CAB-CS: Central Appalachian Basin CarbonSAFE Integrated Pre-Feasibility

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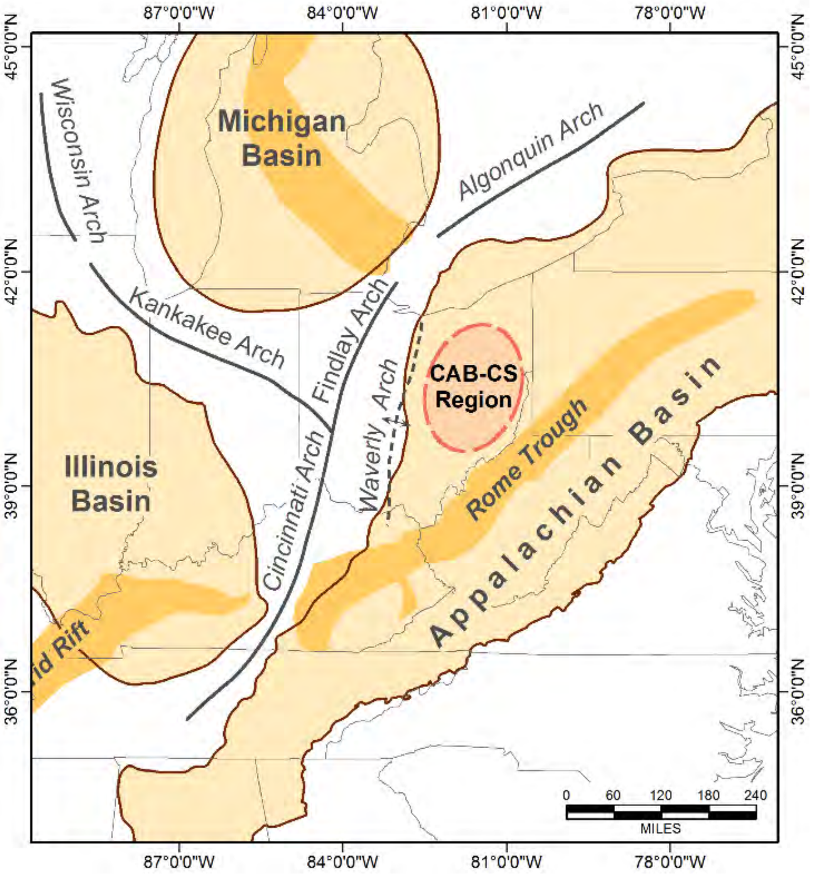
U.S. Department of Energy
National Energy Technology Laboratory
Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting
August 13-16, 2018

Presentation outline

- Introduction
- Technical Status
- Accomplishments To-Date
- Lessons Learned
- Synergy Opportunities
- Project Summary



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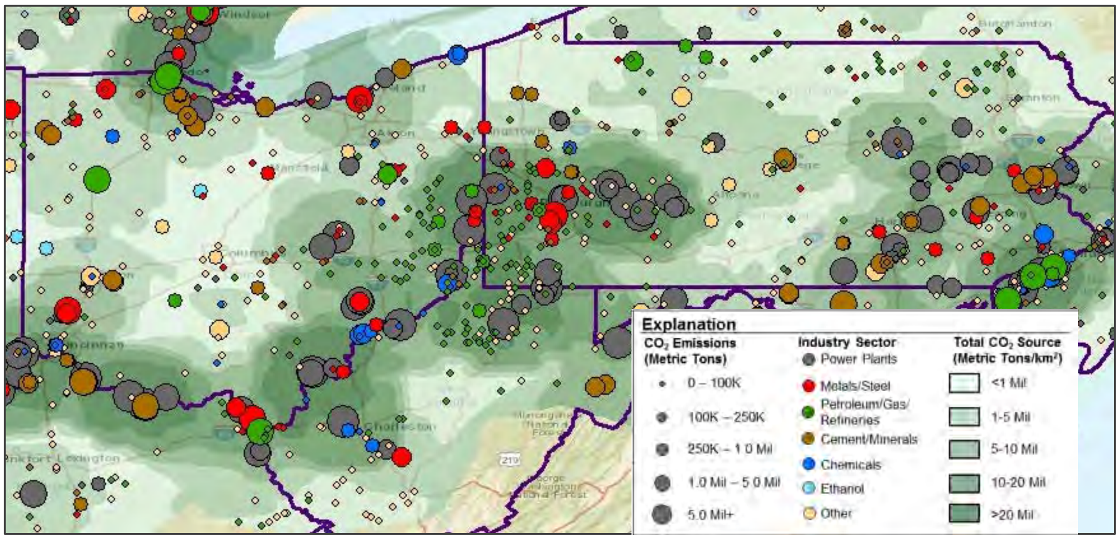
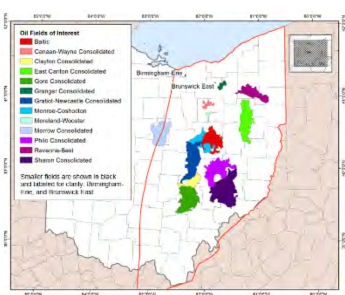
Introduction
Why CAB-CS?

