Emerging Challenges for CCUS Deployment in the Midwest Regional Carbon Initiative (MRCI) Region

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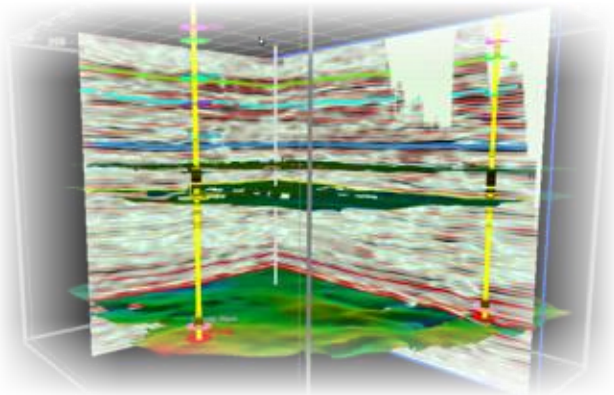
Annual CCUS Conference, Houston, Mar 3-5, 2025



MRCI
Midwest Regional Carbon Initiative

DOE Project DE-FE0031836

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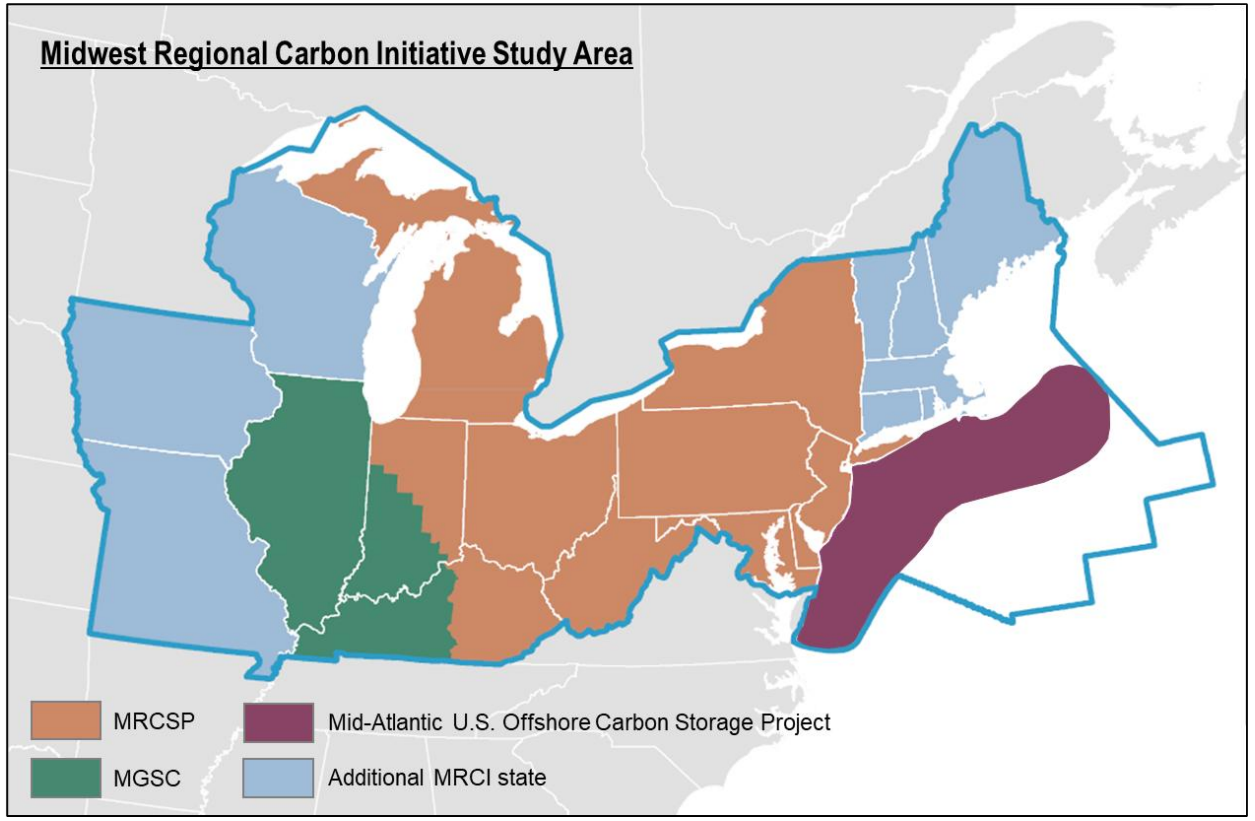
Midwest Regional Carbon Initiative (MRCI)

Accelerate CCUS Across 20 States Region

- Implement a collaborative Regional Initiative to accelerate CCUS in the Midwestern and Northeastern US - build on >20 years of CCUS experience (MRCSP & MGSC).
- Engage national and international stakeholders - States, universities, industrial partners and advisors, fossil fuel production and utilization companies, and NGOs.
- Advanced CCUS research through:
  - Addressing key technical challenges.
  - Obtaining and sharing data to support CCUS.
  - Facilitating regional infrastructure planning.
  - Performing regional technology transfer.



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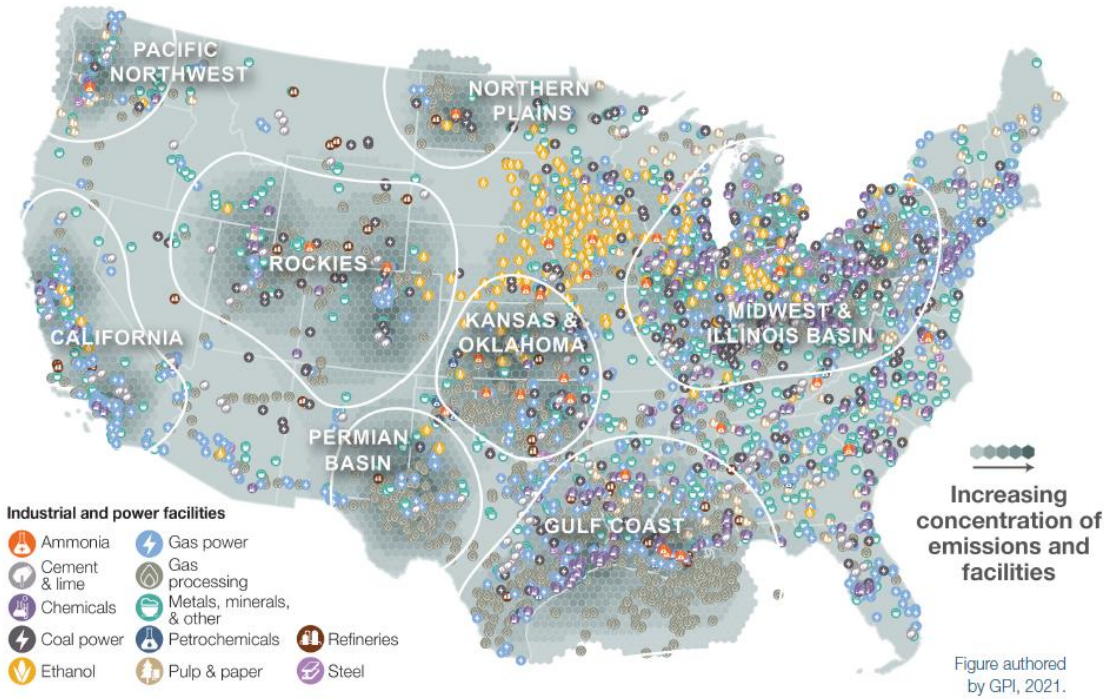
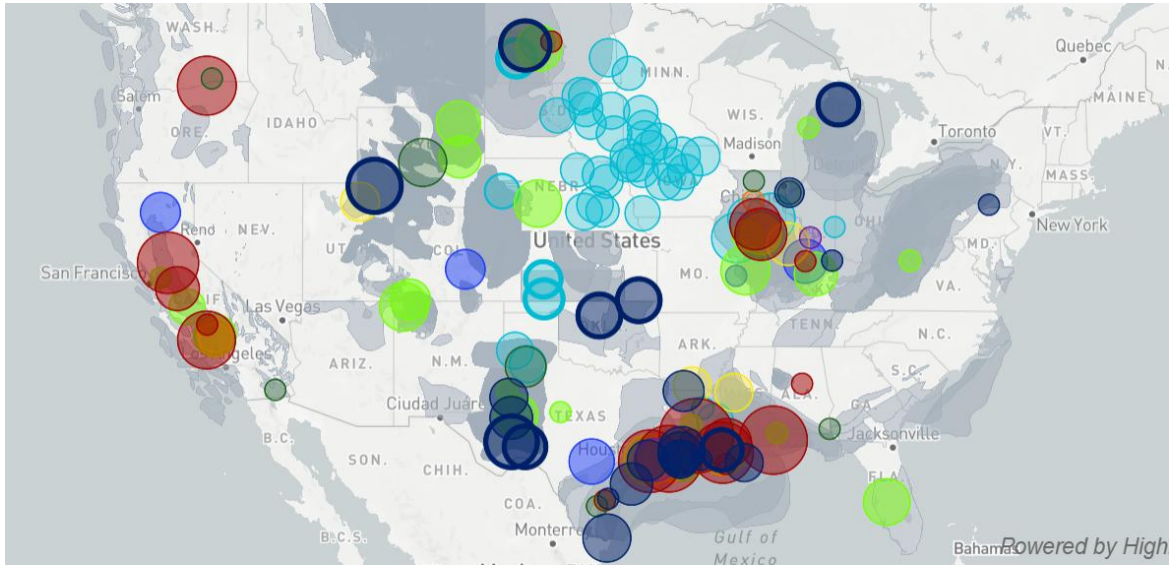
US Clusters – An Emerging National Framework
Numerous current and emerging sources in MRCI Region

