Midwestern Regional Carbon Sequestration Partnership (MRCSP)

Neeraj Gupta, Battelle (gupta@battelle.org)

CSLF Technical Group Meeting, Champaign, Illinois, April 26, 2019

DOE/NETL # DE-FC26-05NT42589

NATIONAL ENERGY TECHNOLOGY LABORATORY

MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

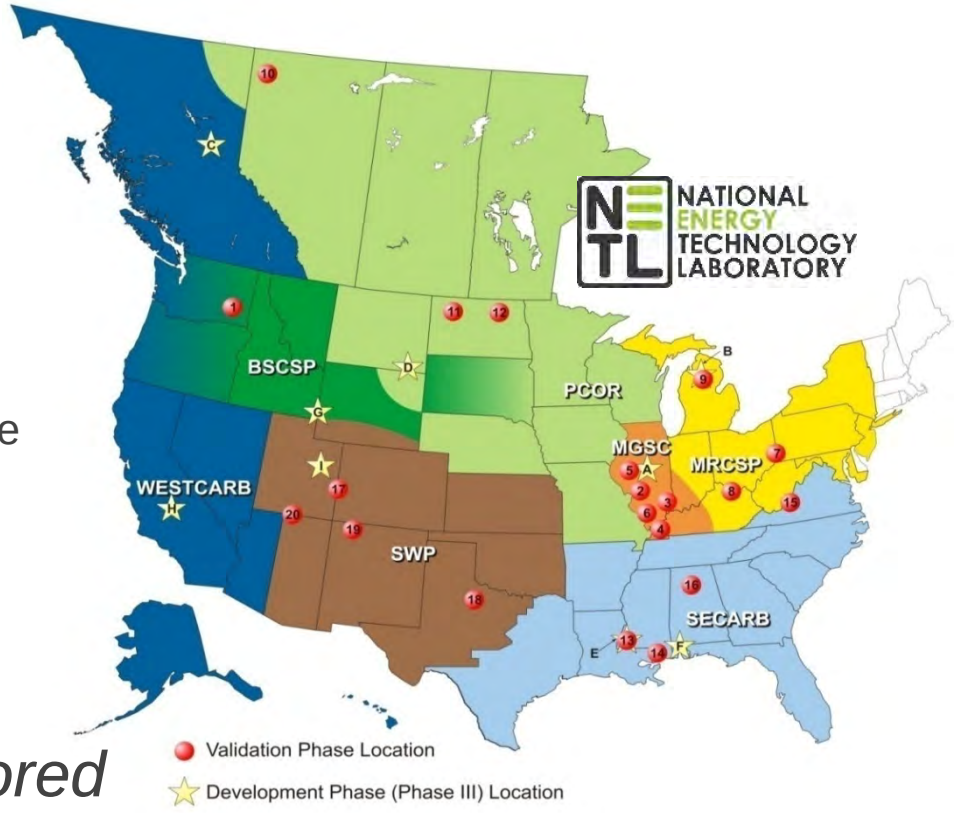
BATTELLE

MRCSP is Part of the Regional Carbon Sequestration Partnership Initiative by US-DOE

Primary goal: To execute a large-scale scale CO_2 injection test to evaluate best practices and technologies required to implement carbon sequestration

Objectives are to advance operational, monitoring, and modeling techniques needed to:

- Develop and validate reservoir models useful for commercial scale applications
- Address public concerns such as leakage and long-term storage security
- Address other topics such as cost effectiveness and CCUS practicability



Over 16 million metric tons stored

MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

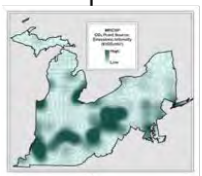
BATTELLE

Historical Snapshot of MRCSP – 16 Years of Progress

- One of seven DOE-funded regional partnerships to develop infrastructure for wide-scale CO_2 sequestration deployment

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

Phase I
Characterization

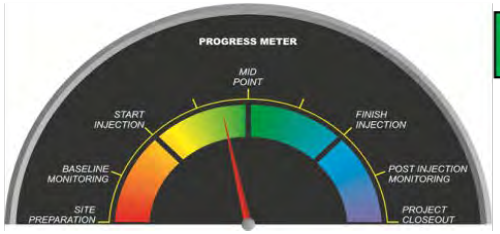

Phase II
Small Scale Validation




Phase III
Large Scale Development Project

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

OH Site | MI Saline | MI EOR Fields



MI Injection Operations (multiple fields)
- Late-stage EOR reef
- Operational EOR reef
- Newly targeted reef

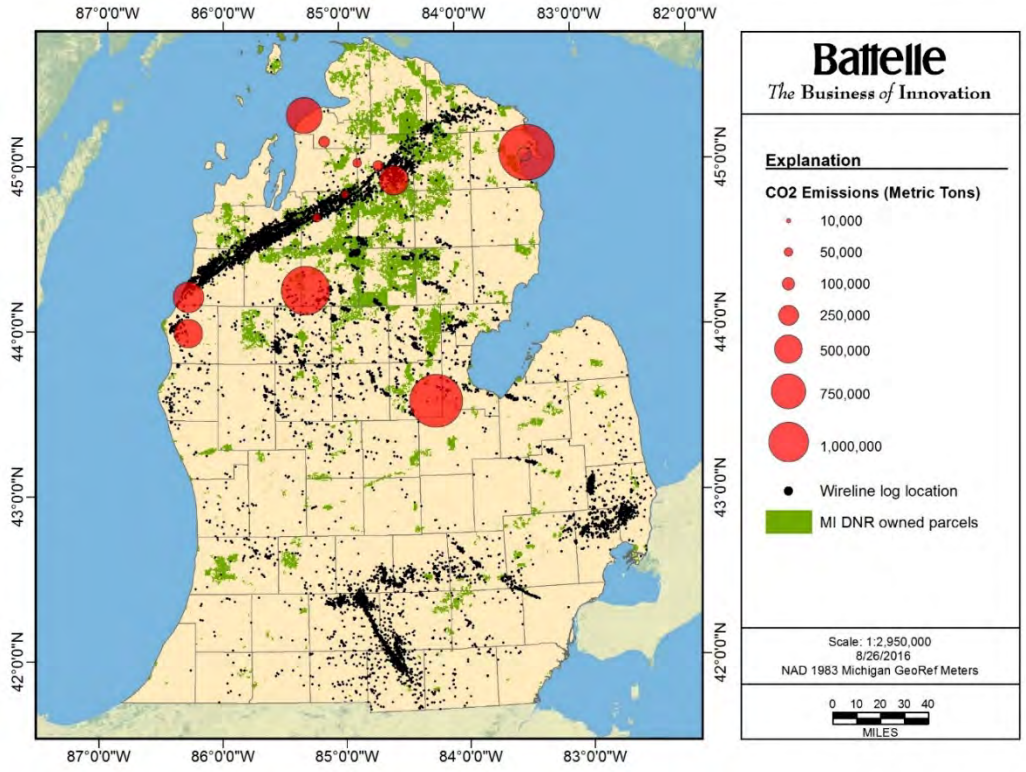
Post Injection Monitoring

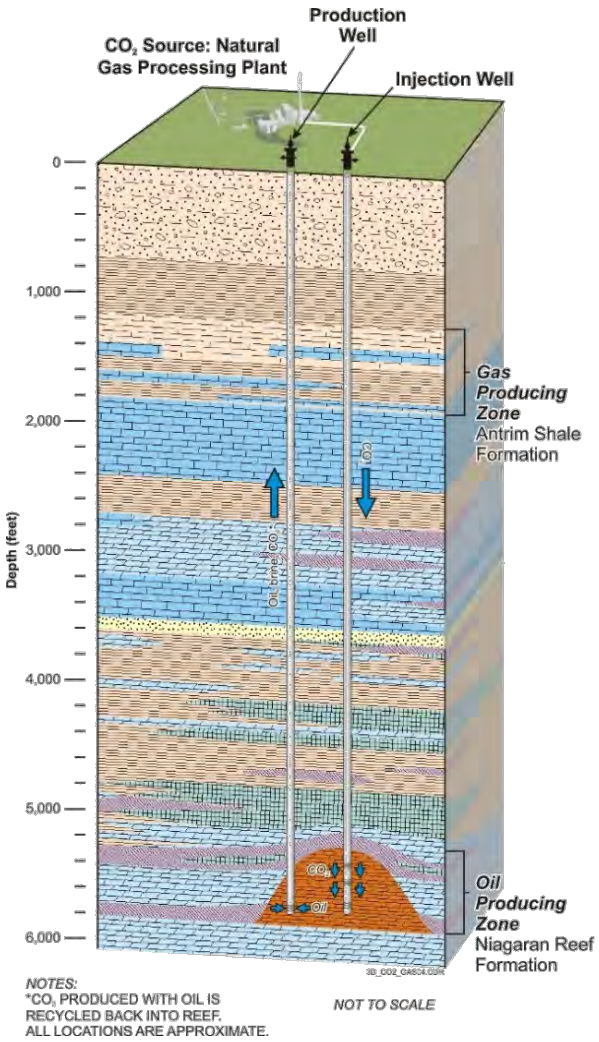
Project updates and results can be found at
www.mrcsp.org

MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP
BATTELLE

MRCSP Michigan Basin Large-Scale Injection

- Objective – Inject/monitor 1 million metric tons of CO_2 in collaboration with EOR operations.
- Evaluate CO_2 injectivity, migration, containment





MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

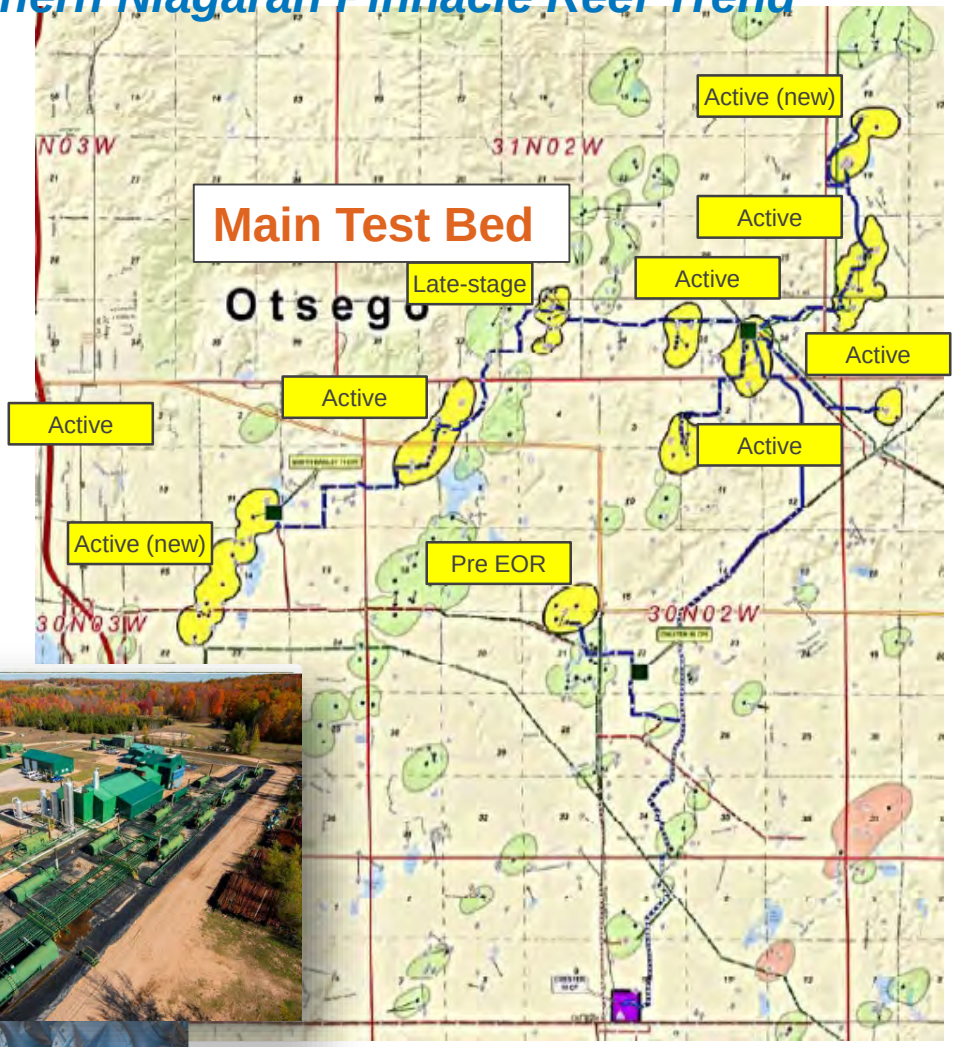
BATTELLE

Large-Scale Injection Test

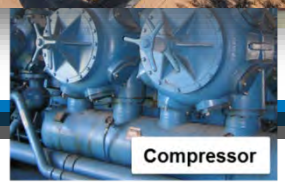
Geologic Setting in Michigan's Northern Niagaran Pinnacle Reef Trend

