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Hydrogen/CO2 Regulation and Economics
February 2024

SARTA Hydrogen Fuel Cell Bus
Refueling Station
Canton, Ohio

MEC Energy Conference
February 27, 2024

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Energy Policy Center
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Cleveland State University

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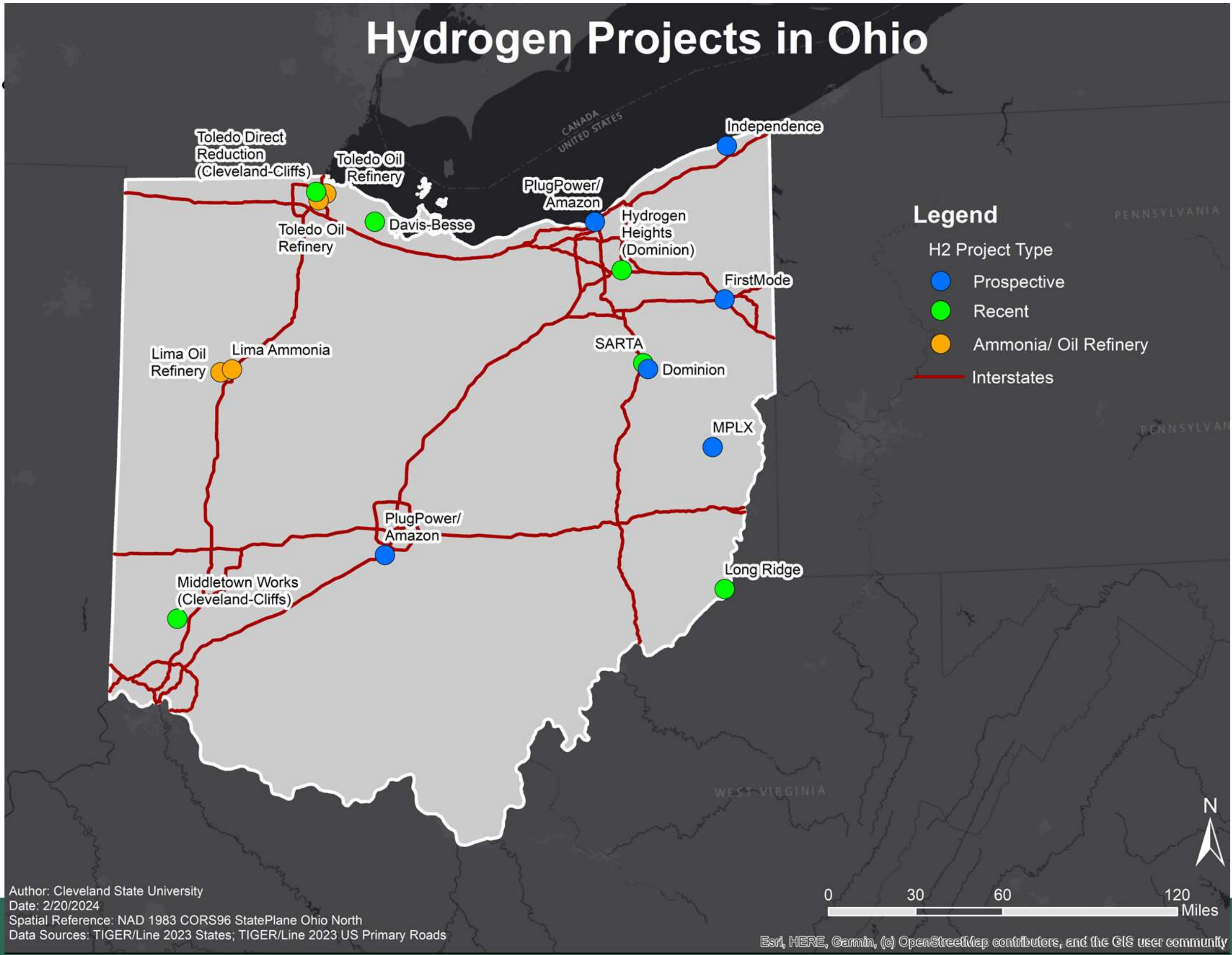
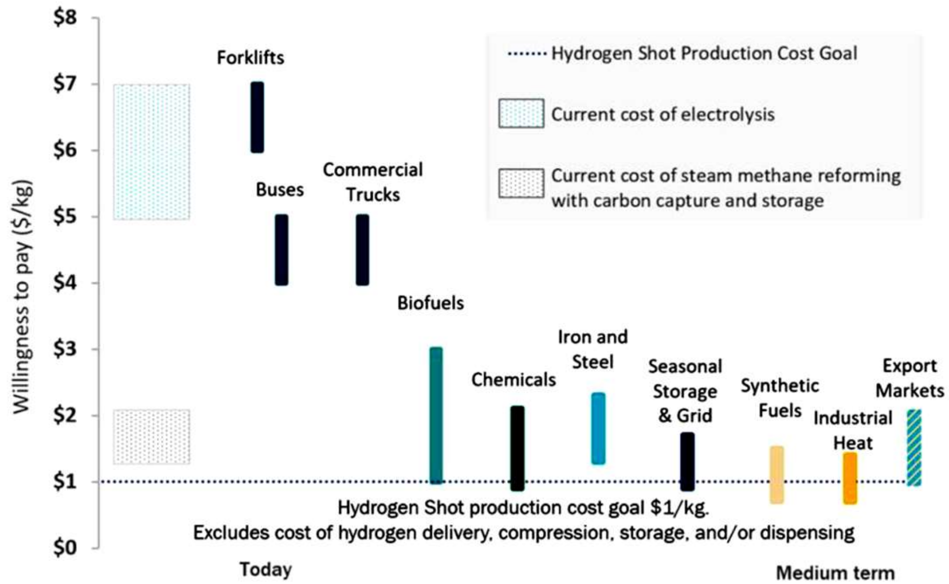


Hydrogen Economics

Willingness To Pay

Willingness to pay, or threshold price, for clean hydrogen in several current and emerging sectors.

- includes production, delivery, and conditioning onsite, such as additional compression, storage, cooling, and/or dispensing.
- Current costs of hydrogen production depicted do not include impacts of regulatory incentives, such as those in IRA.



Source: U.S. Department of Energy Hydrogen Roadmap 2023

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Federal Investment Into Clean Energy

- **Bipartisan Infrastructure Bill**
  - $73 billion over 5 years on grid infrastructure
  - $50 billion over 5 years for weatherization
  - ***$8 billion for clean hydrogen infrastructure***
  - ***$1.5 billion for hydrogen research***
  - *$**12 billion for carbon capture and sequestration***
- **Inflation Reduction Act**
  - No Cap – federal tax credits that can be converted to cash – 30-50% of project cost
  - Covers renewable power, geothermal, microgrids, H2
  - McKinsey estimates credits at over $400 B over ten years – *without H2*
    - ***With H2, estimated at $1 trillion***

