Enhanced Analytical Simulation Tool for CO₂ Storage Capacity Estimation

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Seyyed A. Hosseini The University of Texas at Austin

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Benefit to the Program/Goals and Objectives

- Project benefit
 - Support industry's ability to predict CO₂ storage capacity in geologic saline formations to within ±30 percent.
- Major goal
 - Develop an Enhanced Analytical Simulation Tool (EASITOOI) for simplified reservoir models to predict storage capacity of brine formations.
- Objectives
 - Provide fast, reliable and science-based estimate of storage capacity.
 - Integrate analytical/semi-analytical geomechanical models
 - Integrate brine extraction scenarios.
 - Provide sensitivity analysis.





Technical Status

| EASiToolGUI | | | | |
|-----------------------------|--------------------|--|---------------------------------------|--|
| Main Interface | | | | د د |
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| GCCC | GULECOA | | BUREAU OF JACKSON | 8 50 500 |
| GUP EDAT CARPON CENTE | | | GEOLOGY SCHEDULOT GEOCUSICES | |
| -1-RESERVOIR PARAMETERS | | 3-SIMULATION PARAMETERS | 4-NPV | |
| | Min Ma | | Drilling Cost (SM/well) | VIC S |
| Pressure [MPa] | 20 15 25 | Simulation Time [years] 20 | Drining Cost [sivi/wen] | <u>≱</u> 30 1 2 -500 |
| Tempreture (C) | 65 50 80 | Injection Well Radius [m] 0.1 | Operation Cost [\$K/well/year] 500 | |
| | | Max Injection Pressure (MPa) 30 | Monitoring Cost [\$K/year/km^2] 50 | 0°_{20} -1000 |
| Thickness [m] | 100 50 15 | wax injection r lessure (wir a) | Ten Credit (2011-2) | Number of Injection Wells Number of Injection Wells |
| Salinity [mol/Kg] | 2 1 3 | Estimate Max Injection Pressure Internally | Tax Credit [S/ton] | CO2 Plume Extension Well Rate (ton/day) |
| | 0.2 0.15 0.2 | Density of Porous Media [Kg/m3] | Extractors Drilling Cost [\$M/well] 1 | |
| Porosity | 0.2 0.13 0.2 | | Extractors Operation Cost 500 | |
| Permeability [mD] | 100 10 25 | Total Stress Ratio (V/H) | j\$K/weii/yearj | |
| Rock Compressibility [1/Pa] | 5e-10 3.5e-10 6.5e | Biot Coefficient | 5-EXTRACTION PARAMETERS | |
| | | - Reissen's ratio | Number of Extractors 4 | \succ 4 \succ 4 |
| Reservoir Area [km^2] | 100 | Poisson's faile | Minimum Extraction 29 | |
| Basin Area [km^2] | 100 | Coefficient of Thermal Expansion [1/K] | Maximum Extraction Rate 2000 | |
| Boundary Condition | Clos - | Bottom Hole Temperature Drop [K] | [m^3/day/well] | |
| , | Ci03 • | | Run | X, km X, km |
| 2-RELATIVE PERMEABILITY (| Brooks-Corey) | Young's Modulus [GPa] | Simulation Time [sec]= 100 | |
| Residual Water Saturation | 0.5 0.3 0.7 | Depth [m] | | Permeability Thickness |
| Residual Gas Saturation | | Estimated May Islantian Pressure (MP-1 | Number of Injection Wells 9 | Porosity Rock Comp. |
| Nesidual Gas Saturation | 0.05 0 0.1 | Estimated Max Injection Pressure [MP8] | Export Image and Output Files (Slow) | Temperature |
| m | 3 2 4 | Max Injection Rate [ton/day/well] 2000 | Visit our website | |
| n | 3 2 4 | Max Number of Injectors | | Săr - Kra0 - |
| Kra0 | 1 1 1 | | | |
| K 0 | | | GASILOO | Pressure 3 |
| Krg0 | 0.3 0.20 0.4 | Sensitivity Analysis (Slow) | CO2 Geological Capacity Estimation | 20 30 40 50 60 70 80 |
| | | | | Capacity |





