Development of Defensible CO\textsubscript{2} Storage Methods and Tools to Quantify Prospective Storage in the Subsurface

Carbon Storage DE-FE1022403

Angela Goodman and Kelly Rose
National Energy Technology Laboratory

U.S. Department of Energy
National Energy Technology Laboratory
Addressing the Nation’s Energy Needs Through Technology Innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting
August 26-30, 2019
Resource Assessments: Provides the Department of Energy (DOE) defensible carbon dioxide (CO₂) storage methods and tools to quantify prospective storage for the Carbon Storage Atlas, National Energy Technology Laboratory’s (NETL’s) Regional Carbon Sequestration Partnership (RCSP), and CARBONSAFE projects.

**Task 2:** Develop Defensible DOE Methods, Tools, and Storage Efficiency for CO₂ Storage in Shale Systems – presented by Angela Goodman

**Task 3:** Develop Defensible DOE Methods, Tools, and Storage Efficiency for CO₂ Storage in ROZs – presented by Angela Goodman

**Task 4:** Developing Defensible DOE Methods, Tools, and Storage Efficiency for CO₂ Storage in Offshore Reservoirs – presented by Kelly Rose
Prospective CO₂ Storage in the Subsurface

Prospective CO₂ Storage Resource for U.S. and parts of Canada

<table>
<thead>
<tr>
<th>Regional Carbon Storage Partnerships</th>
<th>Billion Metric Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Oil and Natural Gas Reservoirs</td>
<td>186</td>
</tr>
<tr>
<td>Unmineable Coal</td>
<td>54</td>
</tr>
<tr>
<td>Saline Onshore</td>
<td>2,379</td>
</tr>
<tr>
<td>Shale Formations</td>
<td></td>
</tr>
<tr>
<td>Saline Offshore</td>
<td></td>
</tr>
<tr>
<td>Residual Oil Zones</td>
<td></td>
</tr>
</tbody>
</table>

- Conventional coal-fired power plants release CO₂ directly into the atmosphere. Plants equipped with CCS will capture much of the CO₂ instead.
- Liquid CO₂ can be transported by pipeline or truck.
- CO₂ can be injected and stored deep underground.
Task 2: Develop Defensible DOE Methods, Tools, and Storage Efficiency for CO₂ Storage in Shale Systems

Task Technical Approach and Project Relevancy

- **Objective:**
  - Deliver a quantitative method and CO2-SCREENv2.0 Tool that estimates carbon dioxide (CO₂) storage resource in shale formations.

- **Benefit:**
  - Results to inform high-level decision making related to carbon storage initiatives at the national and regional scale.

- **Challenges:**
  - Lack of detailed geologic and petrophysical data
  - Need to understand the void space within fractures and pores for CO₂ storage and how kerogen and minerals are affected by CO₂ contact.

- **Approach:**
  - Develop method and tool that are accepted by the peer review community for public dissemination.

**Team:** Angela Goodman, Sean Sanguinito, Eugene Myshakin, Bob Dilmore, Grant Bromhal, Harpreet Singh, Scott Frailey, Alex Azenkeng, Beth Kurz, Wes Peck, Charlie Gorecki
Task 2: Project Timeline Overview
Develop Defensible DOE Methods, Tools, and Storage Efficiency for CO₂ Storage in Shale Systems

Key Accomplishments

- Developed U.S. DOE NETL Methodology for Estimating the Prospective CO₂ Storage Resource of Shales at the National and Regional Scale (2016)
- Developed storage efficiency factors for shale storage (2018)
- Deployed beta CO2-SCREENv2.0 Tool for shale for community validation on EDX (2018)
- Modeled flow regimes and storage efficiency of CO₂ injected into depleted shale reservoirs (2019)
- Incorporating image-based techniques to estimate the CO₂ storage resource in shale organic and inorganic components stemming from the efforts at EERC into the SCREEN Tool (2019)
- Developed final CO2-SCREENv2.0 Tool for shale for public access on EDX (2019)
Shale Methodology Equation

\[ G_{CO_2} = A_t E_A h_g E_h [\rho_{CO_2} \phi E_\phi + \rho_{SCO_2} (1 - \phi) E_S] \]

