Overview and Baseline Assumptions for the FE/NETL CO_2 Saline Storage Cost Model

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FE/NETL CO_2 Saline Storage Cost Model

- **What is it?**
  - Spreadsheet-based discounted cash flow model for a saline storage site
  - Uses simplified reservoir engineering equations to “simulate” saline storage
  - Includes cost of complying with EPA’s Class VI well and Subpart RR regulations for saline storage sites
  - Includes cost of complying with financial responsibility requirements of Class VI well regulations
  - Calculates NPV to owners given a first-year price for storing CO_2 or calculates break-even cost (price) for storing CO_2 at specific site
  - Using database of 218 potential storage formations in lower 48 states, generates cost supply curve for saline storage

FE/NETL CO_2 Saline Storage Cost Model

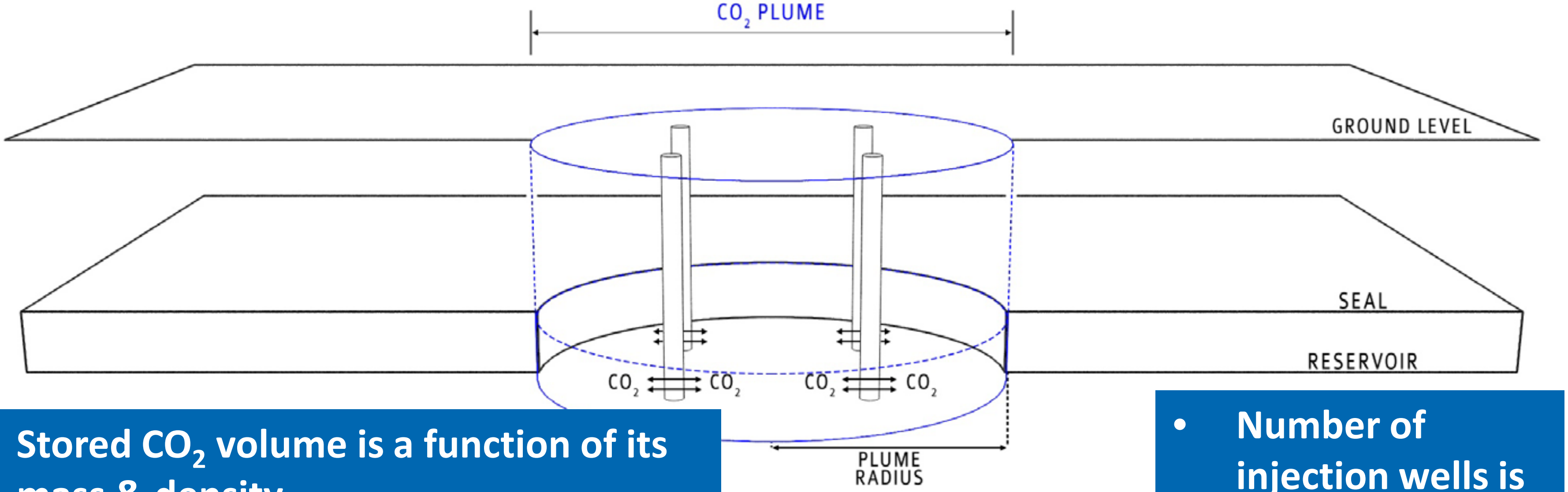
- **How is it used?**
  - How much CO_2 can be stored at what price?
  - How do storage costs vary geographically?
  - What are the main cost drivers for CO_2 storage? What is NOT important?
  - How could changes in policy/regulation affect storage costs?
    - Upcoming 18-month review of Class IV UIC rules