EOR Facilities owned and operated by Core Energy

- Complete CCUS value chain
- >20 years EOR ops.
- Expand research with new reefs
- Flexible research portfolio



Natural gas processing is the source of **the CO_2**



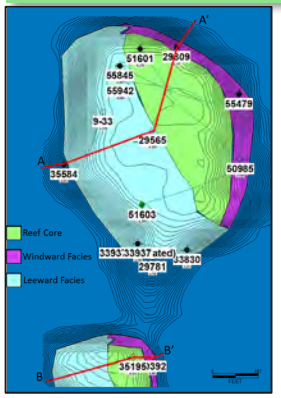
MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

Large-scale Injection Test

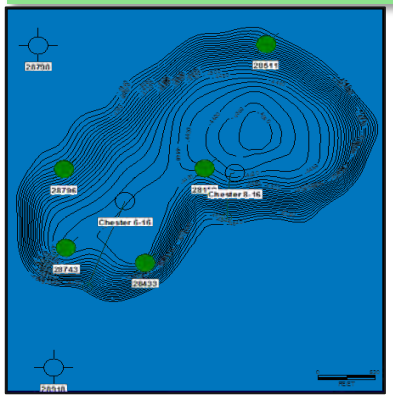
Key Reefs Vary in Setting and Operational History

Late-Stage Reef: Dover 33



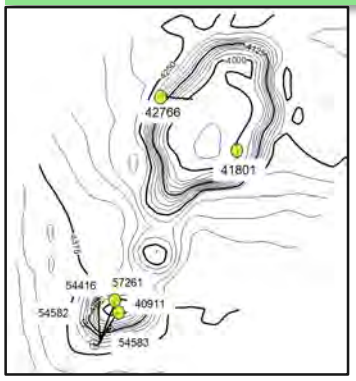
1 Lobe
Operational since 1974
Primary Production + CO_2-EOR
MRCSP CO_2 Injection since 2013
- 1 CO_2 Injection Wells
- 2(+1) Monitoring/ Production Wells

Chester 16



2 Lobes
Operational since 1971
Primary Production + Water EOR
MRCSP CO_2 Injection since 2017
- 1 CO_2 Injection Well
- 1 Monitoring Well

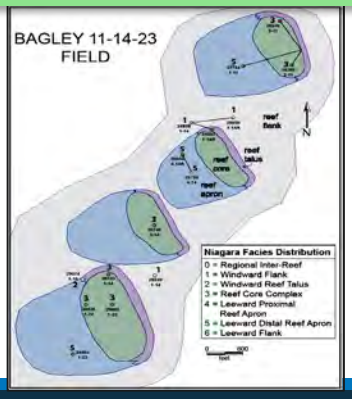
Charlton 19



2 Lobes
Operational since 1988
Primary Production
MRCSP CO_2 Injection 2015-2017
- 1 CO_2 Injection Wells
- 2 Monitoring Wells

Currently in CO_2-EOR

Bagley



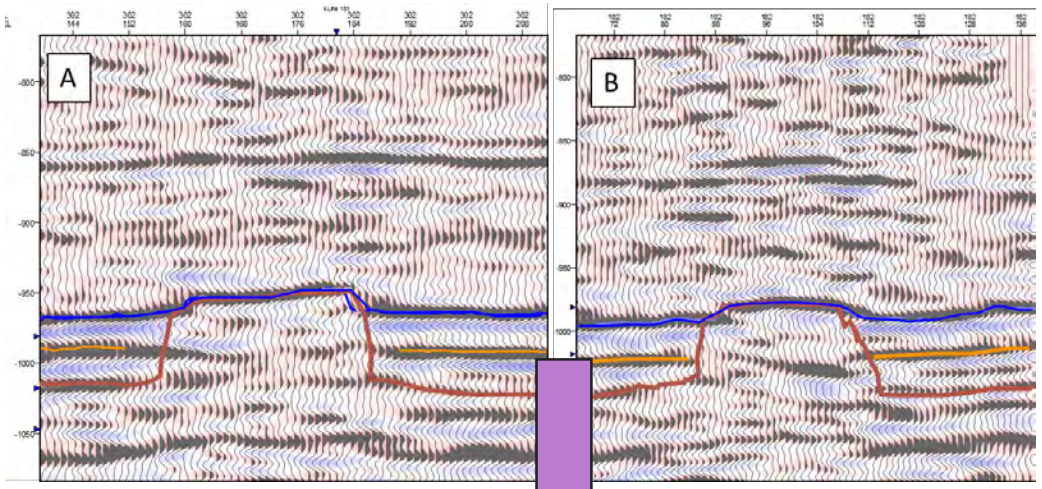
4 Lobes
Operational since 1973
Primary Production only
MRCSP CO_2 Injection since 2015
- 3 CO_2 Injection Wells
- 4 Monitoring Wells

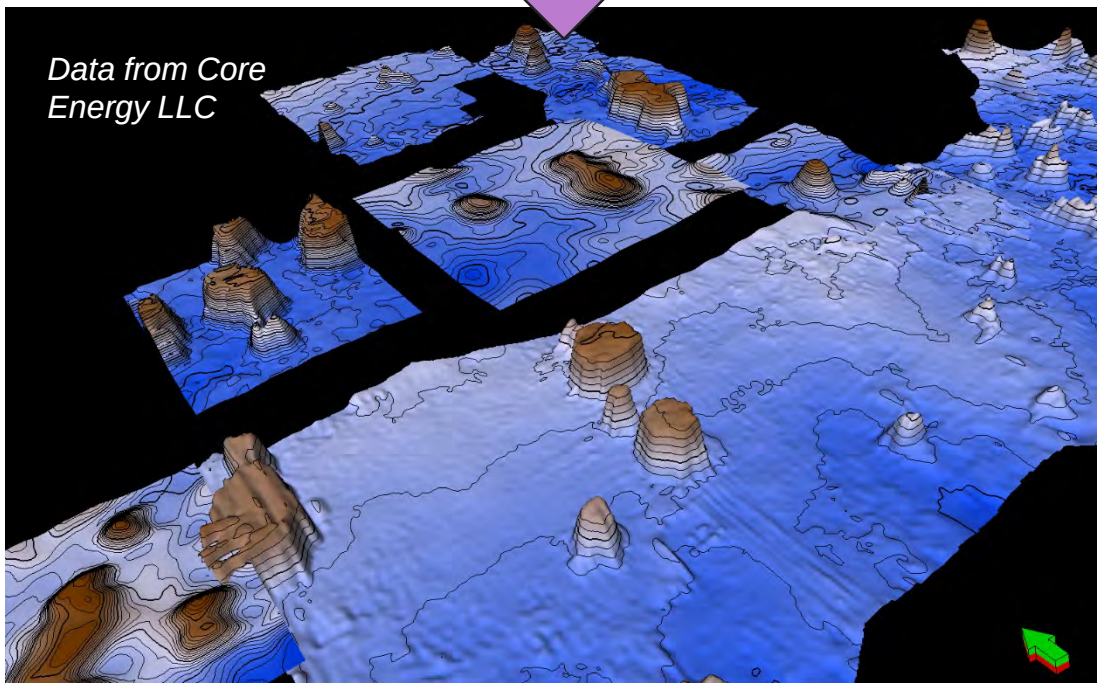
MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

Seismic Analysis to Reduce Uncertainty

- Collaboration with Core Energy
- Extent and reef geometry
- Number of reef pods within a field
- Poor internal resolution- needs integration with log and core





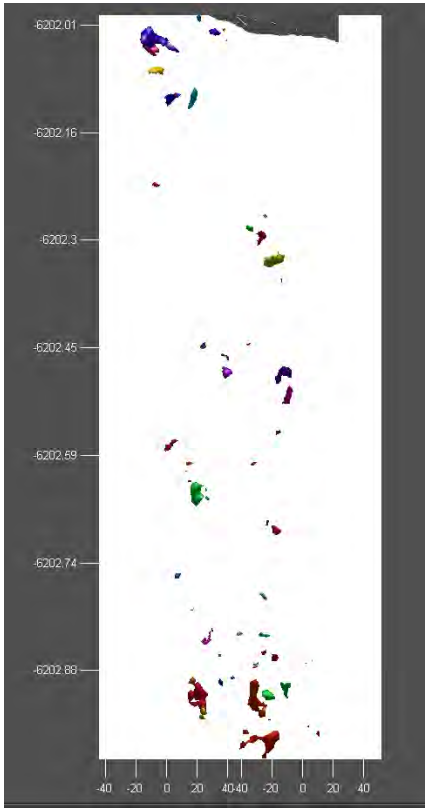
MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

Core Analyses Used to Quantify Reservoir Properties

- Changes in rock type, porosity, permeability, 3D analysis, etc.