- **Net effective formation volume**
- **Efficiency of storage as free gas**
- **Efficiency of storage in sorbed phase**

CO\textsubscript{2}-SCREEN

Log-odds stochastic approach

- \( E_A \)
- \( E_h \)
- \( E_\phi \)
- \( E_S \)

\[
\frac{1}{(1 + e^{-E_A})} \times \frac{1}{(1 + e^{-E_h})} \times \frac{1}{(1 + e^{-E_\phi})} \times \frac{1}{(1 + e^{-E_S})}
\]

10% of values

- \( P_{10} \)
- \( P_{90} \)

\( E_\phi \): P\textsubscript{10} to P\textsubscript{90} range of 0.15 to 0.36
\( E_S \): P\textsubscript{10} to P\textsubscript{90} range of 0.11 to 0.24
Refinements of Storage Efficiency Factors

Flow Regimes and Storage Efficiency of CO₂ Injected into Depleted Shale Reservoirs

Image-Based Approach for Estimating Prospective CO₂ Storage

Regime I Regime II Regime III

10 years 60 years 60 years
Task 3: Develop Defensible DOE Methods, Tools, and Storage Efficiency for CO$_2$ Storage in ROZs

Task Technical Approach and Project Relevancy

- **Objective:**
  - Deliver a quantitative method and CO$_2$-SCREENv3.0 Tool that estimates carbon dioxide (CO$_2$) storage resource in residual oil zone (ROZ) formations.

- **Benefit:**
  - Estimate the CO$_2$ storage potential in ROZs. Results to inform high-level decision making related to carbon storage initiatives at the national and regional scale.

- **Challenges:**
  - Limits on the library of data which characterizes ROZ systems.
  - Industry has not fully recognized ROZ oil resources worthy of exploitation.
  - False indicators of mobile oil in cores may give the impression of a ROZ.
  - CO$_2$ floods for ROZ fairways may take a considerable amount of time to produce a sustainable rate of oil production.

- **Approach:**
  - Develop method and tool that are accepted by the peer review community for public dissemination.

**Team:** Angela Goodman, Sean Sanguinito, Eugene Myshakin, Bob Dilmore, Harpreet Singh, Tim Grant, Dave Morgan, Grant Bromhal, Peter Warwick, Sean T. Brennan, Charles Gorecki, Wesley Peck, Matthew, Scott Frailey, Rajesh Pawar
Task 3: Project Timeline Overview

- Develop Defensible DOE Methods, Tools, and Storage Efficiency for CO₂ Storage in ROZs

<table>
<thead>
<tr>
<th>Year</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Accomplishments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Developed **Methodology and Efficiency Factors** for Estimating the Prospective CO₂ Storage Resource of ROZs at the National and Regional Scale (2019)

- Deployed **beta CO2-SCREENv3.0 Tool** for ROZ for community validation on EDX (2019)

- Develop **final CO2-SCREENv3.0 Tool** for shale for public access on EDX (2020)

- Deploy **CO2-SCREENv1, 2, and 3.0 Tool** without license restrictions (2020)
ROZ Methodology Equation

\[ G_{CO_2} = A_t E_A h_g E_h \phi_{tot} E_\phi \left[ (1 - S_{wirr} - S_{or}) \rho_{CO_2} E_v + S_{or} R_{c/o} E_{Ds} \right] \]

Net effective formation volume

\[ G_{CO_2} = A_t E_A h_g E_h \phi_{tot} E_\phi \left[ (1 - S_{wirr} - S_{or}) \rho_{CO_2} E_v + S_{or} R_{c/o} E_{Ds} \right] \]

<table>
<thead>
<tr>
<th>Total CO₂ Storage (Equation 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>Total CO₂ (P₅₀)</td>
</tr>
</tbody>
</table>