- This area is a good fit because of its existing coal resources, potential EOR opportunities, and potential for capture technology development



Marcellus/Utica Gas Compression/Processing Facilities

PTTGC Ethane Cracker Plant
$5-6 Billion Development



Depleted oil fields

Ethanol Plant

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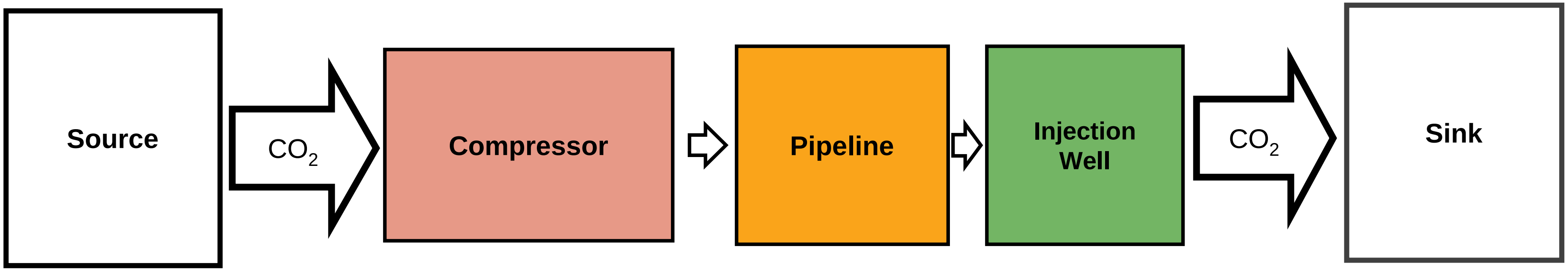
Introduction
Project objectives

- **Form a CCS coordination team** capable of addressing regulatory, legislative, technical, public acceptance, and financial challenges specific to commercial-scale deployment of the CO_2 storage project
- Perform a **high-level technical sub-basinal evaluation** and identify and **evaluate potential CO_2 sources**
- **Develop a general plan for the storage complex and storage site(s)** that would enable an integrated carbon capture and storage (CCS) project to be economically feasible and publicly acceptable



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Introduction

Project organization and team members

Sponsors

U.S. Department of Energy | National Energy Technology Laboratory

Ohio Development Services Agency

Project Lead

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Technical Advisory Committee

AEP, Buckeye Brine,
GE Oil & Gas,
The Energy Cooperative,
Three Rivers Energy

Technical Advisors

Project Management (Task1)

Strategy Advisors

Task 2	Task 3	Task 4	Task 5	Task 6
Carbon Source Review & Assessment	Sub-Basinal Geologic Storage Assessment	CAB-CS Project Definition	CCS Project Integration & Planning	Team Building Activities

PKM Energy · PNNL · Los Alamos National Laboratory (Est. 1943) · WADE · VORYS

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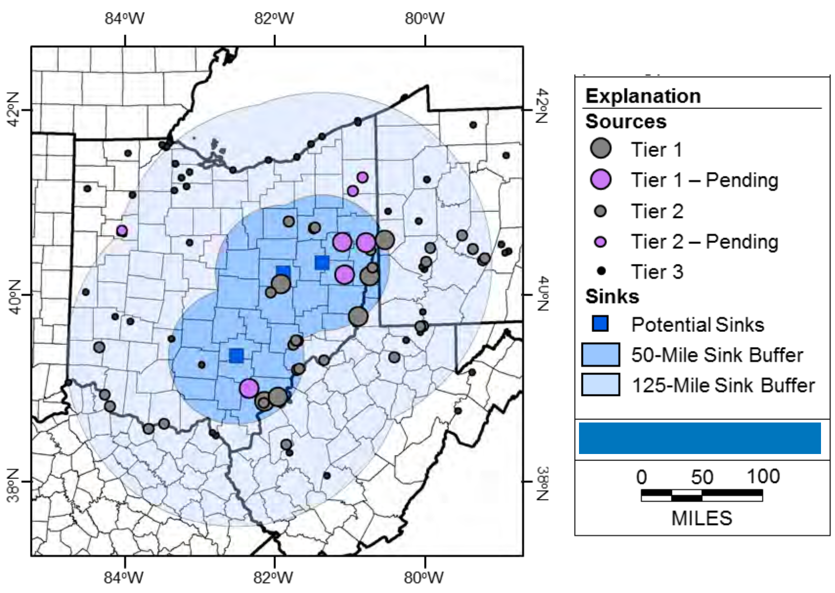
Technical Status