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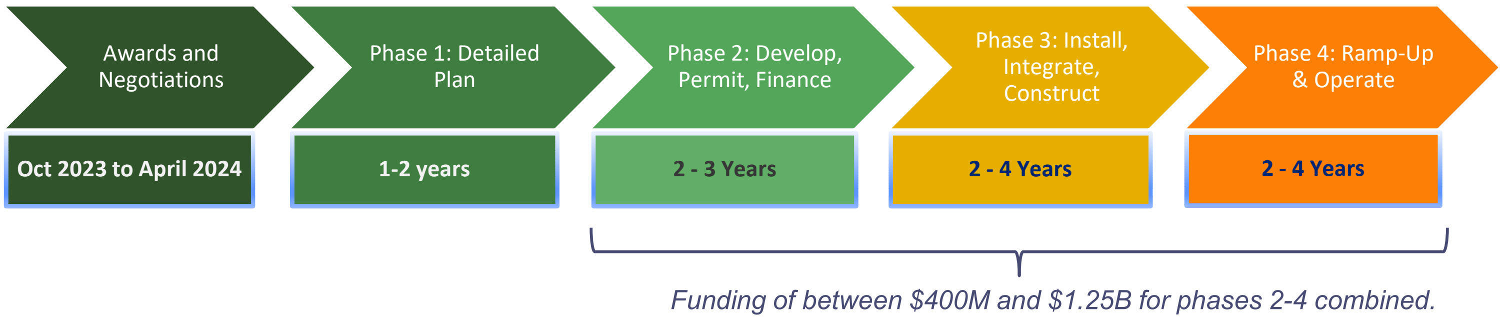
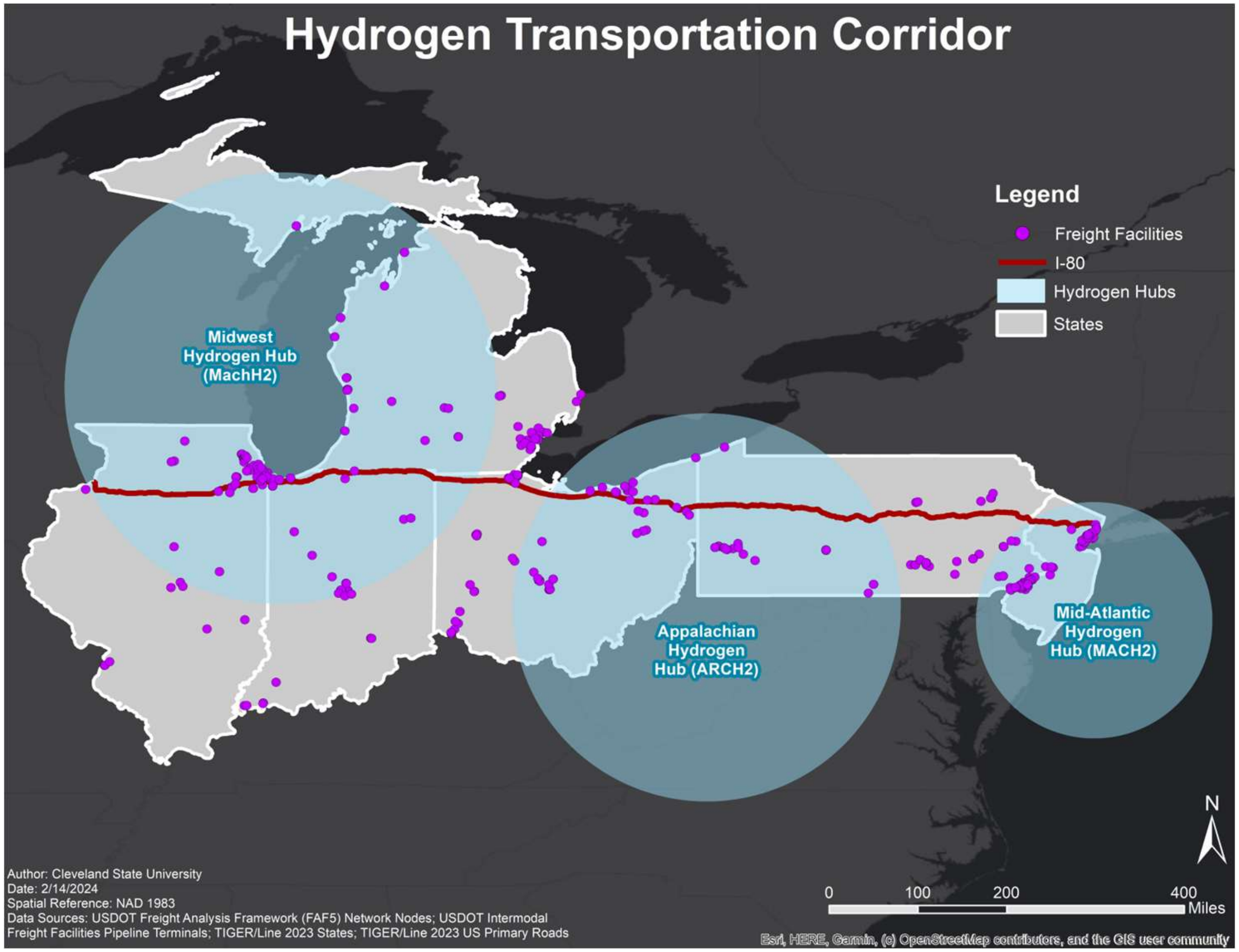
Dept of Energy Clean Hydrogen Hub Timeline



- **$7 Billion in Awards Made in October 2023 for Clean H2 Generation**
  - 7 of 33 finalists awarded hubs
    - **ARCH2 -- $925 mm (led by Battelle)**
      - Ohio, West Virginia, Pennsylvania, Kentucky
    - Other Winners: California, Gulf Coast, Heartland (Minn), Mid-Atlantic, Midwest (Ill), Pacific NW
  - $1 Billion more coming for market development programs
    - Notice of Intent summer 2023 for clean hydrogen off takers
- **Requirements**
  - Production capacity of at least 50 to 100 metric tons/day
  - 50% non-federal cost share
  - Clean H2 defined as less than 4 kg CO2e/kg H2 for lifecycle emissions



Hydrogen Transportation Corridor
Legend
Freight Facilities
I-80
Hydrogen Hubs
States
Midwest Hydrogen Hub (MachH2)
Appalachian Hydrogen Hub (ARCH2)
Mid-Atlantic Hydrogen Hub (MACH2)
N
0 100 200 400 Miles
Author: Cleveland State University
Date: 2/14/2024
Spatial Reference: NAD 1983
Data Sources: USDOT Freight Analysis Framework (FAF5) Network Nodes; USDOT Intermodal Freight Facilities Pipeline Terminals; TIGER/Line 2023 States; TIGER/Line 2023 US Primary Roads
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

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Regulatory Issues for Hydrogen and Carbon Dioxide Economies

MEC Energy Conference February 2024

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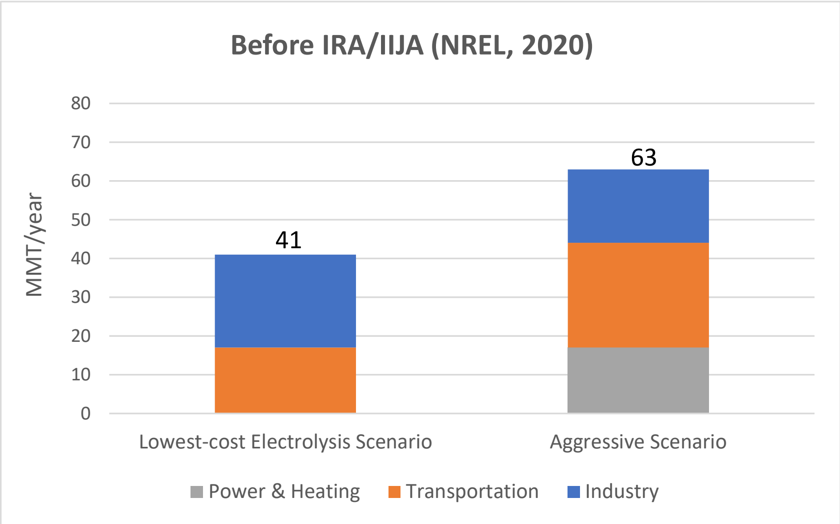
Economics of Hydrogen and 45V Production Credits