Model Framework Based on Project Phases

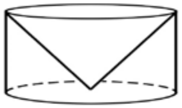
Regional Eval.	Site Selection & Char.	Permitting & Inj. Well Drilling	Operations	Post-Injection Monitoring	Long-Term Stewardship
	UIC Class VI Regulations				Developing State Regulations
			Class VI Permit		
0.5 to 1 year	3+ years	2+ years	30 to 50 years	10 to 50+ years	rest of civilization
gather existing data, develop several prospects	select a site, acquire new data (drill wells, shoot seismic), prepare permitting plans	permit awarded to drill injection wells, final approval to begin injection.	inject CO_2, drill monitoring wells & remediate existing wells as needed, MVA	monitor site, establish non-endangerment, close and restore site	another entity (e.g., a state) takes over
assemble acreage block (surface access/pore space; $50/acre + per tonne royalty)		Secure financial responsibility upon permit application; as required, pay into trust fund for financial responsibility			
	25% success rate assumed		pay $/tonne fees*		
negative cash flow			positive cash flow	negative cash flow	covered by fee paid during ops

* Default assumptions are $0.07/tonne for long-term stewardship, $0.75/tonne for insurance to cover emergency & remedial response during injection/PISC, and $0.05/tonne "royalty" to pore space owner.