- *Current CO_2 Sources Organizing into Clusters in many regions:*
  - *Midwest and Illinois Basin*
  - *Gulf Coast and Permian Basin*
  - *Rockies and northern Plans*





- *Future CO_2 Sources will likely to follow clusters and geologic storage resources:*
  - *Natural gas power generation*
  - *Industrial facilities*
  - *Bio energy*
  - *Natural gas to Hydrogen*
  - *Direct Air Capture*

Map Sources – Great Plains Institute and Clean Air Task Force

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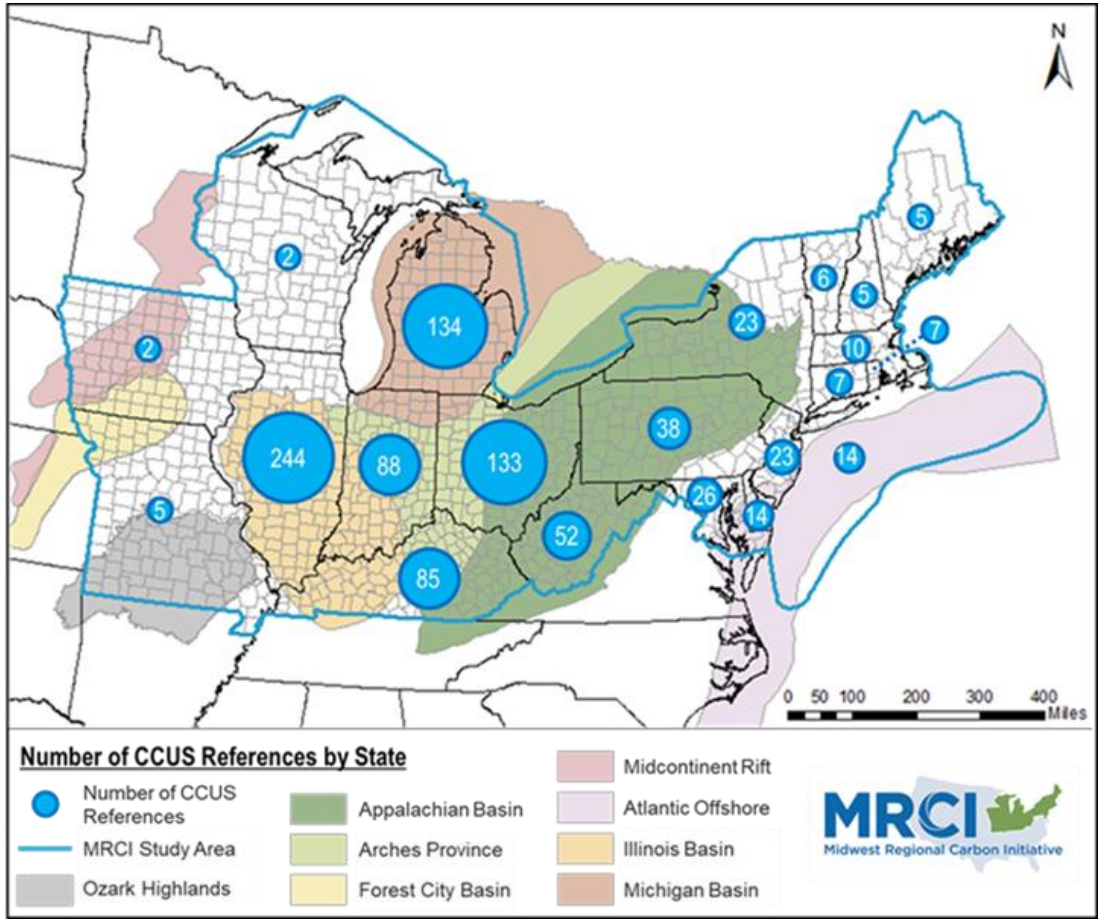
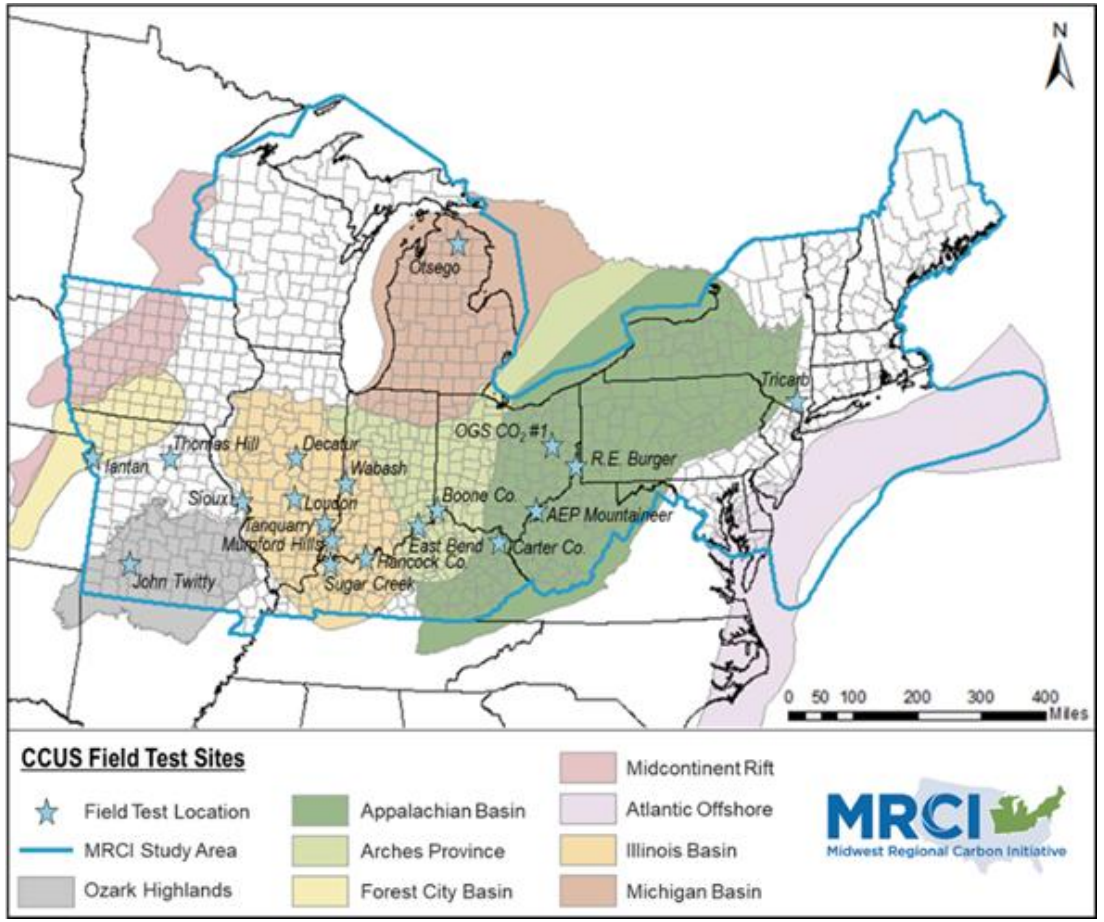
Past Projects and CCUS References in the MRCI
CCS R&D since mid-1990s