Technical Status

| | DOE/NETL | CSLF | USGS | EASiTool | Numerical Simulators |
|----------------------|----------|------|--------|-------------|-------------------------|
| Reservoir scale | Yes | Yes | Yes | Yes | Yes |
| Accuracy | Low | Low | Low | Medium/High | High |
| Boundary conditions | No | No | No | Yes | Yes |
| Rock geomechanics | No | No | No | Yes | Yes |
| Brine management | No | No | No | Yes | Yes |
| Required expertise | Low | Low | Low | Low | High |
| Cost of use | Low | Low | Low | Low | High |
| Speed | High | High | High | High | Low |
| Dynamic | No | No | No | Yes | Yes |
| Sensitivity Analysis | No | No | Simple | Yes | Yes |



Technical Status

Gulf Coast Carbon Center

- Tasks 2-4 completed
- NCE
- User feedback, Verification & Application







· Finding the optimized rate to maximize storage capacity







• Normal fault system

 $P_{\max} = \frac{1}{\left[2\alpha - \beta_v - \beta_h - (\beta_v - \beta_h)\cos 2\theta + (\beta_v - \beta_h)\sin 2\theta / \mu\right]}.$

 $\left[\left\{(1+K)+(1-K)\cos 2\theta-(1-K)\sin 2\theta/\mu\right\}\sigma_{v0}-\left\{(\beta_v+\beta_h)+(\beta_v-\beta_h)\cos 2\theta-(\beta_v-\beta_h)\sin 2\theta/\mu\right\}P_{pi}-\frac{2\alpha_T E\Delta T}{1-2\nu}\right]$

Reverse fault system

 $P_{\max} = \frac{1}{\left[2\alpha - \beta_{h} - \beta_{v} - (\beta_{h} - \beta_{v})\cos 2\theta + (\beta_{h} - \beta_{v})\sin 2\theta/\mu\right]} \cdot \left[\left\{(K+1) + (K-1)\cos 2\theta - (K-1)\sin 2\theta/\mu\right\}\sigma_{v0} - \left\{(\beta_{h} + \beta_{v}) + (\beta_{h} - \beta_{v})\cos 2\theta - (\beta_{h} - \beta_{v})\sin 2\theta/\mu\right\}P_{pi} - \frac{2\alpha_{T}E\Delta T}{1 - 2\nu}\right]$

• Strike-slip fault system

- Kim, S, and Hosseini, S. A., 2014, Geological CO₂ storage: incorporation of pore-pressure/stress coupling and thermal effects to determine maximum sustainable pressure limit: Energy Procedia, v. 63, p. 3339-3346,
- Kim, S, and Hosseini, S. A., 2016, Study on the Ratio of Pore-Pressure/Stress Changes During Fluid Injection and Its Implications for CO2 Geologic Storage, Journal of Petroleum Science and Engineering, in press.











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Accomplishments to Date



Horizontal effective stress, σ'_{h} (MPa)





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Accomplishments to Date

| | | 0.77 | | - | 1.0 |
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Main Interface