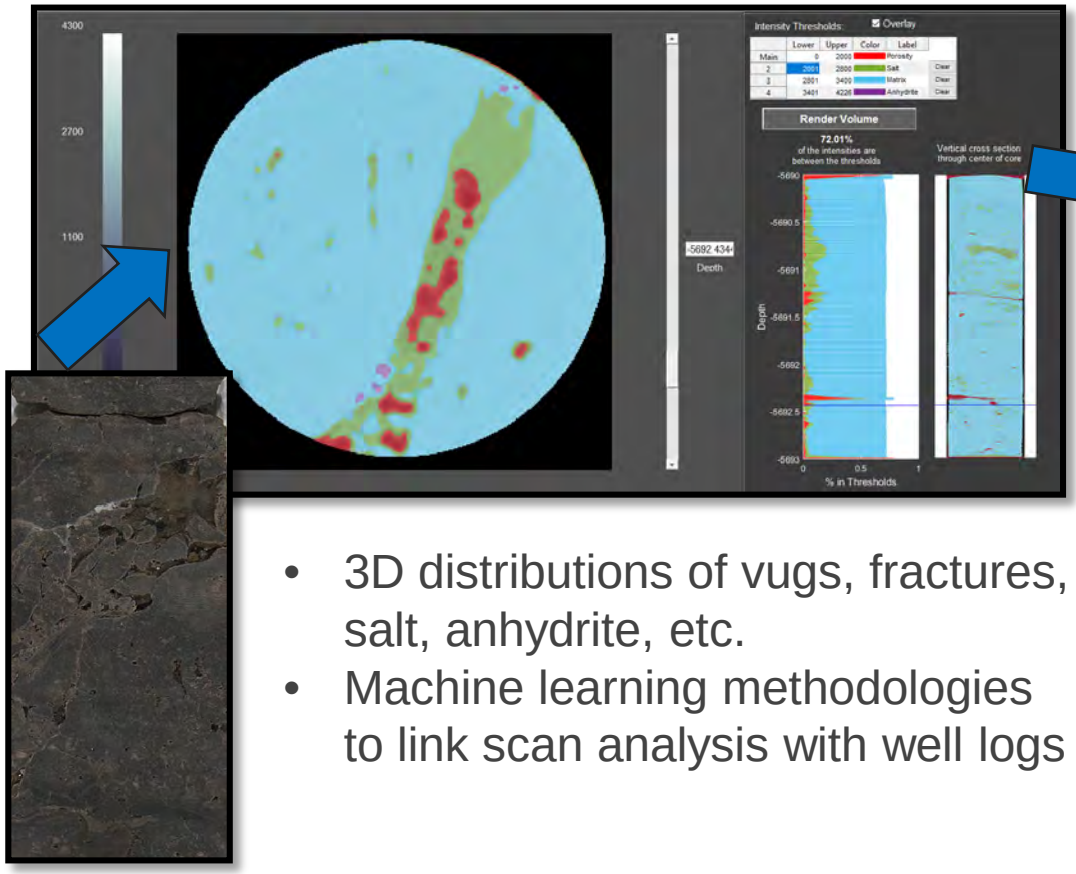
Depth	Lith Log	Core Photo		CT Scan	Depth	Description	Detail Photo	
ft		White Light	UV Light		ft		White Light	UV Light
					6,202	Small vugs, clasts, stylolites, open fractures, filled fractures, oil shows in UV, biologic material	6,202 ft BM STY	6,202 ft OS FF
					6,203	clasts, small vugs, stylolites, open fractures, filled fractures		
					6,204	clasts, small to medium vugs, stylolites, porous dolomite	6,204 ft FP STY V	6,204 ft FP



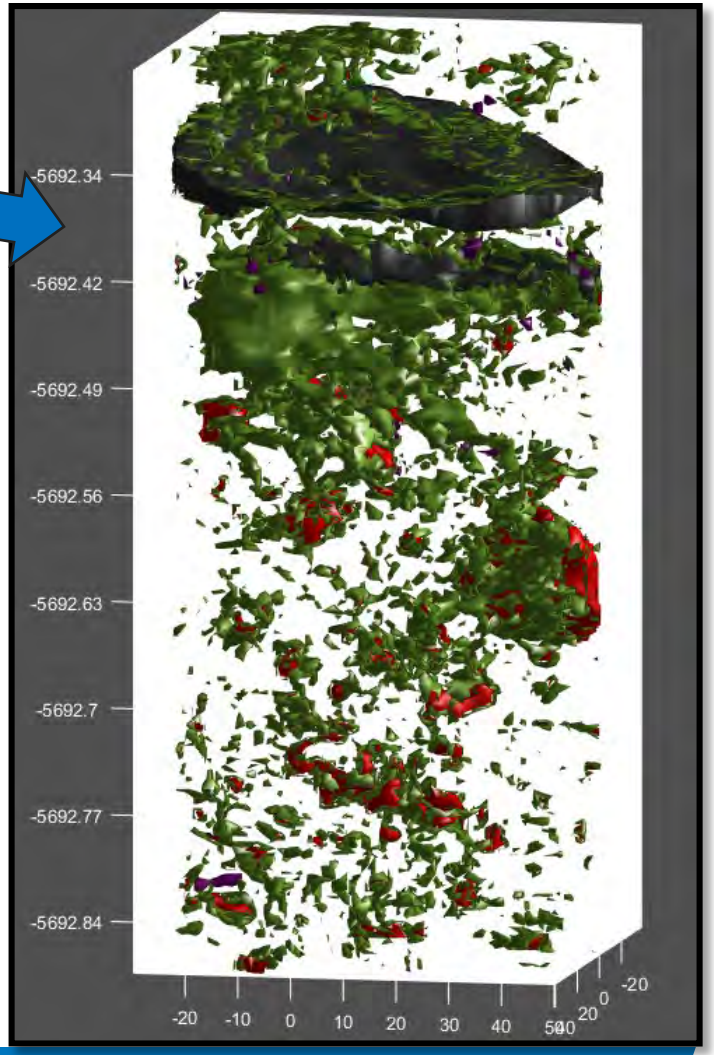
MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

Characterizing and Predicting Reservoir Controls from Core Scans



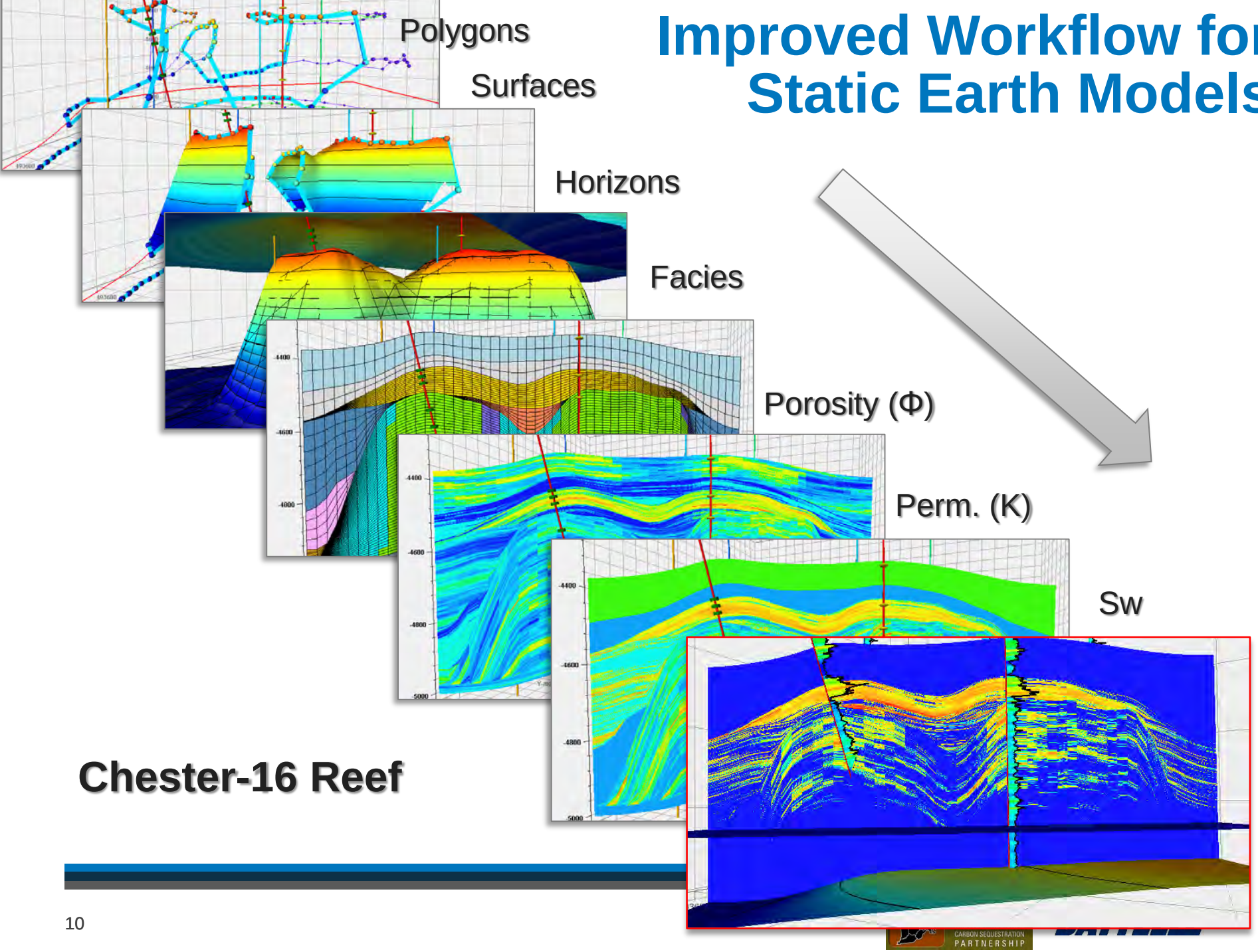
- 3D distributions of vugs, fractures, salt, anhydrite, etc.
- Machine learning methodologies to link scan analysis with well logs



MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

Improved Workflow for Static Earth Models

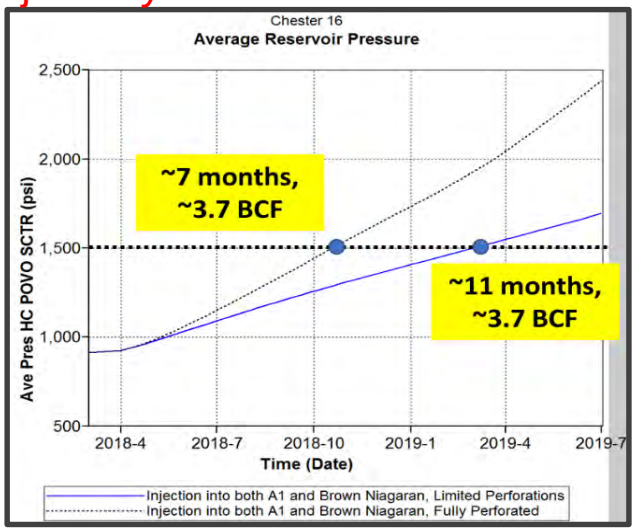


Chester-16 Reef

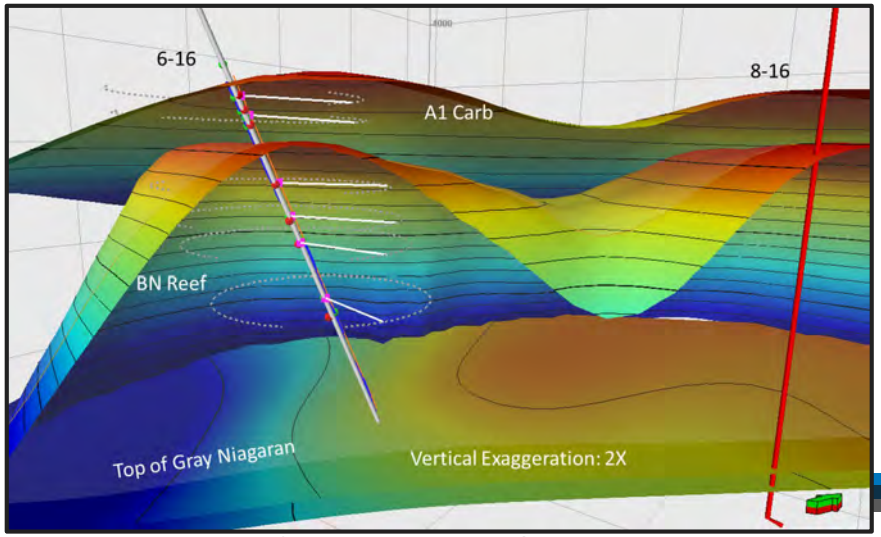
Evaluating Alternate Solutions to Improve CO_2 Injectivity

- Increasing the number of perforations provides only marginal improvement
- Drilling radial "tunnels" is more effective; performs similar to a horizontal well