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Nearly 30 Years of CCUS R&D in MRCI Region Provides a Foundation for Deployment Phase

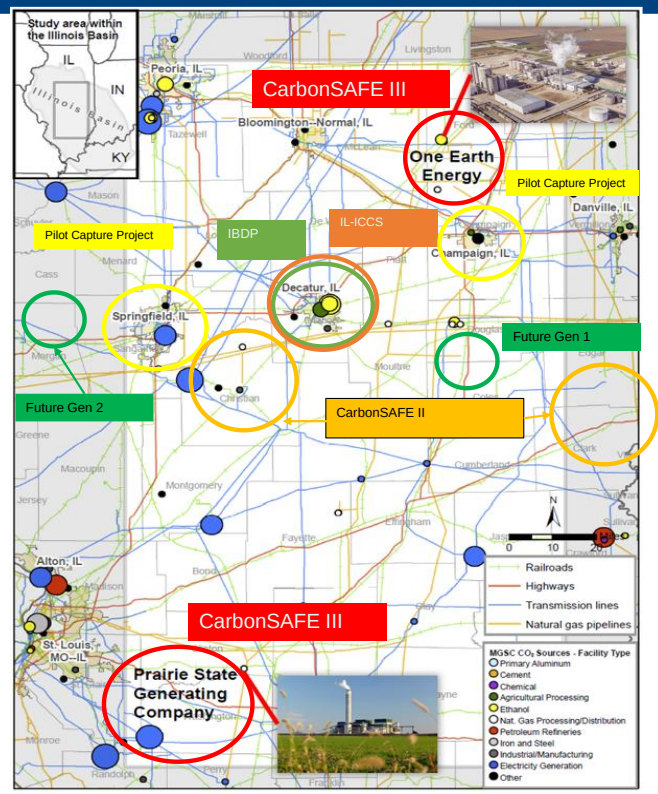
MRCSP/MRCI Large-Scale Public-Private Partnership

MRCSP
MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

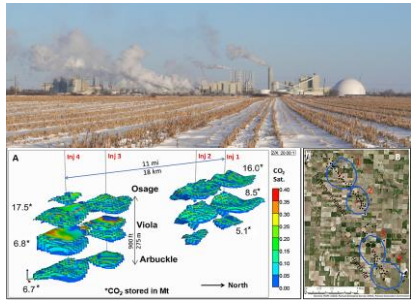
MRCI
Midwest Regional Carbon Initiative

AEP Mountaineer Pilot and FutureGen

Illinois Basin Corridor Cluster

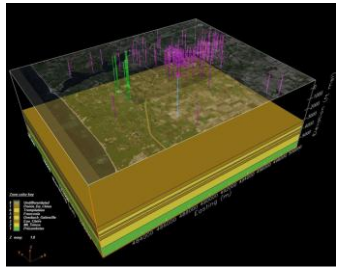


CarbonSAFE - Scaling Up



Illinois,
Indiana,
Ohio,
Michigan
Kentucky
West Virginia

Commercial Carbon Storage Development



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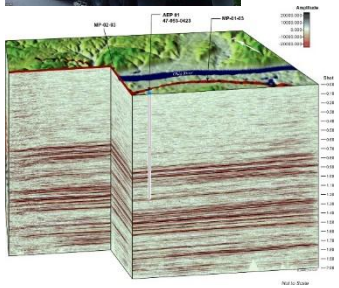
AEP Mountaineer program – full life-cycle CCS spanning 15 years with Battelle as CO_2 storage service provider

Feasibility – Exploration Well

- Seismic survey conducted and AEP-1 test well was drilled in 2002
- Included extensive data collection and community outreach
- DOE and industry funded

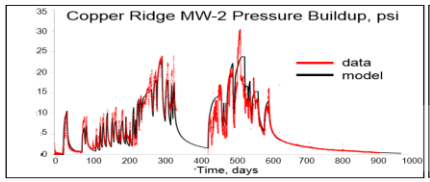


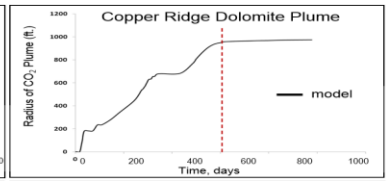
Pilot Construction & Commissioning

- Network of five wells, two injection and three monitoring, constructed (drilling and completion) in 2008-2009
- Integrated with 20MWe chilled ammonia capture system
- Pressure maintenance and monitoring system installed

Injection and Operations Monitoring

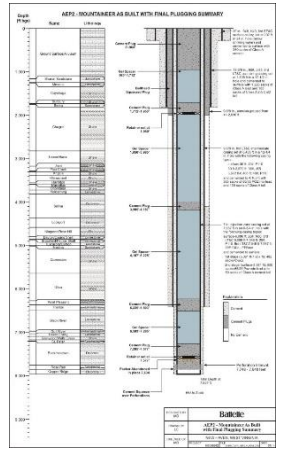
- ~37,000 tonnes of CO_2 was injected and stored over 18 months from 2009 to 2011
- Included monitoring of reservoir pressure, groundwater chemistry, CO_2 injectate, and soil gas





Post-Injection and Site Closure

- Post-injection – pressure, groundwater monitoring, plume modeling
- Well plugging and site closure within 5 years by working with regulators and meeting all permit requirements
- Scale-up design for 235 MWe facility completed