Log-odds stochastic approach

CO₂ dissolution in oil

\[ S_{wirr} \]
\[ S_{or} \text{ (Low)} \]
\[ S_{or} \text{ (High)} \]
\[ R_{c/o} \text{(Low)} \]
\[ R_{c/o} \text{(High)} \]

680 kg/m³
740 kg/m³

Log-odds stochastic approach

Efficiency Factors

<table>
<thead>
<tr>
<th>Parameter</th>
<th>(P_{10})</th>
<th>(P_{90})</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>(E_A)</td>
<td>0.20</td>
<td>0.80</td>
<td>IEA-GHG, 2009</td>
</tr>
<tr>
<td>(E_h)</td>
<td>0.21</td>
<td>0.76</td>
<td>IEA-GHG, 2009</td>
</tr>
<tr>
<td>(E_\phi)</td>
<td>0.64</td>
<td>0.77</td>
<td>IEA-GHG, 2009</td>
</tr>
<tr>
<td>(E_v)</td>
<td>0.16</td>
<td>0.39</td>
<td>IEA-GHG, 2009</td>
</tr>
<tr>
<td>(E_D)</td>
<td>0.35</td>
<td>0.76</td>
<td>IEA-GHG, 2009</td>
</tr>
<tr>
<td>(E_{Ds})</td>
<td>0.009</td>
<td>0.011</td>
<td>MRST</td>
</tr>
</tbody>
</table>

\[ E_D = 1 - S_{wirr} - S_{or} \]
CO₂-SCREEN (Version 1.0, 2.0, 3.0, 4.0)
Storage prospective Resource Estimation Excel aNalysis

- Version 1.0 = Saline Formations
- Version 2.0 = Shale Formations
- Version 3.0 = Residual Oil Zones
- Version 4.0 = Converted to Python

CO₂-SCREEN tool: Application to the Ordovician sandstone to estimate prospective CO₂ storage resource

https://edx.netl.doe.gov/dataset/co2-screen-version-2-0

464 downloads since April 2017
Tasks 2 & 3 Synergy Opportunities

• Developed quantitative statistical methods to estimate the prospective CO₂ storage resource of subsurface geologic formations across the United States [> 2,400 billion metric tons of storage = 400 yrs. of storage space]
  – Significantly advances accuracy and science behind storage estimates
  – First of its kind storage methods meets DOE program goals by directly impacting global energy policy for CCS
  – Provides guidance for other strategic planning by nations worldwide (United States, Canada, Mexico, China, Sweden, Norway, Israel, and South Africa)
  – Publicly accessible via peer-reviewed journals, Carbon Storage Atlas, CO₂-SCREEN (EDX and GoldSim)
  – This estimation tool (CO₂-SCREEN), has been downloaded by external peers over 400 times since it became available on EDX as a public tool in 2017
  – Highly collaborative effort: USGS, EERC, ISGS, CMU, NIST, LANL

• Policy makers and potential investors need reliable estimates of storage estimates for indication of long term sustainability for use in public policy and business investment decisions
  – Reduce CO₂ emissions / Store CO₂ securely
  – Unknown effect causing CO₂ to escape
  – Public health
  – Successfully deploy CCUS technology

• Valuable resources and time could be wasted if sorption estimates are made based on unreliable data
  – MVA, drilling patterns, CO₂ pipelines, etc
Values Delivered

• Improved the **accuracy** of offshore saline resource estimations at multiple spatial scales

• **Offshore tailored efficiency terms** from DOE carbon storage method

• Methodology & tool to execute **data-driven technical assessment** of offshore storage resources

• Extended and integrated **offshore oil/gas spatial, analytical tools** for offshore CS stakeholder needs

• This methodology **complements NETL’s CO₂ Storage prospective Resource Estimation Excel aNalysis (CO₂ Screen) Tool**

\[ G_{CO₂} = A_t h g \phi_t \rho E_{saline} \]

