NETL Storage CO_2 Resource Estimation Excel aNalysis (SCREEN)

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Purpose

- Provide user-friendly platform for estimating prospective CO_2 in saline formations (Fig. 1) at the national, regional, basin (Fig. 2), and formation scale
- Provide a consistent method to calculate prospective CO_2
- Allow for direct comparison of prospective CO_2 storage estimates between RCSPs (Fig. 3), government agencies, and independent research studies

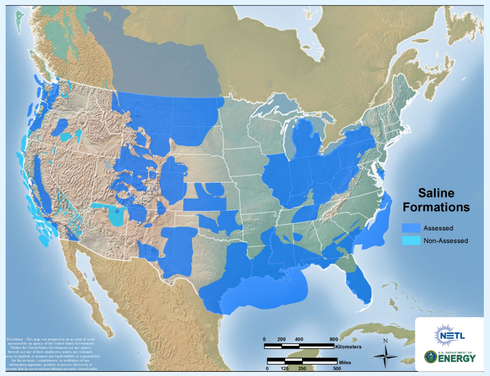


Figure 1. Areal extent of saline formations in the contiguous United States; assessed and non-assessed.

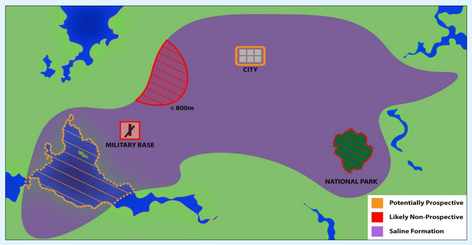


Figure 2. Basin scale map of fictional saline formation. Common limitations (e.g. National Parks) reduce area efficiency.

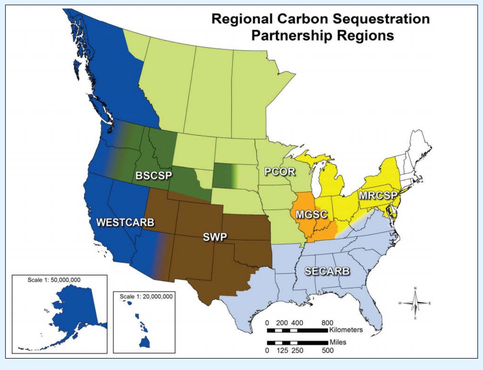


Figure 3. Geographical boundaries of the Regional Carbon Sequestration Partnership Regions. (The United States Carbon Utilization and Storage Atlas, DOE-NETL, 2012)

CO_2 Volumetric Equation

$$G_{CO_2} = A_t h_g \phi_{tot} \rho E_{Saline}$$

$$E_{Saline} = E_A E_h E_{\phi tot} E_v E_d$$

G_{CO_2} = CO_2 storage resource (mass)
A_t = total area
h_g = gross formation thickness
ϕ_{tot} = total porosity
ρ = CO_2 density

E_A = net-to-gross area
E_h = net-to-gross thickness
$E_{\phi tot}$ = effective-to-total porosity
E_v = volumetric displacement
E_d = microscopic displacement

NETL CO_2 SCREEN

Data Inputs

General Information	
Researcher Name	Jane Scientist
Formation Name	Oriskany Formation
Date	8/15/2015

Instructions:

- 1 Type general information into cells I7:I9
- 2 Storage Efficiency Values
  - Option One: Choose the lithology and depositional environment using the drop-down list in cell I17 (yellow). This will autopopulate storage efficiency P_{10} and P_{90} values in cells I21:I25 and J21:J25 (yellow)
  - Option Two: Enter user specific P_{10} and P_{90} values in cells K21:K25, and L21:L25 (light red)
- 3 Formation Data
  - Option One: Skip to step 4 to enter user specific data
  - Option Two: Enter formation data in "Formation Data" tab and follow instructions to autopopulate values
- 4 Storage Parameters
  - Directly enter user specified storage parameters (light red)
- GoldSim will import values from cells O21:O25, P21:P25, J42, J44:J47, and K44:K47 (red font: make sure each cell contains a value)
- Do not alter spreadsheet cell layout as this may cause errors when syncing with GoldSim Player
- After data is input, save and close spreadsheet before running GoldSim Player

*** (Area, Thickness, Porosity)**

These will be treated as gross estimates requiring application of efficiency terms. To use "net" values manually enter 1 for respective P_{10} and P_{90} efficiency terms.

† (Pressure, Temperature)

Ranges are limited by the lookup table in GoldSim

Pressure must range between 0.1 and 60 MPa

Temperature must range between 1 and 180°C

Reference Values		
z_{90}	z_{10}	z_{90}-z_{10}
1.28155157	-1.2815516	2.56310313

1 Lithology and Depositional Environment: Clastics: Shallow Shelf

2 Storage Efficiency Values

Autopopulate: Choose lithology and depositional environment

User Specified: Directly enter P_{10} and P_{90} values

	Autopopulated		User Specified					
	P_{10}	P_{90}	P_{10}	P_{90}	X_{10}	X_{90}	μ_X	σ_X
Net-to-Total Area	0.20	0.80	0	0	-1.39	1.39	0.00	1.08
Net-to-Gross Thickness	0.21	0.76	0	0	-1.32	1.15	-0.09	0.97
Effective-to-Total Porosity	0.62	0.78	0	0	0.49	1.27	0.88	0.30
Volumetric Displacement	0.18	0.63	0	0	-1.52	0.53	-0.49	0.80
Microscopic Displacement	0.39	0.82	0	0	-0.45	1.52	0.53	0.77

3 Formation Data

If user requires processing of data go to "Formation Data" tab to enter multiple storage parameter values which will autopopulate aggregated means and standard deviations for step 4 below. If user already has processed data, proceed to step 4

4 Storage Parameters

Autopopulate: Calculated from step 3

User Specified: Directly enter storage parameters

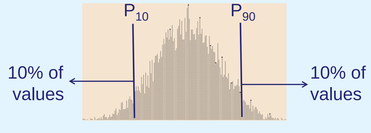
		Autopopulated		User Specified	
Total Area*	(km^2)	100		100	
		Mean	Std Dev	Mean	Std Dev
Gross Thickness*	(m)	50	0	50	0
Total Porosity*	(%)	10.00	0	10	0
Pressure†	(MPa)	20	0	20	0
Temperature†	(°C)	100	0	100	0

Figure 4. Image of "Input" tab in NETL SCREEN spreadsheet.

