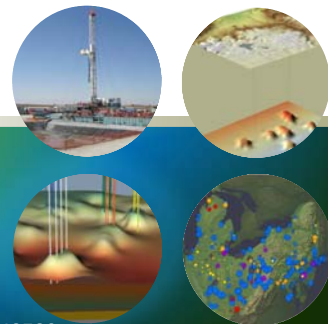
MRCSP - Large-Scale CO_2-Enhanced Oil Recovery and Geologic Storage Test in Midwestern USA

Carbon Sequestration Leadership Forum
PIRT Group Meeting
Washington, DC
November 4, 2013



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DOE/NETL Cooperative Agreement # DE-FC26-0NT42589

MRCSP – cornerstone of the Battelle's program on the CCUS technology development

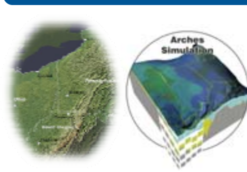
AEP Mountaineer Projects
- Site Characterization, Design
- Permitting, Construction
- Operations, workover
- Post-Injection Monitoring
- >150,000 hours of safe drilling

FutureGen Program
- 1 MT/yr scale
- Design/costing
- Class VI permitting

Wellbore Integrity

Simplified Modeling

Storage Feasibility in Sichuan Basin China



Ohio Valley Characterization, Basin-Scale Modeling

Regional Carbon Partnership

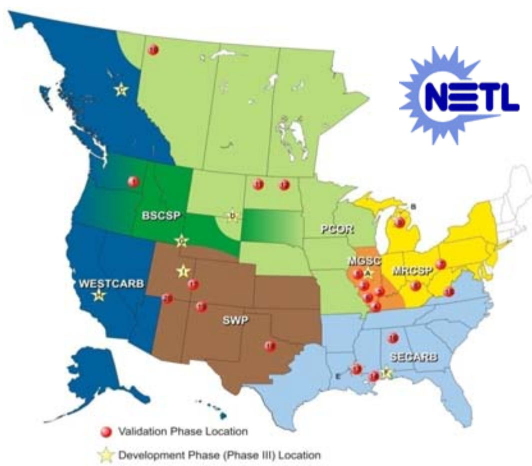
- Regional Mapping
- Policy & Regulation
- Small-Scale Tests
- Large-Scale Test
- EOR and Storage
- Exploration

Private Client Studies – Domestic and Global

Emerging Program in Brine Disposal, EOR, Shale Gas

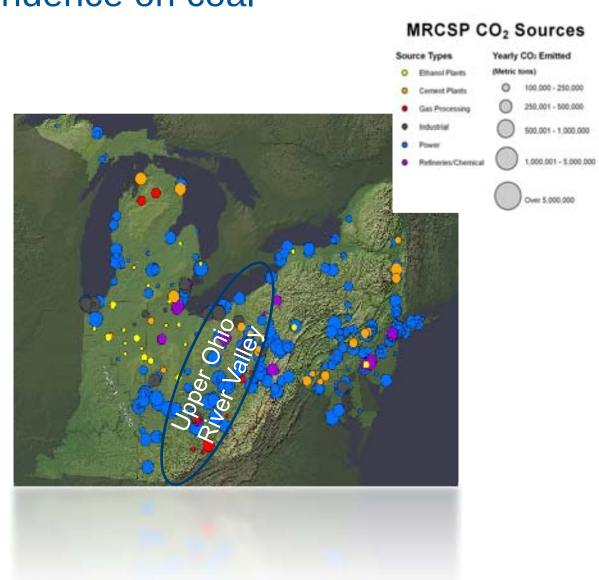
The MRCSP assesses viability of carbon sequestration

- Established in 2003 by Battelle with DOE-NETL funds – Currently in Phase III
- Led by Battelle, there are 40 organizations from non-profit, government, and commercial entities
- Mission – The premier resource for CO_2 storage and utilization expertise in the region



MRCSP region: Many CO_2 emission sources with dependence on coal

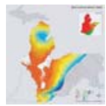
- CO_2 storage/utilization technologies key to affordable energy supplies
- Environmental/climate issues and shale gas, are leading to energy supply transition
- Coal continues to be dominant fuel source, but will be impacted due to emission limits

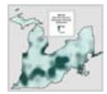


Overall schedule for MRCSP – 10 Years of achievements and more to come!