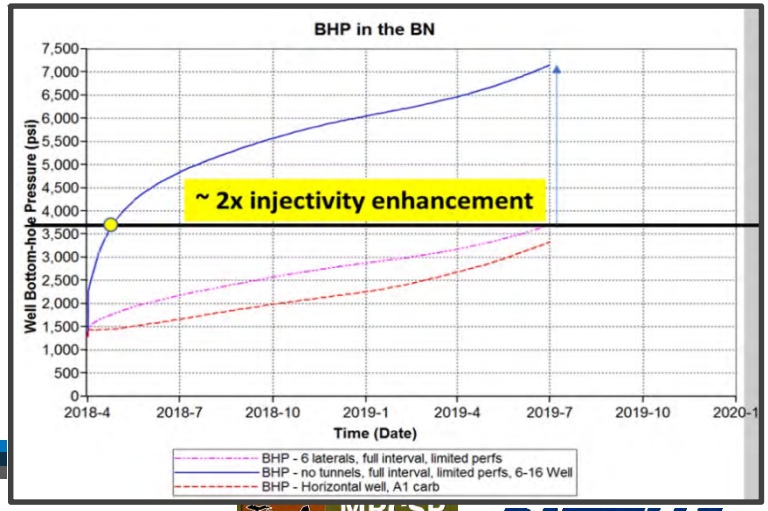
Injectivity with Increased Perforations



Radial Tunnels are small open boreholes drilled laterally from existing well



Injectivity with Radial Tunnels



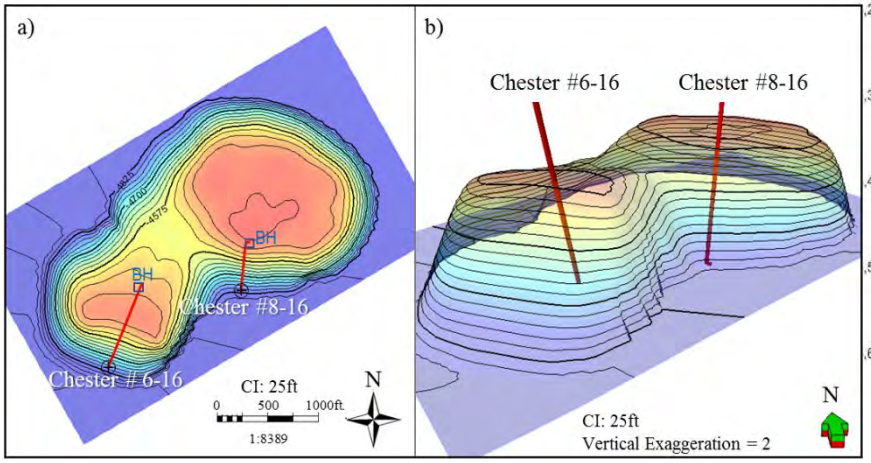
Objectives of MRCSP Monitoring

- Evaluate various monitoring techniques for suitability in pinnacle reef reservoirs
- Tracking CO_2 in the reservoir
- Leak detection/well integrity
- Induced seismicity/uplift monitoring

Monitoring Technology	Account-ing	Leak Detection/ well integrity	CO_2 plume tracking	Induced seismicity /uplift
CO_2 injection rate	X		X	
Reservoir Pressure		X	X	
Temperature (DTS)		X	X	
PNC logging		X	X	
Borehole gravity			X	
Reservoir Geochemistry			X	
Vertical Seismic Profile		X	X	
Cross-Well Seismic		X	X	
Microseismic				X
InSAR (Satellite radar)				X

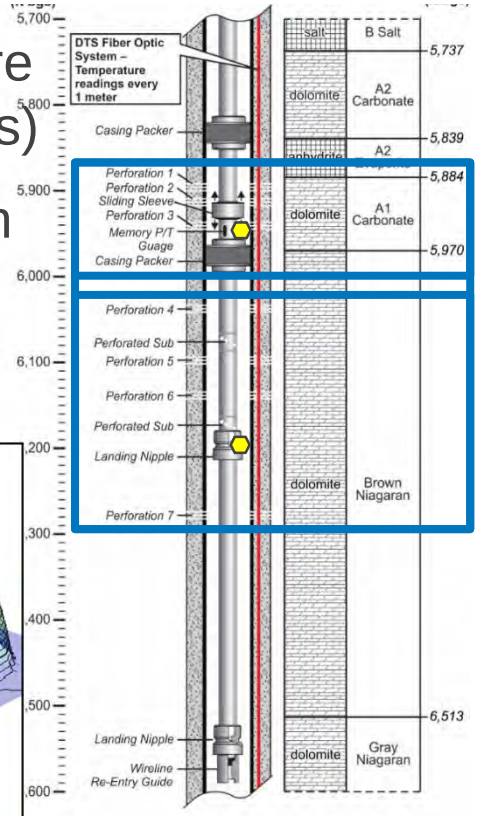
Temperature Monitoring Methods

- DTS – Real-time, fiber-optic data
- Five Behind-casing Temperature (and pressure) sensors (gauges)
- Memory gauges inside injection tubing at reservoir depth



