Resource Assessment Methods for CO_2 Storage in Geologic Formations

Project Number 1022403

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Office of Research and Development / National Energy Technology Laboratory

U.S. Department of Energy

National Energy Technology Laboratory
Carbon Storage R&D Project Review Meeting
Developing the Technologies and
Infrastructure for CCS

August 12-14, 2014

Presentation Outline

- **Resource Assessments**
  - ***CO_2 Storage Method Development for Unconventional Systems, Oil and Gas Systems, and Saline Systems***
  - ***Experimental Measurement of Microscopic Displacement Efficiency in Geologic Systems***

- **Geospatial Data Management**
  - ***Atlas Development and NATCARB***
  - ***Geodatabase Development in Support of Geologic Storage Research (EDX)***

Benefit to the Program

- **Carbon Storage Program Major Goals**
  - Support industry's ability to predict CO_2 storage capacity in geologic formations to within ±30 percent.
- **Project Benefits Statement:**
  - This research project aims at developing and maintaining tools/resources that facilitate regional- and national-scale assessment of carbon storage

Project Overview:
Goals and Objectives

Project Objectives.

- **Resource Assessments** – How can available geospatial data be best used to assess storage resource to ±30% accuracy?
  - **<u>Develop a Defensible DOE Methodology for Regional Assessments</u>**

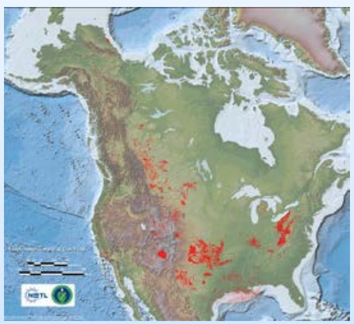
- **Geospatial Data Management (EDX and NATCARB) –** What spatially related datasets exist in support of carbon storage R&D and can they be provided in a user-friendly system to allow for advanced use and research?
  - **<u>Develop and maintain geospatial platforms that support research and assessment and that facilitate preservation and transfer of data (EDX and NATCARB)</u>**

Technical Status

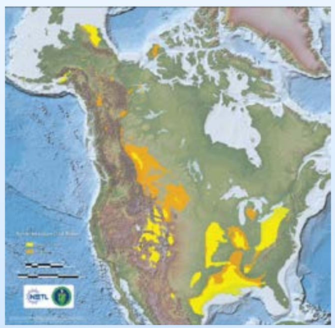
- **Resource Assessments**
  - ***CO_2 Storage Method Development for***
    - ***Unconventional Systems***
    - ***Oil and Gas Systems***
    - ***Saline Systems***
  - ***Experimental Measurement of Microscopic Displacement Efficiency in Geologic Systems***

Prospective Storage Resource for CO_2 storage at the *regional and national scale at the Exploration Phase*.

- Based on **physically** accessible pore volume without consideration of **regulatory** or **economic** constraints.
- broad **energy-related** government policy and business decisions



Saline Formations



Unmineable Coal Seams

Basalt Formations

Oil and Gas Fields

Organic-Rich Shale

Petroleum Industry		CO_2 Geological Storage
Reserves	Implementation	**Capacity**
On Production		Active Injection
Approved for Development		Approved for Development
Justified for Development		Justified for Development
Contingent Resources	Site Characterization	**Contingent Storage Resources**
Development Pending		Development Pending
Development Unclarified or On Hold		Development Unclarified or On Hold
Development Not Viable		Development Not Viable
Prospective Resources	Exploration	**Prospective Storage Resources**
Prospect		Qualified Site(s)
Lead		Selected Areas
Play		Potential Sub-Regions

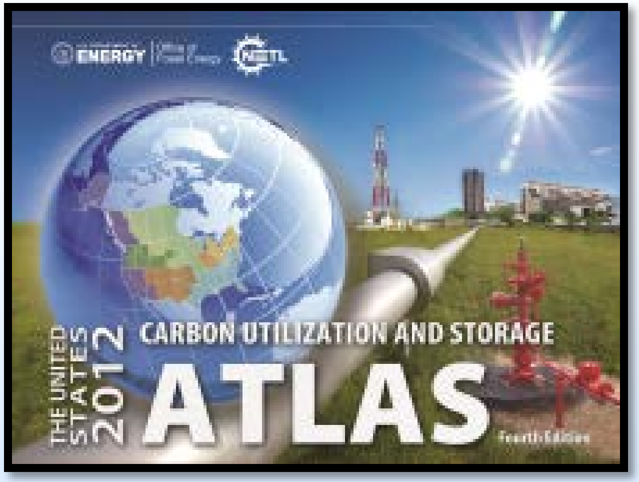
	Prospective Storage Resources	
Exploration	**Project Sub-class**	**Evaluation Process**
	Qualified Site(s)	Initial Characterization
	Selected Areas	Site Selection
	Potential Sub-Regions	Site Screening

DOE Classification of CO_2 Storage Estimates (2010)

Prospective CO_2 Storage Resource Methods

Volumetric approach: *geologic properties & storage efficiency*

- Method for prospective *CO_2 Storage Resource*
  - **Simple Geometric-Based Formula**
  - **Extensive Peer-Review**
  - **Extensive Statistical Rigor**
- Applied by Regional Carbon Sequestration Partnerships
- Refined Estimates in U.S. DOE's Carbon Utilization and Storage Atlas



Geologic Formation	Mass Resource Estimate
(1) Saline	$G_{CO2} = A_t\, h_g\, \phi_{tot}\, \rho\, E$
(2) Coalseams	$G_{CO2} = A_t\, h_g\, C_s\, \rho\, E$
(3) Oil and Gas	$G_{CO2} = A_n\, h_n\, \phi_e\, \rho\, E$
(4) Shale	$G_{CO2} = [(A_t\, h_g\, \phi_{tot}\, \rho_{CO2r} E_{free}) + (A_t\, h_g\, (1-\phi_{tot}) C_s \rho_{CO2s} E_{sorbed})]$

Stochastic Treatment of Storage Efficiency

A **fraction of the total** volume of the formation that will effectively store CO_2

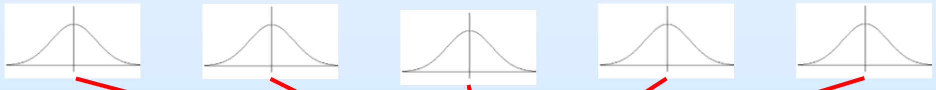
Represents **variability** in geologic parameters used to calculate G_{CO_2}

$$\mathbf{E_{saline}} = E_{An/At}\, E_{hn/hg}\, E_{\phi e/\phi tot}\, E_v\, E_d$$

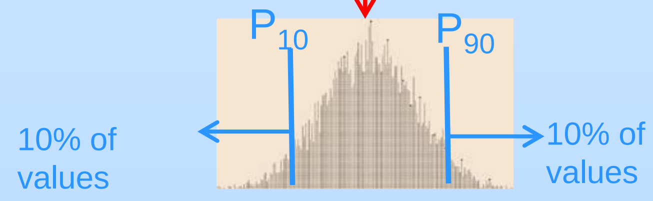
Saline Formation Efficiency Factors		
Lithology	**P_{10}**	**P_{90}**
Clastics	0.51%	5.4%
Dolomite	0.64%	5.5%
Limestone	0.40%	4.1%

Log Odds Method applied with *Monte Carlo* sampling

$E_{An/At}$ $E_{hn/hg}$ $E_{\phi e/\phi tot}$ E_v E_d



$$E = \left(1/_{1+e^{-X(E_{An/At})}}\right)\left(1/_{1+e^{-X(E_{hn/hg})}}\right)\left(1/_{1+e^{-X(E_{\phi e/\phi tot})}}\right)\left(1/_{1+e^{-X(E_v)}}\right)\left(1/_{1+e^{-X(E_d)}}\right)$$



Source: *Goodman, A., Hakala, A., Bromhal, G., Deel, D., Rodosta, T., Frailey, S., Small, M., Allen, D., Romanov, V., Fazio, J., Huerta, N., McIntyre, D., Kutchko, B.,and Guthrie, G. "U.S. DOE methodology for the development of geologic storage potential for carbon dioxide at the national and regional scale. International Journal of Greenhouse Gas Control (2011)*