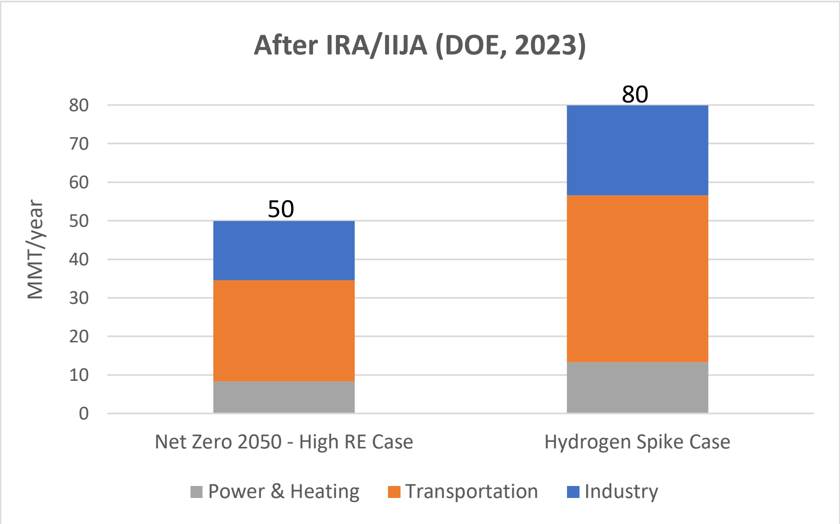
Mark Henning

Energy Policy Center

Cleveland State University

Increase in Projected U.S. Hydrogen Demand Since IRA & IIJA





- Projected 2050 market size by sector for similar scenarios
- Lowest-cost Electrolysis Scenario ≈ Net Zero 2050 – High RE Case
- Aggressive Scenario ≈ Hydrogen Spike Case
- Increase in projected U.S. hydrogen demand for similar cases of 20-25%

Projected Demand for Hydrogen in Ohio Before IRA & IIJA

Sector	2030	2040	2050
Power generation	31,100	88,400	251,200
FCEVs	2,900	35,400	430,600
Forklifts	4,700	8,400	12,700
Oil refining	188,700	202,400	217,000
Metal refining	23,900	96,600	391,000
Ammonia production	114,200	119,600	125,400
Biofuels	400	7,900	148,000
Synthetic hydrocarbons	63,600	85,800	397,700
Other Mfg. markets	8,100	9,100	10,300
TOTAL	**437,600**	**653,600**	**1,983,900**

Units are in metric tons.

- Assumes no state-level carbon regulation such as vehicle mandates.
- Hydrogen for power generation limited to 15% of capacity.

Projected Supply of Clean Hydrogen in Ohio by Source Before IRA & IIJA

Source	2030	2040	2050
Electrolysis via Nuclear Power	9,300	50,700	59,600
Electrolysis via Wind & Solar	86,600	112,800	135,900
Natural Gas (SMR)	341,700	490,100	1,788,400
TOTAL	**437,600**	**653,600**	**1,983,900**

Units are in metric tons.

- Assumes electrolytic production limited to 15% of power generation capacity.
- Hydrogen from natural gas is what must be supplied to meet demand after accounting for pink and green hydrogen.
- 1.8 million metric tons of hydrogen supplied via SMR would require around 280 bcf of natural gas.
    - 280 bcf ≈12.5% of what Ohio shale wells produced annually.

One Driver of H2 Market: 45V Credit for Clean Hydrogen Production

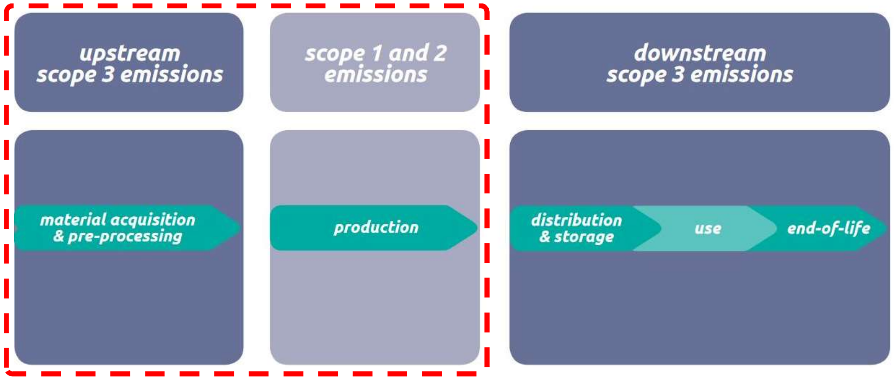
- $ credit per kg of H2 based on life-cycle GHG emissions from production.
  - Non-CO2 GHGs (e.g., methane) converted to CO2-equivalent.
  - Credit maximized if prevailing wage and apprenticeship requirements are met.

kg of GHG Emissions per Kg of H2	Maximum 45V Credit per kg of H2
2.5 to ≤ 4.0	$0.60
1.5 to < 2.5	$0.75
0.45 to < 1.5	$1.00
< 0.45	$3.00

45Q credit ⇒ $0.80 - $0.90 per kg of H2 from SMR with CCS.

- Either 45V or 45Q, but not both.
- 45Q requires at least 12,500 metric tons of CO2 annually.

- Emissions calculation based on “Well-to-Gate” system boundary.
  - Includes Scope 1, Scope 2, & partial Scope 3.
  - Partial Scope 3 includes emissions from feedstock acquisition and processing.
    - Does not include emissions from mfg. capital goods that are used to produce electricity or hydrogen.



Calculating 45V Credit for Clean Hydrogen Production

- Treasury Dept. has adopted special version of ANL's GREET to calculate emissions for 45V credit.

45V2-GREET User Interface

Simulation Year
- 2022
- 2023
- 2024

Hydrogen Production Technologies
- Steam Methane Reforming (SMR)
- Low Temperature Electrolysis
- High-temperature electrolysis (Nuclear)
- Coal Gasification
- Biomass Gasification
- Autothermal Reforming (ATR)

SMR Feedstock
- Landfill Gas
- Fossil Natural Gas

Technology Share [%]
100%
Enter Process Details
Reset
Custom Feedstock Properties
Calculate

Process Inputs	Value	Units	Process Outputs	Value	Units
Steam Methane Reforming (SMR)					
Natural Gas	Enter Value	MMBtu	Hydrogen	Enter Value	kg
Electricity	Enter Value	kWh	Steam Co-Product	0	Btu
Electricity Generation Mix*	User Defined Mix		Hydrogen Production Pressure	300	psia
CO_2 Capture and Storage	Yes		Sequestered CO_2	Enter Value	kg
Technology	**Value [%]**		**Technology**	**Value [%]**	
Residual oil	Enter Value		Hydroelectric	Enter Value	
Natural gas	Enter Value		Geothermal	Enter Value	
Coal	Enter Value		Wind	Enter Value	
Nuclear power	Enter Value		Solar PV	Enter Value	
Combustion of logging residue	Enter Value		ASCC Mix	Enter Value	
NGCC wCCS	Enter Value		**Total**	**0.0%**	

Example Output (SMR fossil gas)

Emissions	Direct Facility Emissions	Indirect Emissions	Co-Product Credits	Total	Units
CO2	96997	13105	0	110102	g/MMBtu H2
CO2 (w/ C in VOC & CO)	97007	13253	0	110260	g/MMBtu H2
GHGs	97123	24353	0	121476	g_CO2e/MMBtu H2
				14	kg_CO2e/kg H2

← Calculated lifecycle emissions for credit

45V2-GREET Emissions by Scope: H2 from SMR

SMR of RNG without CCS

Emissions Type	Description	Calculated GHGs (kg of CO2e/kg of H2)	Share of GHGs
Scope 1	Direct emissions at SMR plant with credit for using LFG that would have otherwise been flared	0.01 (net)	0.3% (net)
Scope 2	Electricity to runs SMR plant	0.25	5.5%
Scope 3	Gathering and processing RNG	4.24	94.2%
	TOTAL	**4.50**	**100%**