Calculation of CO_2 Plume Areal Extent, Inj. Wells

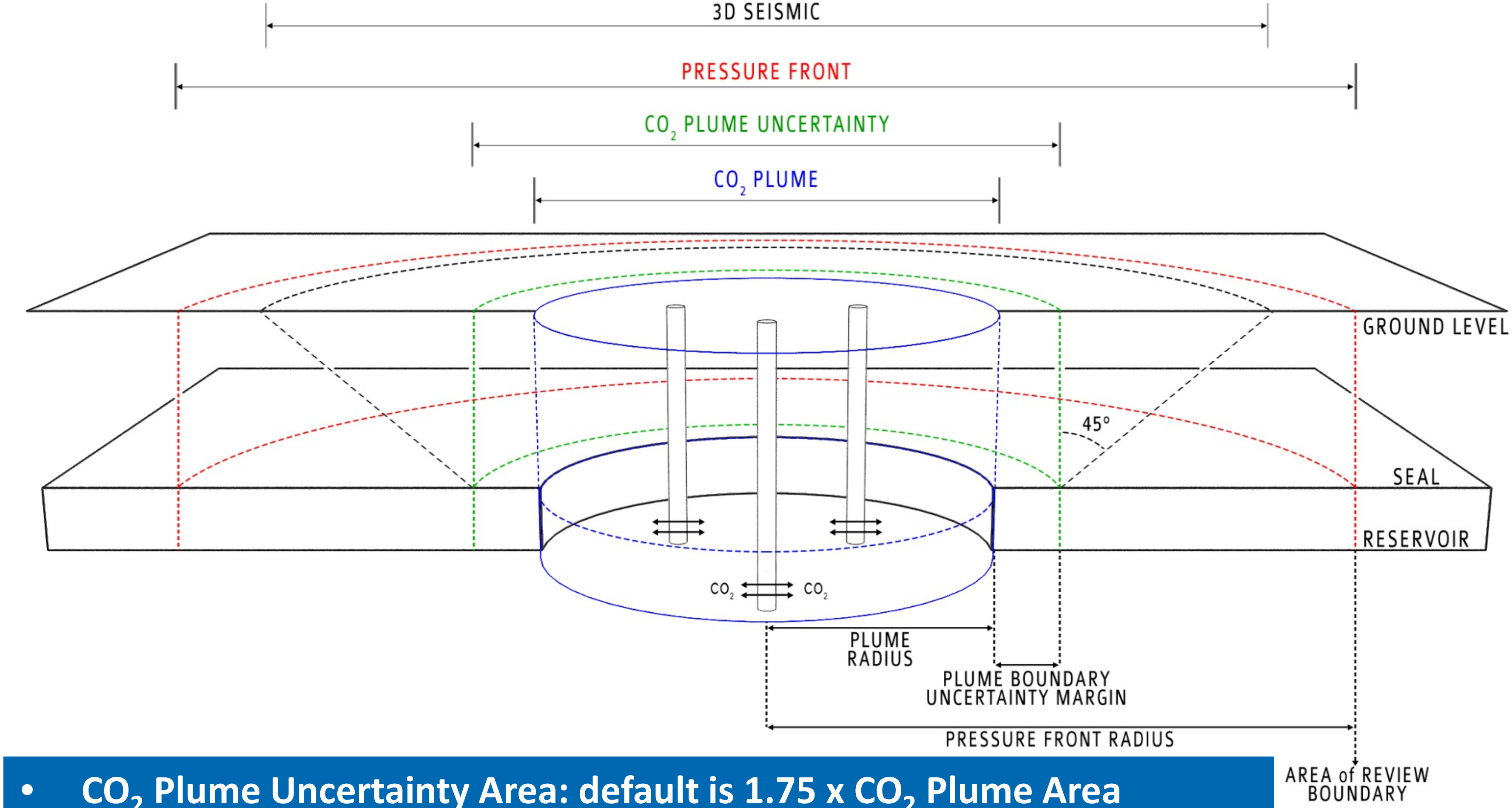


- **Stored CO_2 volume is a function of its mass & density**
  - Total mass injected is defined by user
  - Peng-Robinson eqn of state used for CO_2 density at reservoir conditions
- **CO_2 Plume Area is a function of stored CO_2 volume & the reservoir's height, porosity & storage coefficient (i.e., % of pore space occupied by CO_2)**



- **Number of injection wells is a function of total CO_2 injection rate, the reservoir's height and permeability, and well mechanics**

Important Areal Quantities



- **CO_2 Plume Uncertainty Area: default is 1.75 x CO_2 Plume Area**
  - Used to determine number of deep monitoring wells
  - Used to determine 3D Seismic Area
  - Used to determine CO_2 Pressure Front Area (defines Area of Review): default is **10 x CO_2 Plume Uncertainty Area**

Financial Responsibility

- **Must be demonstrated for Class VI permit**

- **Value of selected financial instrument(s) must cover:**
  - Corrective action
    - As needed during injection and PISC phases
    - e.g., plugging existing wells
  - Plugging injection wells
  - Post-injection site care and closure
    - ALL expenses during PISC (e.g., operating monitoring wells, seismic, sampling, plugging monitoring wells, site closure)
    - Cost of financial responsibility very sensitive to duration of PISC
  - Emergency and remedial response
    - Covered separately by insurance

Financial Responsibility

- **Six financial instruments recognized by EPA**
  1. **Self insurance**
     - "I'm good for it", owner pays costs as they are incurred
     - Owner's tangible net worth must be at least 6x estimated total project costs
  2. **Trust fund**
     - Actively managed fund that provides return
     - Possible 3-year pay-in period with first payment before injection begins
  3. **Escrow account**
     - Lower return than trust fund; same pay-in schedule
  4. **Insurance**
     - Owner pays fee for coverage (up front and/or annually)
  5. Letter of credit
     - Owner pays for access to line of credit (up front and/or annually)
  6. Surety bond
     - Owner pays premiums for bonding company's promise to pay any costs not paid by owner
  - Other: EPA open to suggestions
    - **Modified trust fund** (option in model); pay-in period congruent with operations
  - Note: Trust Fund and Escrow Account effectively move late occurring costs (injection well plugging and PISC) much earlier in the project

options currently available in model

Baseline Assumptions and Uncertainty

- **Baseline Assumptions are point estimates for variables that can encompass significant uncertainty**
- **How EPA will implement the Class VI well regulations and Subpart RR regulations may represent the greatest source of uncertainty**
  - EPA is intentionally imprecise in their requirements
  - Many assumptions used in Baseline Case are inferred from assumptions used by EPA in their cost analysis of the Class VI regulations
    - **More stringent assumptions would increase costs, less stringent assumptions would decrease costs**
  - Financial Responsibility requirements can potentially contribute significantly to cost, but it is uncertain how EPA will allow operators to meet these requirements
- **Another significant source of uncertainty is the location of CO_2 plume**
  - Geology (stratigraphy, depositional history, faults and fractures)
  - Geologic properties (porosity, permeability, thickness)
  - Storage coefficients
  - Applicability of storage coefficients for multiple injection wells

Assumptions for Baseline Case

Duration of Stage	Value	Basis
Regional evaluation and site selection	1 year	Professional judgment
Site characterization	3 years	EPA CA and professional judgment
Permitting (install injection wells)	2 years	EPA CA and professional judgment
Operations (inject CO_2)	30 years	Assumption, matches NETL power plant baseline studies
Post injection site care (PISC) and site closure	50 years	Default value in EPA Class VI regulations
Long-term stewardship	Indefinite future	

