model

CO_2 Storage Cost Sensitivity Analysis



FE/NETL CO_2 Saline Storage Cost Model

CO_2 Storage Cost Sensitivity Analysis

Trust Fund			Self Insurance		
wt. avg. $/tonne	%Δ from baseline	Variable Changed	Variable Changed	%Δ from baseline	wt. avg. $/tonne
5.99	-41.3%	PISC = 10 years	3D seismic = $70,000/mi2	-18.6%	3.38
7.01	-31.2%	3D seismic = $70,000/mi2	D/E = 70%/30%	-9.7%	3.74
7.63	-25.2%	PISC = 25 years	Monitoring well densities reduced	-5.9%	3.90
8.81	-13.7%	D/E = 70%/30%	P90 Storage Coefficient	-4.9%	3.94
9.81	-3.8%	P90 Storage Coefficient	PISC = 10 years	-1.5%	4.09
9.99	-2.1%	Monitoring well densities reduced	PISC = 25 years	-0.4%	4.13
10.20	0.0%	Corrective action well density decrease	Corrective action well density decreased	-0.1%	4.14
10.20	0.0%	P50 Base Case		0.0%	4.15
10.27	0.7%	Corrective action well density increase	Corrective action well density increased:	1.2%	4.20
10.29	0.9%	Site Characterization = 6 years	Site Characterization = 6 years	1.7%	4.22
10.45	2.4%	Site Characterization = 9 years	Site Characterization = 9 years	4.1%	4.32
10.46	2.6%	No dual completion wells	P10 Storage Coefficient	4.4%	4.33
10.74	5.3%	P10 Storage Coefficient	No dual completion wells	5.7%	4.39
11.33	11.0%	D/E = 15%/85%	Permitting = 4 years	7.4%	4.45
11.39	11.7%	Permitting = 4 years	D/E = 15%/85%	8.5%	4.50
12.79	25.3%	Permitting = 6 years	Permitting = 6 years	15.7%	4.80
13.65	33.8%	3D seismic = $260,000/mi2	3D seismic = $260,000/mi2	19.8%	4.97

Early modeling shows that different project parameters will have a different cost impact on a storage project.

FE/NETL CO_2 Saline Storage Cost Model

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FE/NETL CO_2 Saline Storage Cost Model