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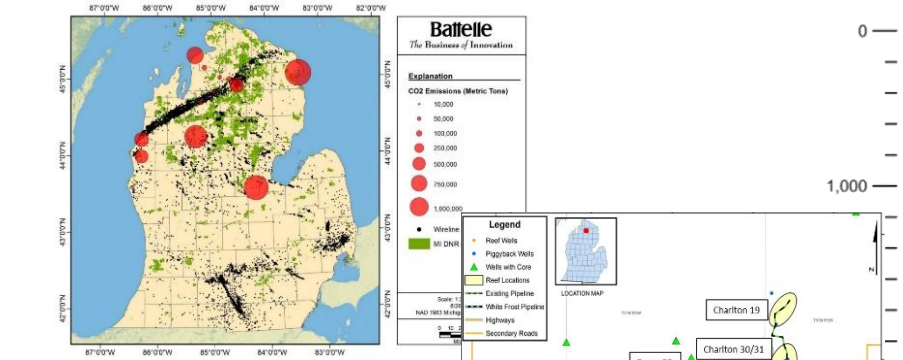
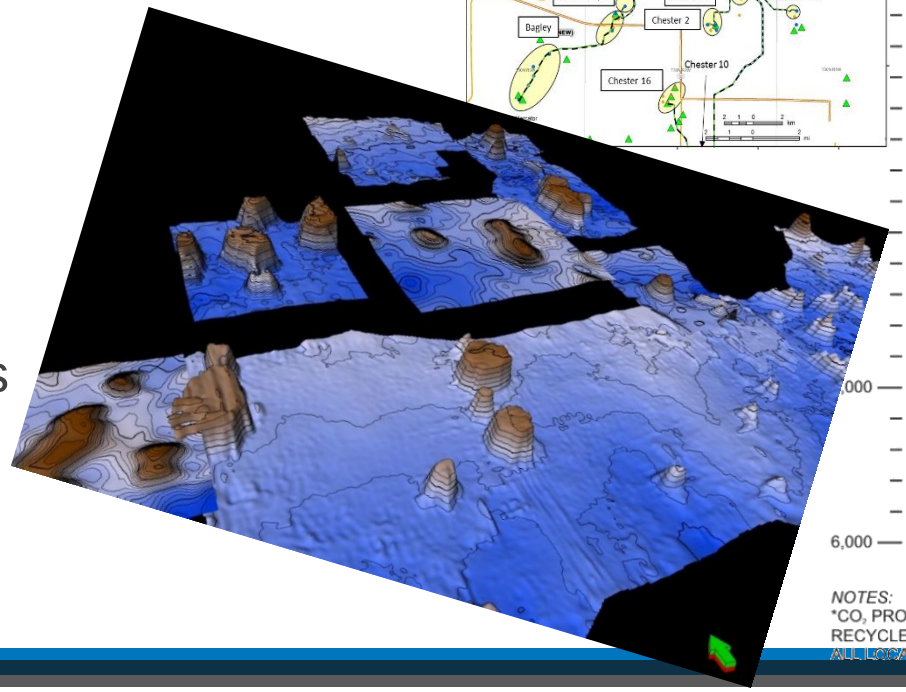
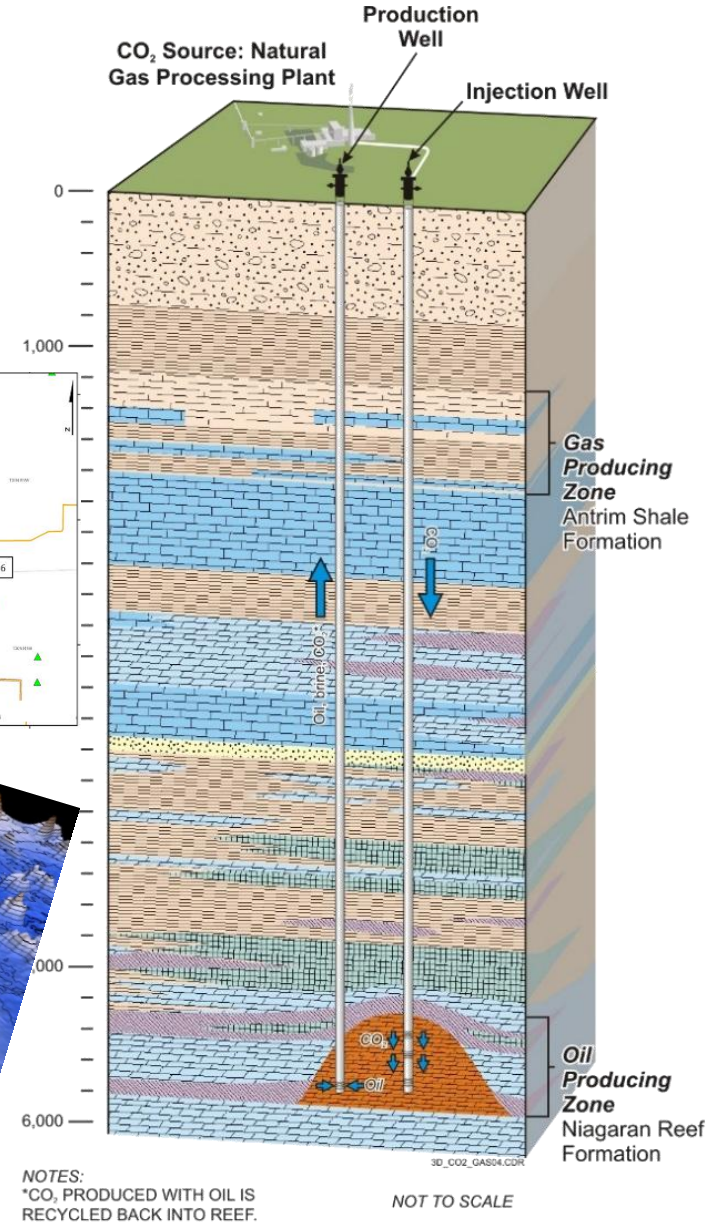
MRCSP Pilots and Michigan Basin Large-Scale CO_2-EOR Assessment

- Three pilot tests under MRCSP II
- MRCSP III - Injected/monitored +2 MMT CO_2 in collaboration with EOR
- Hosted by Core Energy, LLC
- Evaluated CO_2 injectivity, migration, containment
- Tested numerous monitoring options
- Demonstrated net-negative life-cycle
- Evaluated regional storage resources
- Outreach and knowledge share
- Reports available from DOE EDX







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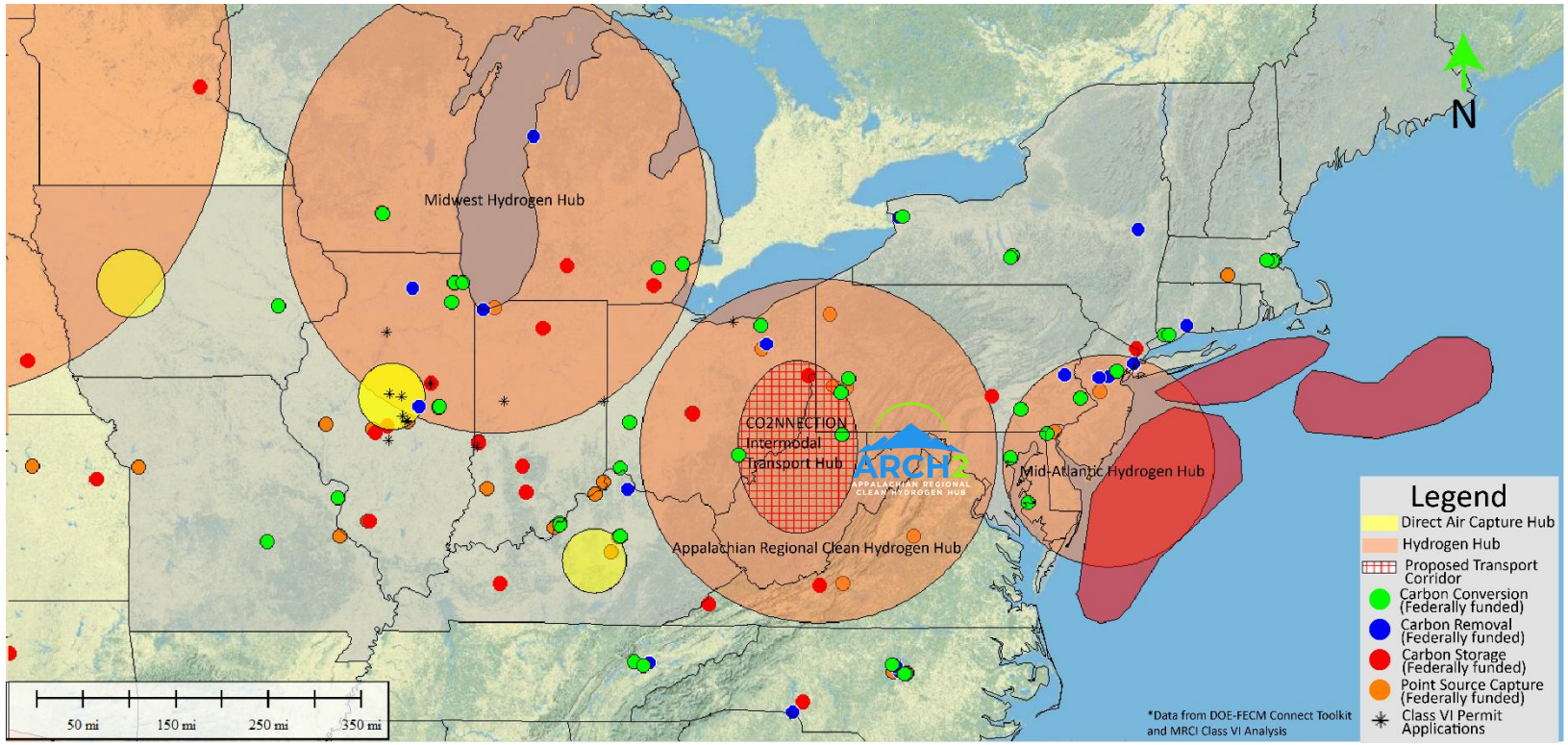
Key/Emerging CCS/CDR Projects in the MRCI

- Regional Initiatives:
  - MRCI (MRCSP/MGSC)
  - FOA2799 – States Surveys
  - FOA2799 – Battelle offshore
  - RITAP – App. and Mich. Basin?
- >10+ CarbonSAFEs I, II, III
- Industrial Decarbonization
- FEED studies
- Three H_2 hubs
- Three DAC hubs
- Transport – CO_2NECTION