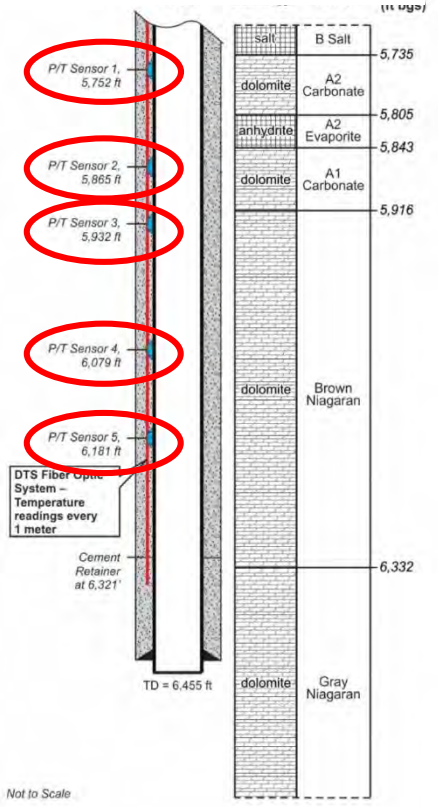
Chester 16 Reef

6-16 Injection Well



- DTS
- 2 Memory gauges inside injection tubing

8-16 Monitoring Well

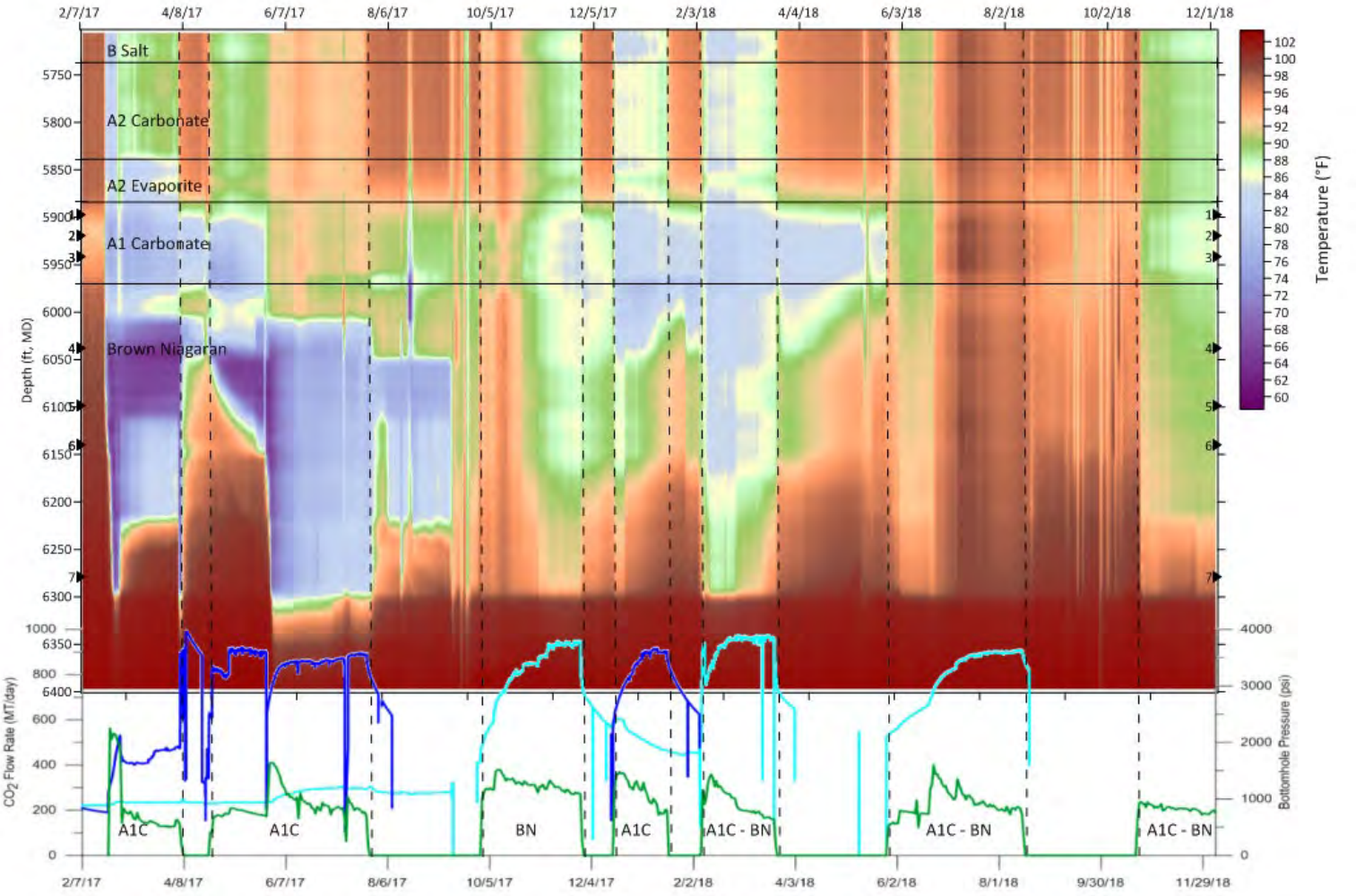


- DTS
- 5 permanent discrete depth gauges

Discerning CO_2 Flow Zones with DTS

Warm-back Maps for CO_2 Intake Zones

Chester 6-16 Master Waterfall Plot



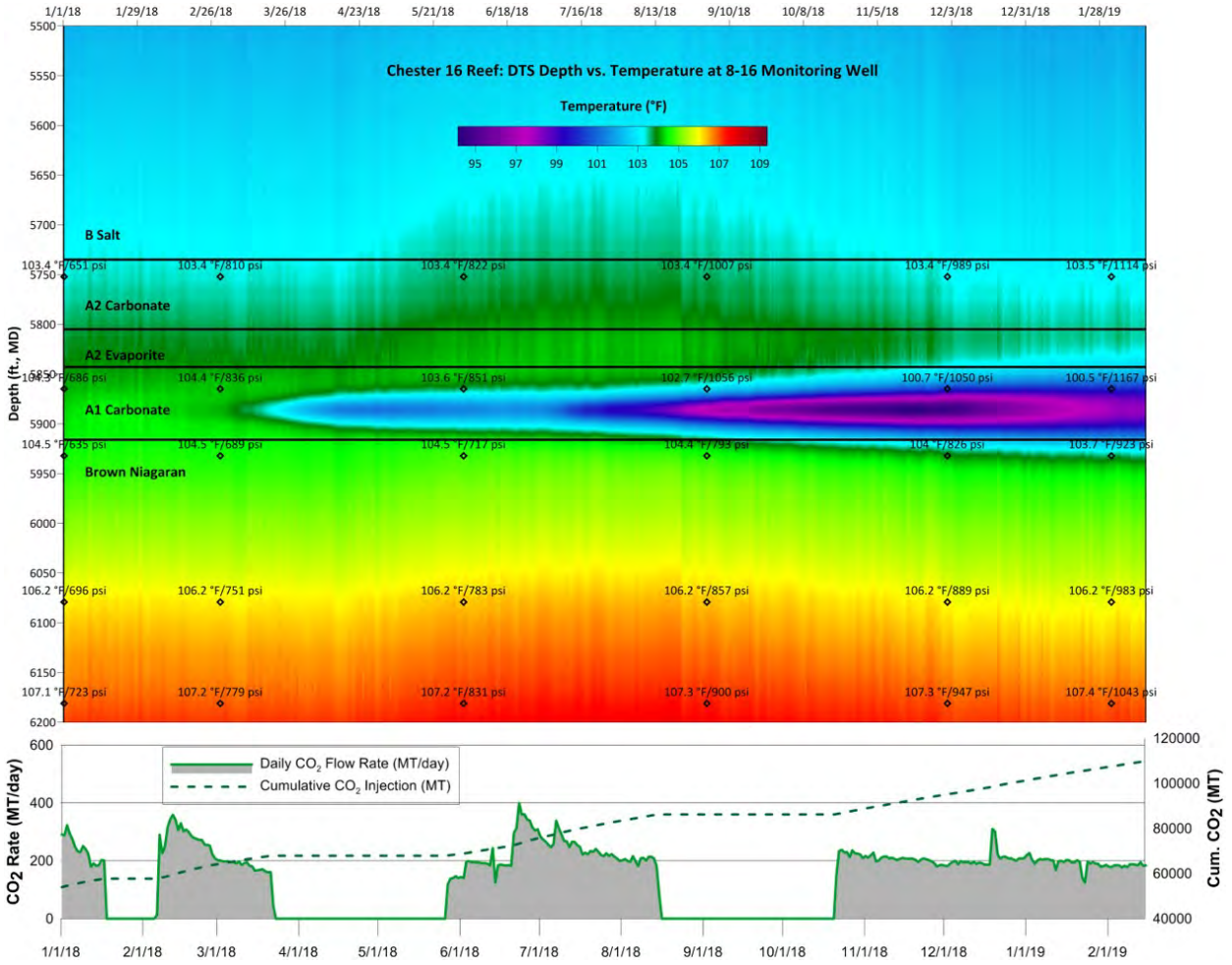
MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

Discerning CO_2 Migration with DTS

CO_2 Moves to the top of reef in Obs. Well

Chester 8-16 Waterfall Plot

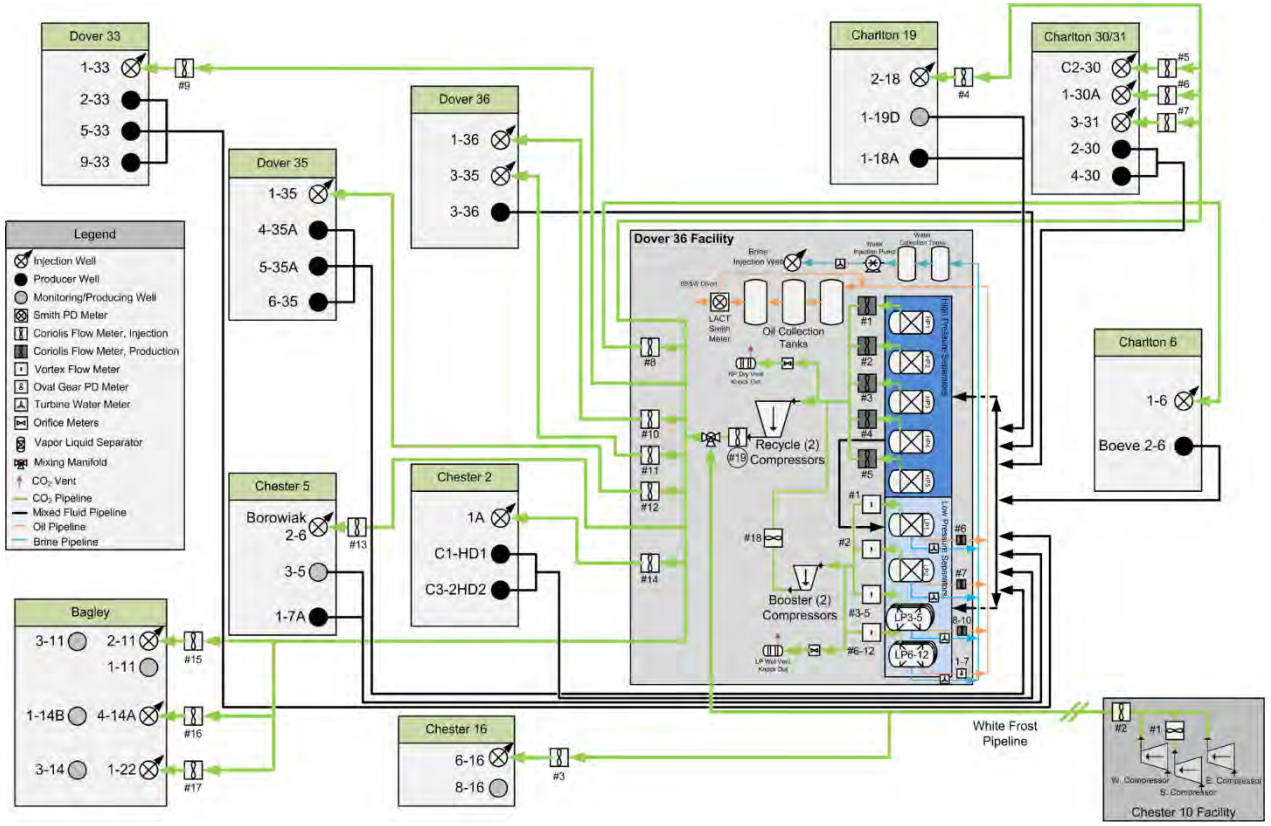


MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

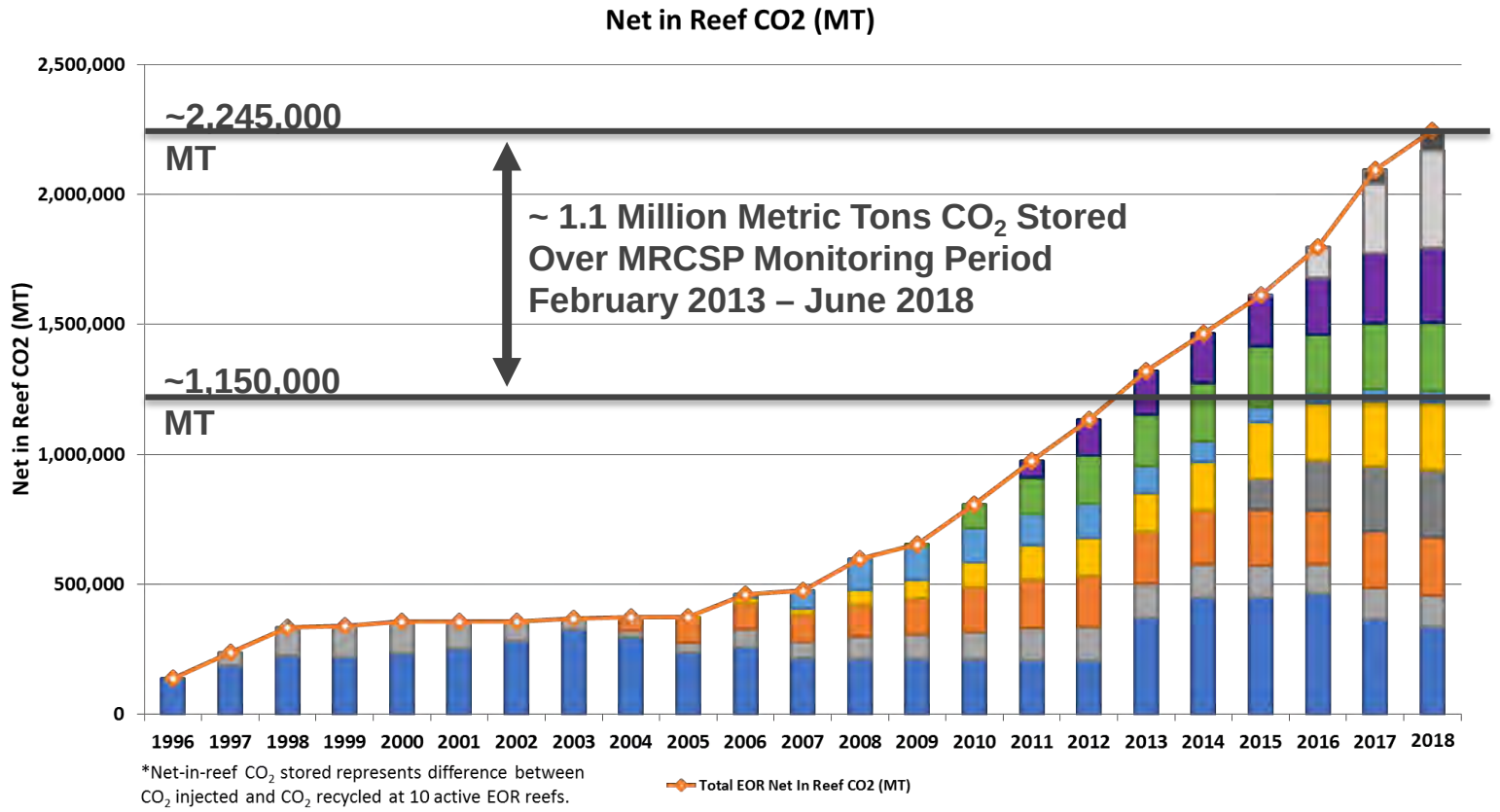
CO_2-EOR Complex & Central Production Facility

- Chester 10 facility provides pure CO_2
- ~80 miles of pipeline network
- 9 reefs interconnected at Dover 36 Facility
- 5 high and 12 low pressure separators
- Recycle/booster compressors
- Coriolis mass flow metering at all critical locations



Dover 36 Facility - Central Production Facility

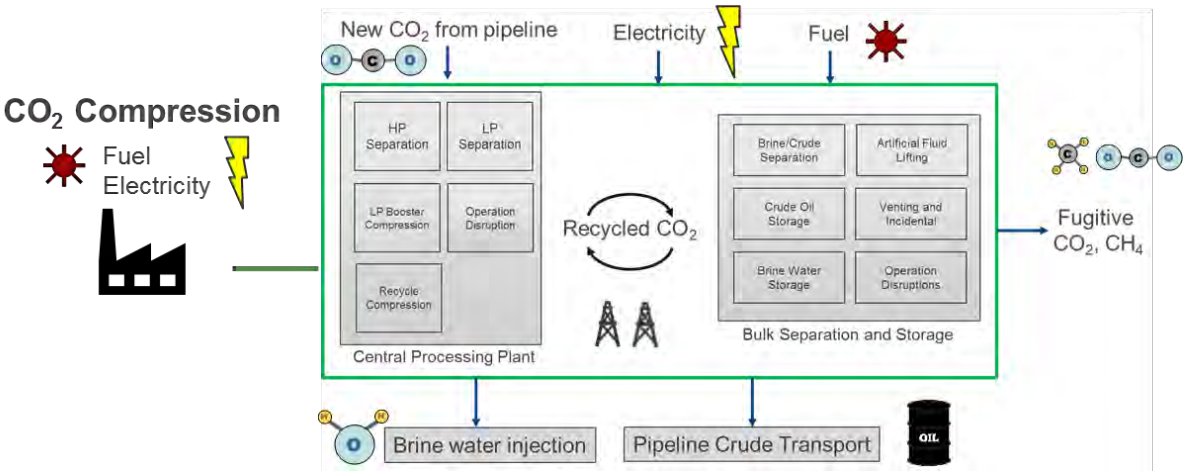
Net CO_2 Stored over MRCSP Monitoring Period