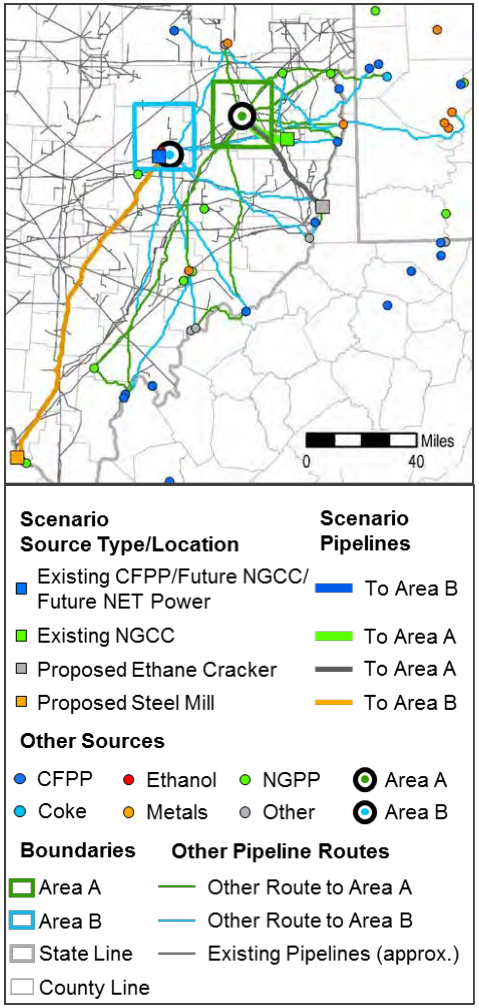
Task 2. Carbon Source Review and Assessment

- Completed the review of CO_2 sources in Central Appalachian Basin using U.S. EPA Greenhouse Gas Reporting Program (GHGRP), U.S. EPA Emissions and Generation Resource Integrated Database (eGRID), trade journals and news reports, and Ohio Public Siting Board.
- Ranked sources into Tiers based on size and proximity to storage location



Technical Status
Task 2. Carbon Source Review and Assessment

- Performed source-sink routing for 25 scenarios to two selected areas using LANL's SimCCS
- Selected six scenarios for more detailed analysis:
  - Existing coal-fired power plant
  - Future new NGCC
  - Future NET Power
  - Existing NGCC
  - Proposed Ethane Cracker
  - Proposed Steel Mill
- Researched capture costs and processes using DOE/NETL, academic and industry sources
- Used results for input for economic analysis under Task 5



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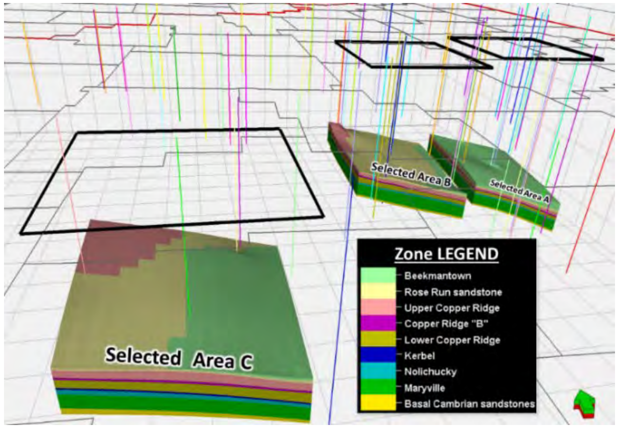
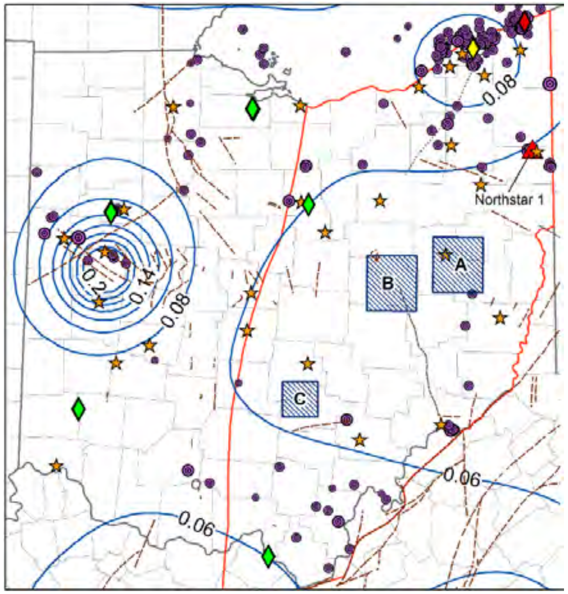
Technical Status
Task 3. Sub-basinal Analysis

- Performed reservoir analysis and caprock assessment using existing geologic data gathered under previous efforts funded by DOE/NETL and Ohio Coal Development Office
  - Calculated storage capacity estimates
  - Identified depleted oilfields near the areas
  - Assessed caprock characteristics, nearby geologic hazards (fractures and faults) and seismic activity
- Used results to identify a primary and a secondary Selected Area for more detailed assessment.





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Technical Status
Task 3. Sub-basinal Analysis

- Tested the National Risk Assessment Protocol (NRAP) tools
  - NRAP-Integrated Assessment Model-Carbon Storage (NRAP-IAM-CS) to determine risk-based AOR
    - assumes open well connects the injection zone and USDW (consistent with EPA guidance)
  - Wellbore leakage model to assess leakage risk from actual wellbore locations
    - locational data and depths for known wellbores, and built-in well permeability distributions
  - Risk from legacy wells were very low (less than 0.001% CO_2 injected)

NRAP Risk-Based AoR Method

Simulate CO_2 injection with CMG-GEM reservoir model (Task 4)

Extract CO_2 saturation and pressure data

Calculate CO_2 and brine influx to USDW aquifer

Calculate area of USDW aquifer impacted above threshold values (AoR)