Trust Fund – Model Different Pay-in Scenarios

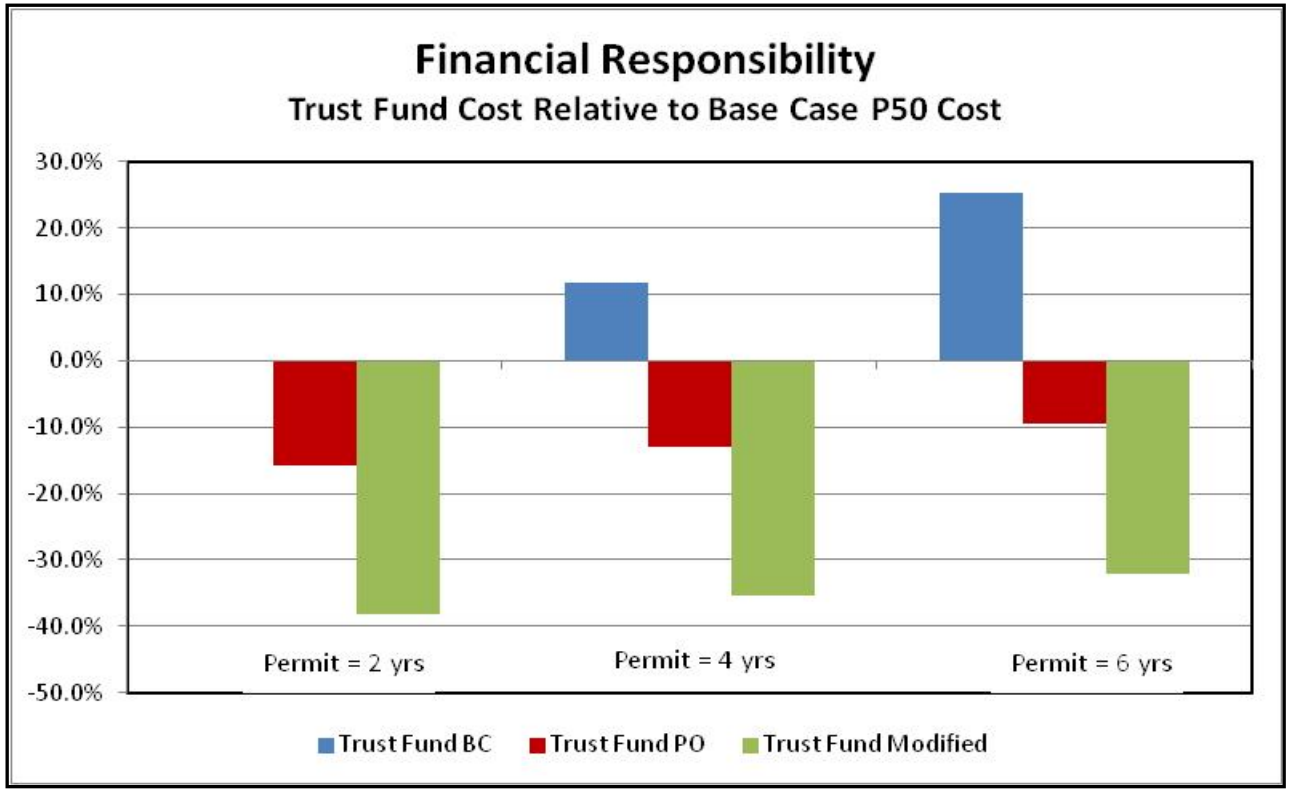
Three methods for paying into and establishing a Trust Fund to meet Class VI Financial Responsibility obligations.

- **Financial responsibility demonstrated upon application for a Class VI permit.**
  - Method used in initial modeling with a 3 year pay-in period.
- **With approval, a Trust Fund can be fully funded over a three year period with the initial payment just before injection begins**
- **Trust Fund grows at 3% per year, the rate of escalation in the model (Since modified to model different rates of growth).**
- **Modeled Base Case (Trust Fund BC):**
  - Trust Fund fully funded upon application for a Class VI permit
  - Fund established over last three years of Site Characterization
  - Method used in test matrix
- **Begin last year of Permitting (Trust Fund PO):**
  - Initial payment into Trust Fund in last year of Permitting
  - Other two annual payments into Trust Fund during first two years of Operations
- **Modified (Trust Fund Modified):**
  - Payments into Trust Fund occur over the period of operations (30 years).
  - Method used for power plant baseline performance modeling

From initial test matrix, re-ran MR-5 Trust Fund P50 Base Case, MR-21 Trust Fund with Permitting = 4 years and MR-22Trust Fund with Permitting = 6years from test matrix for each of the other two Trust Fund scenarios.