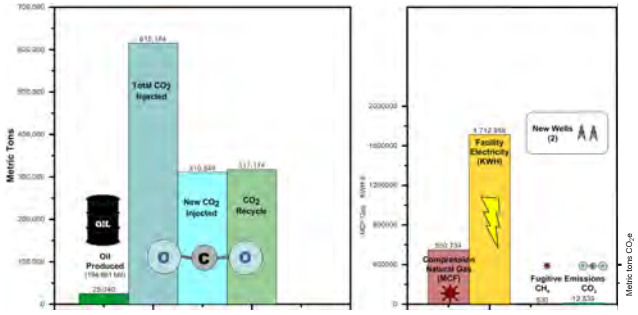
Greenhouse Gas Life Cycle Emissions: Analysis of 20 Years of CO_2-EOR Operations

- Detailed Gate-to-Gate data from MRCSP, Core Energy
  - CO_2 injected, CO_2 recycle, new CO_2, oil produced, brine produced
- Emission Sources
  - Compression natural gas use (MCF), facility electricity use (kWhr), fugitive emissions (CO_2 & methane), venting/flaring, facility construction, new wells, produced water/brine injection, land use.

CO_2 EOR System



CO_2 EOR Operations System Metering

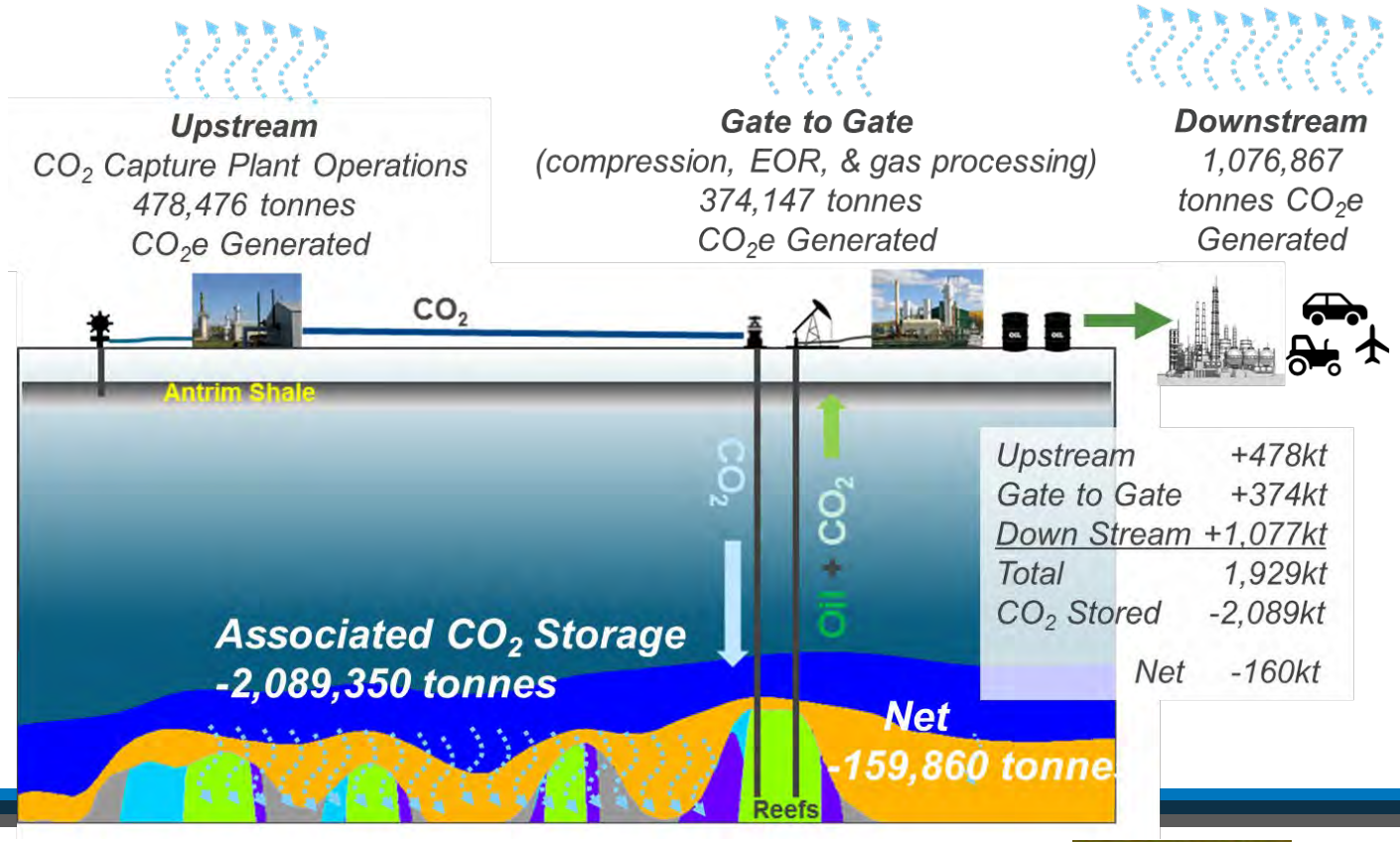


MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

Results- Total LCA results 1996-2017

- Site specific GHG LCA for 20 years of CO_2 EOR operations shows a net -160,000 tons CO_2e GHG “cradle to grave” balance.
- Results certify environmental benefits of CO_2 EOR. Ups & downs of CO_2 EOR operations need to be considered for life cycle GHG analysis.