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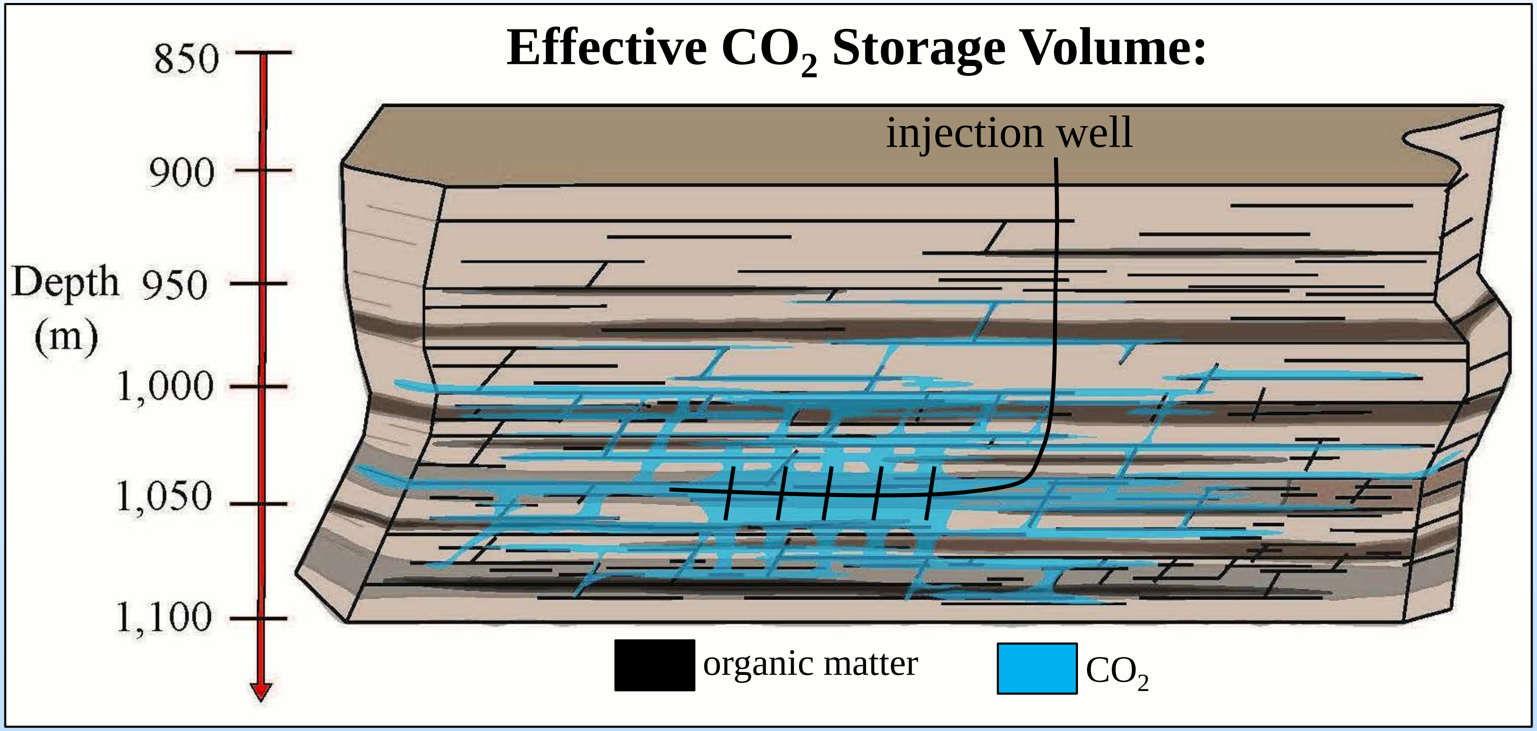
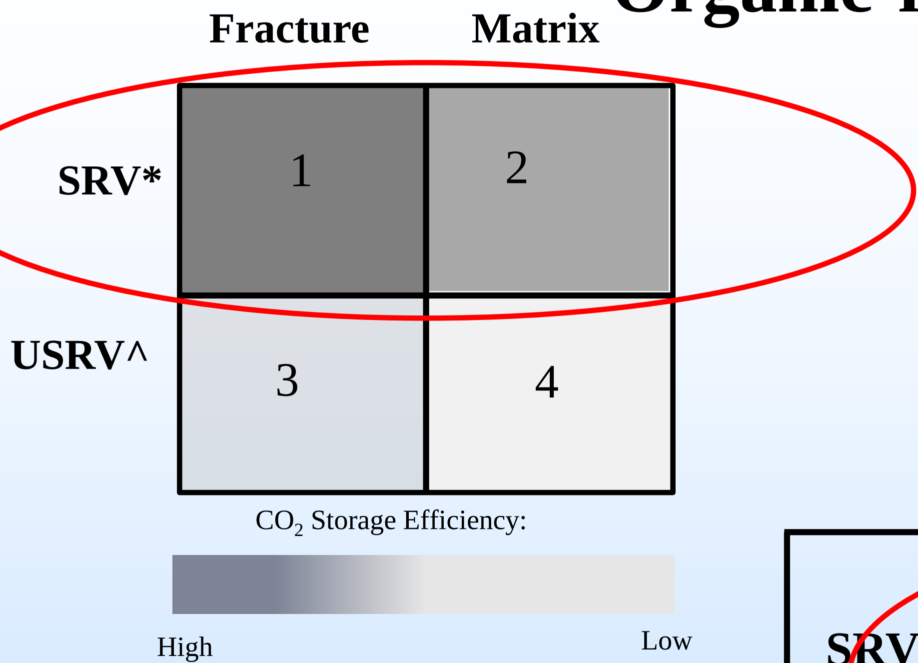
Technical Status

- **Resource Assessments**
  - ***CO_2 Storage Method Development for Unconventional Systems***
  - ***Team Members:*** Isis Fukai[1], Angela Goodman[1], Robert Dilmore[1], Dan Soeder[1], Scott Frailey[2], Grant Bromhal[1], George Guthrie[1], Traci Rodosta[1]



Simplified sketch of an organic-rich shale storage formation showing the portion of the formation that is accessed during CO_2 storage.

Method for Estimating the CO_2 Storage Resource of Organic-rich Shales



***Stimulated Reservoir Volume**

^Unstimulated Reservoir Volume

		fracture	**matrix**
SRV*	free	✓	✓ in ϕ
	sorbed	X	✓ in clay & kerogen
USRV^	free	✓	✓ in ϕ
	sorbed	X	✓ in clay & kerogen

Methodology for Estimating the CO_2 Storage Resource of Organic-rich Shales

Criteria for CO_2 Storage in U.S. Organic-rich Shale Formations
(1) Organic-rich shale formations must have a TOC ≥ 2.0 wt. % and be methane-bearing. These formations have sufficient volumes of sorptive kerogen & void spaces where CH_4 is able to reside, suggesting they will also be amenable for CO_2 storage.
(2) Structural, stratigraphic, & hydrodynamic traps (faults, seals, & capillary pressures) must exist in order to prevent the migration of CO_2 into adjacent formations or to the surface.
(3) The organic-rich shale formation has been, or will be produced for methane before or during implementation of CO_2 storage. This is to reduce the likelihood of formation over-pressurization and ensure space is available to allow in-situ methane and fluids to be displaced and/or managed via production.

CO_2 Storage Resource Methodology for Organic-rich Shales

Represents the physically accessible, *effective* CO_2 storage volume

Volumetric Equation:

$$G_{CO2} = [(A_t\, h_g\, \phi_{tot}\, \rho_{CO2r}\mathbf{E_{free}}) + (A_t\, h_g\, (1\text{-}\phi_{tot})C_s\rho_{CO2s}\mathbf{E_{sorbed}})]$$

(1) *Free phase* storage in Stimulated Reservoir fractures and matrix pores

(2) *Sorbed* storage on kerogen & clays

Efficiency: *fraction* of the total formation volume that will be accessed for CO_2 storage