**Team:** Kelly Rose, Lucy Romeo, Jennifer Bauer, Kate Jones, R. Burt Thomas, & Patrick Wingo
Task 4 Accomplishments

Technical report describing tailoring DOE methodology to the offshore


Interpreted >650 petrophysical well logs for storage resource parameters

- Spans 21 geologic domains, as defined by Subsurface Trend Analysis™ (Mark-Moser et al., 2018; Rose et al., in press)
- Available via Energy Data eXchange (EDX)

Documented integration of NETL’s Offshore Risk Modeling (ORM) suite tools work with CS Offshore Methodology


Rose, K., et al, in press, A Systematic Science-Driven Approach for Predicting Subsurface Properties, Interpretation

https://edx.netl.doe.gov/carbonstorage
Task 4 Accomplishments (cont.)

- **Offshore CO₂ Storage Calculator tool** developed with tailored geologic efficiency terms from DOE storage methodology
  - Data-driven, with spatial data application for area and density
  - Calculates distributions of estimated efficiency and storage resource potential for sand packages
- Initial tool testing uses NETL’s Petrophysical Well Log Interpretation Dataset
- **Manuscript in prep. on methodology** and tool to be submitted to International Journal of Greenhouse Gas Control

### Formula

\[
E_{\text{saline}} = E_A \times E_H \times E_{\Phi} \times E_V \times E_d
\]

\[
G_{\text{CO}_2} = A_T \times H_T \times \Phi_T \times \rho \times E_{\text{saline}}
\]

- \( E_A \): Ratio of net to total area suitable for storage resource
- \( E_H \): Ratio of net to total thickness of formations suitable for storage
- \( E_{\Phi} \): Ratio of effective porosity to total porosity
- \( E_V \) & \( E_d \): Volumetric and microscopic displacement factors
- \( E_{\text{saline}} \): Storage efficiency
- \( A_T \): Total area suitable for storage
- \( H_T \): Gross thickness of suitable formations
- \( \Phi_T \): Total porosity
- \( \rho \): Density of \( \text{CO}_2 \) at pressure and temperature
- \( G_{\text{CO}_2} \): Amount of storable \( \text{CO}_2 \)

[Tool builds distributions for saline efficiency & amount of storage resource by calculating all possible variable combinations](https://edx.netl.doe.gov/carbonstorage)
Offshore \(\text{CO}_2\) Storage Calculator

- Python (version 3.7)
- **Data Table** contains fields for Net and Total Height, and Total Porosity. Other variables (Volumetric and microscopic displacement, net and total area, density) might also be included.
- **Volumetric and Microscopic Displacement** can be based on the lithology & depositional setting (Gorecki et al., 2009).
- **Effective \(\phi\)** based on Gorecki et al. 2009

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Volumetric and Microscopic Displacement can be based on the lithology & depositional setting (Gorecki et al., 2009):

\[
\text{Net and Total Area values can be calculated using spatial data, where net area is the spatial difference between the extent (total area) and buffered leakage pathways.}
\]

---

Effective \(\phi\) based on Gorecki et al. 2009:
Calculating CO₂ Density

Alterations made for the offshore environment, where density (ρ) is derived as a function of subsea pressure and temperature at a given depth (Cameron et al., 2018).

**Density and phase values** are calculated and checked using the Thermophysical Properties of Fluid Systems Model from the National Institute of Standard’s and Technology (Lemmon et al., 2019).

**CO₂ density** values can be calculated using depth & temperature (assumes hydrostatic pressure).

Water depth is used to define the PT regime. Depth can be extracted from a bathymetry dataset, if available.