Wellbore Leakage Model

Leakage risk from legacy wells

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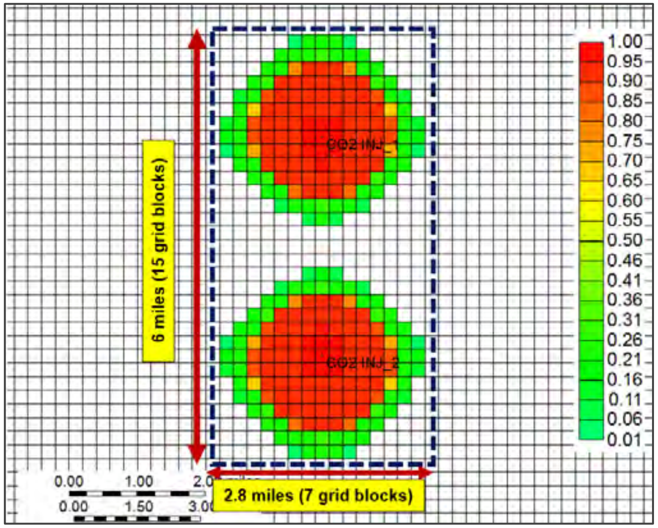
Technical Status
Task 4. Project Definition

- Completed reservoir modeling using CMG-GEM
  - Areal extent of the plume ~17mi^2 was larger than the critical pressure front; thus, plume boundary defines the AOR per EPA rule
- Defined the infrastructure required for:
  - Pipelines, wellhead equipment, injection wells, monitoring
- Identified large property owners within the selected areas



CMG-GEM Model Results
(CO_2 plume is shown with colored contours of gas saturation (~17 mi^2)

Primary Selected Area	
Owner	Total acreage
State of Ohio	28,000
AEP Generation/Ohio Franklin Realty	19,000
Mineral Resources Company #1	6,900
Nonprofit Organization #1	5,800
Private Owner/Farm #3	1,800
Mineral Resources Company #2	1,600
Private Company #1	1,200
Private Owner/Farm #4	1,000
Nonprofit Organization #2	1,000
Private Company #2	1,000

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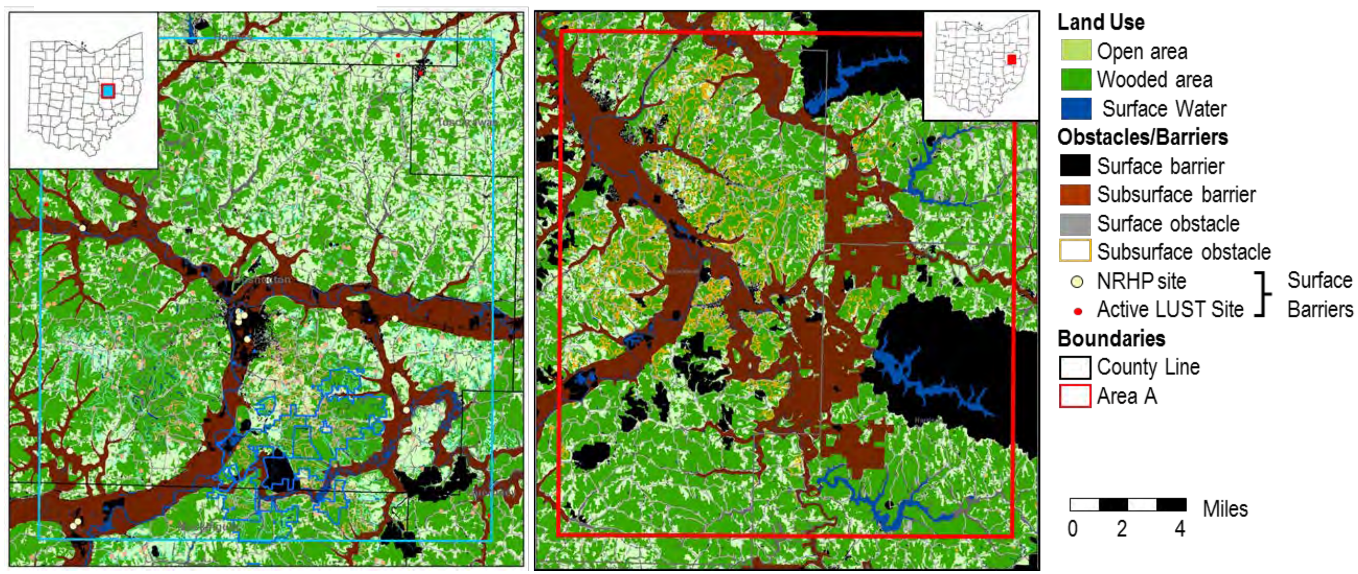
Technical Status
Task 4. Project Definition

- Created simplified land use maps (open areas, wooded areas, and surface water)
- Identified environmentally and other sensitive areas that may not be developed or require special considerations and/or permitting.
- Worked with AEP under Task 6 to identify possible locations on their property for additional characterization in Phase II

Primary Selected Area

Secondary Selected Area



Technical Status
Task 5. Project Integration

- Focused on potential opportunities or hurdles related to regulatory, legislative, public policy, public acceptance, and economic issues
- *Regulatory and legislative assessment*
  - Examined legal feasibility of CCS in Ohio
  - Honed in on questions of property rights and long-term liability
  - Drew on experience in other states and at federal level
  - Currently no comprehensive regulations for CCS in Ohio, but existing Ohio oil, gas, and brine disposal operations and CCS regulations from other states can be used as a model to inform CCS deployment in Ohio.