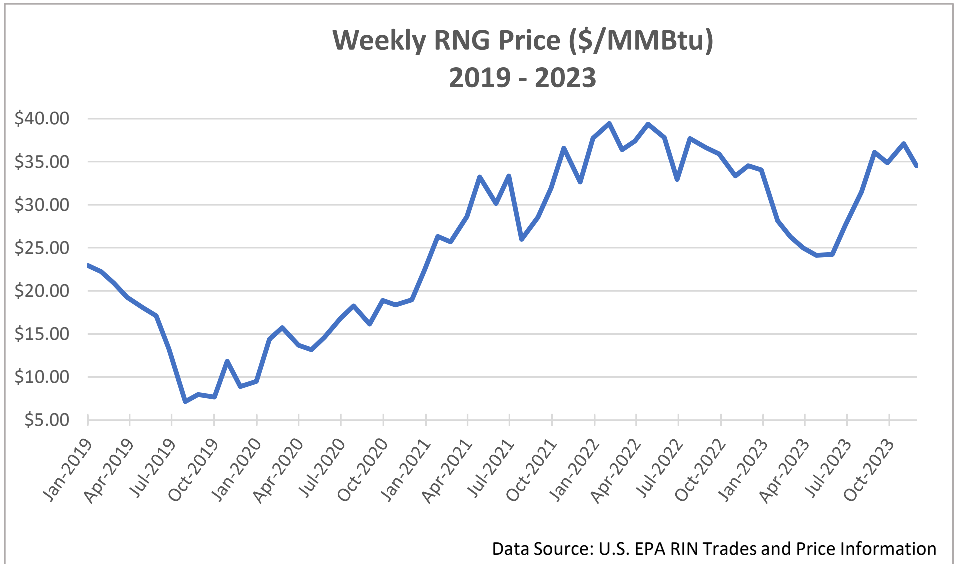
SMR of fossil gas with CCS

Emissions Type	Description	Calculated GHGs (kg of CO2e/kg of H2)	Share of GHGs
Scope 1	Direct facility emissions at SMR plant with credit for captured CO2	0.43 (net)	13.5% (net)
Scope 2	Electricity to runs SMR plant	0.25	7.7%
Scope 3	Gathering and processing fossil gas	2.53	78.8%
	TOTAL	**3.21**	**100%**

- Majority of emissions for purposes of 45V are Scope 3.
- SMR of fossil gas with CCS in this example qualifies for $0.60/kg of H2 under 45V.
  - CO2 yield of 10.63 metric tons per metric ton of produced hydrogen.
  - At $85 per metric ton under 45Q, CO2 yield translates to $0.90/kg of hydrogen.
  - 45Q likely favorable to 45V for SMR of fossil gas with CCS.

45V vs. Cost of Production and Willingness to Pay: Case of RNG

- RNG prices averaging over $25/MMBtu (US EPA)
  - Drives unsubsidized cost of hydrogen production above $4/kg (NREL H2A)
- RNG-SMR with CCS is carbon-negative
  - 45V2-GREET calculates lifecycle emissions of less than 0 kg of CO2e per kg H2
  - Qualifies for max. $3/kg credit
  - Cost to deploy CCS for SMR around $0.48/kg of hydrogen (NETL)
- Additional cost to deliver & dispense
  - At least $4/kg in the near term (Argonne)
  - Ultimate target of at least $2/kg, depending on distribution method (trucking vs. pipeline)
- WTP of $5/kg for near-term transportation markets (DOE National H2 Roadmap)

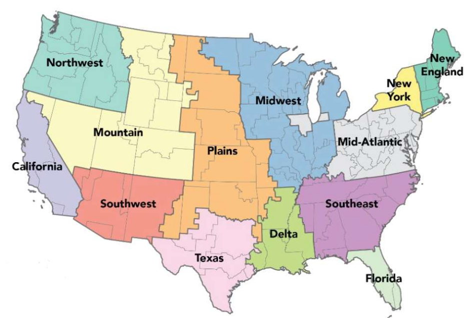


Price of RNG ($/MMBtu)	Unsubsidized Cost of RNG SMR H2 ($/kg)	Cost to Deploy CCS ($/kg of H2)	45V Credit for RNG SMR H2 w/ CCS ($/kg)	Subsidized Cost of RNG SMR H2 w/ CCS ($/kg)
$30	$5.05	$0.48	$3.00	$2.53
$25	$4.27	$0.48	$3.00	$1.75
$20	$3.48	$0.48	$3.00	$0.96
$15	$2.70	$0.48	$3.00	$0.18

(production cost only)

45V Considerations for Electrolytic Hydrogen

- Treasury released proposed guidance for 45V in late December 2023.
  - Public comments closed last week.
- Proposed guidance addresses "three pillars" of electrolytic hydrogen.
  - Additionality/incrementality. Clean power for H2 production should come from new generation sources.
    - Guidance: Clean power generators beginning commercial operations within 3 years of a hydrogen facility being placed into service are considered **new** sources of clean power.
  - Time-matching. Electrolyzer energy consumption should match clean energy production to the hour.
    - Guidance: A transition period will allow annual matching until 2028.
  - Deliverability. Clean power should be sourced from the same region as the hydrogen producer.
    - Guidance: Geographic regions are defined according to the DOE's 2023 National Transmission Needs Study and align with RTO/ISO territories.



Thank You

Cleveland State University

Van Ness Feldman LLP

Regulation of Interstate Carbon Dioxide and Hydrogen Pipelines

Prepared for the
28th Annual Ohio Energy Savings and Management Conference

Michael Diamond

February 28, 2024

Interstate Pipelines

- Need for new CO_2 and H_2 pipelines. There will likely be a need for significant expansion of pipeline infrastructure in the coming years to transport carbon dioxide and clean hydrogen.

- Currently, there are 5,400 miles of CO_2 pipelines in the U.S., used mostly in connection with oil production and in oil producing states. There are 1,600 miles of H_2 pipelines in Texas and Louisiana.

- No federal law. There is no federal law currently governing siting, construction, and operation of interstate CO_2 or H_2 pipelines. This is likely to present a challenge for the buildout of networks of these pipelines.

Regulation of Linear Infrastructure

- It is difficult to obtain land rights for linear infrastructure, particularly as facilities cross state boundaries. For this reason, energy project developers usually are given the right of eminent domain from federal or state authorities.

- Siting of interstate natural gas pipelines is regulated by FERC under the Natural Gas Act. FERC authorization orders preempt conflicting state and local law and provide developers the federal right of eminent domain.

- Siting of interstate oil pipelines and electric transmission lines is regulated by individual states, which typically provide eminent domain rights. Policymakers are trying to address challenges building electric transmission lines, which are slowing the buildout of renewable energy.

Uncertainty in Siting CO_2 and H_2 Pipelines

- No federal law governs siting of CO_2 or H_2 pipelines on non-federal lands

- State and local governments site CO_2 and H_2 pipelines. Their laws vary greatly, adding uncertainty for projects.
  - Some states have long histories of CO_2 pipeline development and have established siting procedures, including the right of eminent domain.
  - Other states have laws in place, but are considering legislation that would restrict eminent domain authority or place moratoria on CO_2 pipelines, and are dealing with contentious disputes over proposed projects.
  - Some states lack laws or rules governing CO_2 and H_2 pipelines. In these cases, local governments have siting authority.
- The availability of eminent domain varies from state to state.

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Recent State Actions

- Cancellations and delays of Midwest CO_2 pipelines. North and South Dakota have denied permits to site major CO_2 pipelines in response to landowner protests related to land use, local ordinances, and safety.
  - Navigator Heartland Greenway Pipeline: 1,300-mile pipeline cancelled after denial of construction permit in South Dakota and delays in Iowa and Illinois, due to the "unpredictable nature" of state and local regulatory proceedings.
  - Summit Carbon Solutions: 2,400-mile pipeline delayed nearly two years after denials of permits in North and South Dakota, challenges obtaining permits in Iowa and Illinois.
  - Wolf Carbon Solutions: 280-mile pipeline withdrew application with Illinois Commerce Commission after staff recommendation to deny permit, will refile

How to Transport CO_2 and H_2 Today

Imagine you own a power plant in New York and want to sequester your CO_2 emissions in a storage site in Illinois. You'll need a pipeline.

How do you get authorization to build it?

- The process is unclear. You'll need state and local authorizations from five different states. Not all states have laws clearly applying to CO_2 pipelines. And any state could veto the project.
- Ability to obtain land rights will vary from state to state.

What are the pipeline's service obligations?

- Some states require "common carriage," which require pipeline to allocate capacity to other shippers in the future. In some states, this will be required to obtain right-of-way.

What will be the costs of transportation?

- There is no single authority to prevent a pipeline from imposing unfair terms, and there may be different rate requirements in different states.

Ohio

- No statute applies specifically to CO_2 or H_2 pipelines.
- Eminent domain is available to pipelines (1) transporting "natural or artificial gas, petroleum, coal or its derivatives. . .," (2) if they serve as common carriers, and (3) they serve a "public use."
- In 2016, Ohio courts found that pipelines transporting Ohio-made propane, butane, and ethane for third parties had eminent domain power:
  1. Propane, butane, and ethane were "petroleum."
  2. A common carrier must "hold 'itself ready to serve the public impartially to the limit of its capacity." Courts cited pipeline open seasons to support finding.
  3. Public use finding was based in part on transportation of Ohio product to market.