Required Inputs

Storage Efficiency Values

- Auto-populate P_{10} and P_{90} efficiency values based on lithology and depositional environment (yellow cells)
- Enter user specified P_{10} and P_{90} values (red cells)
- Efficiency P_{10} and P_{90} values are transformed from P to X terms using log-odds normal distribution (Fig. 5).



$$X = ln\left(\frac{p}{1-p}\right)$$

- Mean (μ_X) and standard deviation (σ_X) are calculated using:

$$\sigma_X = \frac{X_{90} - X_{10}}{Z_{90} - Z_{10}} \quad \text{and} \quad \mu_X = X_{10} - \sigma_X Z_{10}$$

- Where Z_p is the P^{th} percentile value of the standard normal distribution

Geologic Storage Parameters

- Enter mean and standard deviation values

Storage Efficiency Values

Autopopulate: Choose lithology and depositional environment

User Specified: Directly enter P_{10} and P_{90} values

Lithology and Depositional Environment: Clastics: Shallow Shelf

	Autopopulated		User Specified					
	P_{10}	P_{90}	P_{10}	P_{90}	X_{10}	X_{90}	μ_X	σ_X
Net-to-Total Area	0.20	0.80	0	0	-1.39	1.39	0.00	1.08
Net-to-Gross Thickness	0.21	0.76	0	0	-1.32	1.15	-0.09	0.97
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Volumetric Displacement	0.18	0.63	0	0	-1.52	0.53	-0.49	0.80
Microscopic Displacement	0.39	0.82	0	0	-0.45	1.52	0.53	0.77

Figure 5 (above): Zoomed in view of storage efficiency inputs. Efficiency values range between 0 (0% efficiency) and 1 (100% efficiency). Figure 6 (left): Gaussian function showing P_{10} and P_{90} range. Figure 7 (below): Zoomed in view of storage parameters. Storage parameters must be input as mean and standard deviations

Storage Parameters

Autopopulate: Calculated from step 3

User Specified: Directly enter storage parameters

		Autopopulated		User Specified	
Total Area*	(km^2)	100		100	
		Mean	Std Dev	Mean	Std Dev
Gross Thickness*	(m)	50	0	50	0
Total Porosity*	(%)	10.00	0	10	0
Pressure†	(MPa)	20	0	20	0
Temperature†	(°C)	100	0	100	0

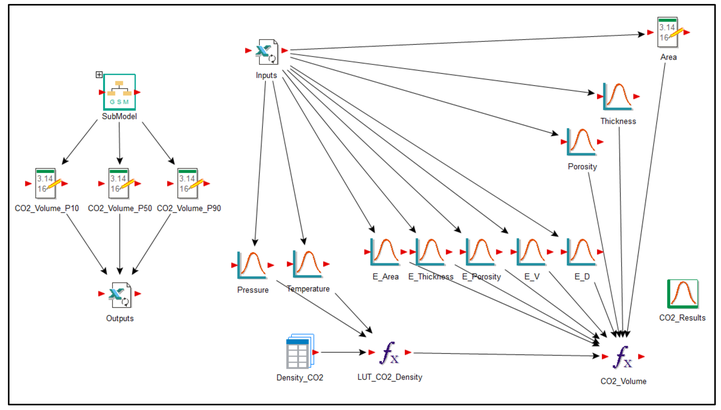

Figure 8. GoldSim model layout. Note: inputs from Excel are used to generate distributions which are then used to calculate CO_2 resource (mass).

GoldSim

- Monte Carlo sampling (n=10,000) using the following equation:

$$CO_2 = \frac{1}{\left(1+e^{(-E_{hg})}\right)} * \frac{1}{\left(1+e^{(-E_{\phi tot})}\right)} * \frac{1}{(1+e^{(-E_V)})} * \frac{1}{(1+e^{(-E_D)})} * A_t * h_g * \phi_{tot} * \rho$$

- Calculates the statistical P_{10}, P_{50}, and P_{90} probability values of volumetric CO_2

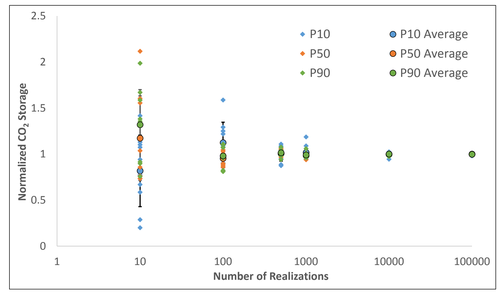

Figure 9. Sensitivity analysis plot. CO_2 storage values normalized to one million realizations vs. number of realizations for that simulation.

Future Work

- Increase SCREEN Capabilities
  - Scale: Add National and Site scale estimations
  - Reservoir: Develop tool for shale formations
  - Automation: Add user requested features (e.g. multiple regions)

References

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