Technical Status
Task 5. Project Integration

- Outlined the permitting process for stratigraphic test wells, UIC permits, pipelines, air quality, and NEPA compliance
  - Permitting will require several years to complete.
  - EPA Region 5 is the UIC Class VI permitting agency, although recommend Ohio EPA consider obtaining primacy to streamline process

Site	Location	Permit Type	Permitting Agency	CO_2 Injection (metric tons)
MRCSP R.E. Burger	OH	Class V	OEPA UIC Program	100
AEP Mountaineer Plant	WV	Class V	WV DEP UIC Prog.	37,000
MRCSP East Bend	KY	Class V	EPA Reg 5 UIC Program	1,000
MRCSP Michigan Basin	MI	Class V	EPA Reg 5 UIC Program	60,000
MGSC IBDP ADM Plant	IL	Class I,VI	EPA Reg 5 UIC Program	999,215
Illinois ICCS ADM Plant	IL	Class VI	EPA Reg 5 UIC Program	TBD
FutureGen	IL	Class VI	EPA Reg 5 UIC Program	NA
Ohio CO_2 Test Well	OH	O&G Test	Ohio DNR Oil and Gas	NA
KYCCS	KY	Class V	EPA Reg 4 UIC Program	500

Note: IBDP = Illinois Basin – Decatur Project; ICCS = Industrial Carbon Capture and Storage.

Technical Status
Task 5. Project Integration

- *Preliminary Social Characterization*
  - Assessed background **P**olitical, **E**nvironmental, **S**ocio-economic, **T**echnology, **E**conomic, and **L**egal (PESTEL) conditions in study area[1]
  - Based on internet study, media search, and discussion with project team
- *Initial Outreach Plan*
  - Established and documented procedures for outreach
  - Developed initial project messaging and engagement materials
  - Guided Stakeholder Engagement
    - One-on-one dialogue with senior staff in the Governor's Office, Cabinet Directors, state agency regulators, congressional staff, regional economic development directors in Appalachia Ohio and leaders in organized labor

[1]https://hub.globalccsinstitute.com/sites/default/files/publications/119186/social-site-characterisation-stakeholder-engagement.pdf

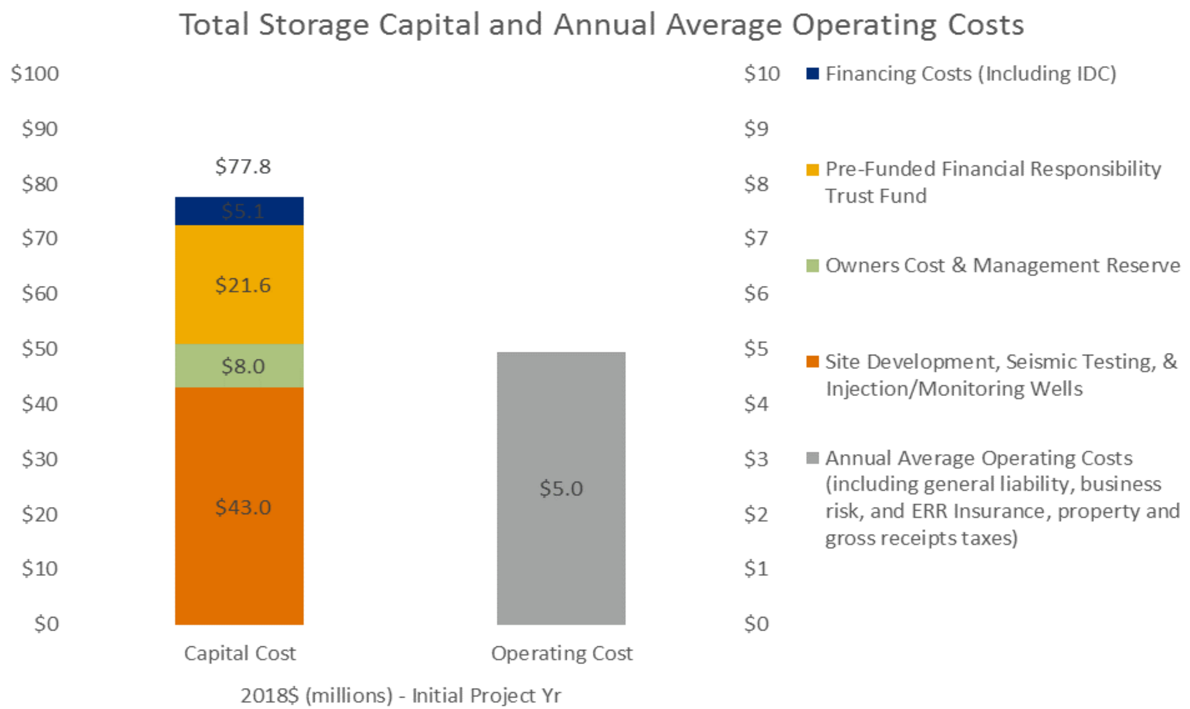
Technical Status
Task 5. Project Integration

Final Outreach Plan and Documentation

- No PESTEL “showstoppers” that indicate either overwhelming support or concern about CCS
- While regional economy is building, opportunity for new jobs and revenue welcome in the region
- Presence of a regional energy industry is positive: increased stakeholder familiarity with aspects of CCS and potential business synergies
- One-on-one stakeholder outreach suggests familiarity with CCS
- Thus, focus on jobs and economy with environmental benefit as a secondary issue. Early public outreach should include business leaders, legislators, and industry experts.