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| | GUL | F COAST | CARBON CENTER | | Bureau of Economic Geology - | JACKS SCHOOL OF SEDEC | ON ESGE |
|---------------------------|-----------|---------|--|----------|---|--------------------------|------------|
| 1-RESERVOIR PARAMETERS | | | 3-SIMULATION PARAMETERS | | 4-NPV | | |
| Pressure IMPa1 | 20 | | Simulation Time [years] | 20 | Drilling Cost [\$M/we | ell] | 1 |
| Tempreture IC1 | 65 | | Injection Well Radius [m] | 0.1 | Operation Cost [\$K/ | well/year] | 500 |
| Thickness [m] | 100 | | Max Injection Pressure [MPa] | 30 | Monitoring Cost [\$K | /year/km^2] | 50 |
| Palinity (mol/Ka) | 2 | | Estimate Max Injection Pressure In | ternally | Tax Credit [\$/ton] | | 10 |
| Dennik (Moling) | 0.2 | | Density of Porous Media [Kg/m3] | | Extractors Drilling C | ost [\$M/weII] | 1 |
| Porosity | 100 | | Total Stress Ratio (V/H) | | Extractors Operation [\$K/well/year] | n Cost | 500 |
| Permeability (mb) | 5e-10 | | Biot Coefficient | | 5-EXTRACTION PA | RAMETERS | |
| Posseniais Area Ikm/21 | 100 | | Poisson's ratio | | Number of Extractor | rs O | • |
| Rasin Area [km^2] | 100 | | Coefficient of Thermal Expansion [1/K] | | Minimum Extraction Pressure [MPa] | n | 29 |
| Boundary Condition | Clas | | Bottom Hole Temperature Drop (K) | | Maximum Extractio [m^3/day/well] | n Rate | 1000 |
| boundary condition | CI0S 🔻 | | Young's Modulus (GPa) | | F | Run | |
| 2-RELATIVE PERMEABILITY (| Brooks-Co | orey) | i oange moonine (or al | | Simulation T | ïme [sec]= * | *** |
| Residual Water Saturation | 0.5 | | Depth [m] | | 6-RESULT CONTRO | OLS | |
| Residual Gas Saturation | 0.1 | | Estimated Max Injection Pressure [MPa] | | Number of Injectio | n Wells | • |
| m | 3 | | Max Injection Rate [ton/day/well] | 500 | Export Image a | and Output Fil | es (Slow) |
| n | 3 | | Max Number of Injectors 4 | 00 👻 | | website. | |
| Kra0 | 1 | | Uniform Injection/Extraction Rate | | | iTo | പ |
| Krg0 | 0.3 | | Sensitivity Analysis (Slow) | | | gical Capacity | Estimation |
| | | | | | | | |





Brine Extraction

• Brine extraction improves injectivity (capacity) and reduce the risk of exceeding the fracture pressure.







• Finding the optimized rate to maximize storage capacity







Closed Boundary, 4 Extractors

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| Main Interface | | | | | ۲. |
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| GUU EDAST CARDON CINID | | | GEOLOGY SCHOOL OF GEORGESCES | | |
| -1-RESERVOIR PARAMETERS | | 3-SIMULATION PARAMETERS | 4-NPV | | |
| | Min Ma | Simulation Time (years) 20 | Drilling Cost [\$M/well] | S S | ~ |
| Pressure [MPa] | 20 15 25 | | | Ž 30 / Z -500 | a |
| Tempreture [C] | 65 50 80 | Injection Well Radius [m] 0.1 | Operation Cost [\$K/well/year] 500 | | ` \$ |
| | 100 50 150 | Max Injection Pressure [MPa] 30 | Monitoring Cost [\$K/year/km^2] 50 | 0 50 100 0 50 | 100 |
| Thickness [m] | | | Tax Credit [\$/ton] 10 | Number of Injection Wells Number of Injection | tion Wells |
| Salinity [mol/Kg] | 2 1 3 | Estimate Max Injection Pressure Internally | | CO2 Plume Extension Well Rate (to | on/day) |
| Porosity | 0.2 0.15 0.25 | Density of Porous Media [Kg/m3] | Extractors Drilling Cost [\$M/well] | 10 | |
| | | Total Stress Ratio (V/H) | Extractors Operation Cost 500 [\$K/well/year] | 8 • • • 8 • • | • |
| Permeability [mD] | 100 10 250 | | | | • |
| Rock Compressibility [1/Pa] | 5e-10 3.5e-10 6.5e-10 | Biot Coefficient | 5-EXTRACTION PARAMETERS | | • |
| Reservoir Area [km^2] | 100 | Poisson's ratio | Number of Extractors 4 | | |
| | _ | Configuration of Theorem I Supervised 14/42 | Pressure [MPa] | 2 2 | |
| Basin Area [km^2] | 100 | Coefficient of Therman Expansion [17K] | Maximum Extraction Rate 2000 [m^3/day/well] | | |
| Boundary Condition | Clos 💌 | Bottom Hole Temperature Drop [K] | | 0 5 10 0 5 | 10 |
| J | | Young's Modulus [GPa] | Run | X , km X , km | · · · · · · · · · · · · · · · · · · · |
| -2-RELATIVE PERMEABILITY (| Brooks-Corey) | | Simulation Time [sec]= 100. | Permeability | |
| Residual Water Saturation | 0.5 0.3 0.7 | Depth [m] | 6-RESULT CONTROLS | Porosity | - |
| Residual Gas Saturation | 0.05 0 0.1 | Estimated Max Injection Pressure [MPa] | Number of Injection Wells 9 | Rock Comp | |
| m | 3 2 4 | Max Injection Rate Iton/day/well1 2000 | Export Image and Output Files (Slow) | Krg0 - m - | - |
| | | | <u>Visit our website.</u> | Sgc - Sar - | - |
| | 3 2 4 | Max Number of Injectors 100 💌 | | - Kra0 - I | - |
| Kra0 | 1 1 1 | | | Salinity Pressure | 13 |
| Krg0 | 0.3 0.20 0.4 | Sensitivity Analysis (Slow) | CASITOOL | 20 30 40 50 60 70 | 80 |
| | | | CO2 Geological Capacity Estimation | Capacity | |