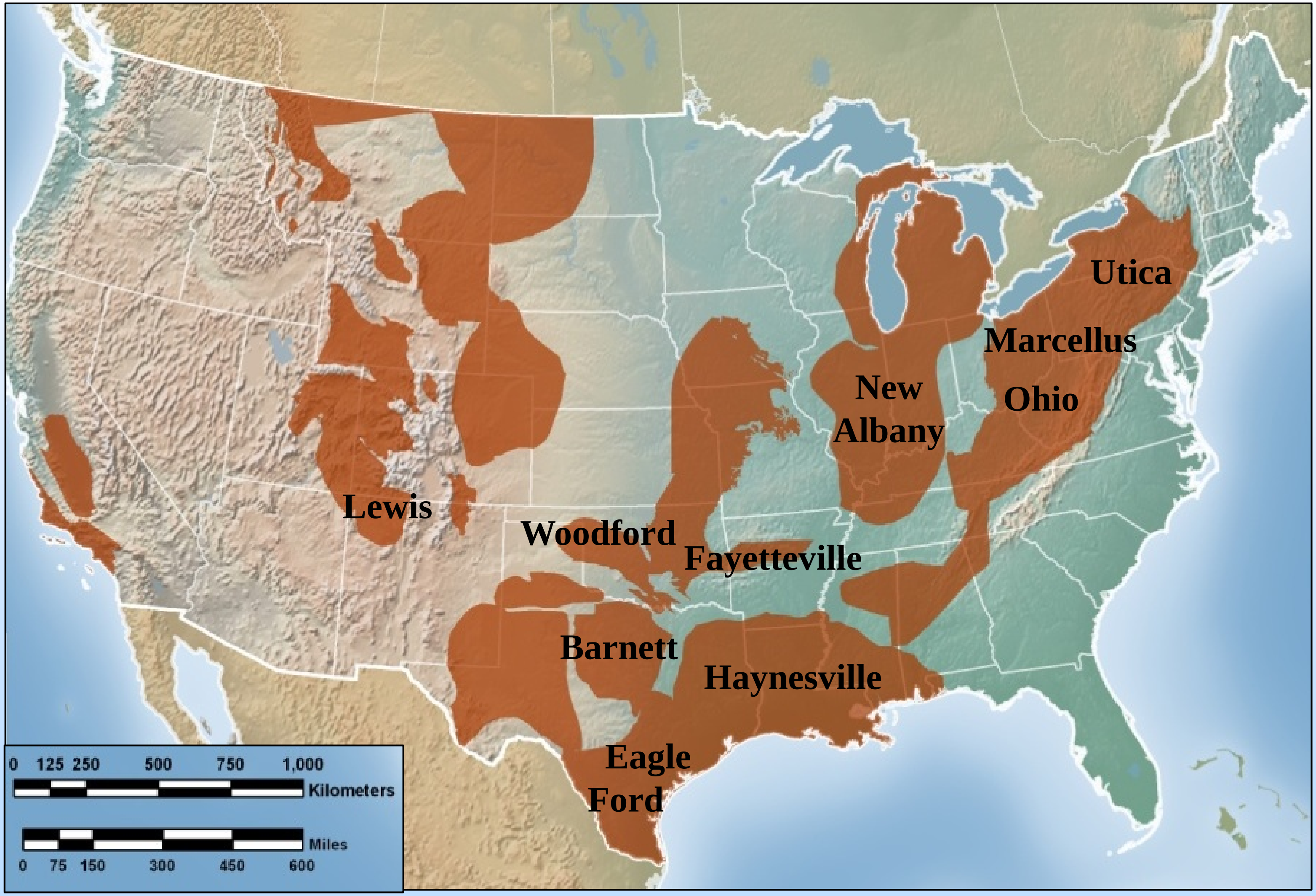
$$\mathbf{E_{free}} = E_{An/At}\; E_{hn/hg}\; \mathbf{E_{\phi e/\phi t}}\; E_V E_d$$

$$\mathbf{E_{sorbed}} = E_{An/At}\; E_{hn/hg}\; \mathbf{E_{Ce/Ct}}\; E_V E_d$$

Accounts for technical storage limitations, *e.g. unconstrained* **geologic** & **displacement** *variables*, that may prevent CO_2 from accessing 100% of the theoretical storage volume (*e.g. Goodman et al., 2011*)

Application of Methodology for Estimating the CO_2 Storage Resource of Organic-rich Shales

10 Major Formations Included in Calculation



Map after NETL-NATCARB (2013)

U.S. Organic-rich Shale Formation Data Incorporated in CO_2 Storage Resource Equation

$$G_{CO2} = A_t h_g [\phi_{tot} \rho_{CO2r} E_{free} + (1-\phi_{tot}) C_s \rho_{CO2s} E_{sorbed}]$$

Formation	Total Area (km^2)	Gross Thickness (m)	Total Porosity	TOC (%)	Shale Density (g/cm^3)	Langmuir Volume (m^3/kg)
Marcellus	246,049	103	0.07	7.3	2.48	0.00852
Barnett	23,310	139	0.05	5.6	2.54	0.00709
Ohio	85,470	135	0.08	3.4	2.60	0.00179
Woodford	28,490	108	0.07	8.3	2.54	0.00933
Haynesville	23,310	70	0.08	2.8	2.60	0.00468
Fayetteville	23,310	52	0.06	6.5	2.54	0.00777
Utica	73,815	133	0.03	2.9	2.69	0.00476
New Albany	22,015	73	0.12	16.0	2.40	0.01592
Lewis	7,122	269	0.04	2.3	2.54	0.00420
Eagle Ford	19,425	65	0.10	4.4	2.60	0.00601

Data Sources: Hill and Nelson, 2000; Curtis, 2002; Nuttall et al., 2005; Braithwaite, 2009; DOE-NETL, 2010; Roth, 2010; Strapoc et al., 2010; Bruner and Smosna, 2011; EIA, 2011; Kulkarni, 2011; Lahann et al., 2011; NY-DEC, 2011; Walls and Sinclair, 2011; Chalmers et al., 2012; Curtis et al., 2012; Jarvie, 2012; Clarkson et al., 2013b; Gasparik et al., 2013; Liu et al., 2013; Ruppert et al., 2013; Yu and Sepehrnoori, 2014

Gross thickness, Total Porosity, TOC-content, and Shale Density values are averages based on 3-7 values reported in peer-reviewed literature.

Estimating CO_2 Storage Efficiency of Organic-rich Shales

Probability (p) values: fractions representing the percentage of each parameter that will be utilized for CO_2 storage

P-values must account for several different storage scenarios

High and Low P-values Assigned to Efficiency Parameters			
Parameter	**Symbol**	**P_{10}** (low)	**P_{90}** (high)
Geologic	$E_{An/At}$	***hydraulically stimulated vs unstimulated shale volumes***	
	$E_{hn/hg}$		
	$E_{\phi e/\phi t}$	*gas porosimetry, SANS/USANS**	
	$E_{Ce/Ct}$	*$Langmuir_{res}$ / $Langmuir_{max}$*	
Displacement	E_V	*injection-well scenarios / infra-structure*	
	E_d		

P-ranges are calculated stochastically to produce $\mathbf{E_{free}}$ and $\mathbf{E_{sorbed}}$ values

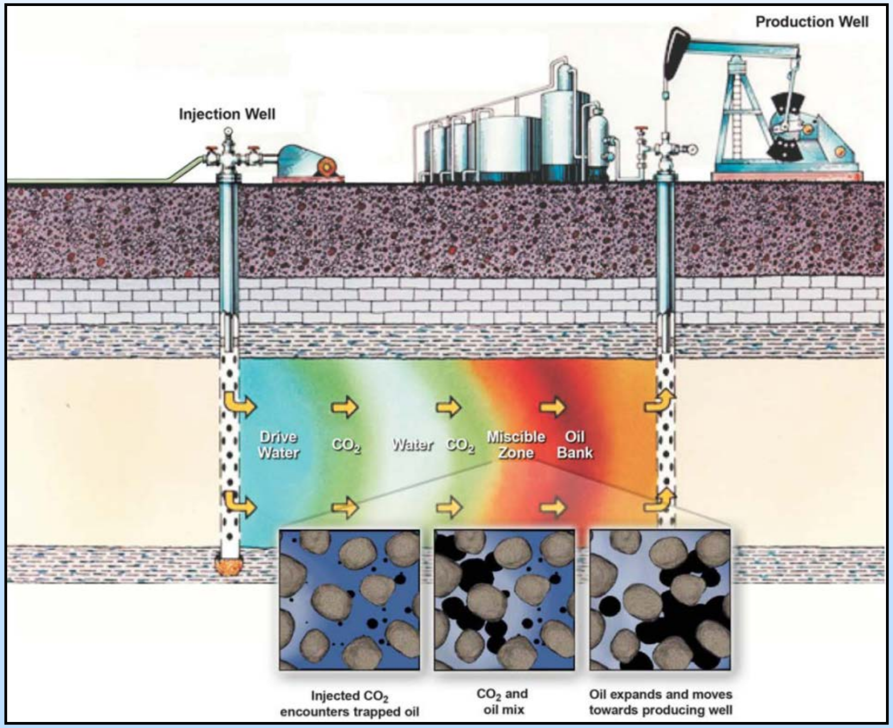
GoldSim v. 11 (*GoldSim Technology Group, 2013*), Monte Carlo simulation (10,000) & Log-Odds distribution