Technical Status
Task 5. Project Integration

- *Examined project economics*
  - Developed a detailed discounted cash flow model to evaluate source-to-sink scenarios
  - The total capital cost for a 50 MMt saline storage complex operating for 30 years is ~$80M with an operating cost of ~$5M per year.



Technical Status
Task 5. Project Integration

- CO_2 pipeline capital and operating costs were developed using the NETL CO_2 Transport Cost Model
- Pipeline routes and distances estimated by Battelle/LANL

Source	Pipeline Distance (mi)	Capital Cost (million 2018$)
SCPC Retrofit	<10	9
NGCC Retrofit	<50	41
New NGCC	<10	9
NET Power NGCC	<10	9
Hydrocarbon Cracker Plant	50	100
Independent Steel Mill	100	221

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Task 5. Project Integration

Preliminary capital and operating costs estimates for the capture of CO_2 were derived from a number of sources:

- NETL's Cost and Performance Baseline for Fossil Energy Plants Vol Rev 3 July 6, 2015 DOE/NETL-2015/1723
- NETL's Cost and Performance Baseline for Fossil Energy Plants Supplement: Sensitivity to CO_2 Capture Rate in Coal-Fired Power Plants; June 22, 2015 - DOE/NETL-2015/172
- Post-Combustion Capture Retrofit: Eliminating the Derate; August 21, 2017
- Cost of Capturing CO_2 from Industrial Sources January 10, 2014 DOE/NETL-2013/1602
- NetPower Literature

Source	Capture Capital Cost (Millions, 2018$)
SCPC Retrofit	940
NGCC Retrofit	674
New NGCC	645
NET Power NGCC	N/A*
Hydrocarbon Cracker Plant	159
Independent Steel Mill	844

*CO_2 is a byproduct

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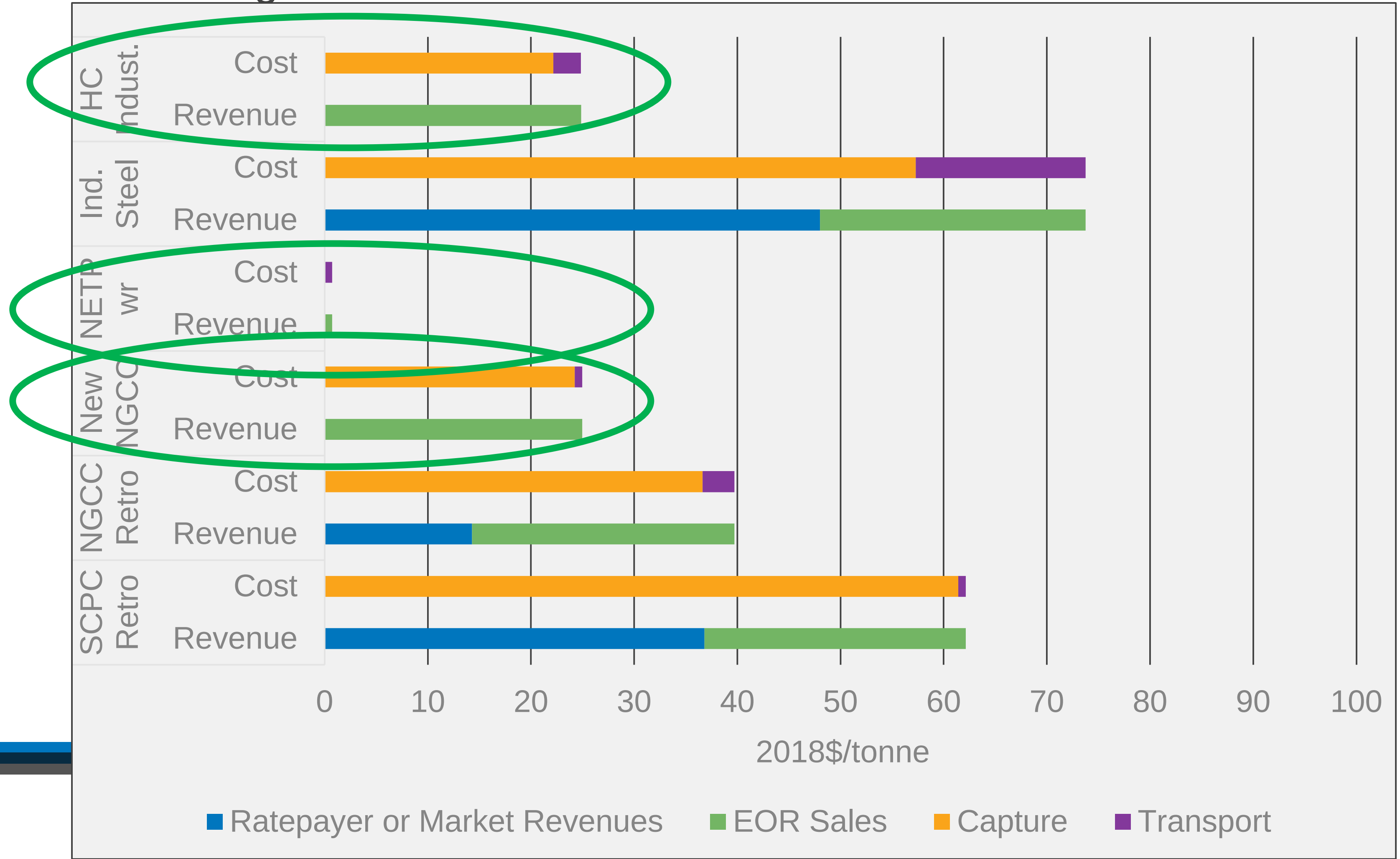
Task 5. Project Integration