Closed Boundary, 8 Extractors

| C EASiToolGUI | | | | | _ _ X |
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| Main Interface | | | | | ע |
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| GUT CONTEMPOR CIVILIA | | | GEOLOGY SCHOOL OF GEORGESCES | 0 5 70 X:25 → 0 | ेष्ठ् |
| -1-RESERVOIR PARAMETERS | (| 3-SIMULATION PARAMETERS | 4-NPV | Y: 60.22 | ×. |
| | Min Ma | Simulation Time (years) | Drilling Cost [SM/well] | ₹ 60 | Q |
| Pressure [MPa] | 20 15 25 | | | | ÌQ I |
| Tempreture [C] | 65 50 80 | Injection Well Radius [m] 0.1 | Operation Cost [\$K/well/year] 500 | | `\` |
| | 400 50 450 | Max Injection Pressure [MPa] 30 | Monitoring Cost [\$K/year/km^2] 50 | 0 50 100 0 | 50 100 |
| Thickness [m] | 100 50 150 | | Tax Credit (S/top) 10 | Number of Injection Wells Numb | er of Injection Wells |
| Salinity [mol/Kg] | 2 1 3 | Estimate Max Injection Pressure Internally | | CO2 Plume Extension We | ll Rate (ton/dav) |
| | 0.2 0.15 0.25 | Density of Porous Media [Kg/m3] | Extractors Drilling Cost [\$M/well] | 10 | , , , , , , , , , , , , , , , , , , , |
| Porosity | | | Extractors Operation Cost 500 | 8 🔺 🔺 8 | · · · · |
| Permeability [mD] | 100 10 250 | Total Stress Ratio (V/H) | , | | • • • • |
| Rock Compressibility [1/Pa] 56 | 5e-10 3.5e-10 6.5e-10 | Biot Coefficient | 5-EXTRACTION PARAMETERS | | |
| | | Paissaa's ratio | Number of Extractors 8 | \succ 4 \land \land \succ 4 | • • |
| Reservoir Area [km^2] | 100 | | Minimum Extraction 29 Pressure (MPa) | | |
| Basin Area [km^2] | 100 | Coefficient of Thermal Expansion [1/K] | Maximum Extraction Rate 2000 | | |
| Boundary Condition | | Bottom Hole Temperature Drop [K] | [m^3/day/well] | | 5 10 |
| | Ja • | | Run | X, km | X, km |
| 2-RELATIVE PERMEABILITY (Bro | ooks-Corey) | Young's Modulus [GPa] | Simulation Time [sec]= 100 | | |
| Residual Water Saturation | 0.5 0.3 0.7 | Depth [m] | 6.RESULT CONTROLS | Permeability Thickness | |
| Peridual Gas Saturation | 0.05 | Estimated New Islanding Deserves (NDs) | Number of Injection Wells 25 | Porosity | - |
| Residual Gas Saturation | 0.05 0 0.1 | Estimated Max Injection Pressure [MPa] | Export Image and Output Files (Slow) | Rock Comp | - |
| m | 3 2 4 | Max Injection Rate [ton/day/well] 2000 | | m Sac | - |
| n | 3 2 4 | Max Number of Injectors 100 - | | Sar - Kra0 - | - |
| Kra0 | 1 1 1 | | | n Salinity | 4.4 |
| _ | | | GASILOOL | Pressure | 14 - |
| Krg0 | 0.3 0.20 0.4 | Sensitivity Analysis (Slow) | CO2 Geological Capacity Estimation | 40 60 80 100 | 120 140 |
| | | | | Capacity | |