Shale Storage Efficiency Preliminary Results			
Percentile:	**P_{10}** (low)	**P_{50}** (mid)	**P_{90}** (high)
$\mathbf{E_{free}}$	***In progress***		
$\mathbf{E_{sorbed}}$			

Values assigned based on professional expertise, experimental data, & model simulations (in-house & external):
Curtis, 2002; DOE-ICMI, 2012; Clarkson et al., 2012; Jarvie, 2012; Ruppert et al., 2013

Technical Status

- **Resource Assessments**
  - ***CO_2 Storage Method Development for Oil and Gas Systems***
  - *Team Members: Russell Johns, Nick Azzolina, Dave Nakles, Liwei Li, Saeid Khorsandi, Angela Goodman*



Refined Methodology

- Production-Based Equation

$$G_{CO2-production} = \frac{A_n \cdot h_n \cdot \phi_e (1 - S_{wi}) \rho_{CO2-standard\ conditions} \cdot E_{oil/gas}}{B_{oil}}$$

- Volumetric Equation

$$G_{CO2-reservoir\ volume\ displacement} = A_n \cdot h_n \cdot \phi_e [E_v \cdot E_d] \cdot \rho_{CO2-reservoir\ conditions}$$

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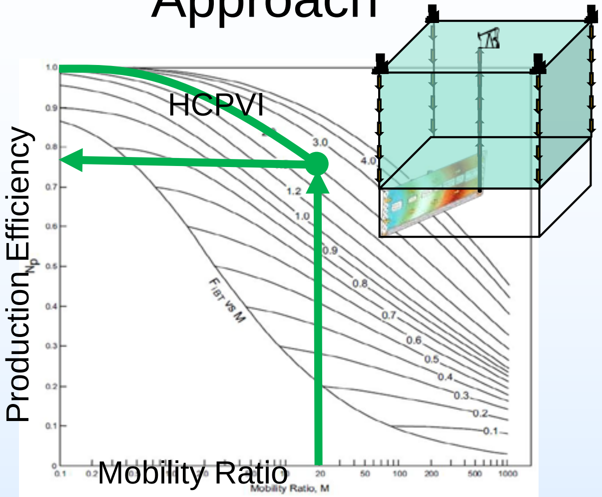
Approaches to Characterize $E_v \times E_d$

Three Approaches

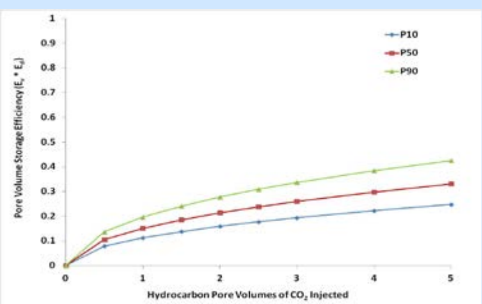
1. Analytical modeling of continuous miscible CO_2 flood
2. Reservoir simulation and reduced order modeling of a next-generation CO_2-EOR scheme with high flood efficiency
3. Performance from a set of industry data with regression of those data to predict reservoir performance at higher HCPV CO_2 injection

1
Koval/Claridge Approach

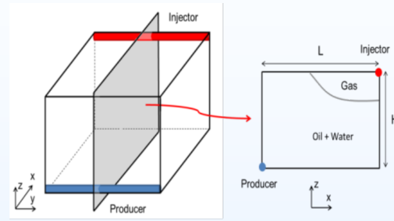


Monte Carlo Simulations varying:
- Oil API Gravity
- Associated gas specific gravity
- Initial Oil Saturation
- Vertical Permeability
- Dykstra-Parsons Coefficient

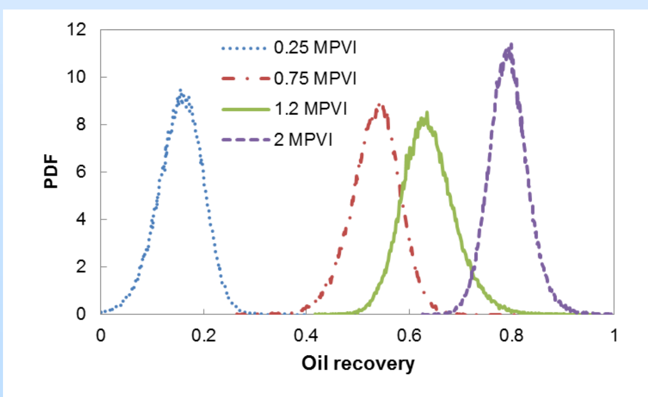
CO2 HPVI up to 5



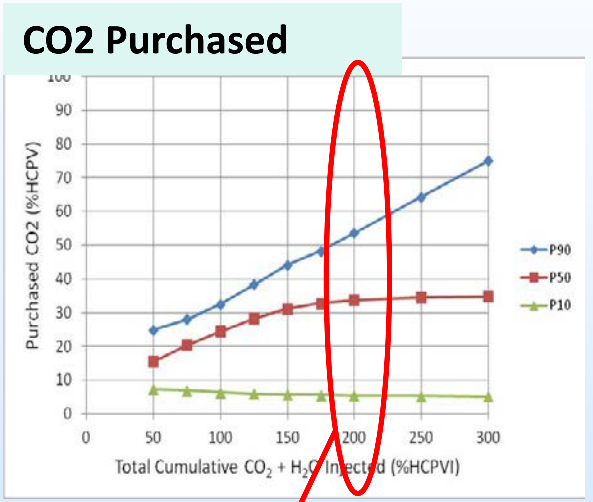
2
Simulation of Gravity-Assisted Flood

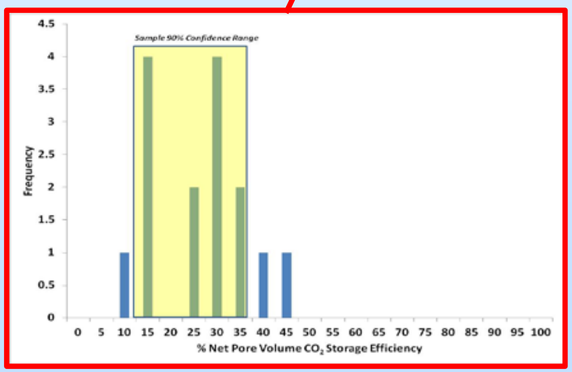


a reduced-order model (ROM) for continuous CO2 flooding in heterogeneous oil reservoirs