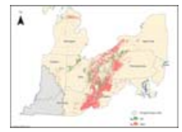
2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018

Phase I
Characterization





Phase II
Small Scale Validation



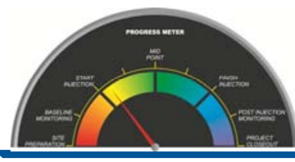
Phase III
Large Scale Field Validation

Site Selection, Permitting, Site Characterization, Site Preparation, and Baseline Monitoring

OH Site | **MI Saline** | **MI EOR Fields**

MI Injection Operations (Multiple Reefs)

Post Injection Monitoring

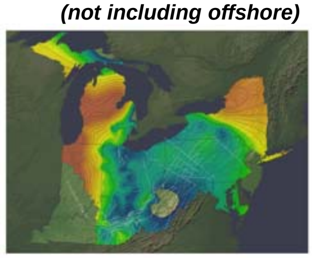


CO_2 Storage resources – significant but heterogeneous potential

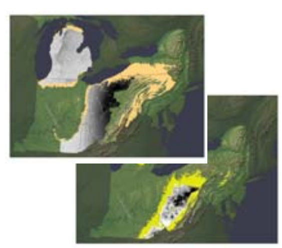
- Many promising units for CO_2 storage including saline formations, depleted oil/gas fields, and potentially organic shales, and coal beds
- Mapping and understanding the storage zones is an ongoing effort
- Primary targets include Mt. Simon Sandstone along the arches and carbonate layers in deeper basins

Depleted Oil and Gas Fields: ~8.500 GT

Deep Saline Formations: ~49-194 GT (not including offshore)

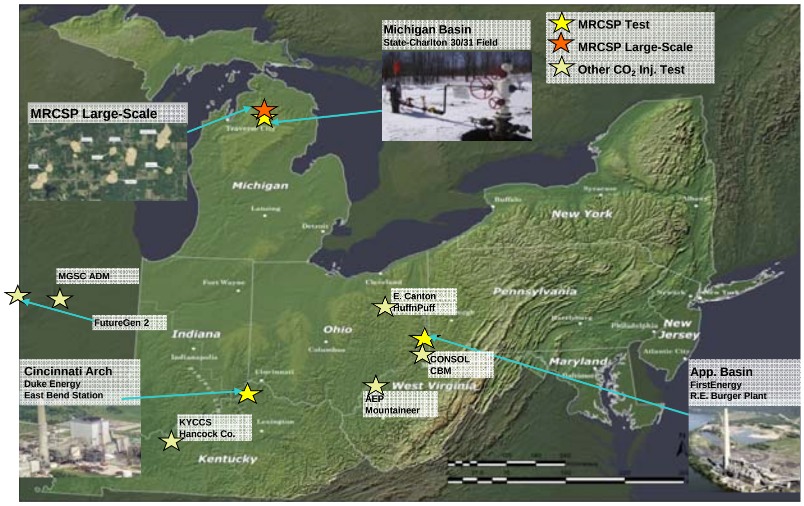


Organic Shales: ~2-30 GT
Unmineable Coal: ~1 GT



Many field tests demonstrate heterogeneous storage potential in MRCSP region

Region is home to several field tests – but many more are needed



MRCSP Ten-Years - Key Observations

Technical Issues

- Small-scale tests extremely useful in proving safety and effectiveness – *we need more of these*
- Injectivity different at each site
- Monitoring data redefined geologic model in all cases
- Regional heterogeneity necessitates extended mapping and multiple field tests
- Continued testing and evaluation of monitoring technologies needed to build confidence

Social Issues

- Proactive outreach and collaboration with host site teams crucial for public acceptance

Permitting

- Class V experimental permits enabled testing
- EOR sites can enable CCUS deployment and research – but only have one site in MRCSP region

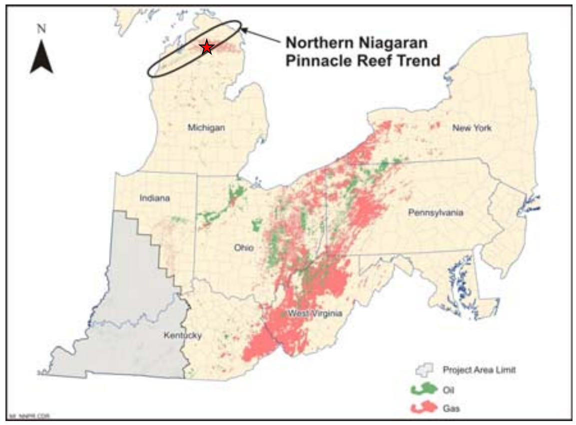
Other

- RCSP research can also benefit other energy R&D – brine disposal, wellbore integrity, shale gas

MRCSP region has many large historic oil and gas producing areas

- ~ 8,500 million metric tons of CO_2 could be stored within depleted O&G fields (~10 years worth of regional emissions)*
- Using CO_2 for EOR could lead to the production of an additional ~1.2 billion barrels* of oil
- However, EOR needs to be proven in the region

Oil and gas fields map for region*



* Source: *Estimates developed by the Geological Surveys within the MRCSP*

MRCSP large-scale test site — only CO_2–EOR site in the Midwest

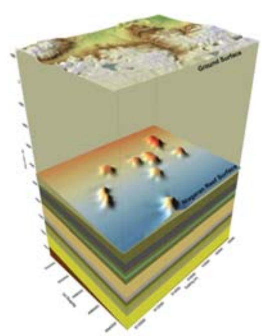
Location:
Otsego County, Michigan

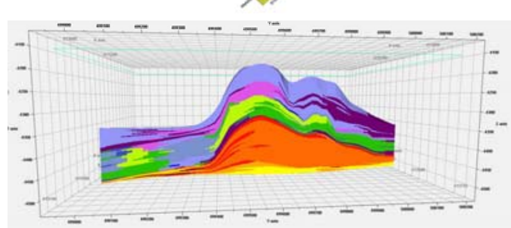
Host Company:
Core Energy LLC

Reservoir Type:
Closely-spaced, highly compartmentalized oil & gas fields located in the Northern Michigan Niagaran Reef Trend