Tool Outputs

Outputs:

- **Output Data Table** containing all variable combinations, where each field represents a variable
- **Statistical Report** with P10, P50, and P90 values for saline efficiency and resource storage potential

Optional outputs:

- **Distribution graphs** for any of the variables used to calculate saline efficiency and resource storage potential
- Net area and buffered leakage pathway **shapefiles**

\[ E_{\text{saline}} = E_A \times E_H \times E_\Phi \times E_v \times E_d \]
\[ G_{CO_2} = A_T \times H_T \times \Phi_T \times \rho \times E_{\text{saline}} \]
Fall 2019 Milestones & Deliverables

- In parallel with testing the tool, evaluate robustness of offshore efficiency factors for saline reservoir assessment for offshore regions in additional offshore regions.

- Submit manuscript on methodology and tool to International Journal of Greenhouse Gas Control (Romeo et al., in preparation).

<table>
<thead>
<tr>
<th>Number</th>
<th>Expected Completion Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>06/29/2018</td>
<td>M.4.1 – Submit the final TRS report describing the Offshore Carbon Storage Methodology for Saline Reservoirs to the Carbon Storage Portfolio page on EDX for release.</td>
</tr>
<tr>
<td>2</td>
<td>08/31/2018</td>
<td>Develop carbon storage prediction surfaces based on well log attributes for multiple domains in the GOM.</td>
</tr>
<tr>
<td>3</td>
<td>11/30/2018</td>
<td>Begin peer-reviewed journal manuscript of the NETL offshore carbon storage methodology.</td>
</tr>
<tr>
<td>4</td>
<td>03/29/2019</td>
<td>Document how integration of NETL’s Cumulative Spatial Impact Layer tool can work with CS Offshore Methodology and Screen Tool to improve CS assessment outcomes.</td>
</tr>
<tr>
<td>5</td>
<td>09/30/2019</td>
<td>Evaluate robustness of offshore efficiency factors for saline reservoir assessment of offshore reservoirs in non-GOM, offshore regions.</td>
</tr>
<tr>
<td>6</td>
<td>3/31/2020</td>
<td>Release updated versions of advanced spatial data computing tool, offshore CS efficiency factors, via EDX.</td>
</tr>
</tbody>
</table>

Alpha version ready for testing!

Interested in early access?
Contact Lucy Romeo at Lucy.Romeo@netl.doe.gov


2020 Deliverables

- Complete tool testing & validation
- Release versions Offshore CO₂ Storage Calculator via EDX
Task 4 Synergy Opportunities

- Provides the DOE with justifiable carbon storage estimates for use in public **policy and business investment decisions**
- Builds off of carbon storage assessment knowledge & capabilities from domestic & international efforts e.g.
  - United States Geological Survey (USGS)
  - Energy & Environmental Research Center (EERC)
  - NETL
  - Norway, Australia, Japan, Brazil, others
- Leverages big-data, spatio-temporal analytical models and tools from DOE FE’s Oil/Gas Program’s Offshore Risk Modeling program
  - [https://edx.netl.doe.gov/offshore](https://edx.netl.doe.gov/offshore)
- Provides offshore storage methodology & data-driven tool for **strategic planning by entities and nations worldwide**
  - United States, NETL CarbonSafe projects, etc

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**Mitigate injection risk by leveraging data-driven analyses to constrain favorable vs. unfavorable storage areas**

- **Potential leakage pathways**
- **Leakage Pathway Density**

Development of Defensible CO₂ Storage Methods & Tools to Quantify Prospective Storage in the Subsurface

Tasks 2 & 3 PI
Angela Goodman
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Task 4 co-PI’s
Kelly Rose & Lucy Romeo
Kelly.rose@netl.doe.gov
Lucy.Romeo@netl.doe.gov

For the publications, tools & datasets from these studies please visit:
https://edx.netl.doe.gov/carbonstorage

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Acknowledgement: Parts of this technical effort were performed in support of the National Energy Technology Laboratory’s ongoing research under the Carbon Storage Field Work Proposal DE-FE-1022403 by NETL’s Research and Innovation Center, including work performed by Leidos Research Support Team staff under the RSS contract 89243118CFE000003.
Appendix

- These slides will not be discussed during the presentation, **but are mandatory.**
Lessons Learned

- Research gaps/challenges.
- Unanticipated research difficulties.
- Technical disappointments.
- Changes that should be made next time.
- Multiple slides can be used if needed.