3
Projection from Production History in Real Fields

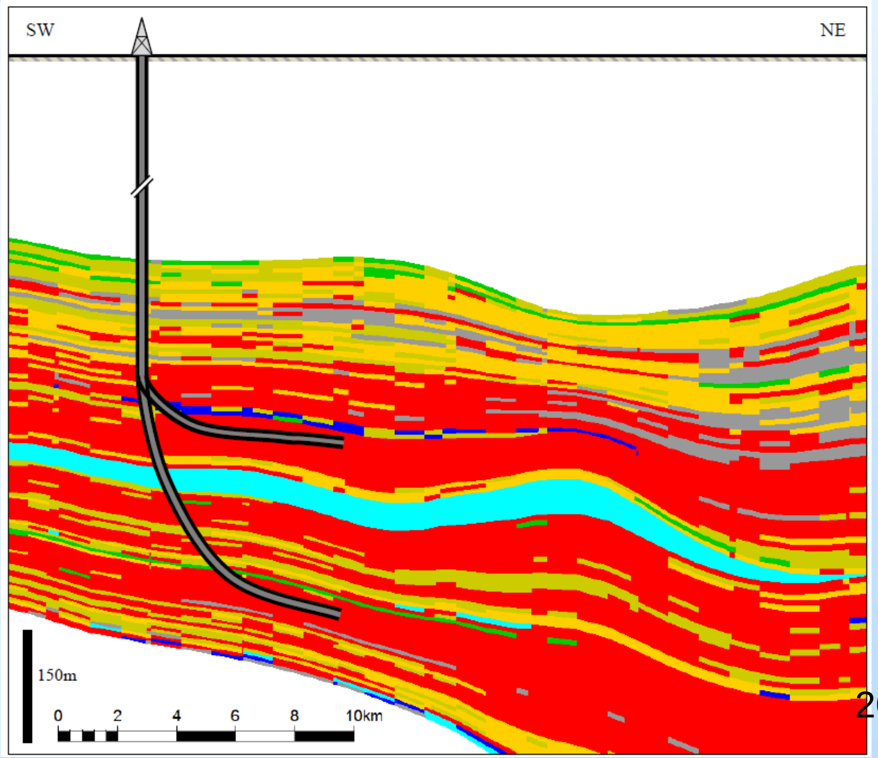




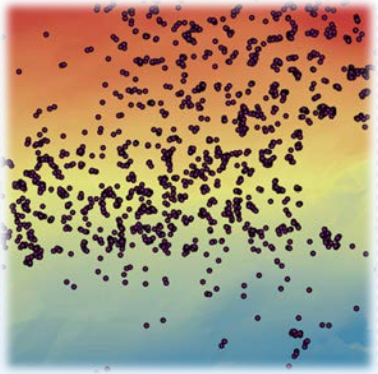
SOURCES: Claridge, E.L. Prediction of Recovery in Unstable Miscible Flooding. SPE Journal, 1972. 12(2): p. 143-155.;
Shaw, J., Bachu, S. (2002) Screening, Evaluation, and Ranking of Oil Reserves Suitable for CO2-Flood EOR and Carbon Dioxide Sequestration. J. Can. Pet. Technol., 41(9), 51-61.
Source: Azzolina, N.A.; Nakles, D.V.; Gorecki, C.D.; Peck, W.D.; Pu, H.; Ayash, S.C.; Melzer, S. (2014) "Statistical Analysis of CO_2 EOR Production and Injection Data to Examine On-Going and Ultimate CO_2 EOR Incidental Storage." Manuscript submitted for publication.
SOURCE: Li, Liwei , Khorsandi, Saied Johns, Russell T. Dilmore, R. **Reduced-Order Model for CO_2 Enhanced Oil Recovery and Storage Using a Gravity-Enhanced Process. SPE-ATCE,**

Technical Status

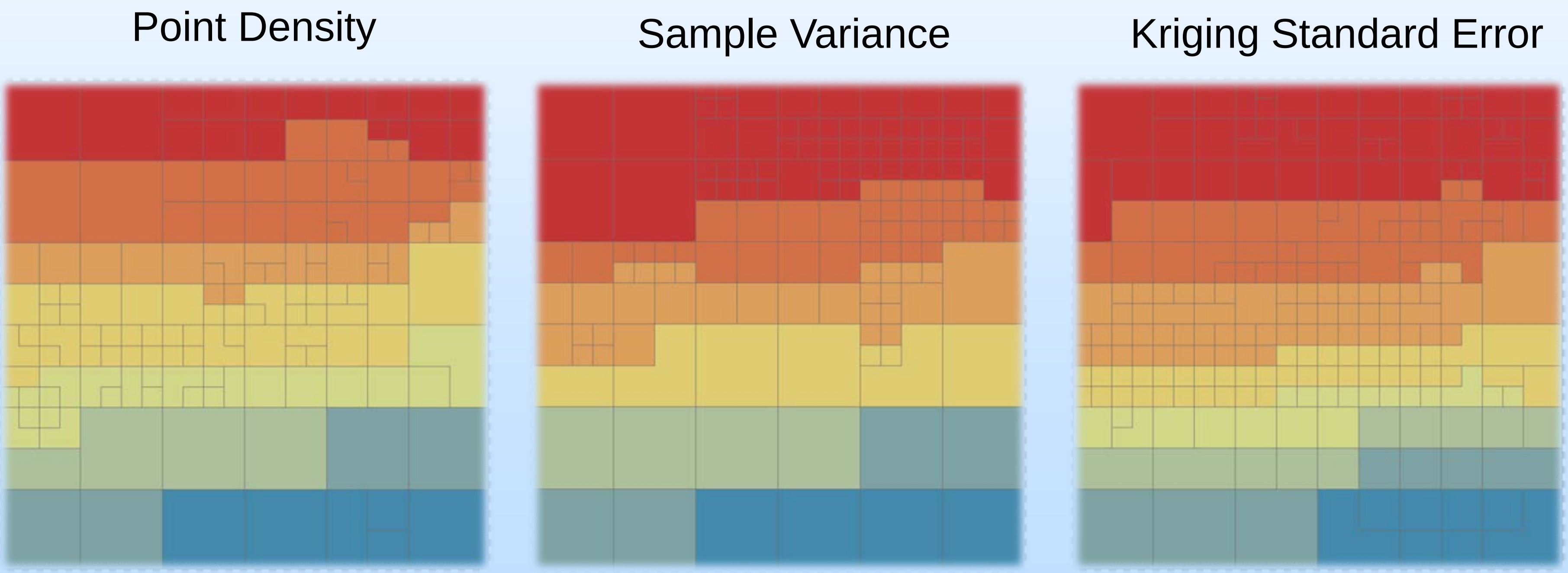
- **Resource Assessments**
  - ***CO_2 Storage Method Development for Saline Systems***
  - *Team Members:* Angela Goodman, Kelly Rose, Jen Bauer, Corinne Disenhof, Grant Bromhal, Bob Dilmore, and George Guthrie



NETL's Variable Grid Method (VGM)



The VGM is a *flexible method* that allows for the communication of different data and uncertainty types, while still preserving the *overall spatial trends and patterns*



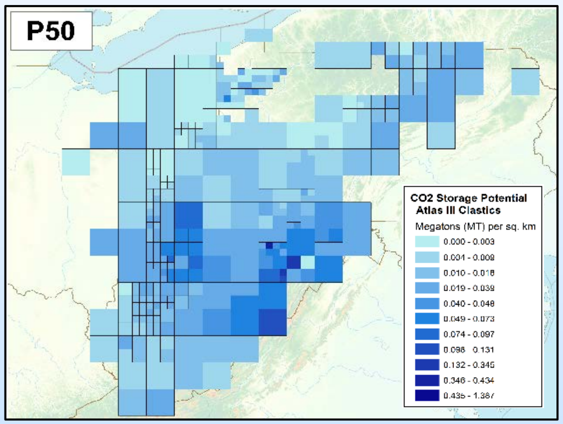
Applications of the VGM at NETL

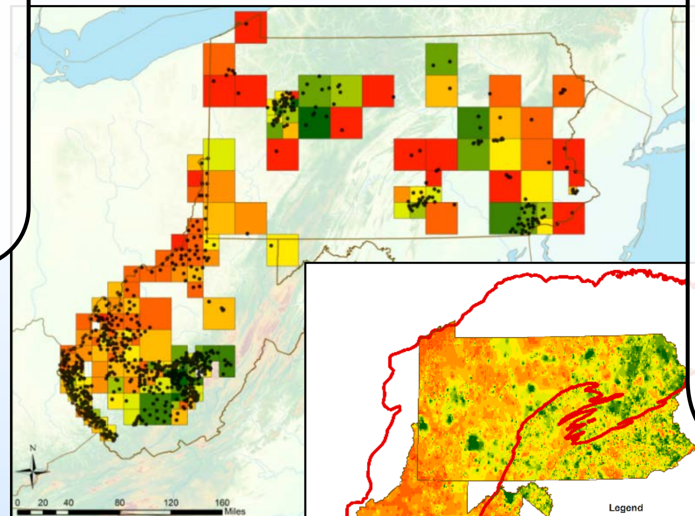
VARIABLE GRID METHOD

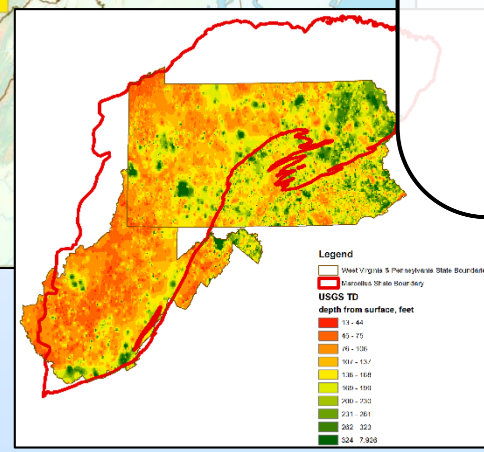
CO_2 Storage Assessment

Oriskany Formation

New approach for defining spatial uncertainty & trends for CO2 Storage estimates







Unconventional Resource Risk Assessments

Estimating the depth to the base of groundwater to evaluate risks of groundwater contamination

NETL VGM approach can be used to address questions such as:

- Resources evaluation
- Impact assessments
- Identifying Knowledge Gaps
- Understanding trends in the data
- Calculating Project Feasibility

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Useful Links:

VGM Technology Sheet:

http://www.netl.doe.gov/File%20Library/Business/patents/PON-14-016-variable-grid-method.pdf