Application to CO_2 or H_2 pipelines:

1. No court has had occasion to determine whether this law covers CO_2 or H_2.
2. Unclear how much third-party access is needed to qualify as a "common carrier."
3. If a pipeline merely passes through Ohio without "off-ramps" it might not satisfy the State's "public use" requirement.

Other States

<u>Illinois</u>

- Illinois' Carbon Dioxide Transportation and Sequestration Act covers CO_2 pipelines and requires "certificate of authority" from Commerce Commission.
  - Certificate only available based on finding that project is consistent with the "public interest, public benefit, and legislative purpose" of the State CO_2 law. This may require pipeline to support state coal industry (see report on Wolf application)
- Common carriage is not required for eminent domain, but may be needed to receive a certificate
- State legislature is considering a moratorium on CO_2 pipelines until PHMSA completes its rulemaking, and bills to eliminate eminent domain for CO2 pipelines

Questions About Economic Oversight

- To date, interstate transportation of CO_2 and H_2 has been unregulated.
  - CO_2 pipelines may be subject regulation by the Surface Transportation Board (STB) under the Interstate Commerce Commission Termination Act, but the STB's predecessor agency disclaimed jurisdiction in 1980, and the STB has not attempted to exercise jurisdiction.
  - H_2 pipelines are not subject to any federal law, though blended H_2/natural gas pipelines would fall under the Natural Gas Act

- As the market grows, there may be greater need for oversight of transportation rates and access to transportation services. Regulation would ensure that companies shipping CO_2 and H_2 pay reasonable rates and can access transportation services without unfair discrimination.

- Without federal regulation, states may lack the ability to regulate rates or services on interstate pipelines in their boundaries, under the Dormant Commerce Clause.

Paths Forward

- Status quo: State-by-State clarifications
  - Retaining existing state-by-state process would avoid disrupting states with well-developed regulatory regimes, where development is already occurring.
  - Would create risk of lopsided growth.

- Interstate compacts
  - States could agree on similar standards that would facilitate construction and operation of multi-state projects, or could agree to create multi-state siting authorities

Paths Forward

<u>Federal siting</u>

- Federal siting has supported massive buildout of natural gas pipeline infrastructure. There are several favorable aspects of FERC oversight.
- In recent years there has been greater uncertainty in FERC permitting
- Federal siting would remove authority from states with favorable processes

<u>Federal legislation</u>

- Senator Manchin's 2022 permitting legislation would classify hydrogen as "natural gas," placing under the Natural Gas Act. This would provide federal siting authority along with rate and service regulation.
- No similar legislation has been introduced for CO_2 pipelines

Paths Forward

<u>Opt-in Authority</u>

- Applicants could be given the ability to choose whether to be sited under state authority or by FERC.

<u>Federal backstop siting authority</u>

- FERC could be permitted to step in if a state denies a permit or fails to act within a year of an application
  - Navigator – project cancelled after state permit rejections
- This has been attempted for electric transmission lines, without success

Any federal siting would likely need to be accompanied by federal economic regulation over rates and access.

Paths Forward

Third-party access and rate regulation

- CO_2 and H_2 are fundamentally different from other rate-regulated commodities, in that policymakers would regulate rates to facilitate growth of a new industry, rather than to check monopoly power of existing businesses

- But some amount of light-handed regulation could help to set conditions for broader market access and faster growth. For example:
  - Allow private contracting, but ensure open access
  - Permit pipelines to set their own rates, but allow federal regulator to ensure reasonableness

Thank you!

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Developing Carbon Carbon Capture and Storage for Energy Infrastructure

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Columbus, Ohio, USA

Ohio Energy Savings & Management Conference 2024
27-28 February 2024

BATTELLE
It can be done

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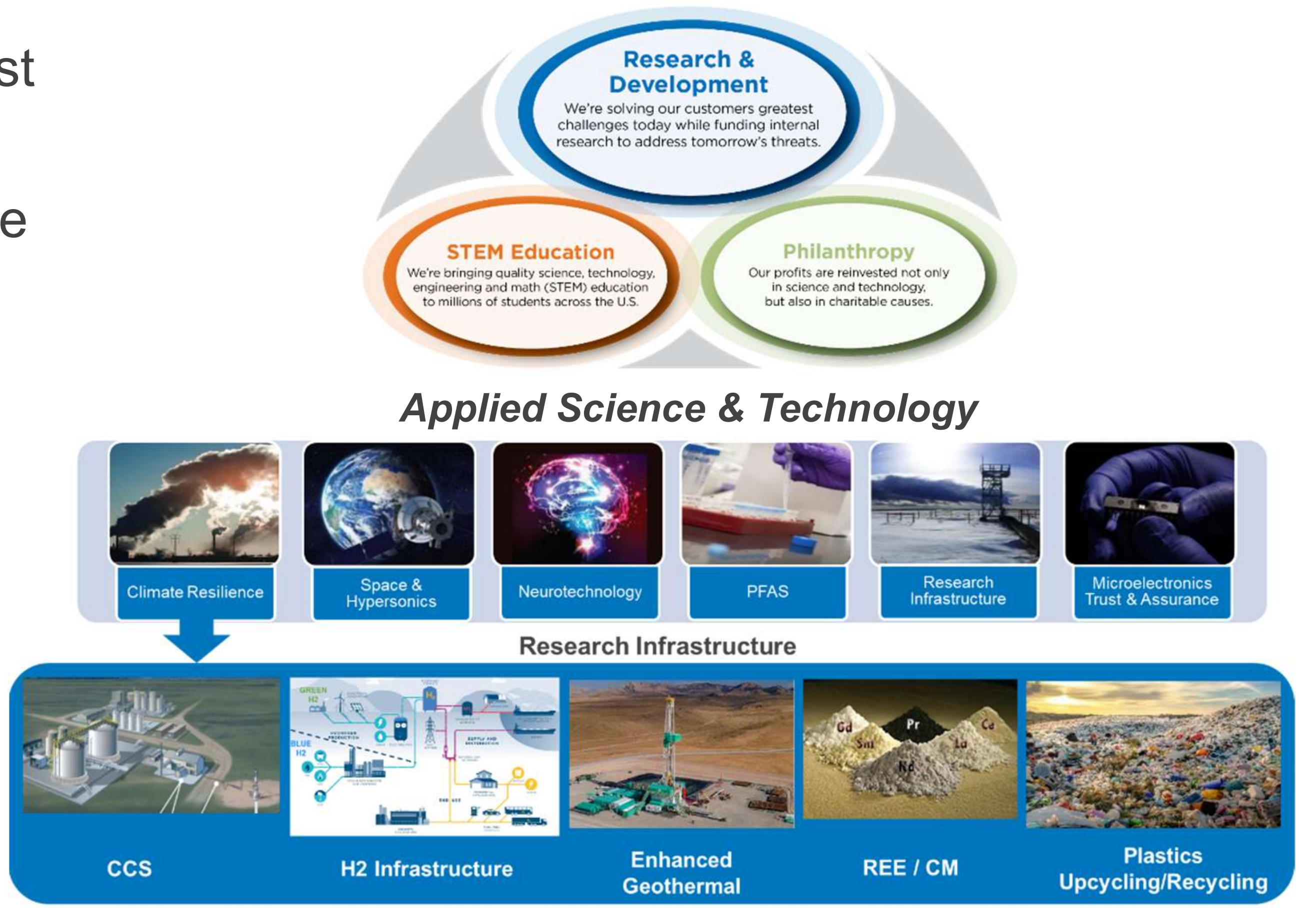
Outline

1. Introduction to CO_2 Capture and Storage (CCS)
2. Carbon Capture and Storage Status
3. Midwest Regional Carbon Initiative (MRCI)
4. Carbon Management Emerging Trends
   - CO_2 Storage and Transport Infrastructure Development
   - Hydrogen hubs
   - Direct Air Capture Technologies