EPA CA refers to cost analysis EPA performed for the regulations governing Class VI CO_2 injection wells

Assumptions for Baseline Case

Item	Value	Basis
CO_2 injected	3.2 Mtonne/yr	NETL power plant baseline studies
Storage coefficients	Site-specific coefficients	IEAGHG (2009) report
Fraction of structure: Dome Anticline Regional dip	1.25% 1.25% 97.5%	Based on USGS report that identified 2.5% of Tensleep formation had structural closure
Usable fraction of structure Dome Anticline Regional dip	 80% 80% 40%	Professional judgment; These numbers reflect institutional constraints and pressure interference between injection projects
CO_2 Plume Uncertainty Area Multiplier	1.75	Professional judgment
CO_2 Pressure Front Multiplier	10.0	Discussions with practitioners
Sites pre-characterized	4	EPA CA, professional judgment

Assumptions for Baseline Case

Item	Value	Basis
Deep monitoring wells above seal in CO_2 Plume Uncertainty Area	1 well/2 mi2	EPA CA
Deep monitoring wells above seal in CO_2 Pressure Front Area	1 well/50 mi2	Professional judgment
Deep monitoring wells in reservoir in CO_2 Plume Uncertainty Area	1 well/4 mi2	EPA CA
Deep monitoring wells in reservoir in CO_2 Pressure Front Area	1 well/50 mi2	Professional judgment
Groundwater wells and vadose zone wells	1 well/injection well	Professional judgment
Aqueous sampling frequency - Deep monitoring wells - GW & vad. zone wells	 Annually Quarterly	 Professional judgment Professional judgment

Assumptions for Baseline Case

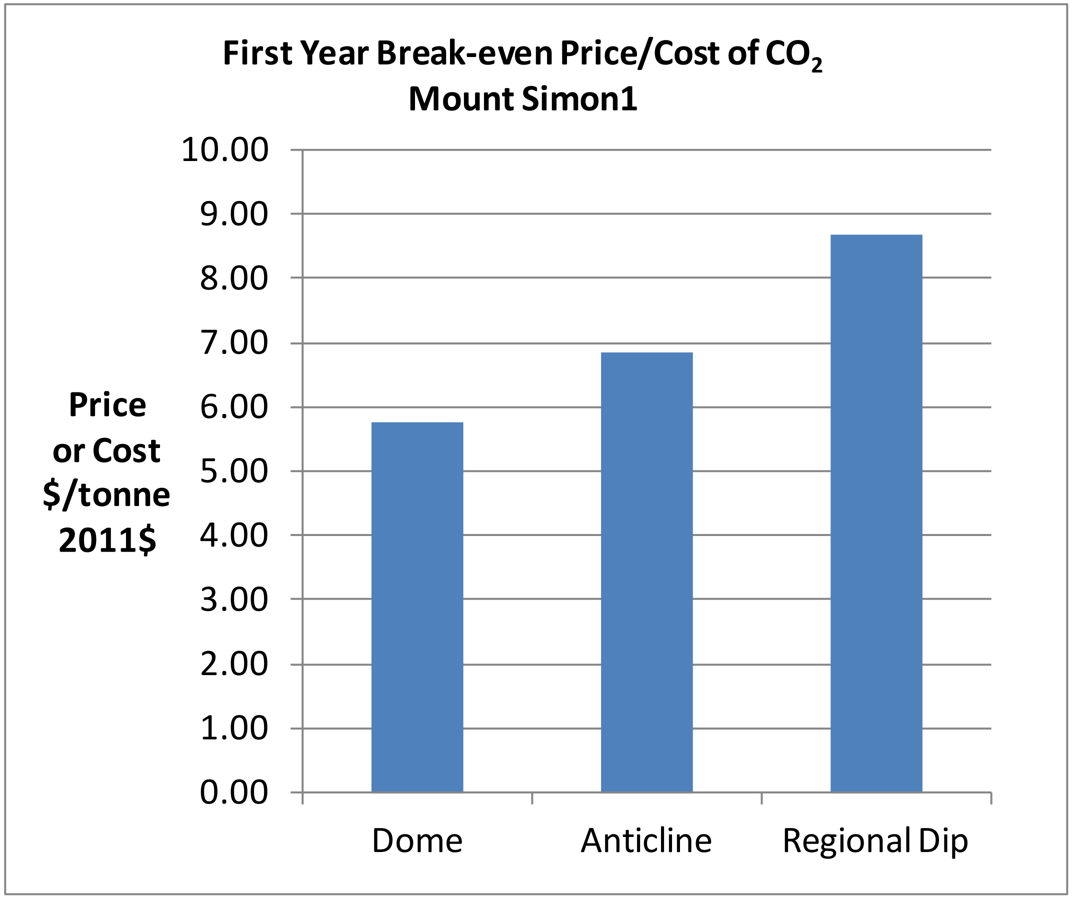
Item	Value	Basis
Cost of plume monitoring with geophy. tech. (e.g., 3D seismic)	$160,000/mi2	Mid-range value for high res. 1 component 3D seismic
Frequency of plume monit. w/ geophy. tech. during ops. & PISC	Once every 5 years	EPA CA
Cost of near surface and above surface gaseous CO_2 monitoring (Eddy cov., flux chmb., vad. z. wells)	$670,000 $60,000/yr	Capital cost (EPA CA) Annual cost (EPA CA)