Source of CO_2:
Natural Gas Processing Plant

Injection Goal:
At least 1 million metric tons of CO_2 over ~four years

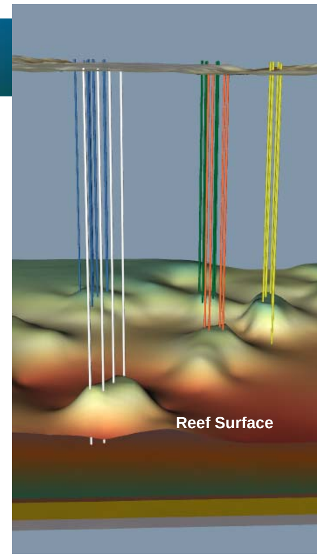




MRCSP study fields are in multiple oil production stages

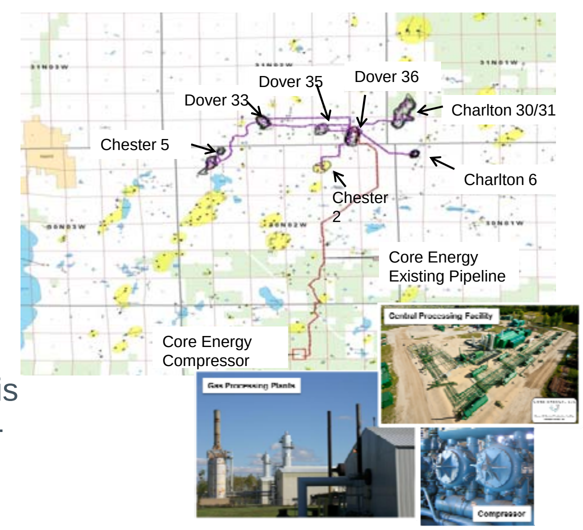
Oil fields are in various production life-cycle stages

- **Late-Stage EOR Reefs**
  Undergone extensive primary and CO_2-EOR – highly depleted
- **Active EOR Reefs**
  Completed primary oil recovery and CO_2-EOR is under way
- **Pre-EOR Reefs** – New CO_2 EOR
  Undergone primary oil recovery but no CO_2-EOR yet



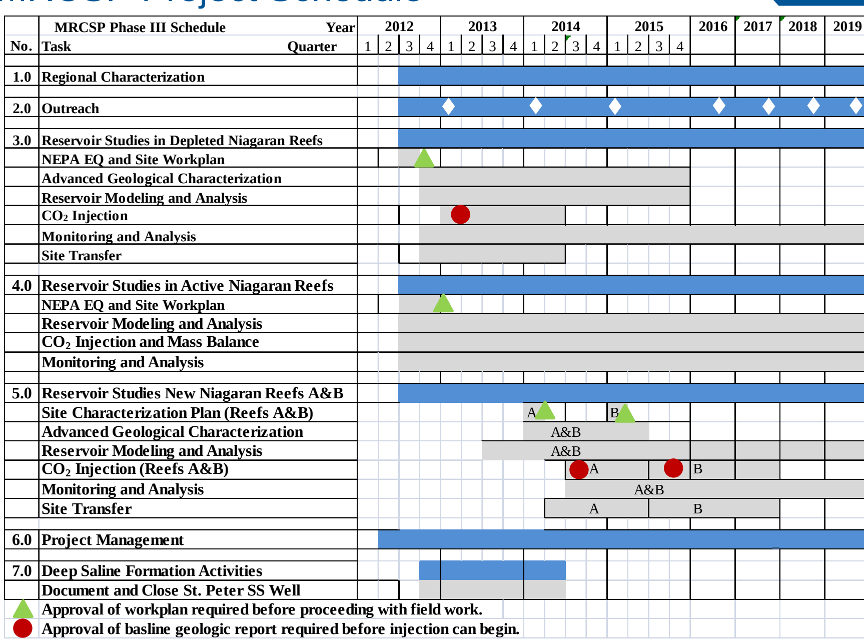
Existing EOR infrastructure enables cost effective research for MRCSP tests

- Infrastructure:
  - CO_2 uptake from capture
  - Compression and dehydration systems
  - Pipelines for transport
  - Central processing facility (Dover 36)
  - Injection and production-monitoring wells (7 fields)
  - Monitoring and measurement systems
- Total system capacity is >1200 tonnes/day (10-15% of 500MW coal-based plant)