See project slides above
Project Summary

– Key Findings.
– Next Steps.

See project slides above
Benefit to the Program

- **Specific Goals & Benefits**
  - 1. Develop and validate technologies to ensure for 99 percent storage permanence.
  - 2. Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness.
  - 3. Support industry’s ability to predict CO2 storage capacity in geologic formations to within ±30 percent.
  - 4. Develop Best Practice Manuals (BPMs) for monitoring, verification, accounting (MVA), and assessment; site screening, selection, and initial characterization; public outreach; well management activities; and risk analysis and simulation.
Project Overview

Goals and Objectives

• **Resource Assessments:** Provides the Department of Energy (DOE) defensible carbon dioxide (CO2) storage methods and tools to quantify prospective storage for the Carbon Storage Atlas, National Energy Technology Laboratory’s (NETL’s) Regional Carbon Sequestration Partnership (RCSP), and CARBONSAFE projects.
• *Resource Assessments* theme will provide DOE defensible CO2 storage methods and tools to quantify prospective storage for the Carbon Storage Atlas, the NETL’s Regional Carbon Sequestration Partnership (RCSP), and CARBONSAFE projects.

Task 2. Develop Defensible DOE Methods, Tools, and Storage Efficiency for CO2 Storage in Shale Systems
Task 3. Develop Defensible DOE Methods, Tools, and Storage Efficiency for CO2 Storage in ROZs
Task 4. Developing Defensible DOE Methods, Tools, and Storage Efficiency for CO2 Storage in Offshore Reservoirs
Gantt Chart

- Provide a simple Gantt chart showing project lifetime in years on the horizontal axis and major tasks along the vertical axis. Use symbols to indicate major and minor milestones. Use shaded lines or the like to indicate duration of each task and the amount of work completed to date.
Task 2: Project Timeline Overview

Develop Defensible DOE Methods, Tools, and Storage Efficiency for CO₂ Storage in Shale Systems
(PI: Angela Goodman)

<table>
<thead>
<tr>
<th>Year</th>
<th>Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>($125k)</td>
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<tr>
<td>2016</td>
<td>($125k)</td>
</tr>
<tr>
<td>2018</td>
<td>($191k)</td>
</tr>
<tr>
<td>2019</td>
<td>($129k)</td>
</tr>
<tr>
<td>2021</td>
<td></td>
</tr>
</tbody>
</table>

Milestones

B. Acceptance of storage efficiency factors by the peer review community.
C. Deploy beta CO2-SCREEN Tool for shale for community validation on EDX.
D. Incorporation of improved techniques to estimate the CO₂ storage resource potential of unconventional formations stemming from the efforts at EERC into the SCREEN Tool.
E. Publish effect of flow regimes on storage efficiency during injection of CO₂ in depleted shale reservoirs.
F. Develop final CO2-SCREEN Tool for shale for public access on EDX.

Impact

Key Accomplishments/Deliverables

2016: Methodology for Assessment of Shale Systems.

Value Delivered

- Quantitative method and CO2-SCREENv2.0 Tool to estimate how much CO₂ can be stored in depleted shale formations.

Go / No-Go

2. To move past this milestone, method and storage efficiency factors must be fully developed and accepted in a peer review journal.
## Task 3: Project Timeline Overview

**Develop Defensible DOE Methods, Tools, and Storage Efficiency for CO2 Storage in ROZs**  
(PI: Angela Goodman)

<table>
<thead>
<tr>
<th>Year</th>
<th>Budget</th>
<th>Milestone Dates</th>
<th>Go / No-Go</th>
</tr>
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<tbody>
<tr>
<td>2017</td>
<td>$40K</td>
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</tr>
<tr>
<td>2018</td>
<td>$191k</td>
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<tr>
<td>2019</td>
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<td>2020</td>
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<td>3/2020</td>
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### Milestones

A. Develop working draft of ROZ method that has been reviewed by external stakeholders.
B. ROZ method accepted by the peer review community and ready for the next Carbon Storage Atlas.
C. Deploy beta CO2-SCREENv3.0 Tool for ROZs for community validation on EDX.
D. Develop final CO2-SCREEN Tool for ROZs for public access on EDX.
E. Deploy CO2-SCREEN v1.0, v2.0, and v3.0 Tools into a format that does not depend on license restrictions.