BATTELLE

Introduction- Battelle mission and purpose

- Nonprofit, charitable trust formed in 1925
- Our mission: To translate scientific discovery and technology advances into societal benefits



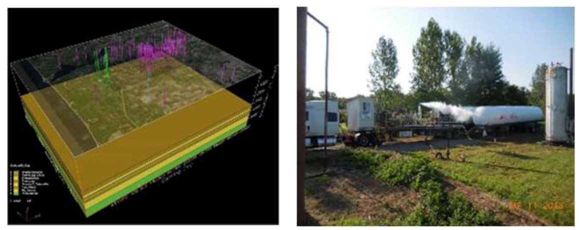
Introduction- Battelle CCS includes government, industry, & field projects on CO_2 storage over 25 years

MRCSP/MRCI Large-Scale Public-Private Partnership

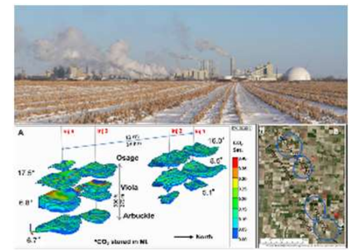
MRCSP
MIDWEST REGIONAL CARBON SEQUESTRATION PARTNERSHIP

MRCI
Midwest Regional Carbon Initiative

Commercial Carbon Storage Development



CarbonSAFE Scaling Up



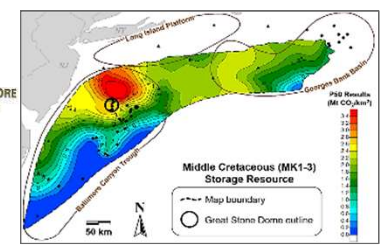
Nebraska & Kansas, Ohio, Michigan

International CCUS Development

AEP Mountaineer Pilot and FutureGen

Offshore Carbon Storage

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



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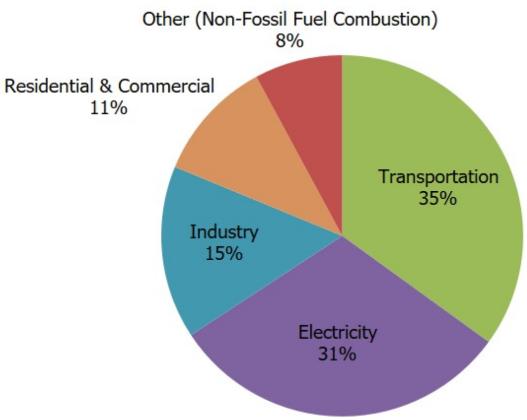
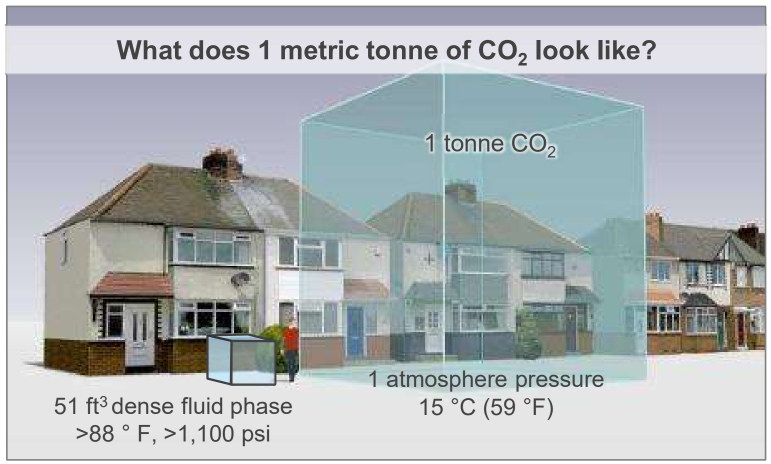
Introduction: CO_2 emissions from industrial sources



U.S. Environmental Protection Agency (2023). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021

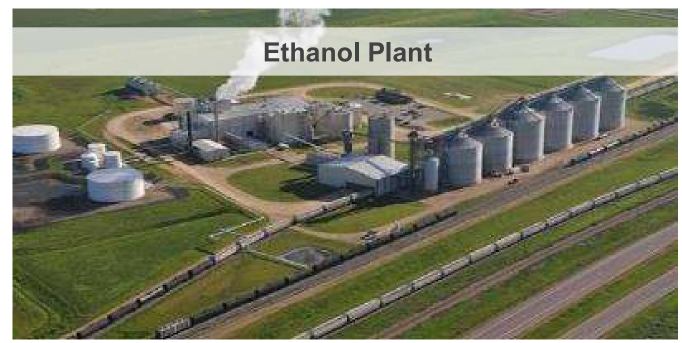
US 2021 Total Emissions = 6,340 million metric tonnes CO_2 equivalent

https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions



Typical ethanol plant ~300,000 metric tons/year

https://www.flickr.com/photos/carbonquilt/8801363368/in/photostream/



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Introduction: Carbon capture and storage Value Chain

Value chain – underpinned by subsurface science and engineering

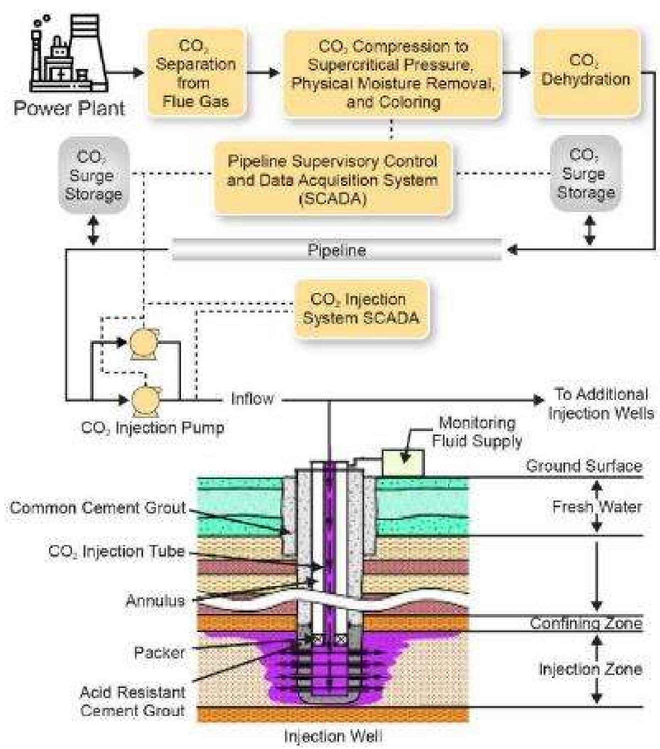
Enterprise Strategic Planning
- Carbon footprint analysis – local, corporate, regional, national, global scales

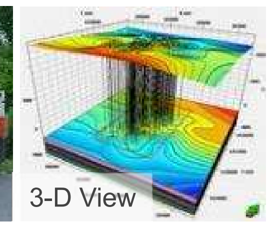
CO_2 Sources and Capture
- High purity – ethanol, ammonia (NH_3), gas processing
- Low purity – power, steel, cement etc.
- Atmospheric – direct air capture

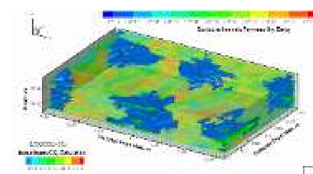
CO_2 Handling and Transport
- Regional infrastructure
- Compression, pipeline, or truck
- Optimization and regional integration
- Monitoring (inspection, corrosion analysis)

Subsurface and Injection
- Site characterization – geoscience, reservoir engineering
- Permitting and environmental
- Well field design and implementation
- Injection operations

Measurement, Monitoring, and Verification
- Long-term monitoring technologies
- Data analysis and machine learning
- Site closure and handover