- 30-Yr levelized CCS cost and revenue needs with 100% EOR Sales, 45Q, low cost financing



Technical Status

Task 5. Project Integration

Takeaways from the economic assessment

- Estimated storage costs are not a key driver on the overall cost of CCUS
- Full utilization of enhanced Section 45Q tax credits critical to future CCUS opportunities
- Additional sources of revenue from ratepayers or a long-term PPA are required for coal and gas retrofit applications even with enhanced Section 45Q tax credits
- New conventional NGCC with 100% EOR sales could cover the costs of capture and transport when coupled with Section 45Q tax credits and low cost financing
- New technologies like Net Power that require little or no backend capture costs potentially make CCUS competitive even without EOR

Technical Status

Task 6. Team Building

- Held three technical advisory meetings
- Worked with AEP on planning and siting review for Phase II
  - AEP agreed to provide a location on its Conesville Plant property
  - A list of potential locations for a stratigraphic test well was developed.

Desirable Reservoir Geologic Characteristics

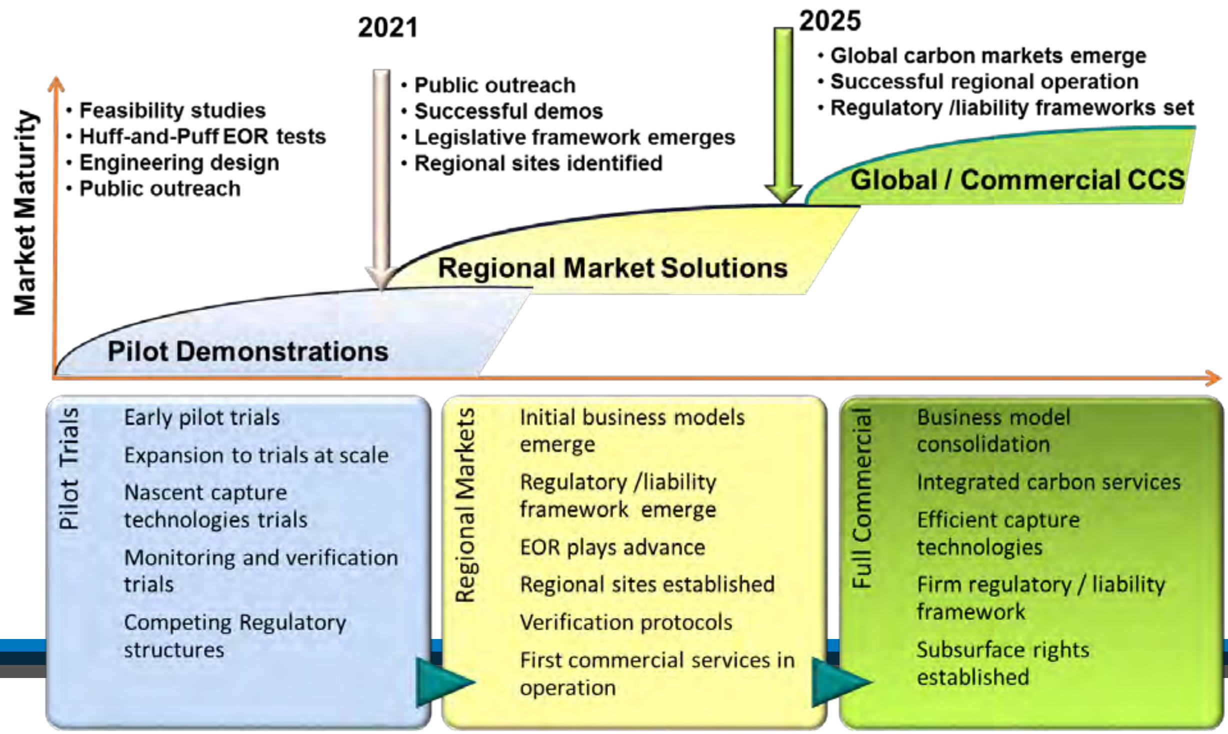
>3,000 ft deep
>10,000 ppm TDS
Saline or depleted O&G reservoirs
Few well penetrations
Existing characterization data
Overlain by low permeability caprock
High storage potential
Amenable to monitoring
Low seismicity, faulting