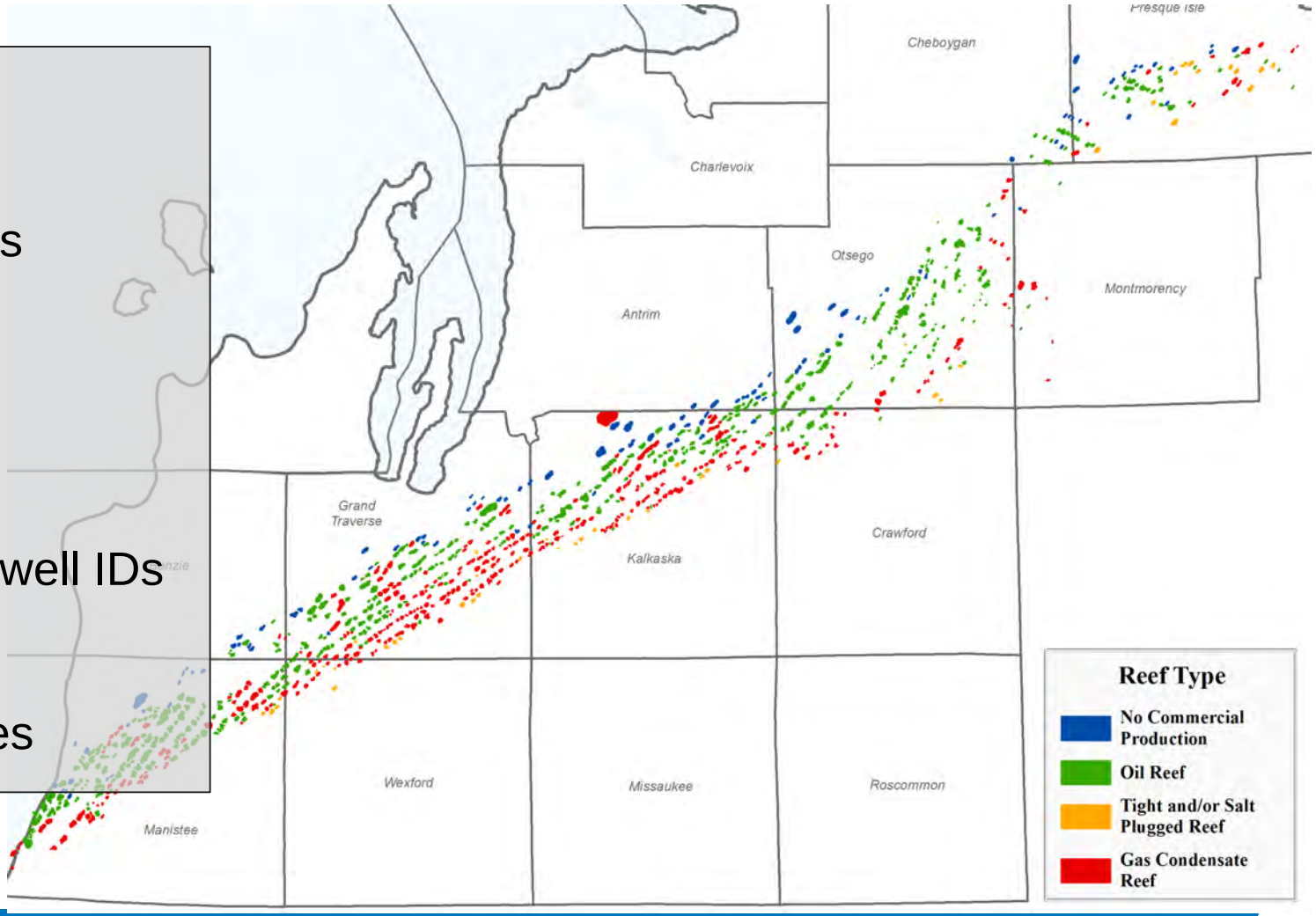


MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

Development of a Reef Atlas

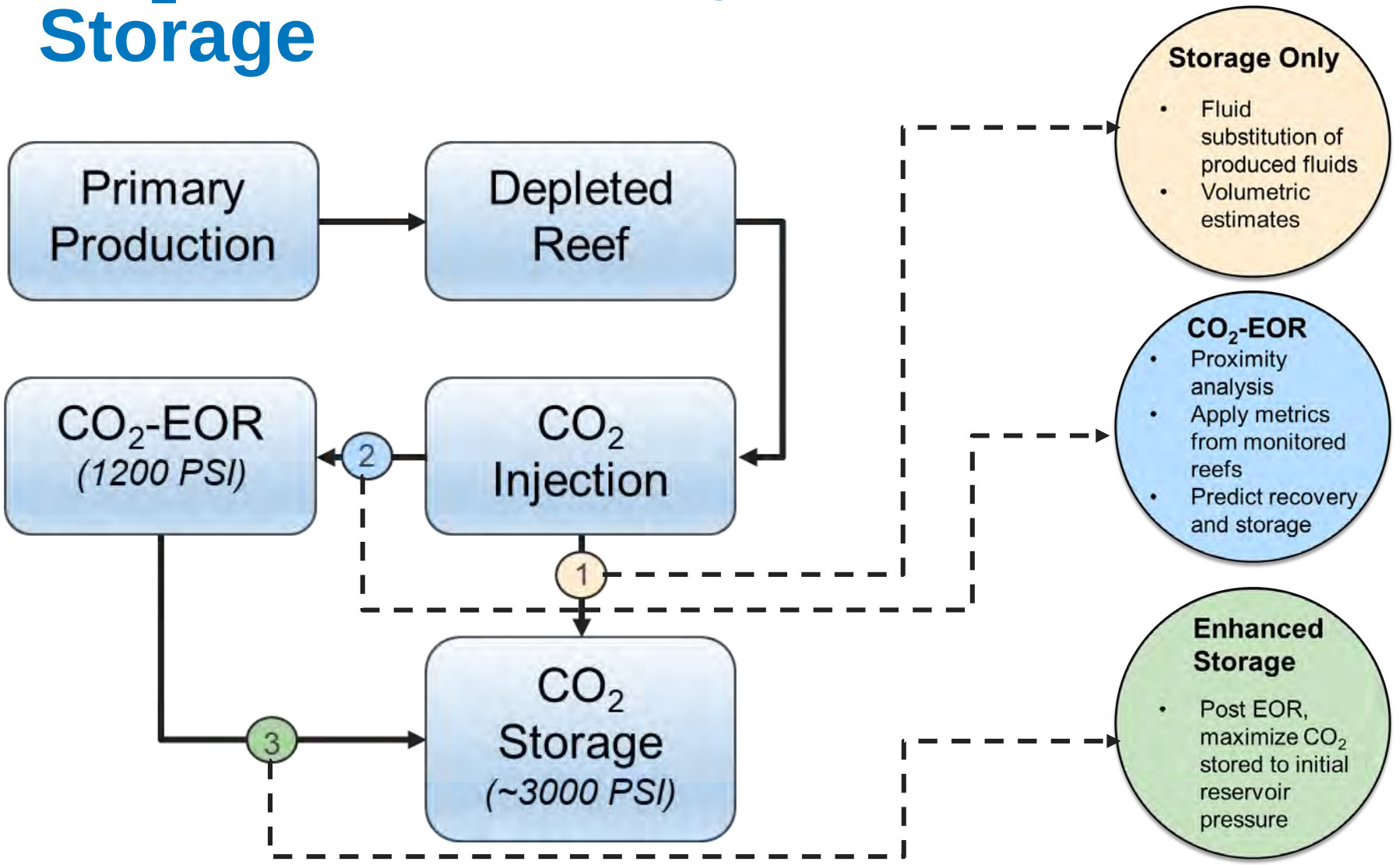
- Type
- Status
- Produced fluids
- Pressure
- OWC
- Reef height
- # of wells and well IDs
- Operators
- Additional notes



MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

CO_2-EOR Feasibility and Associated Storage

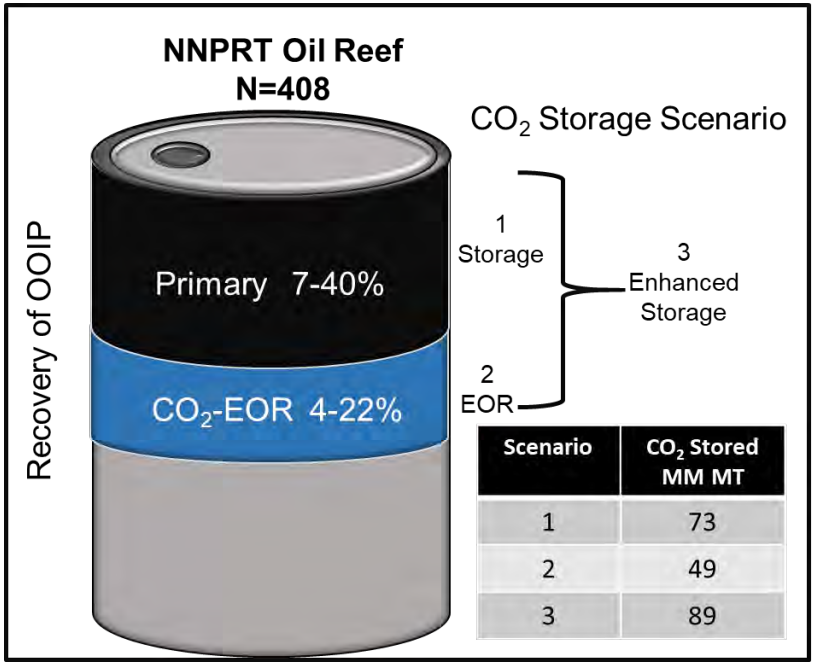


MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

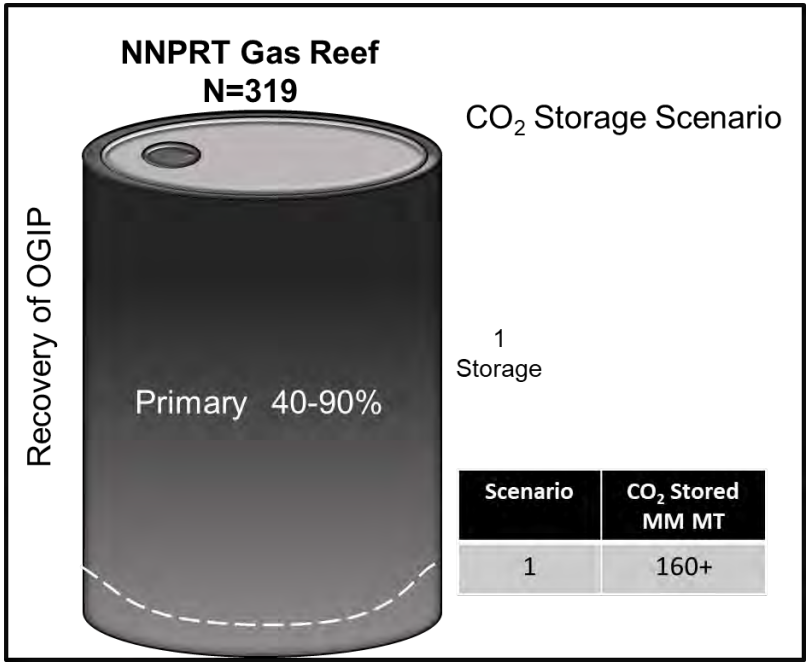
BATTELLE

Significant Regional Potential

- > 250 MM MT storage possible across the NNPRT
- >100 MM STB oil recoverable across the NNPRT
- Stacked storage also an option



Scenario	CO_2 Stored MM MT
1	73
2	49
3	89



Scenario	CO_2 Stored MM MT
1	160+

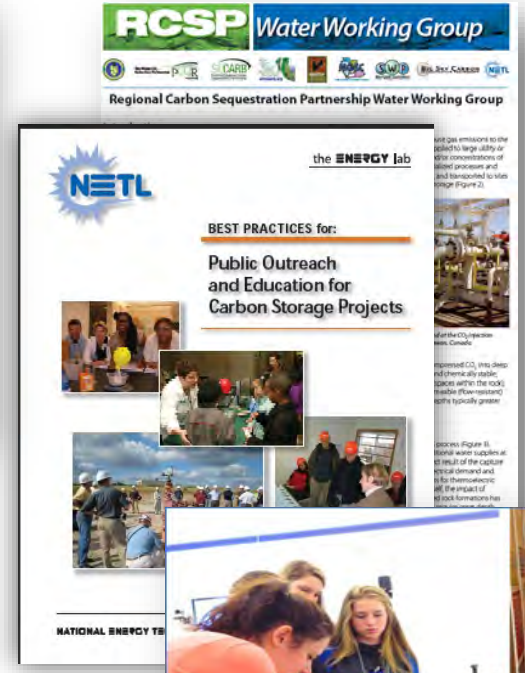
MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

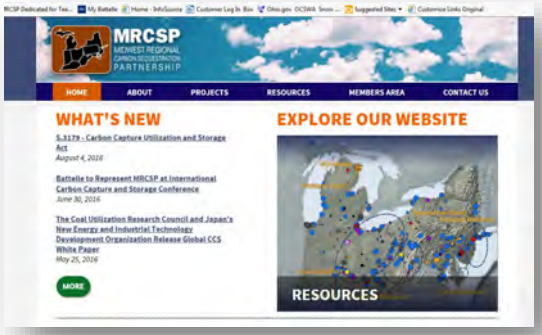
MRCSP Outreach

Sharing Lessons Learned to Foster CCUS Development

Stakeholder Meetings



Conferences and Papers



www.mrcsp.org

Factsheets and BPMs

Michigan Tech Savvy

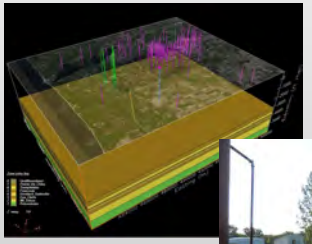
MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

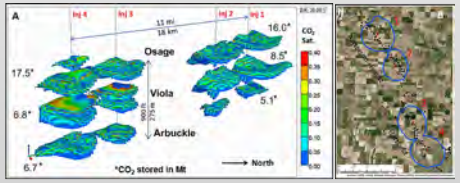
MRCSP Related Work - Building Blocks for CCUS Deployment

MRCSP Large-Scale EOR Public-Private Partnership

Carbon Storage/EOR 45Q Screening/Feasibility

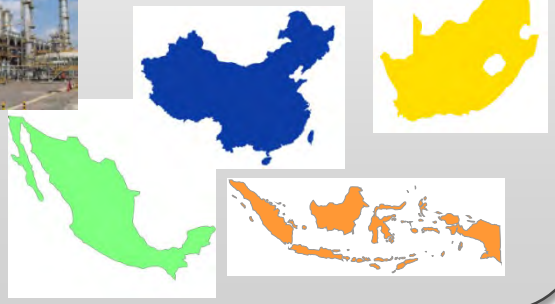


CarbonSAFE

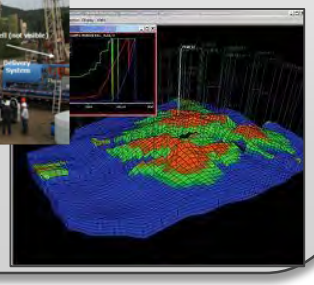


Integrated Mid-Continent Stacked Carbon Storage Hub (Nebraska & Kansas)