Dover 36 Processing Facility – central hub for fluids and data flow

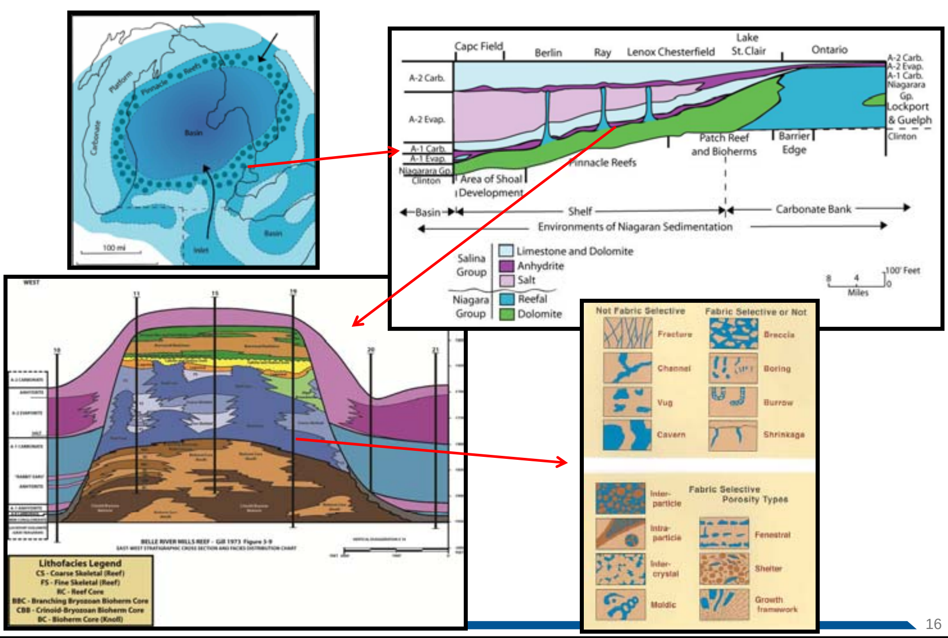
MRCSP Project Schedule



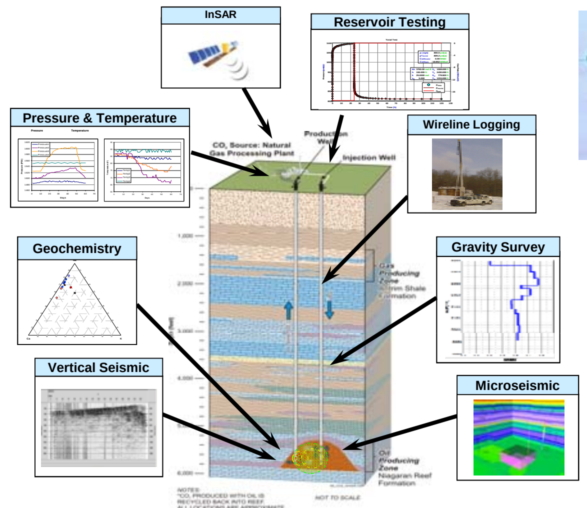
MRCSP field test research objectives

Site Characterization	Assess the variability among adjacent reefs
Reservoir Models	Validate using injection and production
Operational Models	Predict CO_2 storage and oil production; suggest approaches to optimize both
Monitoring Techniques and Equipment	Identify cost effective and useful techniques and methods
Reef Capacity and Injectivity	Identify key parameters and variability; address uncertainty

Geologic Setting – Complex Reef Structures



Highly depleted field provides a test bed for advanced monitoring technologies



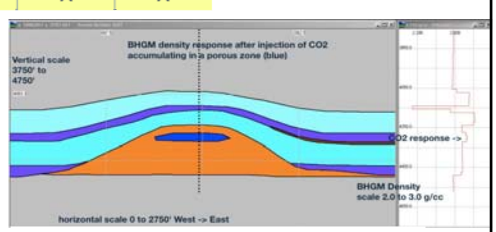
Monitoring options under testing at Dover 33 field

MRCSP Dover 33 field monitoring program

Activity	Before Injection	Early Injection	Mid Injection	Late Injection	After Injection
CO_2 Injection		X	X	X	
Pressure and temperature	X	X	X	X	X
Wireline Logging	X		X		X
Fluid Sampling	X		X		X
Borehole Gravity	X				X
VSP	X				X
Microseismic	X			Maybe	
InSAR	X	X	X	X	X

Borehole gravity meter being assembled

- Late stage, Dover 33, serves as main test bed for monitoring techniques
- Instrumented wells and pipelines in active fields to track CO_2 injection and CO_2, brine, and oil production
- Lessons learned will be applied to design MVA plan for newly targeted field for EOR (to be determined)



Model assessing feasibility of the borehole gravity meter to measure changes in formation density in response to CO2

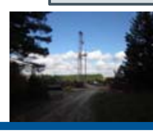
MRCSP Phase III Field Activities – Dover 33

2012			2013											
Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Baseline Characterization							Long-Term Injection Operations							

- Baseline Geochemical Sampling
- Well Workovers and Wireline Logging
- Gravity Survey
- Vertical Seismic Profiling
- Reservoir Testing and Microseismic Testing
- Start of Long-Term Injection – April 23
- Repeat Geochemical Sampling
- Pressure Fall Off Testing
- Repeat Geochemical Sampling






Safety Considerations for MRCSP Fieldwork

- Wide variety of work -- wide range of safety considerations
- All work completed safely to date!