Closed Boundary, 16 Extractors

| EASiToolGUI | | | | |
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| 1-RESERVOIR PARAMETERS | | 3-SIMULATION PARAMETERS | 4-NPV | |
| | Min Ma | Simulation Time (menu) | Drilling Cost (SM/well) | Ž ¹¹⁰ X: 25 |
| Pressure [MPa] | 20 15 25 | Simulation Time (years) 20 | Contraction of the second | |
| Tempreture [C] | 65 50 80 | Injection Well Radius [m] 0.1 | Operation Cost [\$K/well/year] 500 | |
| rempretare [0] | | Max Injection Processo (MRs) 30 | Monitoring Cost [\$K/year/km^2] 50 | |
| Thickness [m] | 100 50 150 | | | Number of Injection Wells Number of Injection Wells |
| Salinity [mol/Kg] | 2 1 3 | Estimate Max Injection Pressure Internally | Tax Credit [\$/ton] 10 | CO2 Plume Extension Well Pate (top/day) |
| | 0.2 0.45 0.25 | Density of Porous Media [Kg/m3] | Extractors Drilling Cost [\$M/well] 1 | |
| Porosity | 0.2 0.15 0.25 | | Extractors Operation Cost 500 | |
| Permeability [mD] | 100 10 250 | Total Stress Ratio (V/H) | [\$K/well/year] | |
| Pack Comprossibility [1/Pa] | 5e-10 3 5e-10 6 5e-10 | Biot Coefficient | 5-EXTRACTION PARAMETERS | |
| Rock compressionity [1/1 a] | | | Number of Extractors 16 💌 | \succ 4 \land |
| Reservoir Area [km^2] | 100 | Poisson's ratio | Minimum Extraction 29 | |
| Basin Area [km^2] | 100 | Coefficient of Thermal Expansion [1/K] | Pressure [MPa] | |
| | | Bottom Hole Temperature Drop (K) | [m^3/day/well] | |
| Boundary Condition | Clos 💌 | Bottom Hole Femperature Brop [K] | Run | X.km X.km |
| 2-RELATIVE PERMEABILITY | Brooks-Corev) | Young's Modulus [GPa] | | |
| Pasidual Water Saturation | 05 02 07 | Depth [m] | Simulation Time [sec]= 103. | Permeability |
| Residual Water Saturation | 0.3 0.3 0.7 | | 6-RESULT CONTROLS | |
| Residual Gas Saturation | 0.05 0 0.1 | Estimated Max Injection Pressure [MPa] | Number of Injection Wells 25 | |
| m | 3 2 4 | Max Injection Rate [ton/day/well] 2000 | Export image and Output Files (Slow) | m |
| n | 3 2 4 | | Visit our website. | Sgc Sar |
| | | Max Number of Injectors 100 | · | Krau |
| KraU | 1 1 1 | | | Salinity 15 |
| Krg0 | 0.3 0.20 0.4 | Sensitivity Analysis (Slow) | | 50 100 150 200 250 |
| | | | COL GEOIGECEI CAPACITY ESTIMATION | Capacity |