International CCUS Development

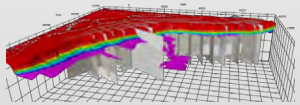


CO_2-EOR and Storage Exploration

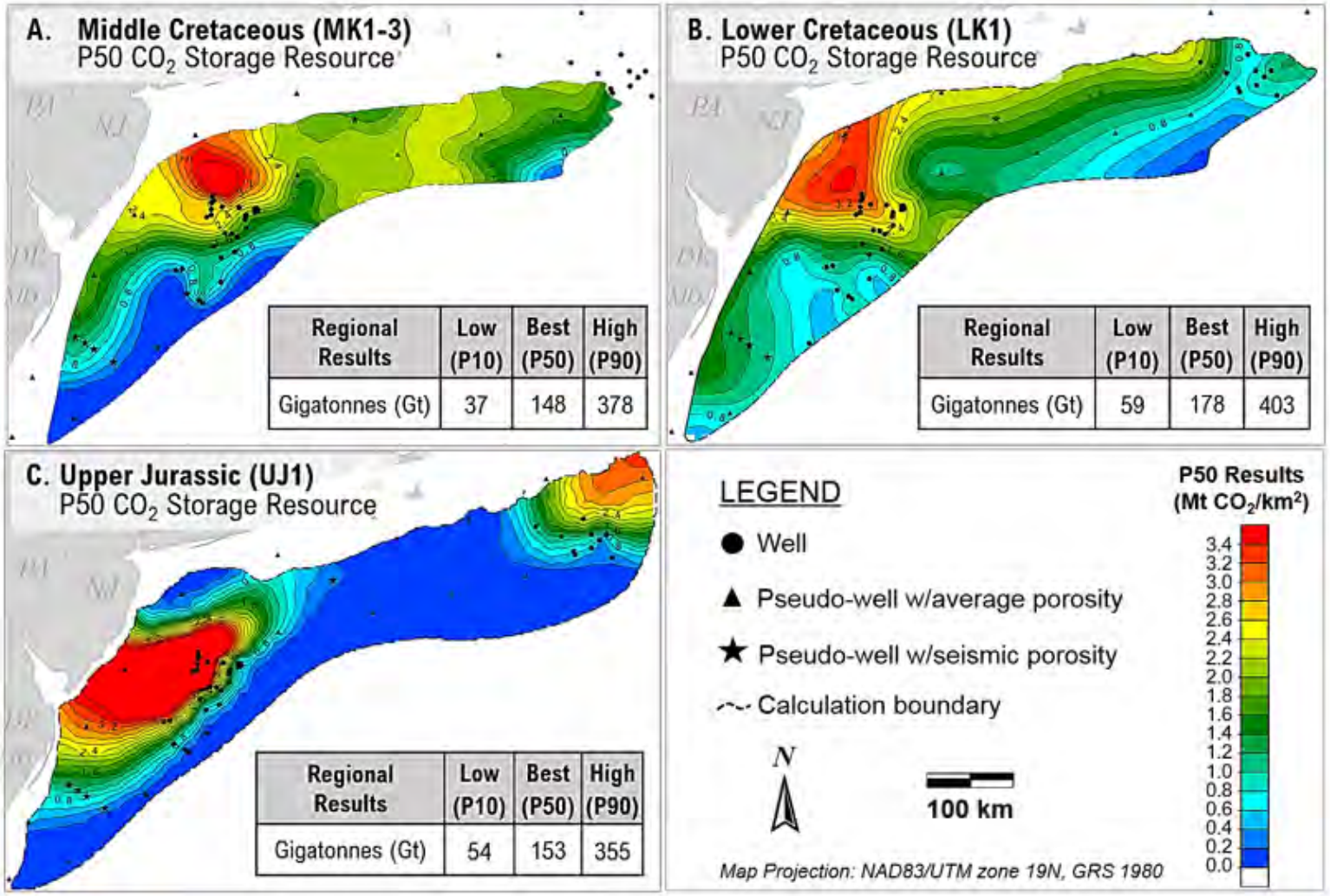


Offshore Carbon Storage

MID-ATLANTIC U.S. OFFSHORE CARBON STORAGE RESOURCE ASSESSMENT PROJECT



Mid-Atlantic Offshore Storage Resource Preliminary Estimate



MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

Ohio's Oilfields of Interest

30

Depleted Oil Fields

8,851

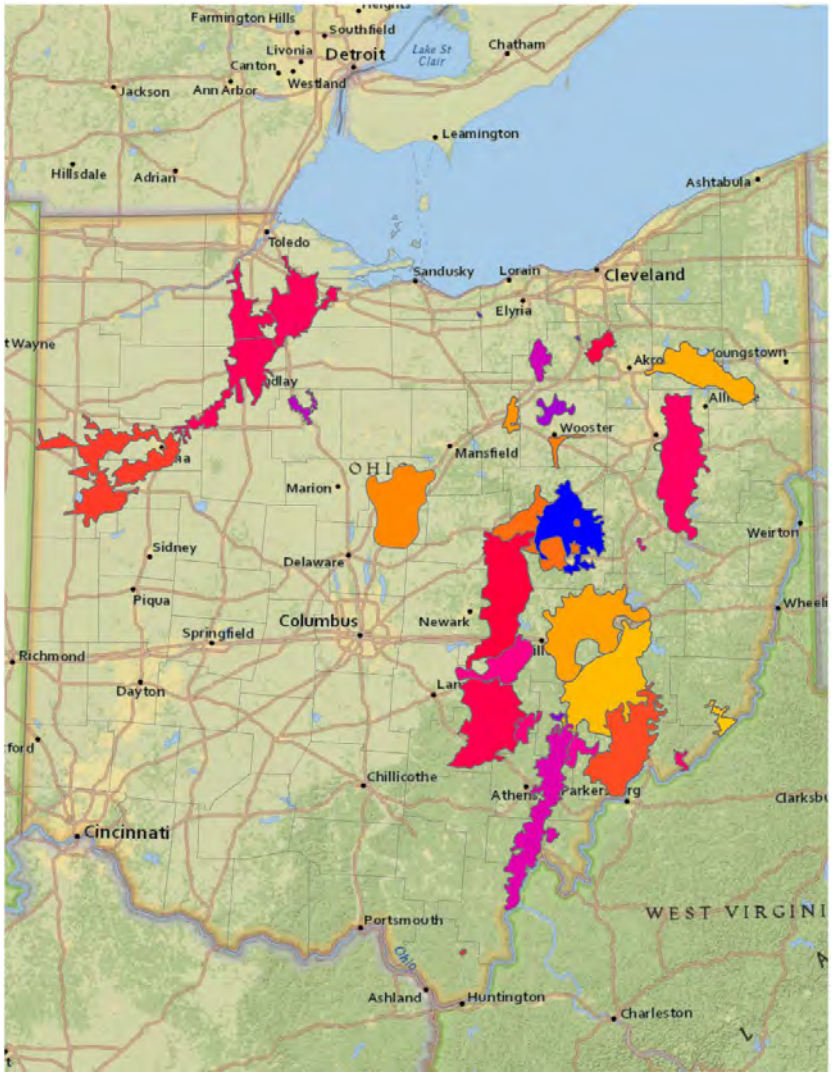
Original Oil in Place [MMbbls]

1,274

Cumulative Production [MMbbls]

878

CO_2 Storage Capacity [MMt]



- Baltic
- Birmingham-Eric
- Brunswick East
- Buck Run Consolidated
- Canaan-Wayne Consolidated
- Carey Consolidated
- Chatham Consolidated
- Cheshire Consolidated
- Chesterhill Consolidated
- Clay Consolidated
- Clayton Consolidated
- Corning Consolidated
- Cow Run Consolidated
- East Canton Consolidated
- Findlay Consolidated
- Gore Consolidated
- Granger Consolidated
- Gratiot-Newcastle Consolidated
- Greasy Ridge
- Lima Consolidated
- Macksburg Consolidated
- Mill Creek
- Monroe-Coshocton
- Moreland-Wooster
- Morrow Consolidated
- Perry-Ashland
- Philo Consolidated
- Ravenna-Best
- Sharon Consolidated
- Sistersville Consolidated

Co-Funded by ODSA/OCDO Project D-13-24, D-15-08

MRCSP MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

BATTELLE

CO_2-EOR Monitoring Challenges

- Potential interference with existing profitable business operations
- Selection of cost-efficient suite of technologies
- Accuracy of monitoring and safeguards in disturbed settings (i.e. going back into multiple-well areas that have been produced and shut-in many times, sometimes over period of decades)
- Quantification of net GHG benefits
- Impact of timing of monitoring requirements vs timing of normal EOR business decisions
- Tapping into the vast experience / knowledge of oil field geology
- Optimizing the synergy between EOR and CO_2 storage

MRCSP - All Critical Milestones and Objectives On Track

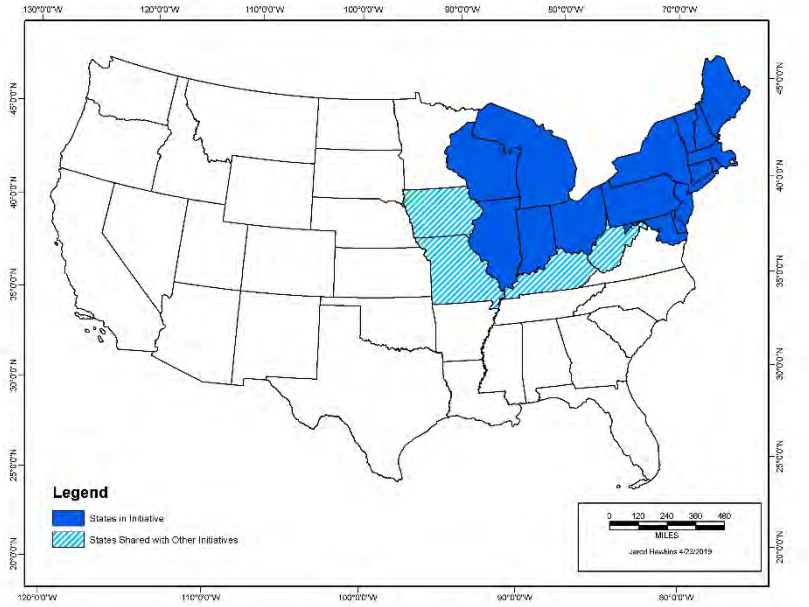
- ~1.2M MT net stored under MRCSP monitoring, >2.4M MT stored since start of EOR in 1996
- Completed injection at main test bed in late-stage reef
  - Micro-seismic, Post-injection PNC, microgravity, and VSP completed, Post-injection test well drilled and characterized
  - Returned to normal EOR operations, with selected monitoring continued
- Added new EOR reefs with complex geology to monitoring
  - Distributed temperature and Acoustic Monitoring
- Advancements in static and numeric modeling processes
- MRV Plan and Life-Cycle Analysis completed
- Modeling and reporting underway
- National and international outreach and synergistic projects

Regional Partnerships Essential For Advancing CCUS - Locally, Regionally, and Globally

- Partnerships have contributed significantly towards CCUS development in the US and globally
- The program has been highly recognized under several peer-reviews
- The overall program has excelled in meeting key objectives
- Partnerships remain a major resource in their study regions
- Significant work still remains to be done to advance CCUS and share knowledge from the programs

A Glimpse of the Future!

Naming Rights still available!



Source Type	Sum of 2017 Emissions (MMt)	% of Total
Power Plant	694	73%
Metals	72.5	8%
Minerals	44.4	5%
Chemicals	38.3	4%
Petroleum, Natural Gas, and Refineries	28.4	3%
Other	28.0	3%
Ethanol	16.9	2%
Pulp and Paper	10.7	1%
Waste	7.9	1%
Manufacturing	3.5	<1%
TOTAL	945	-

- Decarbonization Initiative for the Midwest and Eastern Region (DIMER)
- Industrial CARbon Utilization and Storage (ICARUS) Initiative☺
- Carbon Initiative of the Northeast and Midwest and Atlantic (CINEMA)☺
- Laurentia Industrial Carbon Initiative!

Partners over 15 years have helped make MRCSP successful

Acknowledgements

Battelle's MRCSP Current Contributors – Mark Kelley, Srikanta Mishra, Matt Place, Lydia Cumming, Sanjay Mawalkar, Charlotte Sullivan, Priya Ravi Ganesh, Autumn Haagsma, Samin Raziperchikolaee, Amber Conner, Glen Larsen, Joel Main, Jacob Markiewicz, Isis Fukai, Ashwin Pasumarti, Manoj Kumar Valluri, Andrew Burchwell, Jackie Gerst, Rod Osborne, and numerous others

DOE/NETL – Agreement # DE-FC26-0NT42589, Andrea McNemar (PM)

Core Energy, LLC – Bob Mannes, Rick Pardini, Allen Modroo, Bob Tipsword, Kim Sanders, Kathy Dungey, and several others

Ohio Development Services Agency's **Ohio Coal Development Office**

MRCSP's technical **partners, sponsors, and host sites since 2003**

The MRCSP Region's State **Geology Survey and University team members**

Thanks

Please visit www.mrcsp.org