Reservoir Modeling

Sandstone

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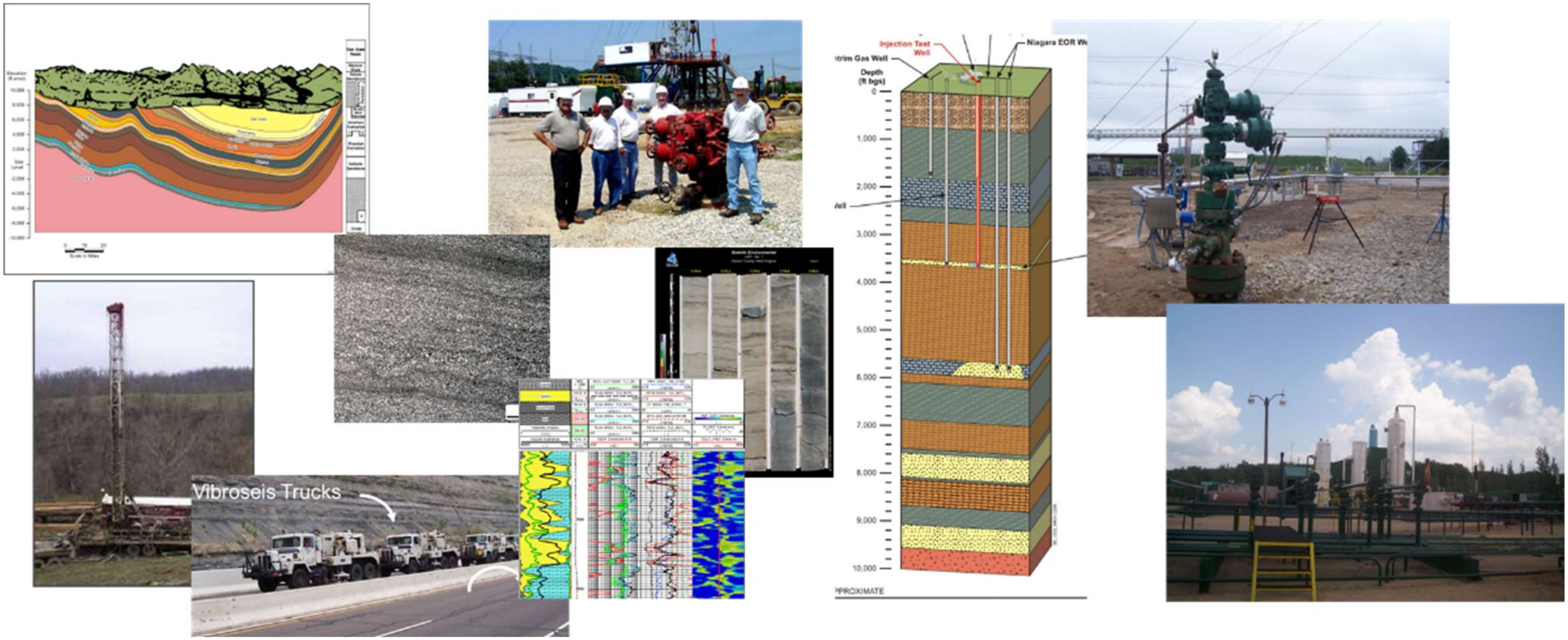
Introduction: Carbon Capture and Storage Status

Pilot scale tests→ Industrial scale demonstrations → Commercial Facilities



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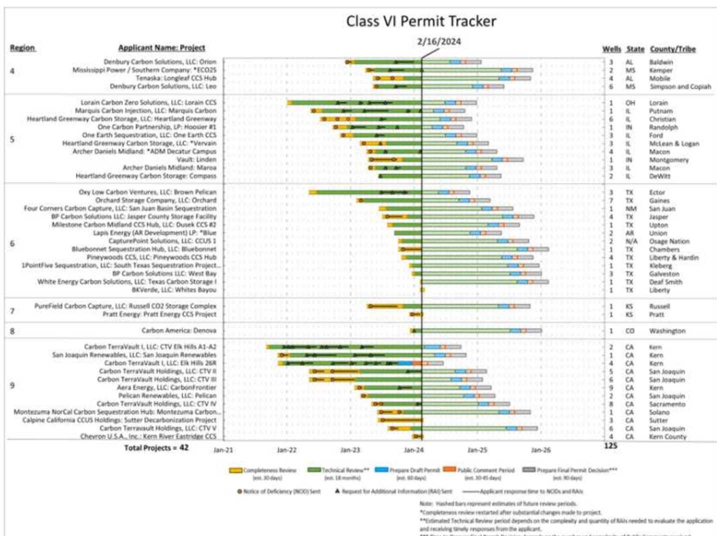
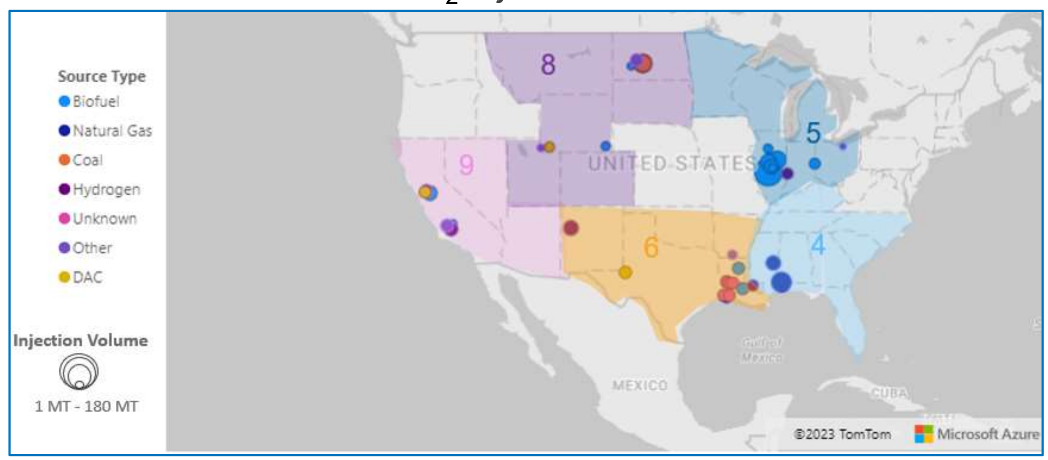
Overview of Submitted Class VI Permit Applications

- 125 U.S. EPA Class VI CO_2 Underground Injection Control permit applications as of winter 2024
- 42 projects (most have multiple wells)
- Ohio Class VI primacy application in progress, WV primacy under review by EPA



Total CO_2 Injection Mass and Source



https://www.epa.gov/uic/class-vi-wells-permitted-epa

CCS Status: Projects are Happening in Midwest U.S.

CO_2 Storage Projects in MRCI
(not including CO2-EOR)

- **1 Active Class VI Well.**
- **~9 CCS project sites pending.**
- **~20 Class VI UIC permits** with EPA Region 5
- **~10-15 additional CCS projects** under development in MRCI.
- **4 post injection or closed out projects**
- **OH Class VI primacy-application in progress (WV Class VI under review)**

State	County	Permittee/Permit Applicant	Proposed CO2 Injection Rate	Maximum Total CO2 Injection Volume	Current Status	Current Project Phase
IL	Christian	Heartlnd Grnway Navigator	N/A	N/A	Pending (6 permits)	Pre-construction
IL	Ford	One Earth Sequestration, LLC	N/A	N/A	Pending (3 permits)	Pre-construction
IL	Sangamon	City, Water, Light, & Power	N/A	N/A	(FEED)	(CarbonSAFE)
IL	Macon	ADM (IBDP)	**1.0-1.2 Mt/year**	**6.0 Mt**	**Active**	**Injection**
IL	Macon	ADM (IL ICSP)	N/A	N/A	Pending	Pre-Construction
IL	Macon	ADM (Maroa Campus)	N/A	N/A	Pending (3 permits)	Pre-Construction
IL	Mclean	Heartlnd Grnway Navigator	N/A	N/A	Pending (2 permits)	Pre-Construction
IL	Putnam	Marquis Carbon Injection, LLC	N/A	N/A	Pending	Pre-Construction
IL	St. Clair	Carbon SAFE IL Corridor	NA	NA	Class VI prepared	Pre-Construction
IN	Randolph	One Carbon Partnership, LP	N/A	N/A	Pending	Pre-Construction
IN	Vigo	Wabash Carbon Services, LLC	0.834 Mt/year 0.834 Mt/year	10 Mt 10 Mt	Pending Pending	Pre-Construction Pre-Construction
IN	Lawrence	Heidelberg Materials	N/A	N/A	(FEED)	(CarbonSAFE)
OH	Lorain	Lorain Carbon Zero Solutions	N/A	N/A	Pending	Pre-Construction
KY	Boone	Duke East Bend	0.001 Mt/yr	0.001 Mt	Class V	Closed
IL	Macon	ADM	0.3 Mt	1.0 Mt	Class V	Post-Injection
MI	Otsego	Core Energy	0.5 Mt/year	0.06 Mt	Class V	Closed
WV	Mason	AEP Mountaineer	0.12 million metric tons/year	0.037 million metric tons total	Class V	Closed