Assumptions for Baseline Case

Item	Value	Basis
Percent equity	55%	Perf. Div. Baseline Stud.
Interest on debt	5.5%	Perf. Div. Baseline Stud.
Internal rate of return	12%	Perf. Div. Baseline Stud. High risk IOU
Escalation rate	3%	Perf. Div. Baseline Stud.
Tax rate	38%	Perf. Div. Baseline Stud.
Financial responsibility -Modified Trust Fund for corr. action, inj. well plugging, PISC (interest rate) -Insurance for Emerg. & Rem. Resp. (ERR)	5%/yr $0.75/tonne	Net rate of return after taxes & admin. fees Professional judgment
Lease bonus	$50/acre	EPA CA
Pore space fee	$0.25/tonne	Professional judgment
Long-term stewardship fund	$0.07/tonne	Professional judgment

Results for Baseline Case

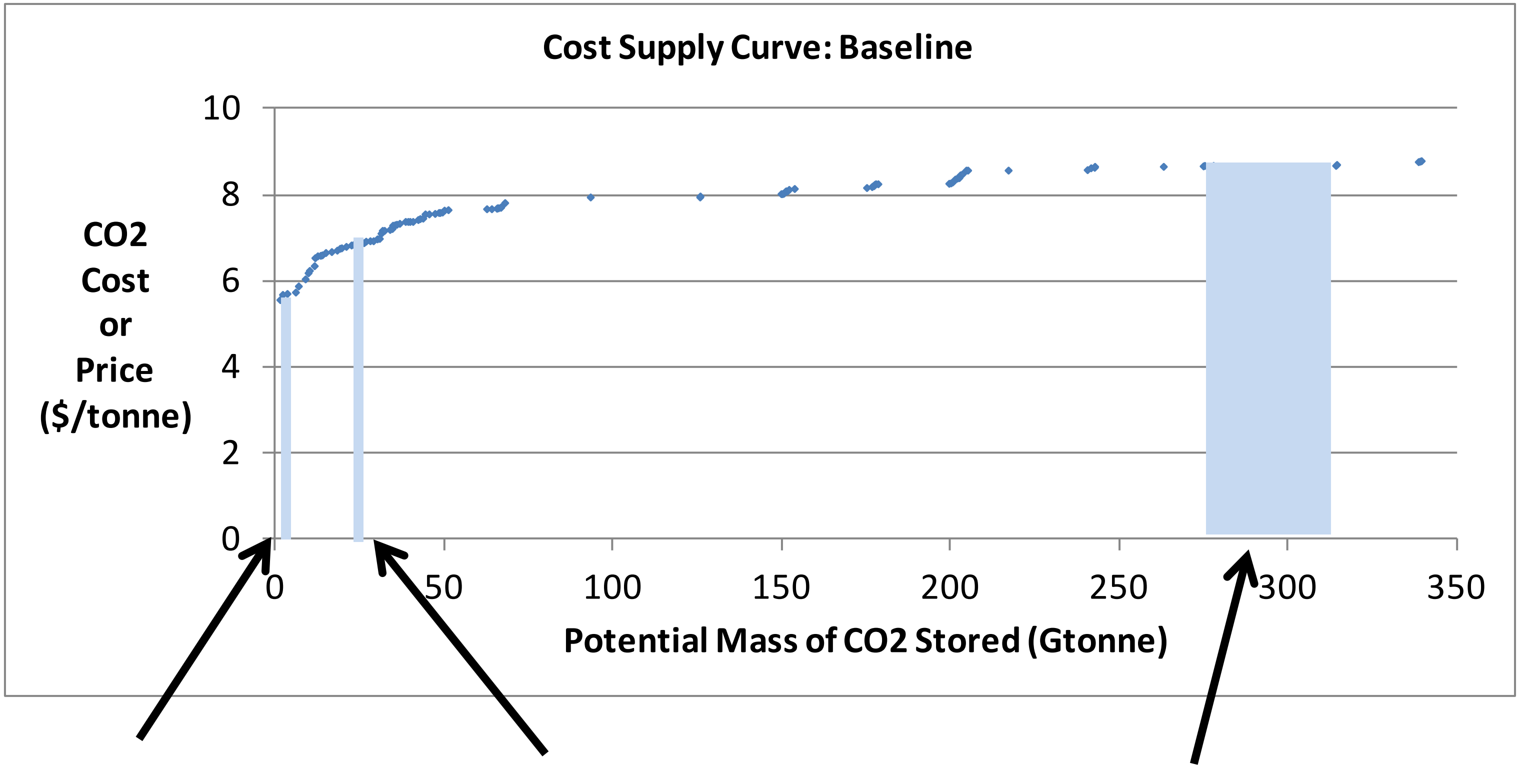
- **Mount Simon1 formation is a promising formation for storage in IL**