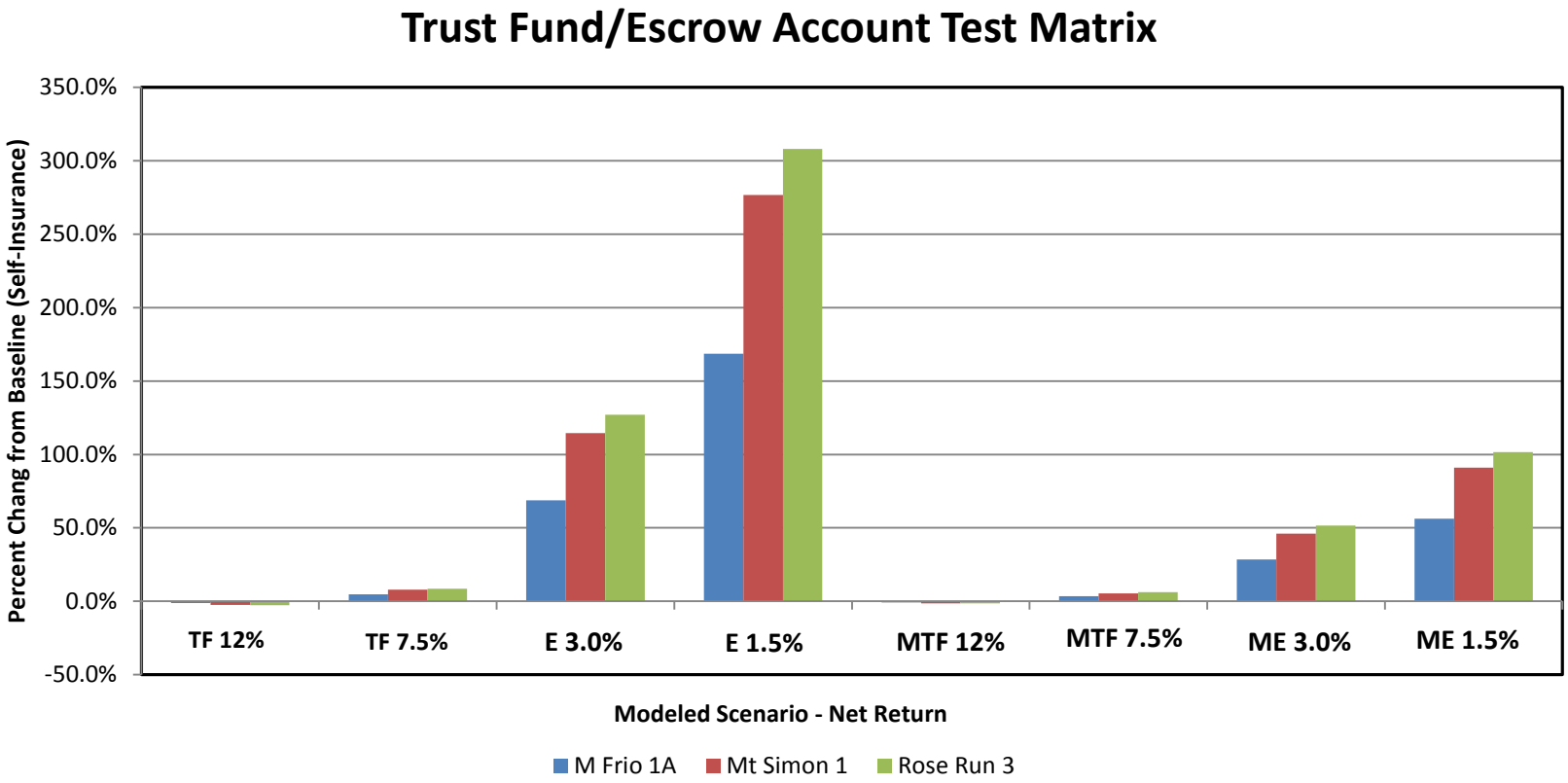
FE/NETL CO_2 Saline Storage Cost Model

Class VI Financial Responsibility: Trust Fund (TF)



- Trust Fund Base Case: established prior to permitting, TF cost increases with increasing time needed for final to complete Permit process (final injection approval)
  - Base Case is zero, 4 yrs of permitting increases TF cost ~12%, 6 yrs of permitting increases TF cost ~25%.
- Trust Fund established in last yr of permitting-1st two yrs operations reduces TF cost
  - This cost reduction diminishes with increase time needed for permitting.
- Modified Trust Fund provides lowest cost.

FE/NETL CO2 Saline Storage Cost Model



- **Trust Fund (TF) & Escrow Account (E) paid in over 3 year period beginning last year of permitting.**
- **Modified Trust Fund (MTF) & Modified Escrow Account (ME) paid in over operational period.**