In Addition, numerous private projects are not shown on the Map

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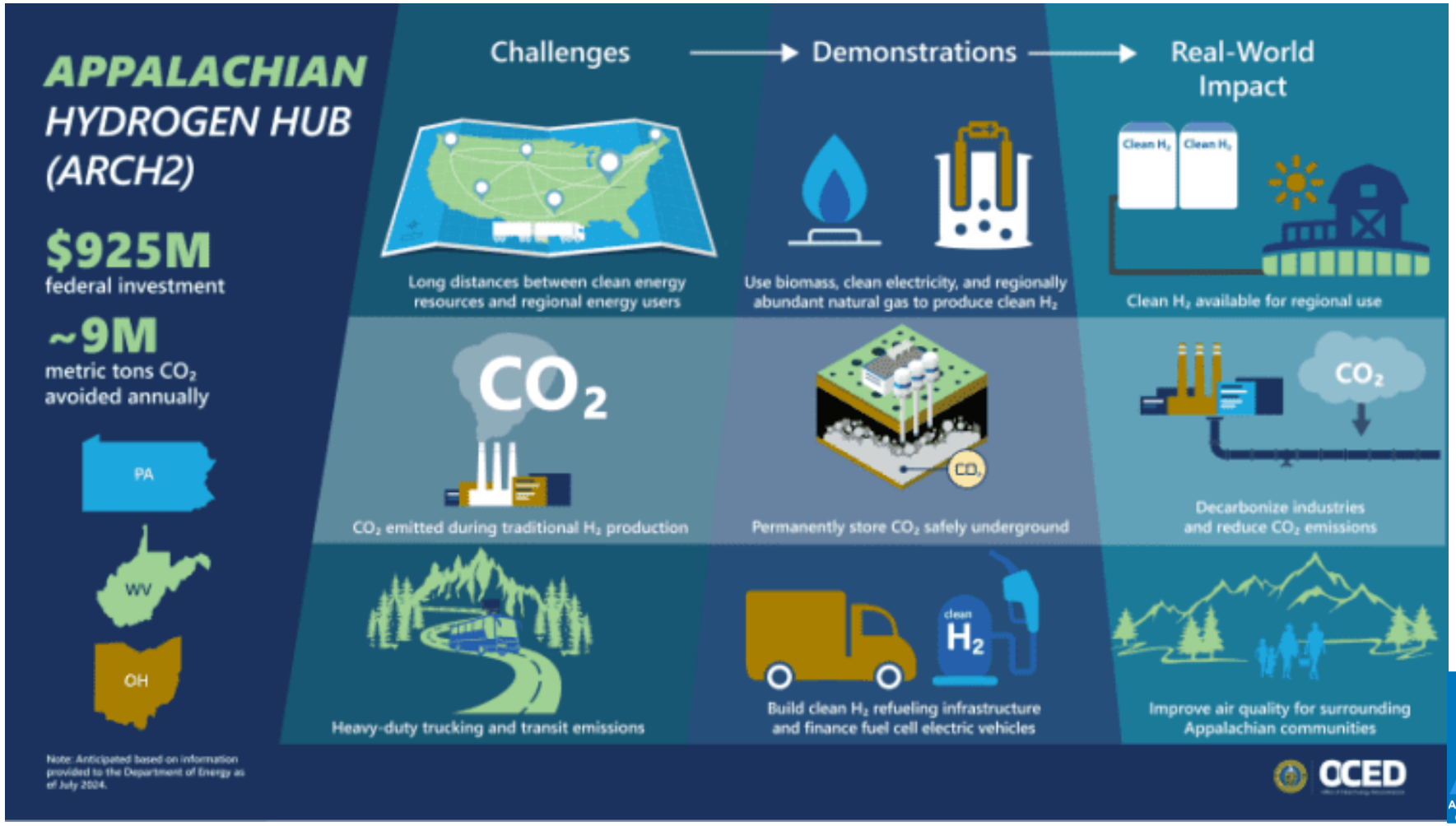
Appalachian Regional Clean Hydrogen Hub (ARCH2) – Emerging CO_2 Source in Deeper Basins



ARCH2 APPALACHIAN REGIONAL CLEAN HYDROGEN HUB

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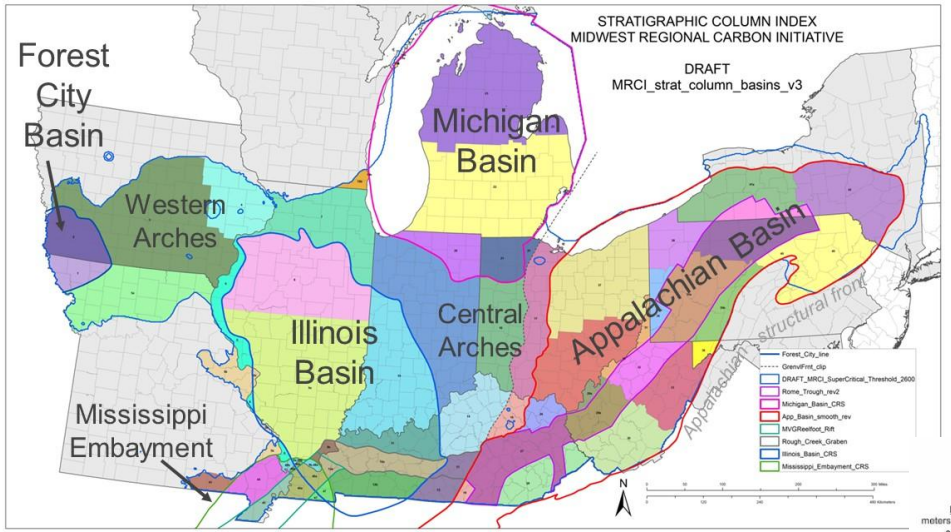
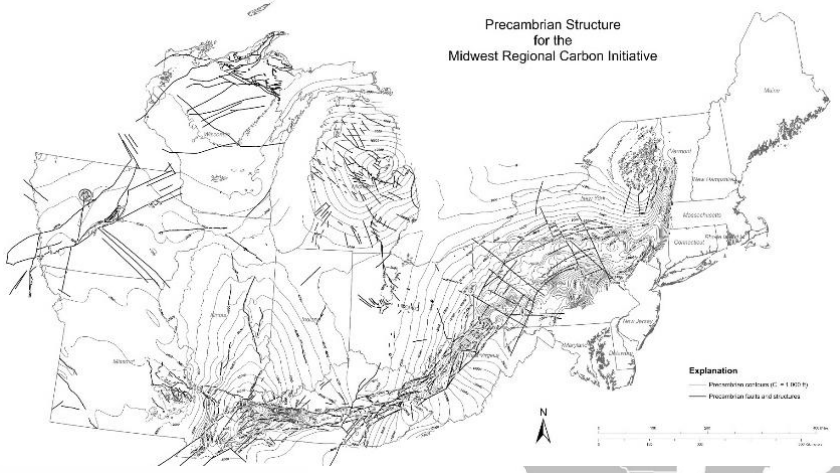
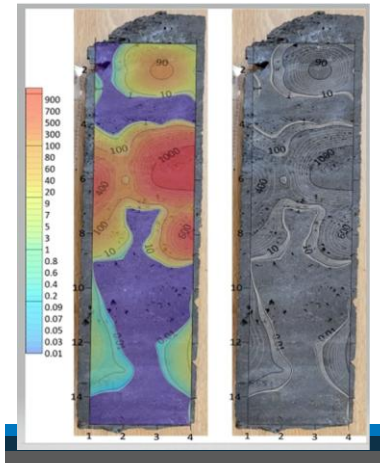
Despite Tangible Progress, Significant Challenges Remain for Broad-Scale Deployment of CCUS

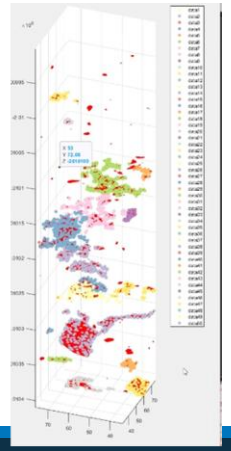
- Finding/qualifying storage resources for project life-cycle to meet business goals
  - Where is the storage – no proven large hub-scale fields yet, except central Illinois Basin
  - MRCI region projects still limited to Mt. Simon Sandstone. We need deeper basin and carbonate fields
  - Scale-up will require use of well fields, stacked storage, multilateral wells. How to permit these
  - Managing plume and pressure interference, cross-boundary projects
  - Legacy wells remain a major issue and can impede scale-up – need to assess and manage project risk
  - Materials and corrosion issues – increased risk and cost. More monitoring. Regulatory compliance
- Regulatory permitting, due-diligence, up-front well costs for large hubs are significant
- Stakeholder acceptance, community benefits challenges scaling up as projects scale up
- *Alignment of projects components – capture, transport, storage development; variable nature of sources; financing, permitting (Class VI, pipeline, source reviews, NEPA, federal lands, state commissions), stakeholder acceptance*