Closed Boundary, 16 Extractors

| EASiToolGUI | | | | |
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| GCCC | GULF COAST | CARBON CENTER | BUREAU OF ECONOMIC CEOLOGY | 8 130 600 600 |
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| 1-RESERVOIR PARAMETERS | Min Ma | 3-SIMULATION PARAMETERS | 4-NPV | |
| Pressure [MPa] | 20 15 25 | Simulation Time [years] 20 | Drilling Cost [\$M/well] 1 | |
| Tempreture [C] | 65 50 80 | Injection Well Radius [m] 0.1 | Operation Cost [\$K/well/year] 500 | |
| Thickness [m] | 100 50 150 | Max Injection Pressure [MPa] 30 | Monitoring Cost [\$K/year/km^2] 50 | 20 40 60 80 100 20 40 60 80 100 |
| Salinity [mol/Kg] | 2 1 3 | Estimate Max Injection Pressure Internally | Tax Credit [\$/ton] | CO2 Plume Extension Wells Well Rate (ton/day) |
| Porosity | 0.2 0.15 0.25 | Density of Porous Media [Kg/m3] | Extractors Drilling Cost [\$M/well] 1 | |
| Permeability [mD] | 100 10 250 | Total Stress Ratio (V/H) | Extractors Operation Cost [SK/well/year] 500 | |
| Rock Compressibility [1/Pa] | 5e-10 3.5e-10 6.5e-10 | Biot Coefficient | 5-EXTRACTION PARAMETERS | |
| Reservoir Area [km^2] | 100 | Poisson's ratio | Number of Extractors 16 Minimum Extraction 20 | |
| Basin Area [km^2] | 100 | Coefficient of Thermal Expansion [1/K] | Pressure [MPa] Maximum Extraction Rate 2000 | |
| Boundary Condition | Clos 🔻 | Bottom Hole Temperature Drop [K] | [m^3/day/well] | |
| | Brooks-Corev) | Young's Modulus [GPa] | Run | X , km X , km |
| Residual Water Saturation | 0.5 0.3 0.7 | Depth [m] | 6-RESULT CONTROLS | Permeability Thickness |
| Residual Gas Saturation | 0.05 0 0.1 | Estimated Max Injection Pressure [MPa] | Number of Injection Wells 25 | Porosity Krg0 - |
| m | 3 2 4 | Max Injection Rate [ton/day/well] 2000 | Export Image and Output Files (Slow) | Rock Comp. |
| n | 3 2 4 | Max Number of Injectors | Wist our Website. | Sar Kra0 |
| Kra0 | 1 1 1 | | | Salinity Pressure 16 |
| Krg0 | 0.3 0.20 0.4 | Sensitivity Analysis (Slow) | CO2 Geological Capacity Estimation | 50 100 150 200 250 |
| | | | | Capacity |