Desirable Surface Characteristics

Low population density
Outside sensitive areas/USDWs
Proximity to major roads, power
Proximity to oil & gas operators
(Collocated with oil/gas production)
Subsurface rights

Technical Status
Task 6. Team Building

- Developed a commercialization plan for implementation in 2025
  - Pilot projects are the first steps in the maturation of the commercial market.
    - Can reduce risk and costs by providing mechanisms to learn through experience, work through legislative and regulatory issues, develop verification protocols, and determine the best business models



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Accomplishments to date

- Technical work completed for the project
- Draft Final Technical Report submitted to DOE/NETL on July 31, 2018
  - Report will be finalized after comments received from DOE/NETL and OCDO
  - Several manuscripts for peer-reviewed journals are planned
- Significance of work
  - Learning by doing
  - Adding to NETL best practices and tools
  - Building the elements of the CCS roadmap for CAB-CS area
    - While project was not selected for Phase II, the project helped to define future research needs and the results confirm the project would greatly benefit the region

Lessons learned

- Fossil fuels will continue to be important in the CAB-CS region for the foreseeable future
- Innovative CCUS policy development needed for CAB-CS region
- Data collection and analysis needed to demonstrate storage certainty – existing wells/data identified in both selected areas
- Capture costs are a limiting factor for making CCUS economical

Synergy opportunities

- Commercial market for CCUS is emerging
- Existing oil and gas infrastructure can be used for CCUS projects
- Leverage current R&D efforts funded by the DOE/NETL and the State of Ohio for CCUS development
  - Utica/Point Pleasant tight oil play in eastern Ohio
  - Current and future opportunities funded by OCDO
  - Stakeholder outreach and education conducted under Midwest Regional Carbon Sequestration Partnership (MRCSP)

Project summary

- Prefeasibility study for the implementing a commercial-scale CCUS project in the CAB-CS region completed
- Specific accomplishments include:
  - Assessed six source-sink storage scenarios
  - Identified two candidate storages sites
  - Defined project dimensions and infrastructure requirements and strategies to deal with property/mineral rights and site screening
  - Studied project economics, regulatory and technology requirements, permitting, public outreach, and liability
  - Identified team-building requirements and path forward
- Next steps include identifying funding opportunities for future research into implementing CCUS in the CAB-CS region

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Appendix

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

Benefit to the program
Major Program Goals

- Develop and validate technologies to ensure 99% storage permanence
- Develop technologies to improve storage efficiency while ensuring containment effectiveness
- Support industry's ability to predict CO_2 storage capacity in geologic formations to within ±30 percent
- Develop Best Practice Manuals for MVA; site screening, selection, and initial characterization; outreach; well management activities; and risk analysis and simulation.

Benefit to the program
Benefit Statement

- This project is designed to integrate storage with existing and emerging CO_2 sources in an area with a dense concentration of power plants, natural gas processing facilities, and other industry through the completion of a CarbonSAFE pre-feasibility plan for the Central Appalachian Basin.

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Benefit to the program
Project overview goals and objectives

Objectives	Tasks
Perform a **high-level technical sub-basinal evaluation** to identify a potential storage complex with storage site(s), including a description of the geology and risks associated with the potential storage site. **Identify and evaluate potential CO_2 sources**	2 – Source Review 3 – Sub-Basin Assessment
Develop a general **plan for the storage complex and storage site(s)** that address the challenges and would enable an integrated capture and storage project to be economically feasible and publicly acceptable	4 – Project Definition 5 – Project Integration
Formation of a CCS coordination team capable of addressing regulatory, legislative, technical, public policy, and financial challenges specific to commercial-scale deployment of the CO_2 storage project	6 – Team Building

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Benefit to the program

Gantt chart

Task Name	FY2017			FY2018			
	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1: Project Management & Planning	━	━	━	━	━	━	━
Project Kickoff Meeting	◆						
Task 2: Carbon Source Review & Assessment	━	━	━				
Complete Review of Carbon Sources, Capture Feasibility			◆				
Task 3: Sub-Basinal Geologic Storage Assessment		━	━	━			
Complete Sub-Basinal Geologic Storage Assessment				◆			
Task 4: CAB CarbonSAFE Project Definition		━	━	━			
Complete Project Definition				◆			
Task 5: CCS Project Integration & Planning	━	━	━	━	━	━	
Develop Plan for Next Phase of CAB-CS Complex Development				◆			
Task 6: Team Building Activities	━	━	━	━	━	━	━
Finalize Commercialization Plan						◆	

*Final deliverable is due 90 days after project end date of 7/31/2018.

Benefit to the program
Bibliography

- The CAB-CS project has been recommended for inclusion in a Special Issue of the International Journal Greenhouse Gas Control (IJGGC), published by Elsevier. This virtual special issue will collect peer-reviewed, full papers describing work presented at the GHGT-14 conference that are published in IJGGC. We plan to prepare a manuscript accordingly.
- The NRAP team (LLNL, LANL, PNNL, Battelle) plans to include the CAB-CS project in a joint paper they are preparing for peer review. Journal to be identified.