FE/NETL CO_2 Saline Storage Cost Model

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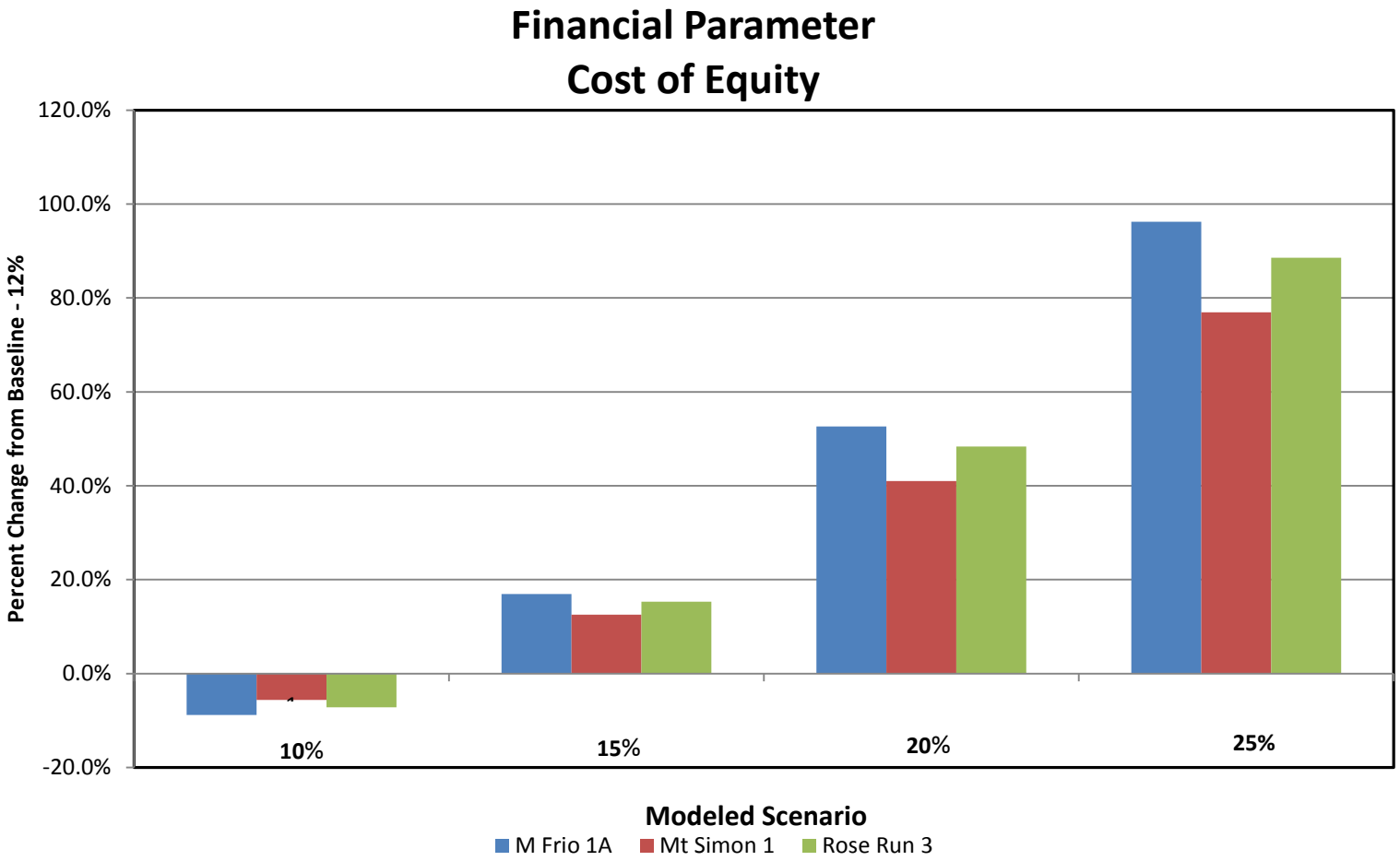
- Storage Project Cost by Stage