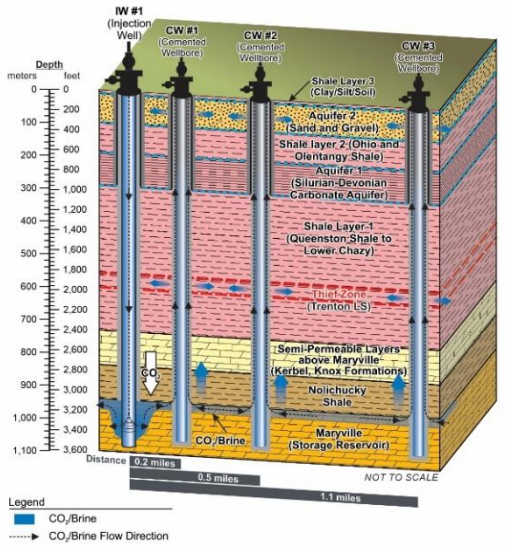
MRCI Technical Challenges – Developing Geologic Storage Framework and Addressing Risk Factors

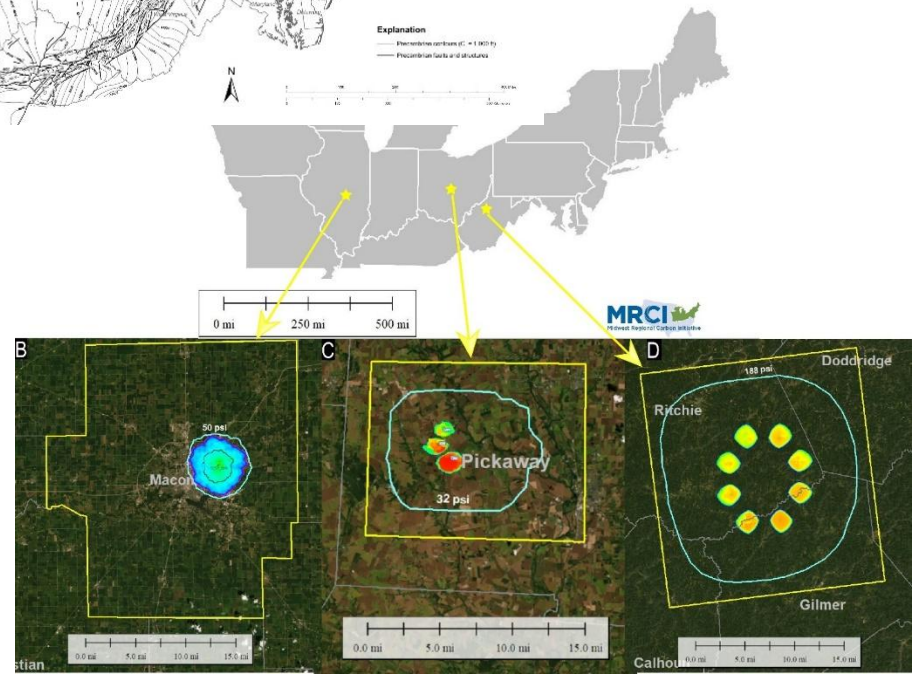












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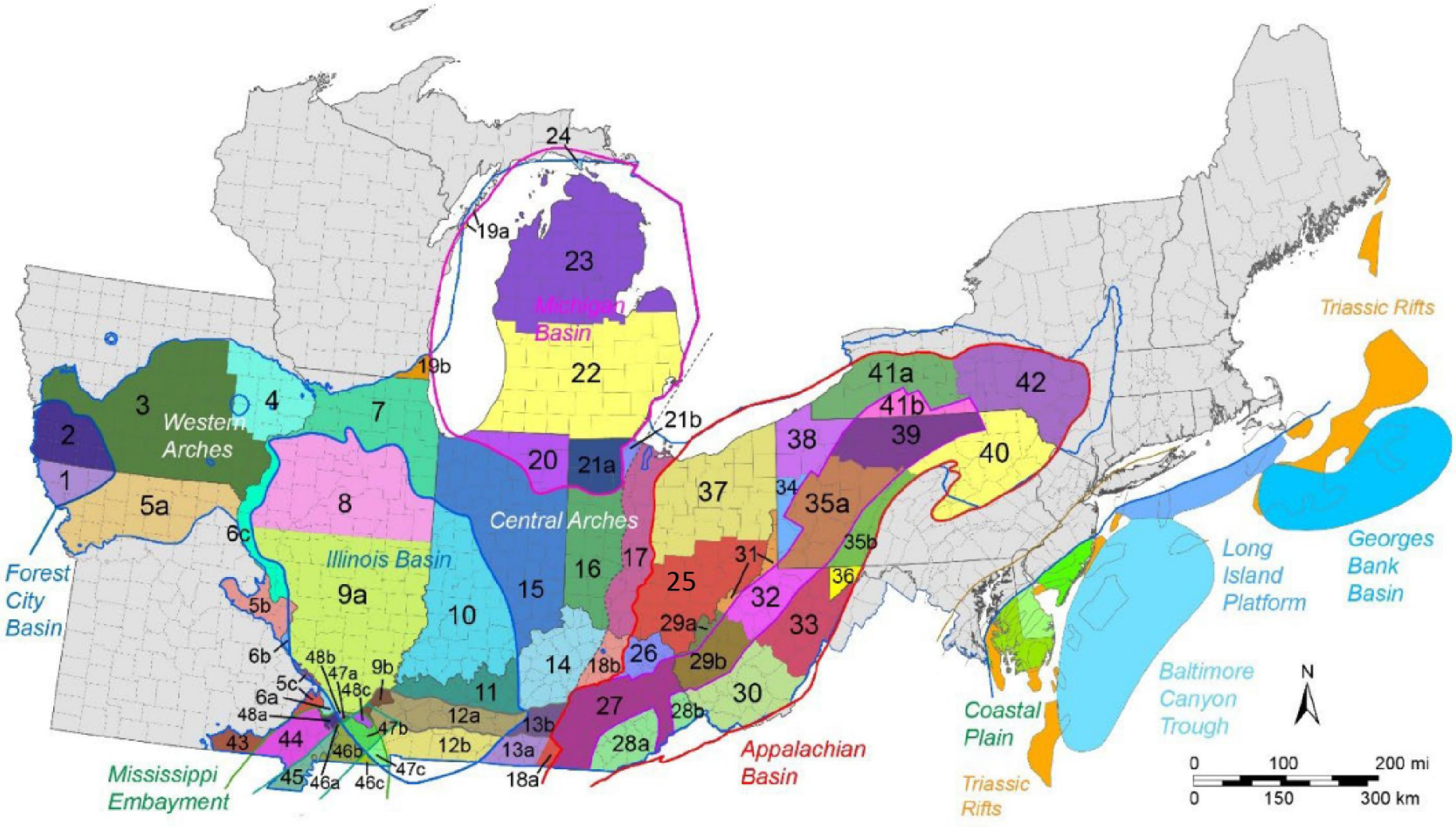
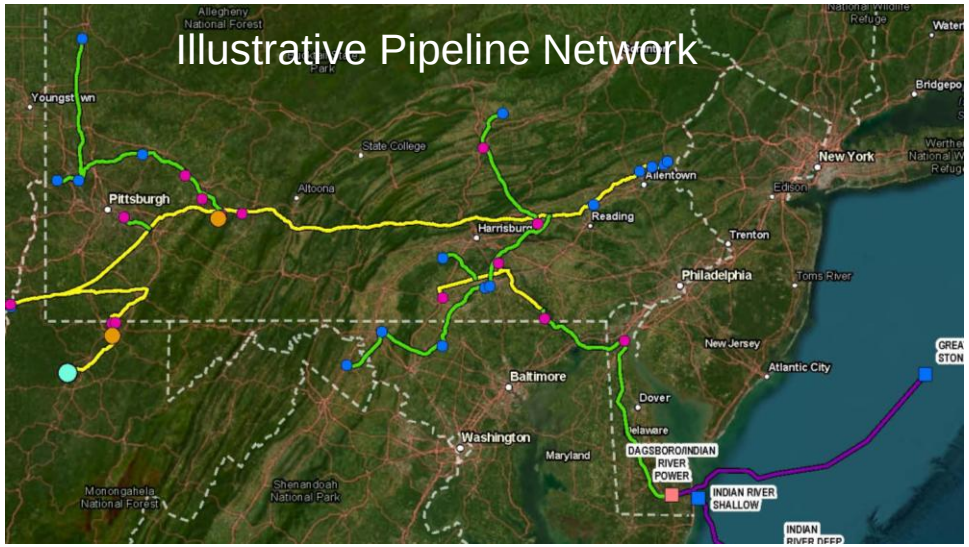
Subregions of the MRCI study area based on Stratigraphy