- **Structure (dome, anticline or regional dip) is important determinant of cost**



Constructing a Cost Supply Curve

- Run model for all 218 formations and 3 structural settings to give 654 data points
- Sort results for all 654 formation-structure combinations from lowest to highest first year break-even price or cost for CO_2
- Calculate the cumulative mass of CO_2 that can be stored in all formations assuming the lowest cost formation is filled first to capacity, followed by the next lowest cost formation, and so on
- Plot the first year break-even price or cost of CO_2 for each formation on the y-axis and the cumulative mass of CO_2 that can be stored associated with each formation on the x-axis

Constructing a Cost Supply Curve



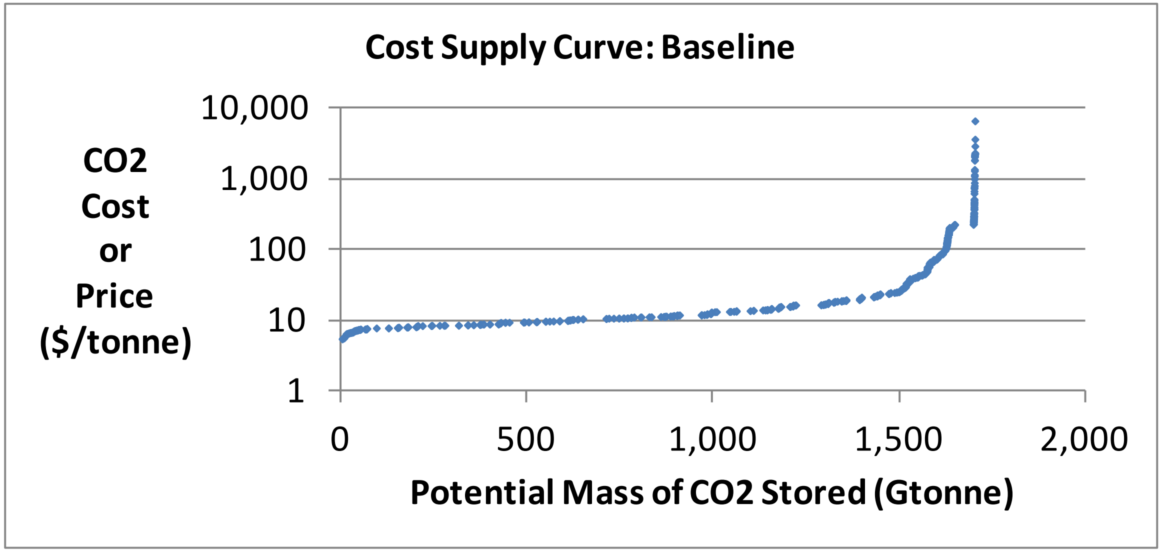
Mount Simon1
Dome
$5.75/tonne
2.5 Gtonne