NETL CO2 Saline Storage Cost Model



- **Increasing use of debt financing will lower the cost of storage.**

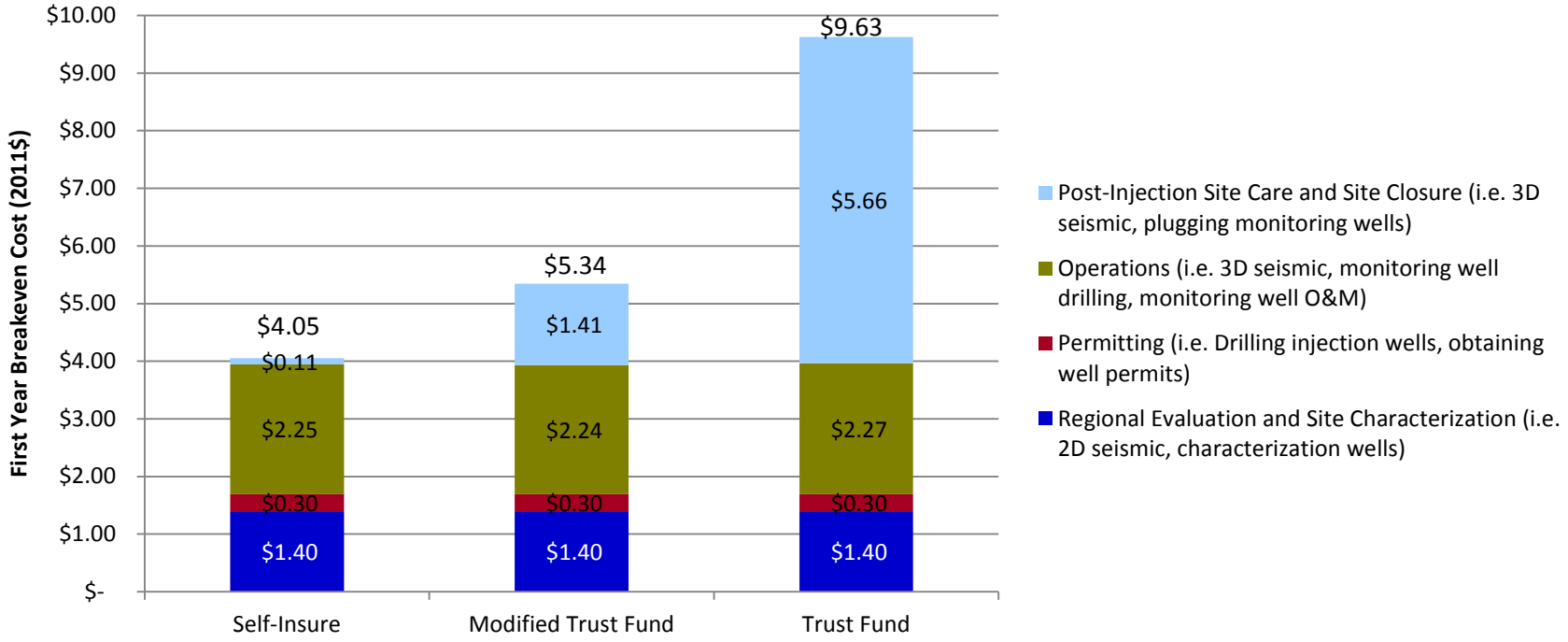
FE/NETL CO_2 Saline Storage Cost Model

- Four Basin Study
- Early Test Matrix Results
- Financial Responsibility – Trust Fund/Escrow
- Financial Parameters – Cost of Equity
- **Storage Project Cost by Stage**

FE/NETL CO_2 Saline Storage Cost Model

Breakout of Cost to Store by Project Stage

First Year Breakeven Cost (2011$) for Storage in Mt. Simon with a Dome structure



Project Stages Defined

Regional Evaluation (Year 1)
Site Characterization (Years 2-4)
Permitting (Years 5-6)
Operations (Years 7-36)
Post-Injection Site Care (Years 37-86)

NETL CO_2 Saline Storage Cost Model

Conclusions:

- **Model provides versatility in sorting out the various aspects of storage cost with respect to:**
  - Quality of reservoir,
  - Technology,
  - Number of years for a particular stage of a storage project, or
  - Regulatory impact.
- **More details need to be sorted out for the model:**
  - Cost data and how items are costed
  - What level of granularity is suitable for the model

NETL CO_2 Saline Storage Cost Model

Questions?