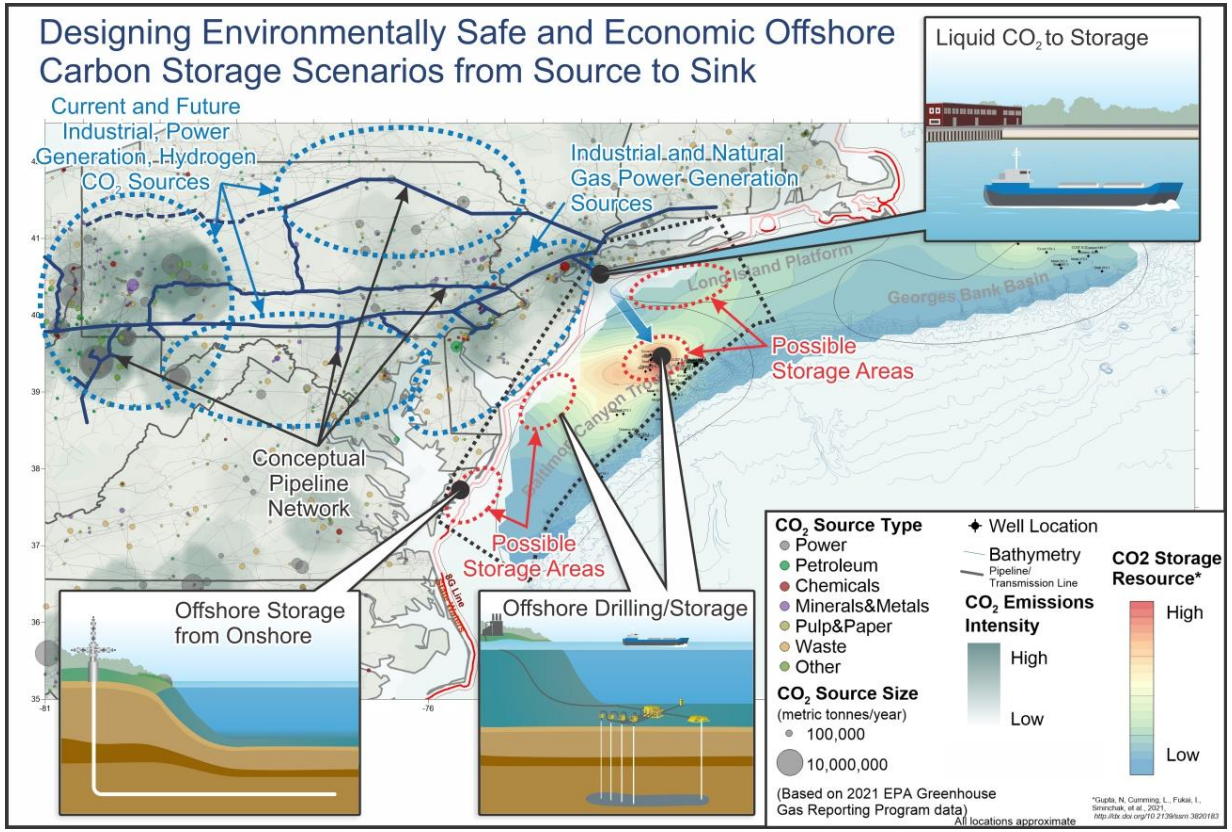


MRCI Midwest Regional Carbon Initiative

Mid-Atlantic Offshore Storage Cluster – Potential major solution for Eastern US?

- Sources – East Coast, Central PA/MD, Appalachian Basin
- Sinks – Baltimore Canyon Trough; maybe Long Island Platform rift basins
- 100s of Giga tonnes storage resources





- Transport – onshore pipelines, offshore pipeline/ shipping
- Societal and policy considerations are key

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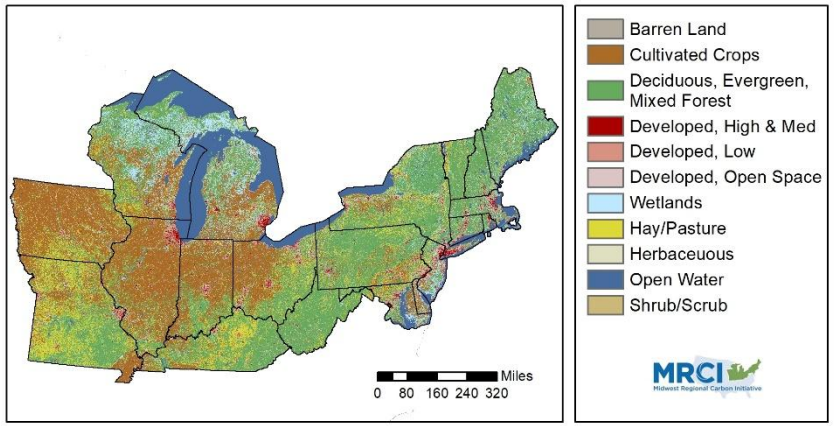
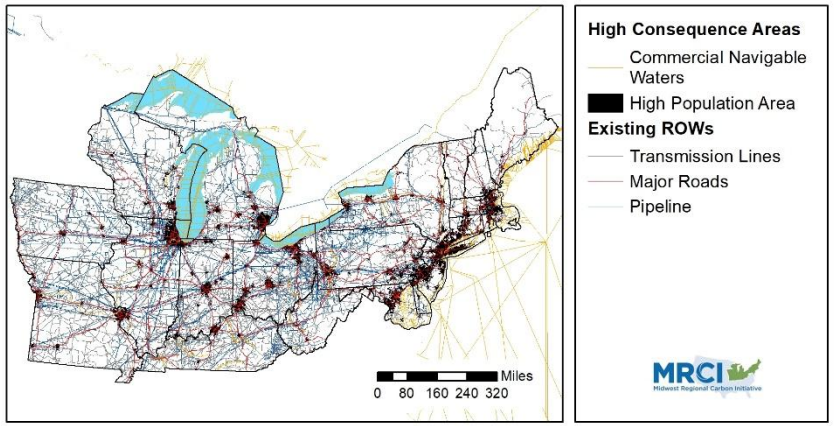
Regional Infrastructure and Societal Factors

Transport and storage infrastructure must consider other than sources and sinks

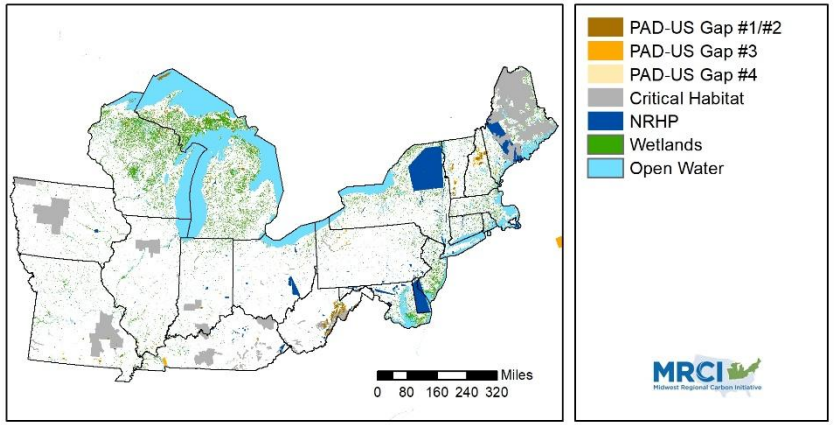
Land cover data = project feasibility



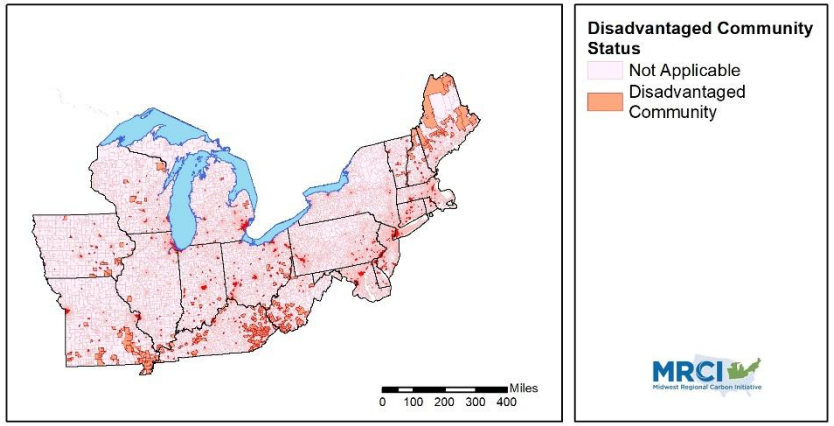
Existing infrastructure = obstacles or opportunities