VGM Technology Video:

http://youtu.be/9vLa1HM1IKY

Acknowledgements

Thank you to my other developer, Kelly Rose, the ‘brains’ behind the idea, as well as the NETL Technology Transfer Team for their help developing and submitting the patent, Corinne Disenhof and Angela Goodman for their help with applying the VGM to CO_2 storage estimates, and Aaron Barkhurst and Tim Jones working on the development of the Variable Grid Tool

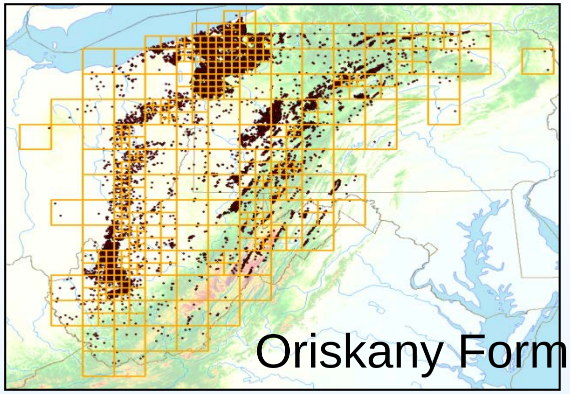
Notes

A U.S. provisional patent application was filed February 12, 2014 (61/938,862)

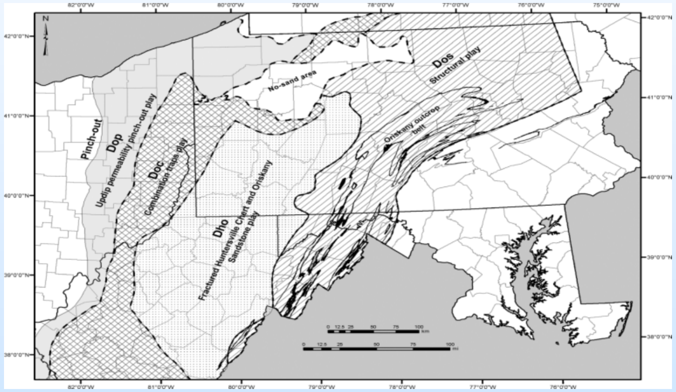
New Geospatial Approach for CO_2 Storage Assessment

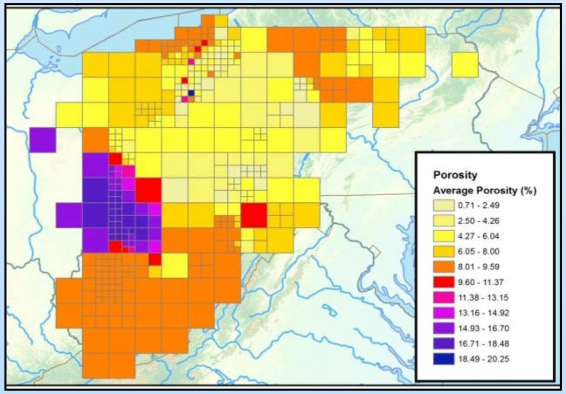
Developing new geospatial analysis approach to characterize, interpret, and display subsurface geologic characteristics to provide detailed inputs needed for assessing Prospective CO_2 Resource Storage Estimates.

					Clastics		
					P10	P50	P90
Ea/a	Eh/h	Ephi/phi	EV	Ed	0.5%	2.0%	5.4%
	Eh/h	Ephi/phi	EV	Ed	1.6%	4.4%	9.5%
		Ephi/phi	EV	Ed	5.2%	9.9%	17.2%
			EV	Ed	7.4%	14.1%	24.1%
					Dolomite		
					P10	P50	P90
Ea/a	Eh/h	Ephi/phi	EV	Ed	0.7%	2.2%	5.4%
	Eh/h	Ephi/phi	EV	Ed	2.0%	5.0%	9.1%
		Ephi/phi	EV	Ed	9.3%	12.7%	16.9%
			EV	Ed	15.7%	20.6%	26.3%
					Limestone		
					P10	P50	P90
Ea/a	Eh/h	Ephi/phi	EV	Ed	0.4%	1.5%	4.0%
	Eh/h	Ephi/phi	EV	Ed	1.3%	3.4%	6.9%
		Ephi/phi	EV	Ed	7.2%	10.4%	14.7%
			EV	Ed	10.4%	15.0%	21.0%



Oriskany Formation



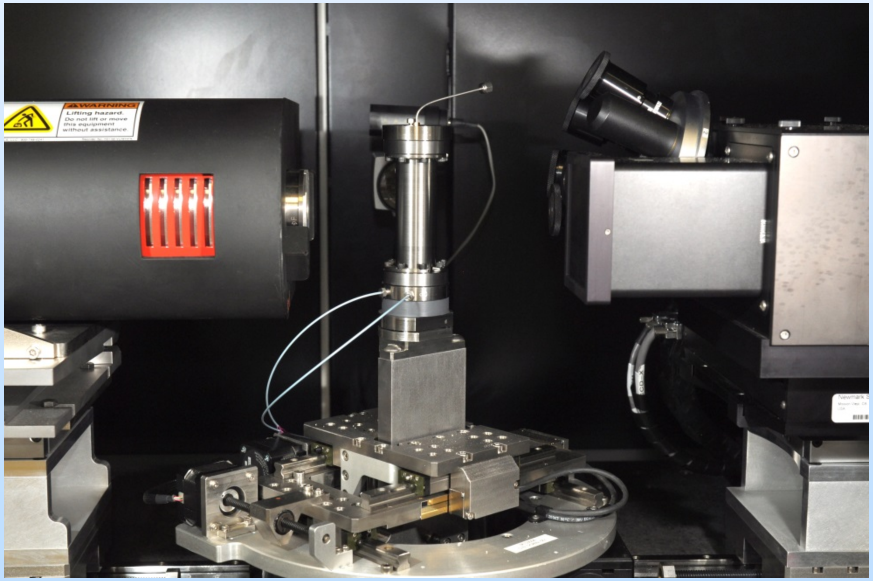


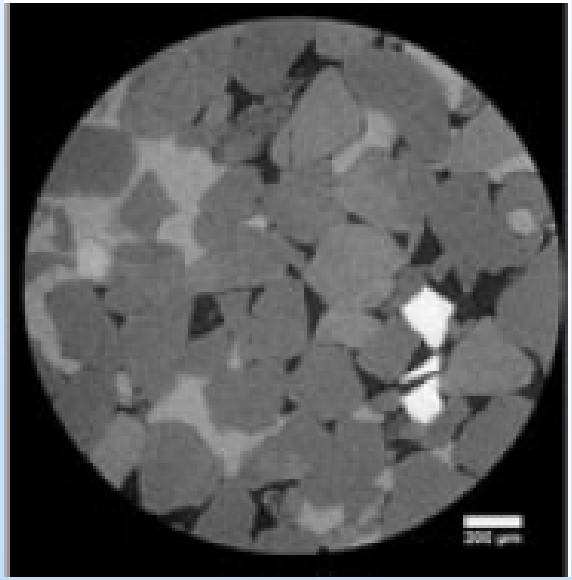
Technical Status

- **Resource Assessments**
  - ***Experimental Measurement of Microscopic Displacement Efficiency in Geologic Systems***
  - *Team Members: Dustin McIntyre and Angela Goodman*

High Resolution CT Imaging

- Image resolution <5 micron
- Custom X-ray scannable Hassler style core holder
- Pressure and temperature control of confining pressure
- Injection fluid pressure and temperature control
- Micro-displacement efficiency measurement
- Vary brine composition
- Initial saturation composition (Oil/brine/mixed)