Fluid Sampling and Reservoir Testing – high pressure fluids, well work

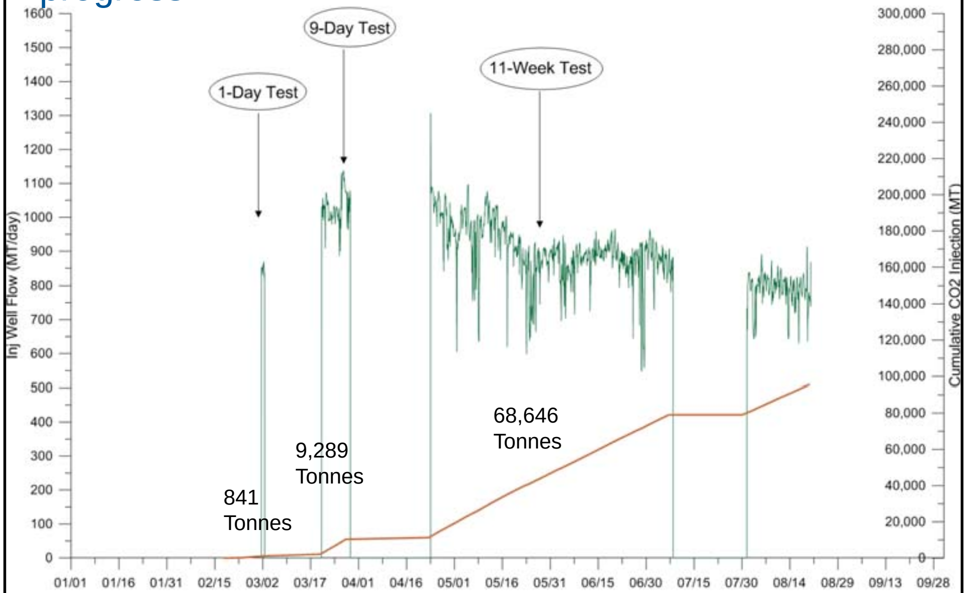
InSar ACRs – heavy equipment operation

Well Workovers – well control, overhead hazards, heavy equipment

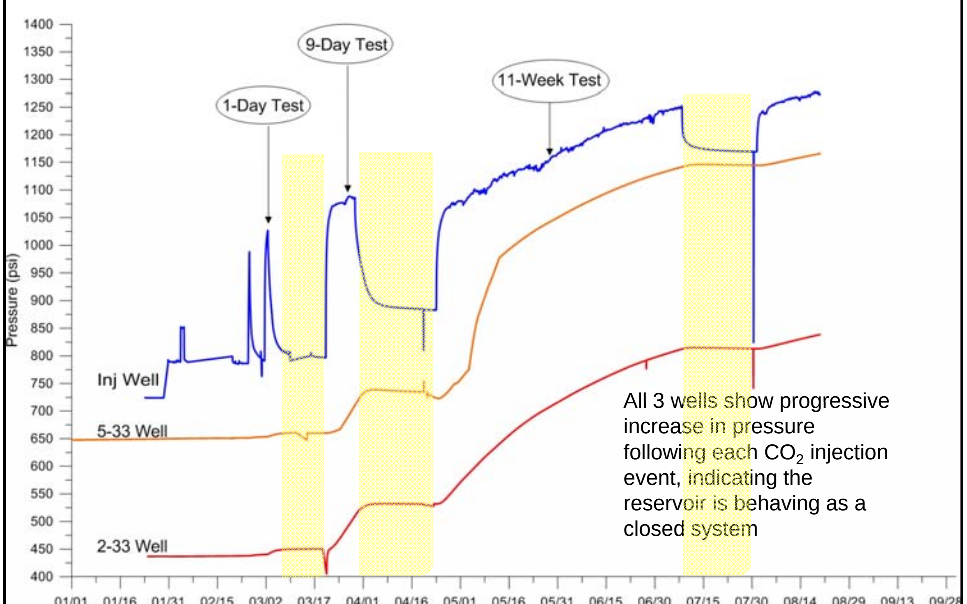
Seismic Activities – well work, explosive hazards