Sensitive areas = potential project pitfalls



Societal acceptance remains a key challenge



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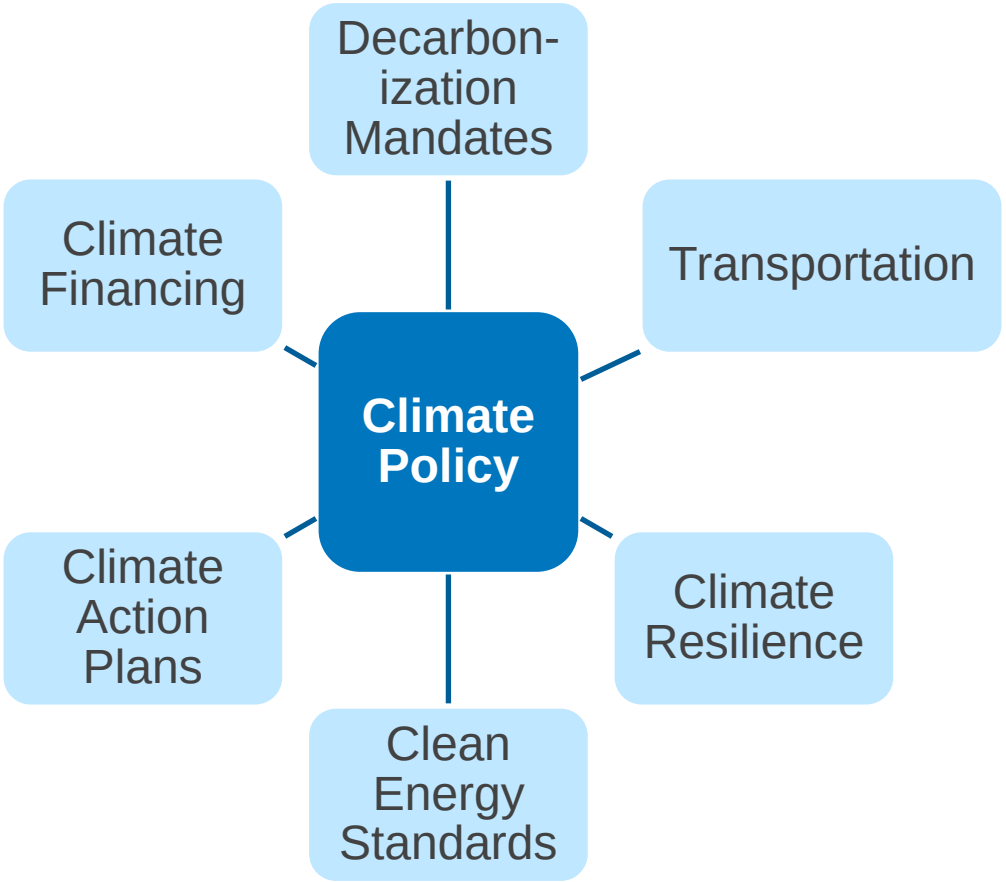
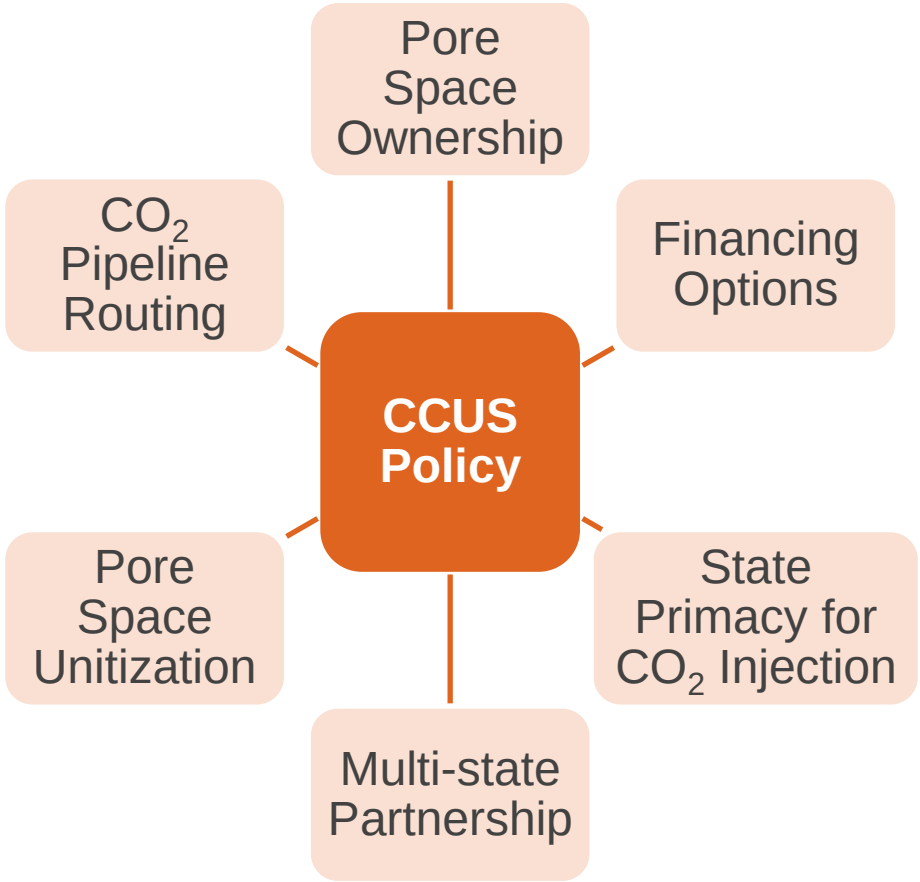
State/Regional Policies Influence CCUS Development

Codifying State and Regional Climate Goals



CCUS Rules Development by States



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CCS Regulatory Advancement and Legislation In The Region Paving the way for Deployment

- Pennsylvania CCUS Enabling legislation in place!
- The Illinois Senate establishing additional requirements for CO_2 pipeline development, permitting for sequestration projects, and protections for pore space owners.
- West Virginia primacy and enabling legislations passed. Class VI primacy achieved!
- Ohio DNR directed to develop primacy application
- Indiana enabling legislation passed
- Other states considering regulatory roadmap

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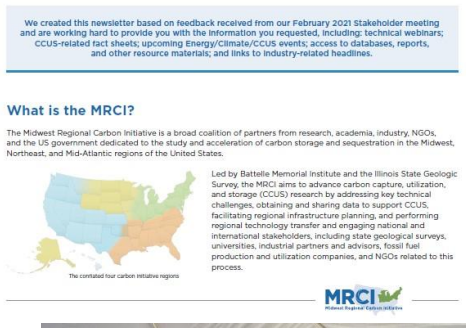
Outreach Issues and Regional Technology Transfer

- Promote CCUS deployment through commercialization and technology transfer
- Communicate information from technical tasks to stakeholders
  - ***MRCI reports to be released in coming weeks***
- Engage with federal and state governments, industry consortia and NGOs
- Engage with global institutions
- Continued outreach is a must for advancing CCUS in the region and nationally



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CCUS in MRCI Region – Poised for Growth but Numerous Challenges to Address!

- A successful 25+ years history of research, pilots, and demonstration projects
- An early microcosm for CCS deployment
- Established broad-based consortium of researchers and stakeholders
- Regional storage assessment and validation is only in it's infancy – geology, well fields, regional monitoring, crisis management)
- Infrastructure challenges (transport, hubs, power) are only beginning to be addressed
- Policy, economic, and social issues can hamper progress, if not address properly
- Continued education and public advocacy for CCS by respected researchers is needed
- Public-private collaboration – financial, technical, basin-scale management is essential