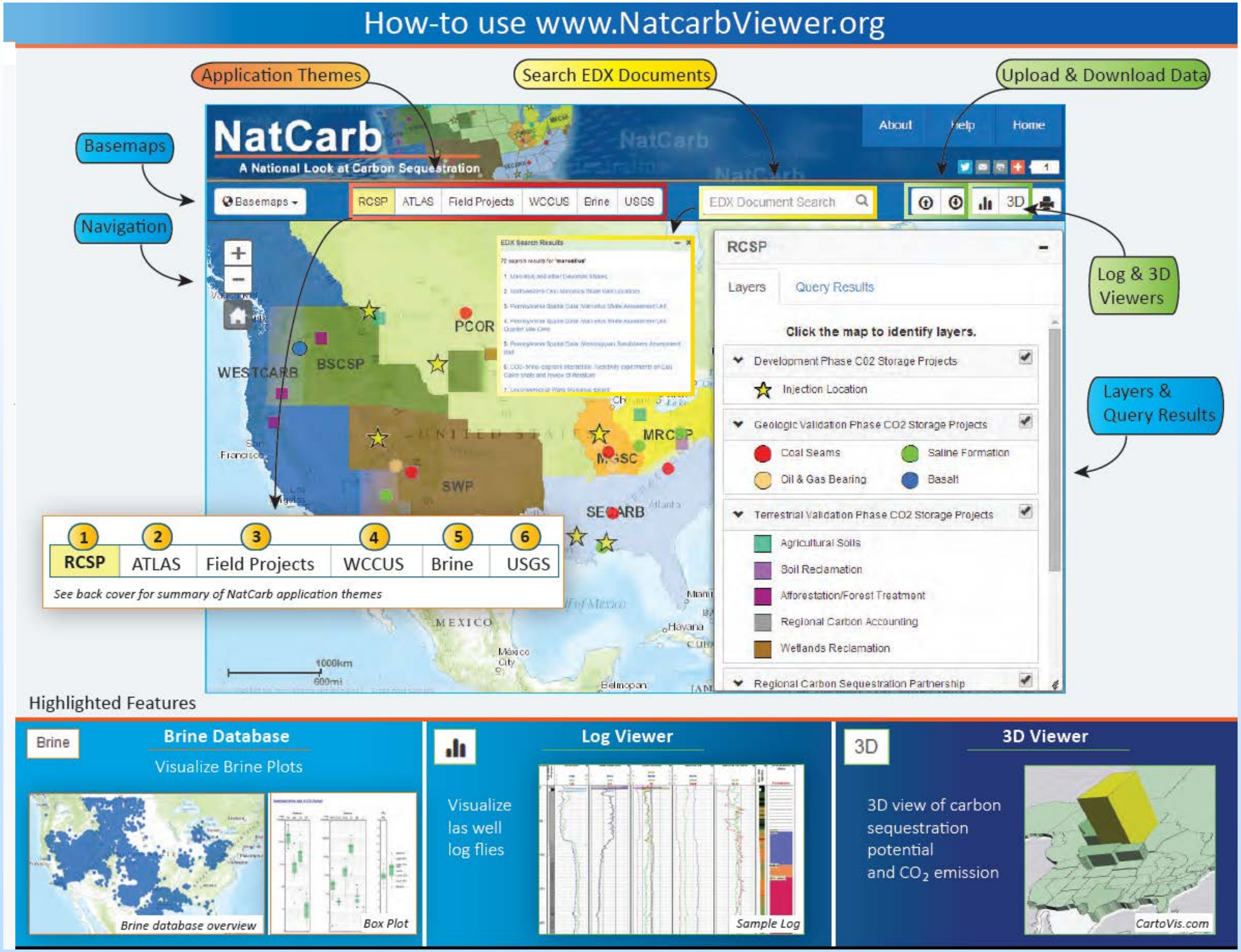




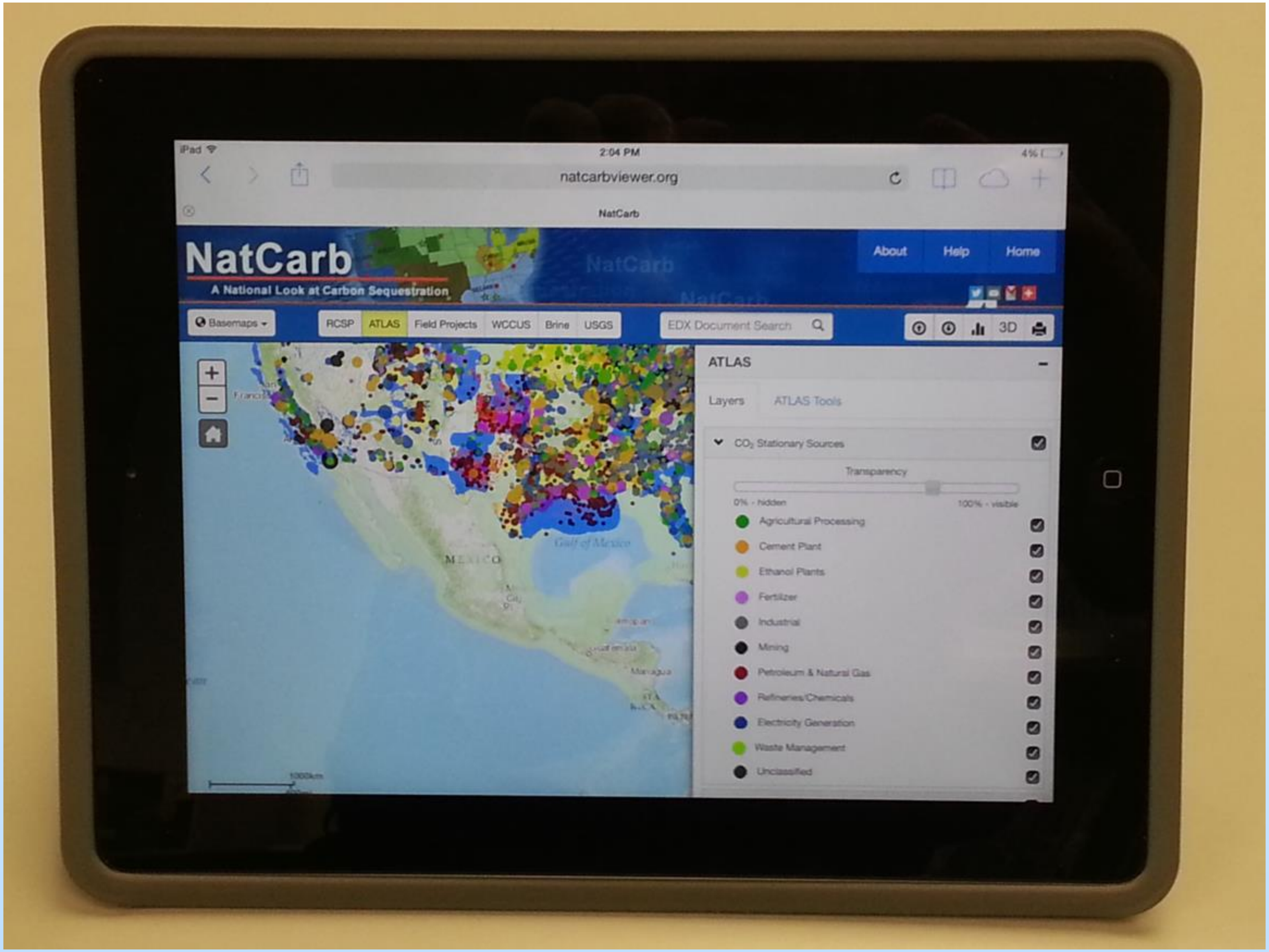
Technical Status

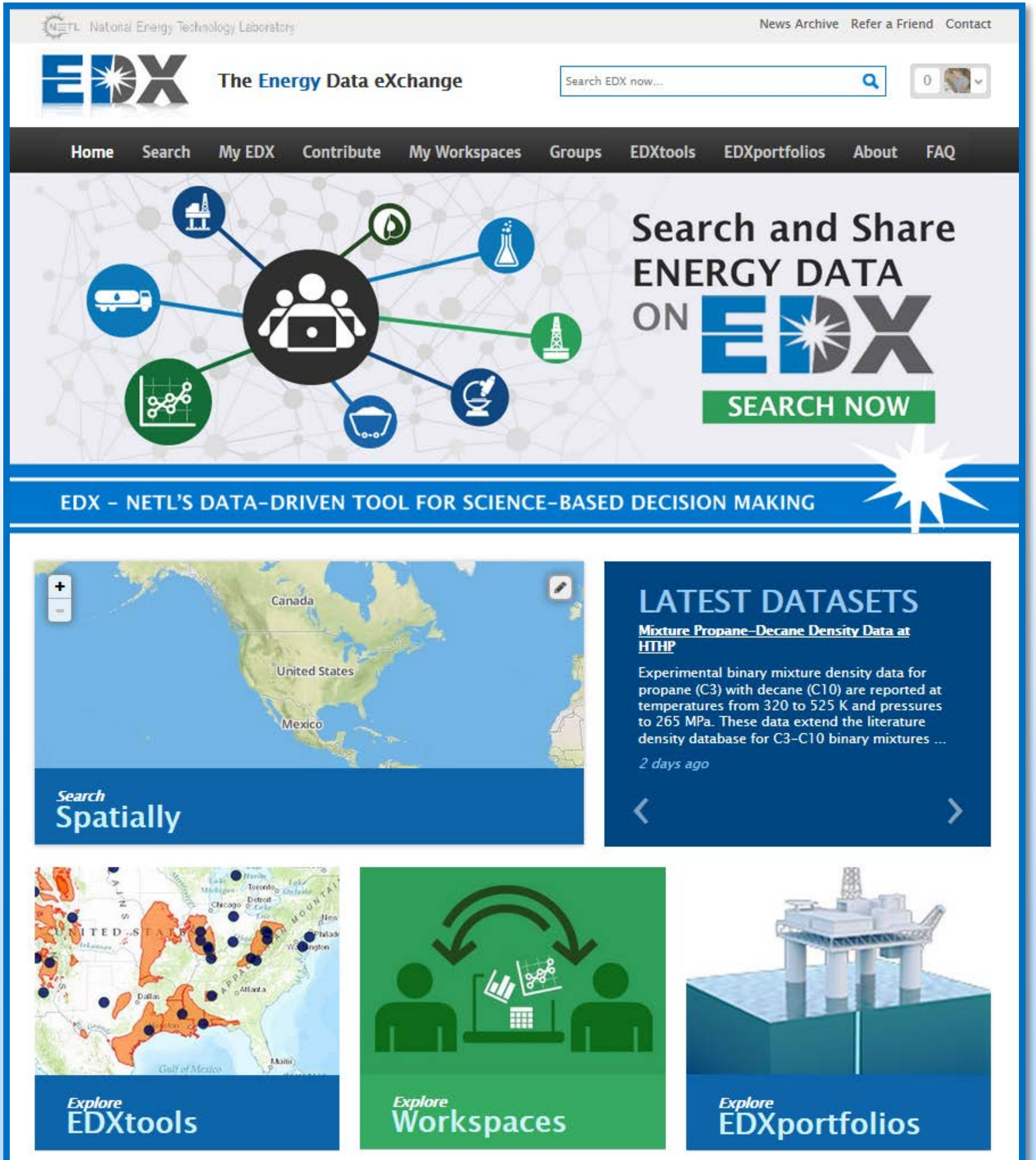
- **Geospatial Data Management**
  - ***Atlas Development and NATCARB***
  - ***Geodatabase Development in Support of Geologic Storage Research (EDX)***

Atlas Development and NATCARB



Atlas Development and NATCARB





What is EDX...

- An online platform for **rapid and efficient access** to priority datasets
- Provides an opportunity for researchers to **share** and "publish" online **datasets & data-driven products**
- A **secure** environment for **multi-organizational** research **teams** to share, build, and **collaborate** in a common workspace
- **Online** tool to **disseminate** data, information, and results from **DOE's Fossil Energy** intramural **research** portfolios

https://edx.netl.doe.gov/

Accomplishments to Date

- Draft of new methodology for accessing storage potential in organic-rich shale
- Draft of new methodology for accessing storage potential in conventional oil reservoirs
- Development of the VGM flexible method that allows for the communication of different data and uncertainty types, while still preserving the overall spatial trends and patterns
- DEVELOP A NEW VIEWER FOR NATCARB
- EDX DEVELOPMENT- COORDINATION AND COLLOBORATION TOOL --- Online tool to disseminate data, information, and results from DOE's Fossil Energy intramural resea rch portfolios

Summary

– Key Findings

- **Resource Assessments**
  - **<u>Develop a Defensible DOE Methodology for Regional Assessments</u>**

- **Geospatial Data Management (EDX and NATCARB)**
  - **<u>Develop and maintain geospatial platforms that support research and assessment and that facilitate preservation and transfer of data (EDX and NATCARB)</u>**

– Future Plans

- **Develop Defensible DOE Methodology for Regional Assessments**
- **Expand to Include Stochastic Approach for Key Parameters**
- **Expand Methodology to Include Geospatially Variable Key Parameters**
- **EDX and NATCARB : Develop and maintain geospatial platforms that support research and assessment and that facilitate preservation and transfer of data**

Appendix

Organization Chart

- **Task 4.0 Resource Assessments and Geospatial Resources**
  - **Subtask 4.1 Resource Assessments (TTC: Goodman)**
  - ***Sub-subtask 4.1.1 Methodology for Assessment of Unconventional Systems (Goodman, NETL)***
  - ***Sub-subtask 4.1.2 Methodology for Assessment of Oil and Gas Systems (Dilmore, NETL; Johns, PSU)***
  - ***Sub-subtask 4.1.3 Methodology for Assessment of Saline Systems(Goodman & Rose, NETL)***
  - ***Sub-subtask 4.1.4 Experimental Measurement of Microscopic Displacement Efficiency in Geologic System (McIntyre & Goodman, NETL)***
- **Subtask 4.2 Geospatial Data Management (TTC: Soeder 4.2.1/Rose 4.2.2)**
  - ***Sub-subtask 4.2.1 Atlas Development and NATCARB (TTC: Soeder)***
  - **Sub-sub-subtask 4.2.1.1 NATCARB Database and Viewer Development (Carr, WVU)**