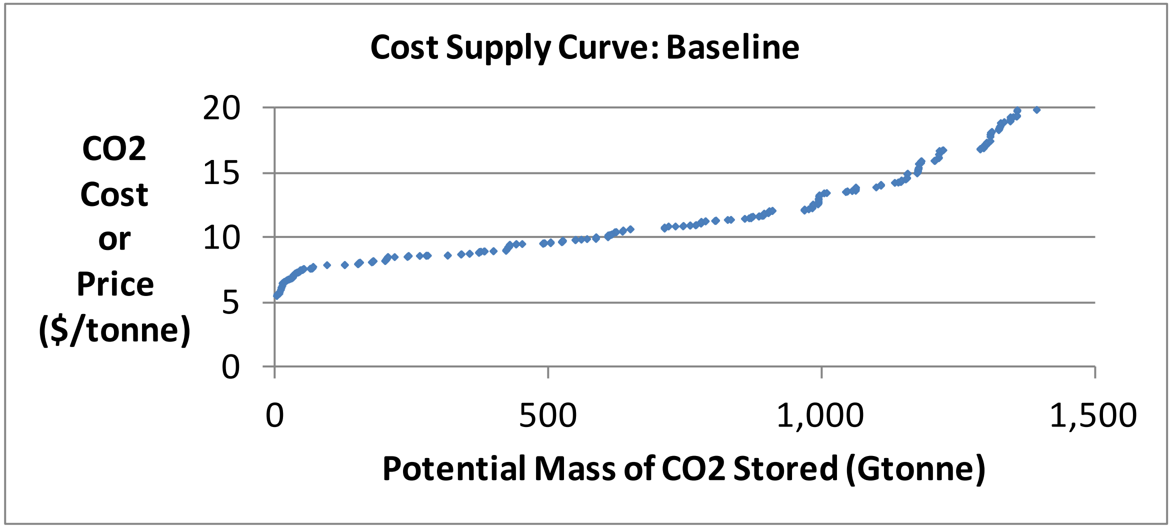
Mount Simon1
Anticline
$6.84/tonne
1.5 Gtonne

Mount Simon1
Regional Dip
$8.69/tonne
36.3 Gtonne

Cost Supply Curve for Baseline Case

- **First year break-even price or costs range from $5.60/tonne to over $1,000/tonne**
- **Approximately 580 Gtonne of storage at less than $10/tonne**





Model Demonstration and Request for Data

- We will have a table setup at the Poster Secession this afternoon to further discuss and demonstrate the FE/NETL CO_2 Saline Storage Cost Model.
- We will also solicit cost information and observations for the model

Contributors

- **This presentation represents the result of a collaborative effort from a number of individuals within NETL, including:**
  - Traci Rodosta (Technology Manager, Carbon Storage Program)
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  - Grant Bromhal (Office of Research and Development)
  - Angela Goodman (Office of Research and Development)
  - Robert Dilmore (Office of Research and Development)
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  - Derek Vikara (KeyLogic Systems, Inc.)
  - Malcolm Webster (KeyLogic Systems, Inc.)
  - Michael Tennyson (KeyLogic Systems, Inc.)
  - Christa Court (MRI Global)
  - Paul Myles (WorleyParsons Group, Inc.)
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Questions?