Wireline Logging – well work, radiologic hazards

Late-Stage reef (Dover 33) CO_2 injection progress

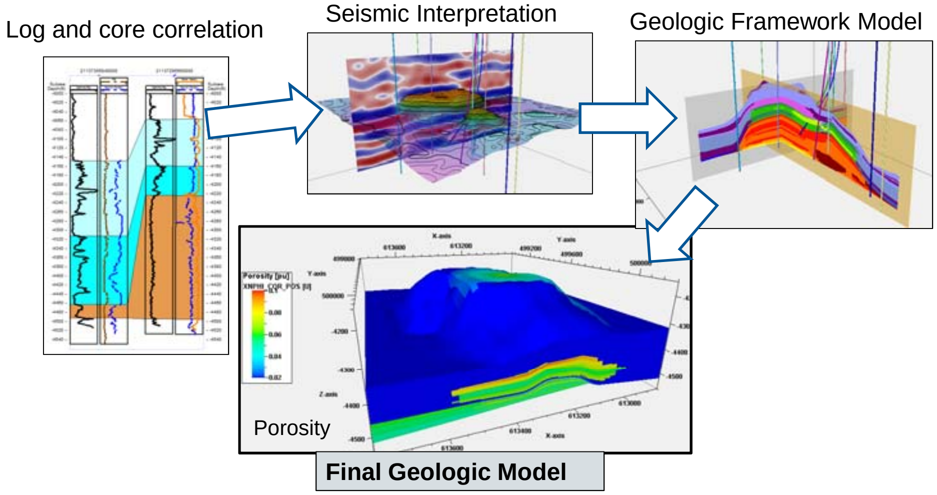


Pressure response in 3 wells in late-stage reef



All 3 wells show progressive increase in pressure following each CO_2 injection event, indicating the reservoir is behaving as a closed system

Developing detailed geologic model work for MRCSP based on seismic and well log data



The modeling integrates seismic and well log data
Provides basis for fluids flow models

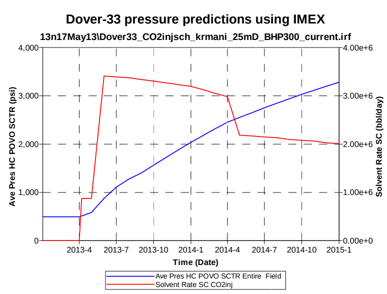
MRCSP Dynamic reservoir simulations

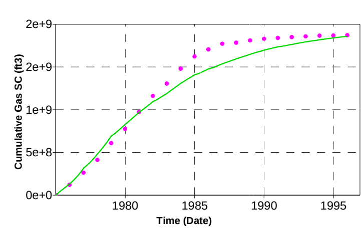
Expected Outcome:

- Full accounting for (1) reservoir geology and (2) compositional phase behavior

Strategy:

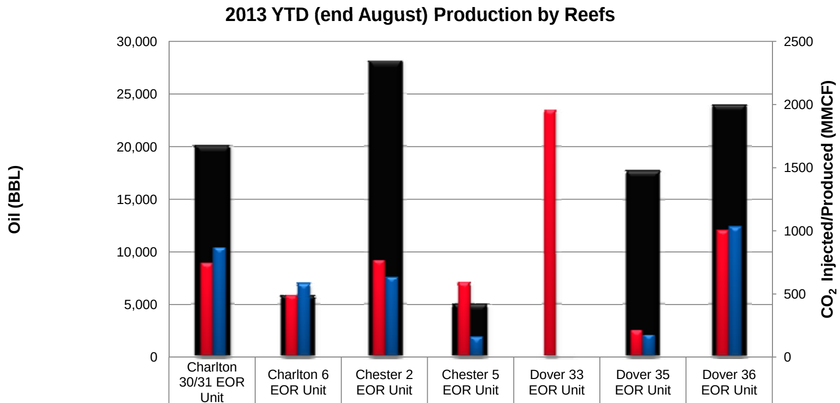
- **CO_2-Prophet** for initial simulations
- **GEM** (Computer Modeling Group) to model multiphase flows for CO_2-EOR
- Requires detailed information about (1) rock / fluid properties and (2) production history
- Can be used for all phases of history matching (primary, CO_2-EOR, depleted), flood design and production forecasting
- Possible partial or full coupling of flow, geochemistry, and geomechanics





MRCSP – Understanding CO_2-EOR System-wide operations

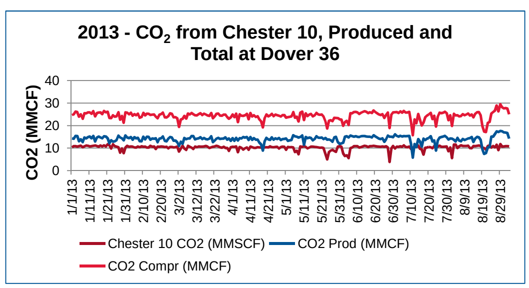
- Data collection and reporting from all fields
- Compilation and review of historic operations data
- Systematic calibration of flow meters