  - **Sub-sub-subtask 4.2.1.2 Update the Carbon Storage Atlas of the United States and the North American Carbon Atlas (Soeder, NETL)**
  - ***Sub-subtask 4.2.2 Geodatabase Development in Support of Geologic Storage Research (Rose, NETL)***
  - **Sub-sub-subtask 4.2.2.2 Evaluation and if Appropriate Development of an ORD CO_2 Storage Program EDX Portfolio**
  - **Sub-sub-subtask 4.2.2.3 EDX operations support for collaborative workspace development for CO_2 Storage intramural and extramural projects as requested. To create a collaborative workspace the administrator of the space is required to have a contr.netl.doe.gov or .netl.doe.gov email address however members approved by the workspace administrator with valid EDX accounts can be from outside entities. Thus, EDXsupport@netl.doe.gov will be on hand to support the development, maintenance and improvement of these spaces in support of CO_2 Storage R&D in FY14.**
  - **Sub-sub-subtask 4.2.2.4 Additional support by the EDX Team for key development and potential integration with outside partners (e.g., PNNL GS3 system) will be supported in FY14 but will be limited by the amount of funding available versus the level of support and development required on a request-by-request basis.**

Milestone Identifier	Title	Planned Date	Verification Method
Task 4.0 Resource Assessments and Geospatial Resources			
M1.14.4.A	Provide draft methodology products for oil and gas formations.	03/30/14	Draft report

Gantt Chart

Carbon Storage
FWP Number Car Stor_FY14
Schedule and Milestones

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Task No.	Activity Name (Task/Sub-task)	Start	Finish	FY14 (Q1: O N D; Q2: J F M; Q3: A M J; Q4: J A S)
1.0	**Project Management**	**10/1/13**	**9/30/14**	
1.1	Project Management	10/1/13	9/30/14	
2.0	**Reservoir and Seal Performance**	**10/1/13**	**9/30/14**	M1.14.2.A
2.1	Impact of CO_2-Brine-Rock Chemistry on Storage Formations and Seals	10/1/13	9/30/14	
2.2	Impact of Microbial Processes on Storage Formations and Seals	10/1/13	9/30/14	
2.3	Impact of CO_2 on Shale Formations as Seals	10/1/13	9/30/14	
2.4	Characterization of Reservoir and Seal Material Performance	10/1/13	9/30/14	
2.5	Understanding of Multiphase Flow for Improved Injectivity and Trapping	10/1/13	9/30/14	
2.6	Geochemical Model Sensitivity at Caprock Interfaces	10/1/13	9/30/14	
3.0	**Monitoring Groundwater Impacts**	**10/1/13**	**9/30/14**	M1.14.3.A
3.1	Natural Geochemical Signals for Monitoring Groundwater Impacts	10/1/13	9/30/14	
4.0	**Resource Assessments and Geospatial Resource**	**10/1/13**	**9/30/14**	M1.14.4.A
4.1	Resource Assessments	10/1/13	9/30/14	
4.2	Geospatial Data Management	10/1/13	9/30/14	
5.0	**Monitoring CO_2 and Pressure Plume**	**10/1/13**	**9/30/14**	M1.14.5.A
5.1	Development of Technology to Monitor CO_2 and Pressure Plume	10/1/13	9/30/14	
6.0	**Catalytic Conversion of CO_2 to Industrial Chemicals**	**10/1/13**	**9/30/14**	M1.14.6.A
6.1	Catalytic Conversion of CO_2 to Industrial Chemicals	10/1/13	9/30/14	

Milestone | Summary | Page 1 of 1

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