### Impact

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<thead>
<tr>
<th>Key Accomplishments/Deliverables</th>
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<tbody>
<tr>
<td>2017:</td>
<td></td>
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<tr>
<td>Conducted an extensive literature review.</td>
<td>Quantitative method and CO2-SCREENv3.0 Tool to estimate how much CO2 can be stored in ROZs.</td>
</tr>
<tr>
<td>Assembled a group of collaborators and experts with USGS, LANL, ISGS, EERC to provide key input for developing method.</td>
<td>Method and tool ready for inclusion in the next DOE’s Carbon Storage Atlas in 2020.</td>
</tr>
</tbody>
</table>
**Task 4: Project Timeline Overview**

Developing Defensible DOE Methods, Tools, and Storage Efficiency for CO₂ Storage in Offshore Reservoirs (PI: Kelly Rose)

![Timeline Diagram](image)

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</tr>
<tr>
<td>7</td>
<td>10/31/2019</td>
<td>Evaluate potential of adapting saline offshore methodology for use with Offshore CO2 EOR storage approach.</td>
</tr>
<tr>
<td>8</td>
<td>03/31/2020</td>
<td>If appropriate release advanced data computing tool for offshore CS efficiency factors, spatial analysis &amp; SCREEN via EDX app store.</td>
</tr>
</tbody>
</table>

**Past milestones 4 & 6, scope proposed is dependent on Program input and alignment to needs.**

- *2017 funds spanned 18 months of work, 10/01/2016 through 03/31/2018*
- **Pending outcome of go/no-go milestone 7**

**Key Accomplishments/Deliverables**

- 2018, TRS report describing CS methodology for saline reservoirs & database of offshore efficiency factors for geol terms
  - 2018, a beta Python scripted tool was developed to automate the methodology for calculating offshore storage resource efficiency and potential
  - 2019, Journal manuscript submitted for peer review describing Offshore CS in saline reservoir methodology
  - 2020, Release versions 1 of advanced spatial data computing tool offshore CS efficiency factors outside GOM, via EDX

**Value Delivered**

- Improving accuracy of offshore saline resource estimations
- Tailored geologic efficiency terms from DOE carbon storage method that improve characterization of offshore carbon storage reservoirs
- Adaptation of data computing tools and algorithms to support efficient and data-driven technical assessment of offshore carbon storage resources through integration of NETL’s spatial, analytical tools (first developed under FE32 projects)
- Integration of carbon storage tools, data and models for resource assessment via EDX to improve external stakeholder access and utility
Bibliography


• Goodman, Angela; Fukai, isis; Dilmore, Robert; Frailey, Scott; Bromhal, Grant; Soeder, Dan; Gorecki, Charlie; Peck, Wesley; Rodosta, Traci; Guthrie, George “Methodology for assessing CO2 storage potential of organic-rich shale formations” Energy Procedia 2014, 63, 5178-5184.


• Myshakin, E., Singh, H., Sanguinito, S., Bromhal, G., Goodman, A. Flow Regimes and Storage Efficiency of CO2 Injected into Depleted Shale Reservoir Fuel, 2019, 246, 169-177


• Sanguinito, S., Singh, H., Myshakin, E., Goodman A., Dilmore, R., Grant, T., Morgan, D., Bromhal, G. “U.S. DOE NETL methodology for estimating the prospective CO2 storage resource of residual oil zones at the national scale” under review Int. J. Greenhouse Gas Control