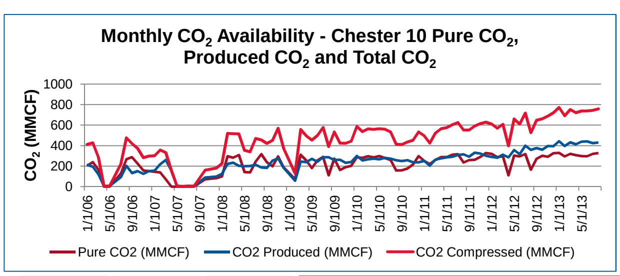


	Charlton 30/31 EOR Unit	Charlton 6 EOR Unit	Chester 2 EOR Unit	Chester 5 EOR Unit	Dover 33 EOR Unit	Dover 35 EOR Unit	Dover 36 EOR Unit
Gross Oil (BBL)	20,037	5,836	28,166	4,997	45	17,706	23,982
CO2 Injected (MMCF)	738	488	765	587	1960	204	1004
CO2 Produced (MMCF)	863	583	631	149	3	168	1029

MRCSP Facility-wide CO_2 supply and injection/production history

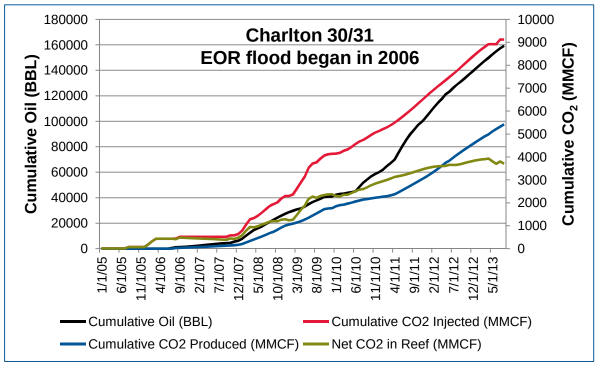
- Chester 10 and recycled CO_2 Supply since 2006 and during 2013
- Data useful for history matching in models and evaluating CO_2 retention





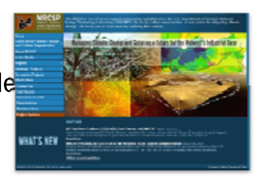
Monitoring in Active EOR Reefs

- Work plan approved by DOE
  - Review historical operations
  - Selected piggyback monitoring
  - Model one reef in detail
  - Evaluate mass balance and retention



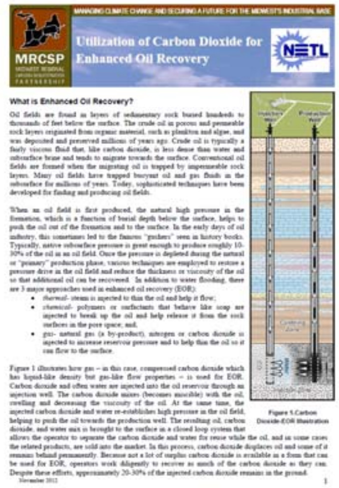
MRCSP Outreach Goals

- Support the large volume injection test
  - Updated communication plan for restructured project
- Maintain reputation of MRCSP as a neutral and credible source of scientific information on CCS
  - Over 20 Topical Reports available
  - Over 30 Presentations and Briefings available on MRCSP Website
- Improve public understanding and acceptance of CC
  - Synthesizing project results into key findings and messag for stakeholders.
- Increase public understanding of EOR, subsurface activities, and their role in the larger energy mix
  - Speaking at conferences and meeting with trade associations



Site Specific Outreach Activities

- Maintaining regulatory and community relationships
  - ~250 VSP shot points and 29 artificial reflectors installed on private property
- Monitoring events and issues that could have a bearing on public views of the project (e.g., shale plays, “fracking”).
- Building upon a broad suite of communications materials and tools to support project
  - Developing new outreach materials
  - Posting “Project Snapshots” on the MRCSP website
- Hosting site tours

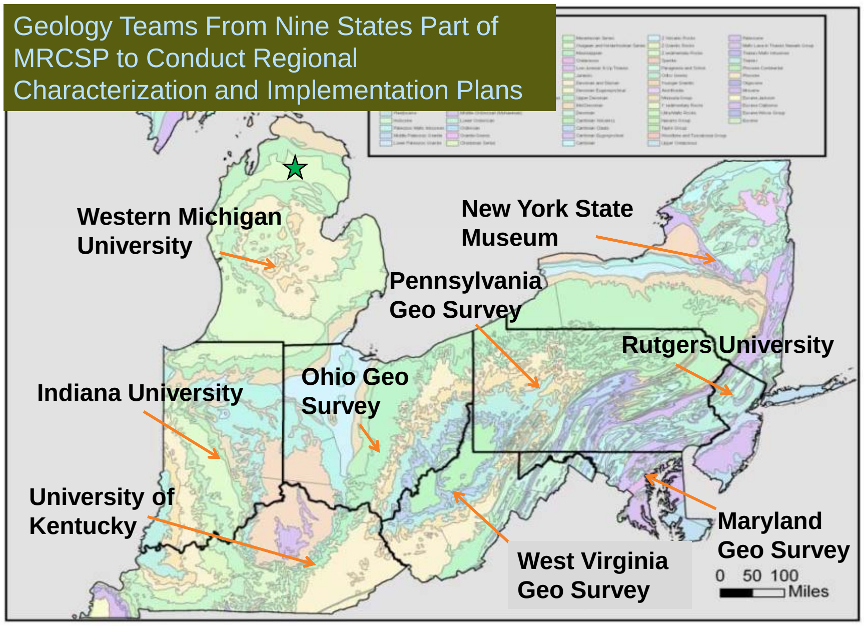


MRCSP Fact Sheet on Enhanced Oil Recovery (EOR)