Sensitivity Analysis

| EASiToolGUI | | | | | | | | | | | | | x |
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| Main Interface | | | | | | | | | | | | | ۲ |
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| GUP LOAT CAREON CENT | | | | | | | accessors | | -0-0-0-0-0-0 | $\rightarrow - \ominus - \phi$ | | | |
| -1-RESERVOIR PARAMETERS | | | | 3-SIMULATION PARAMETERS | | 4-NPV | | su | φ φ | ¥¥ | | 2a a | |
| | | Min | Ma | | | | | ₩ 12.5 | | 2 - | 500 | ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ | |
| Pressure [MPa] | 20 | 15 | 25 | Simulation Time [years] | 20 | Drilling Cost (\$W/Weil) | | 12 | X: 1 | Ľ۳ ا | 000 | ~ ` | a |
| Tamanahan (C) | 65 | 50 | 80 | Injection Well Radius [m] | 0.1 | Operation Cost [\$K/well/year] | 500 | bad | Y: 11.56 | -1 | 000 | | P |
| rempreture [O] | | | | | 20 | Monitoring Cost [\$K/year/km^2] | 50 | Ö 11.5 | | -1 | 500 | 50 | |
| Thickness [m] | 100 | 50 | 150 | Max Injection Pressure [MPa] | 30 | | | , i | Number of Inject | ion Wells | Nur | mber of Injection | Wells |
| Salinity (mol/Kol | 2 | 1 | 3 | Estimate Max Injection Pressure In | ternally | Tax Credit [\$/ton] | 10 | | | | | | |
| | | | | Density of Porous Media (Ko/m3) | | Extractors Drilling Cost [\$M/well] | 1 1 | 10 | CO2 Plume Ext | ension | 10 ľ | vell Rate (ton/da | iy) |
| Porosity | 0.2 | 0.15 | 0.25 | benary of 1 orona media (righno) | | Extractors Operation Cost | 500 | | | 1.1 | | | |
| Permeability [mD] | 100 | 10 | 250 | Total Stress Ratio (V/H) | | [\$K/well/year] | 500 | 0 | | | ° [| | |
| | 5 . 40 | 25-4 | 0 5 0 40 | Biot Coefficient | | 5-EXTRACTION PARAMETERS | s ——— | ⁶ ع | | Ē | 6 | | |
| Rock Compressibility [1/Pa] | 56-10 | 5.5e-1 | 0.58-10 | | | Number of Extractors | 0 👻 | | | , | 4 | • | |
| Reservoir Area [km^2] | 100 | | | Poisson's ratio | | Minimum Extraction | 29 | | | | | | |
| Basin Area [km^2] | 100 | | | Coefficient of Thermal Expansion [1/K] | | Pressure [MPa] | | 2 | | 1.1 | 2 | | |
| | | | | | | [m^3/day/well] | 2000 | 0 | | | <u>م</u> | | |
| Boundary Condition | Clos | | | Bottom Hole Turngerature Drop [K] | | Bup | ך | C |) 5 | 10 | 0 | 5 | 10 |
| | (Dec. 21) - | | | Young's Modulus [GPa] | | Kull | | <u> </u> | | | <u> </u> | A , KIII | <u> </u> |
| Z-RELATIVE PERMEABILITY | (BIOOKS- | lorey | | Dooth [m] | | Simulation Time [sec]= | 99 | Thic | kness | | | | ▰ ┤ │ |
| Residual Water Saturation | 0.5 | 0.3 | 0.7 | Debru [m] | | 6-RESHLT CONTROLS | | Rock C | rosity - Comp | | | | - |
| Residual Gas Saturation | 0.05 | 0 | 0.1 | Estimated Max Injection Pressure [MPa] | | Number of Injection Wells 1 | • | | Krg0 - m - | | | | - |
| m | 3 | 2 | 4 | Max Injection Rate (ton/day/well] | 2000 | Export Image and Output | iles (Slow) | | Sgc - Sar - | | | | 1 |
| | | | | | | <u>Visit our website.</u> | | | Kra0 - | | | | |
| | 3 | 2 | 4 | Max Number of Injectors 1 | 00 🔻 | | | S: Perme | alinity - ability - | | | | - |
| Kra0 | 1 | 1 | 1 | | | | 2 | Temper | aturé - | | | 1 | 7 |
| Krg0 | 0.3 | 0.20 | 0.4 | Sensitivity Analysis (Slow) | | -ASI IC | JUI | . 10 | 8 | 10 12 | 14 | 16 18 | 20 |
| | | | | | | CO2 Geological Capacit | y Estimation | | 0 | Ca | pacity | | 20 |





Reservoir Area = 219 km^2



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Synergy Opportunities

- EASiTool is an analytical simulation tool for capacity estimation in saline aquifers.
- Input data required for EASiTool is typically available for most of the projects.
- EASiTool results can be compared with the results obtain in other projects via other methods (static, simulation, etc).





Future Plans

- User defined locations for injection and extraction wells
 - Adding multiple reservoirs within the same basin
 - Pressure maps
- Improving the user interface
- Improving sensitivity analysis
- Application of to USGS database (36 Basins)
- Funding to maintain and further develop EASiTool





Summary

- Third version of EASiTool has been released.
- Calculations for maximum injection pressure.
 Integrates thermal and pore pressure stresses.
- Brine extraction option.
- Constant rate injection option.
- Sensitivity analysis.
- EASiTool is available for download:
 - <u>http://www.beg.utexas.edu/gccc/EASiTool/</u>







»Questions/Comments





Appendix

- Organization Chart
- Gantt Chart
- Bibliography
- Extra Slides





Organization Chart







Organization Chart

| Project PI: Seyyed A. Hosseini | | | | | | | | |
|--|---|---|---|--|--|--|--|--|
| Task 1 Project Management and Planning | Task 2 Development of Analytical Solutions for Pressure Buildup | Task 3 Rock Geomechanics Impact on Pressure Buildup and Capacity Estimation | Task 4Brine-ManagementImpact on CO2Injectivity and StorageCapacity | | | | | |
| Task Leader/Backup Nicot/Hosseini | Task Leader/Backup Hosseini/Sun | Task Leader/Backup Hosseini/Sun | Task Leader/Backup Hosseini/Sun | | | | | |
| Task 1 Team Nicot/Hosseini/ Young/Hovorka | Task 2 Team Subtask 2.1 Hosseini/Sun/ Postdoc/s Subtask 2.2 Hosseini/Sun/C12 Energy Subtask 2.3 Sun/Hosseini Subtask 2.4 Sun/Hosseini | Task 3 Team Subtask 3.1 Hosseini/Sun/ Postdoc/s Subtask 3.2 Hosseini/Sun/ Postdoc/s Subtask 3.3 Sun/Hosseini Subtask 3.4 Hosseini/Sun Subtask 3.5 Sun/Hosseini Subtask 3.6 Sun/Hosseini | Task 4 Team Subtask 4.1 Hosseini/Sun/ Postdoc/s Subtask 4.2 Sun/Hosseini/ Postdoc/s Subtask 4.3 Sun/Hosseini Subtask 4.4 Sun/Hosseini | | | | | |





Gantt Chart







Bibliography

Journals

- Kim, S., Hosseini, S.A, 2013, Above-zone pressure monitoring and geomechanical analyses for a field-scale CO₂ injection project in Cranfield, MS, Greenhouse Gases: Science and Technology, 4 (1), 81-98, DOI: 10.1002/ghg.1388
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 - Kim, Seunghee, Hosseini, S. A., 2014, Optimization of Injection Rates for Geological CO₂ Storage in Brine Formations, 13th Annual Conference on Carbon Capture Utilization & Storage.
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Analytical model



Radial distance from injection well





- Pore pressure stress coupling
 - Change in total stress ($\Delta \sigma$)is coupled with change in pore pressure(ΔP).
 - We define $\beta_h = \Delta \sigma_h / \Delta P$ and $\beta_v = \Delta \sigma_v / \Delta P$ & typically $\beta_h > \beta_v$
- Thermal stress
 - Injected CO_2 is generally colder than formation brine.
 - shrinkage of the rock formation (specially near the injection well) by $\sigma^{\Delta T} = 2\alpha_T E \Delta T / (1-2\vartheta)$
- Mohr-Coulomb shear failure criterion

$$\tau = c + (\sigma_n - \alpha \cdot P_{max})\mu$$

Kim, S, and Hosseini, S. A., 2014, Geological CO₂ storage: incorporation of pore-pressure/stress coupling and thermal effects to determine maximum sustainable pressure limit: Energy Procedia, v. 63, p. 3339-3346, http://doi.org/10.1016/j.egypro.2014.11.362.









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Verification of EASiTool Models



Permeability X-EASiTool2