Knowledge sharing continues to be an important outcome of the MRCSP program

- FutureGen2.0 geologic storage program
- Appalachian Basin and Ohio
  - AEP Mountaineer site
  - CO_2-utilization for EOR and storage options
  - Wellbore integrity assessment
  - Brine disposal options
- International - World Bank CCUS capacity building in China
  - Hosting delegation visits
  - Sichuan basin storage potential
- Dialogue with other partnerships

Geology Teams From Nine States Part of MRCSP to Conduct Regional Characterization and Implementation Plans



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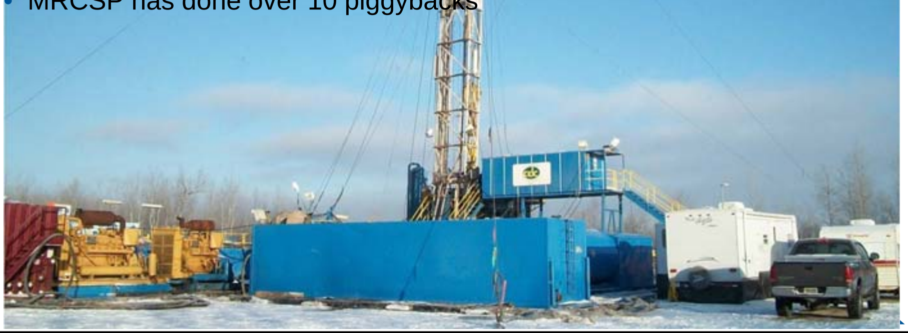
MRCSP Phase III piggy-back geology characterization efforts

- Adams Well (Deep Geology)
- Cargas Well (Pipe Conveyed)
- Cutter Well (Promising Targets)
- 3D/3C Seismic Data (Niagaran Reefs)
- 2-D Seismic (Over 200 miles of new lines)
- MRCSP has done over 10 piggybacks



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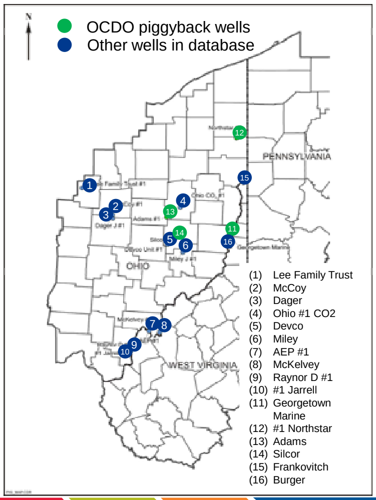
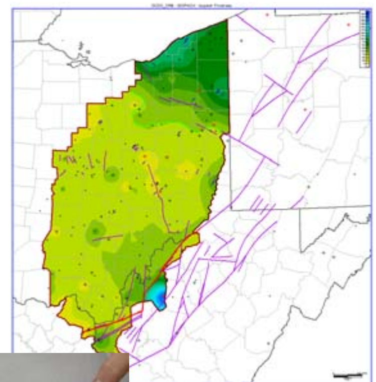
Finding storage options in Appalachian Basin

- Battelle is working with oil/gas operators to obtain crucial geologic data for mapping storage zones
- Funded by Ohio Coal Development Office as a joint effort with MRCSP

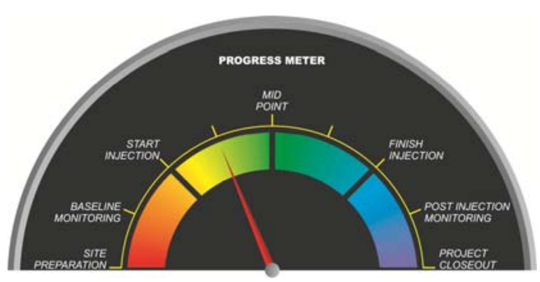




Copper Ridge vuggy Dolomite Core 8370’

MRCSP status and plans

- MRCSP Phase III injection began Feb. 2013 –
- ~350K tonnes till Oct. 2013 in Dover 33 and other active reefs
- Up to 500,000 tonnes of CO_2 injection planned in Dover 33 depleted reef
- Additional fields for new CO_2-EOR tests with ~500,000 tonnes planned
- >200,000 tonnes injection monitored in active reefs by Oct. 2013
- A period of monitoring after completion of injection
- Wells to be returned for normal operations by Core Energy at the end




Battelle
Acknowledgements
Work presented here has been conducted by Battelle Geosciences team, our collaborators, and field services providers
Projects have been sponsored by The US DOE, The Ohio Coal Development Office, and several companies
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