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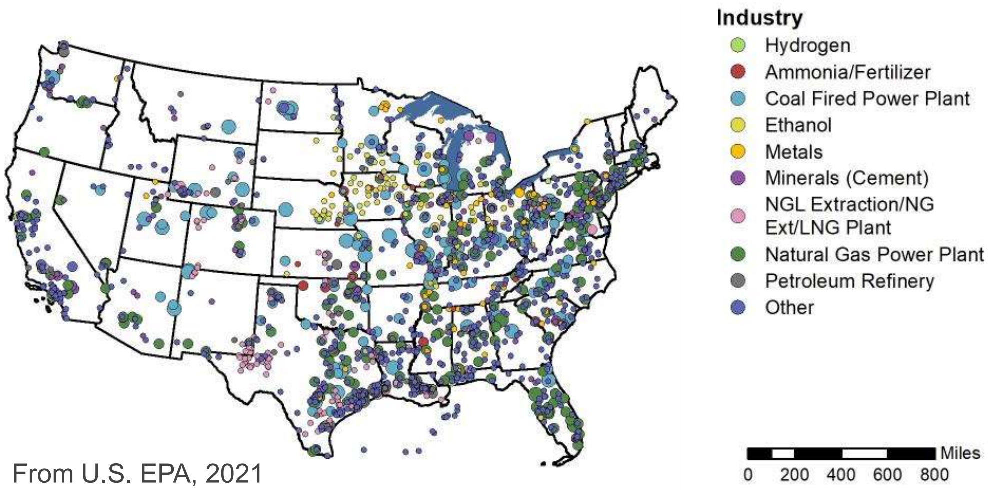
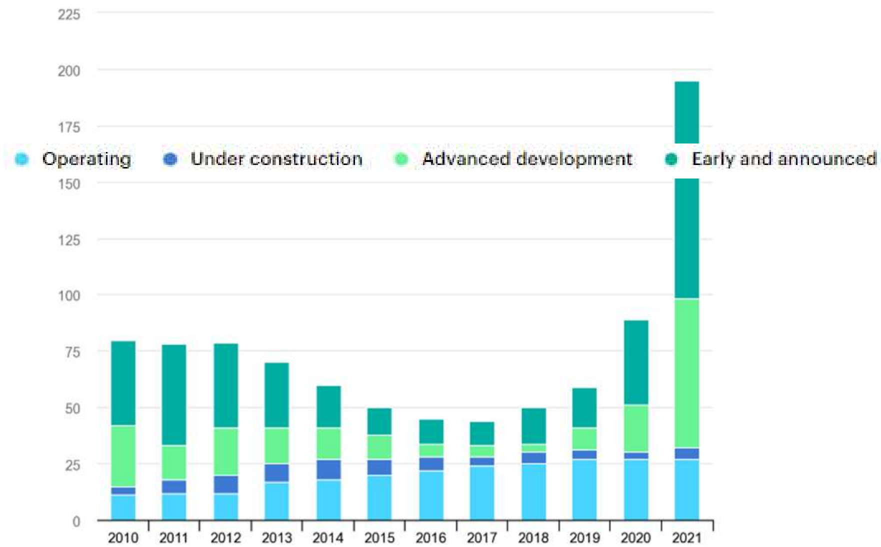
CCS Status: Current Infrastructure & CCUS Development

Industrial sources in the US



From U.S. EPA, 2021

Global pipeline of commercial CCUS facilities operating and in development, 2010-2021



From IEA, 2022

- Early entry CCS projects are in the Midwest, Great Plains, and Gulf Coast (and California?)
- The US currently has around 5,000 miles of CO_2 pipelines from natural sources

CCS Status: 45Q Near-Term CCS Driver in U.S.

- **45Q Tax Credits**– up to $85/metric ton in federal tax credit for capture and storage ($60/metric ton for EOR, $180/metric ton direct air capture)
- Business case strong for high purity sources (ethanol, ammonia, gas processing)
- Example: 100 million gallon/yr ethanol plant = $25 million/year in 45Q credits for ~300,000 metric tons CO_2 storage.

CCS Status: Bipartisan Infrastructure Law (BIL)

BIL provides more than $20 billion for integrated CCUS Carbon Dioxide Removal (CDR), and clean hydrogen projects in the US

Funding Category	Funding Level
Carbon Capture	$3.5B for Demo/Pilot Projects $100M for capture FEED projects
Carbon Transport	$2.1B for CIFIA loan program
Carbon Storage	$2.5B for storage validation and testing $75M for permitting support for US EPA
CDR	$3.5B for DAC hubs $115M for DAC precommercial and commercial prize competitions
Clean Hydrogen	$9.5B for clean hydrogen efforts $8B for H_2Hubs $1B for hydrogen electrolysis $500M for H_2 Manufacturing and Recycling

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Midwest Regional Carbon Initiative

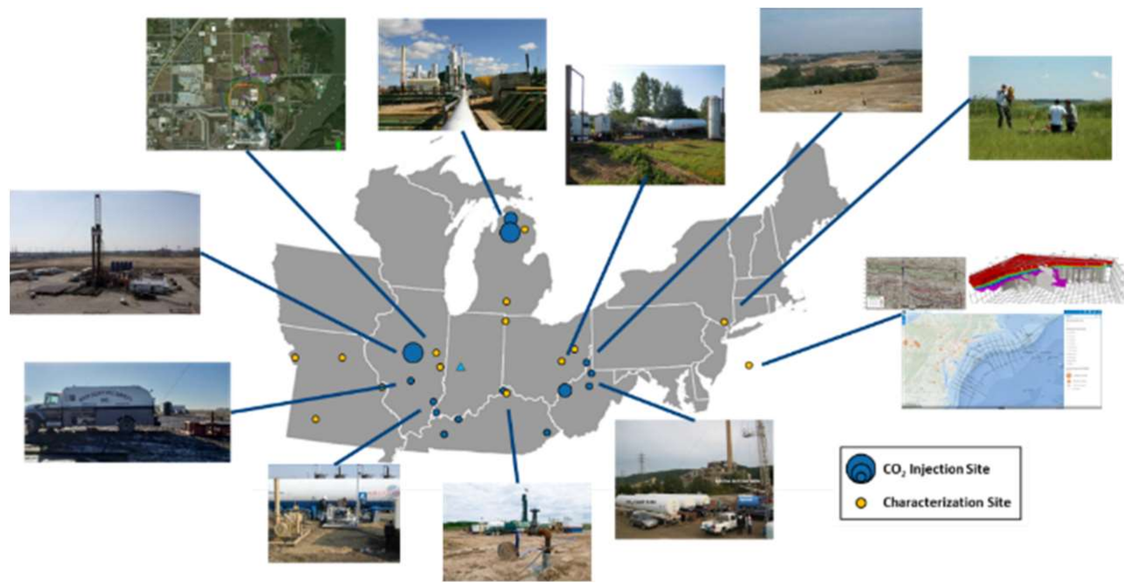
- Midwest Regional Carbon Initiative (DE-FE0031836), a US-DOE regional initiative to accelerate CCUS deployment in the Midwestern and Northeastern US.
- Builds on more than 20 years of CCUS experience in the region.

Midwest Regional Carbon Initiative

U.S. DEPARTMENT OF ENERGY

NATIONAL ENERGY TECHNOLOGY LABORATORY

www.midwestCCUS.org



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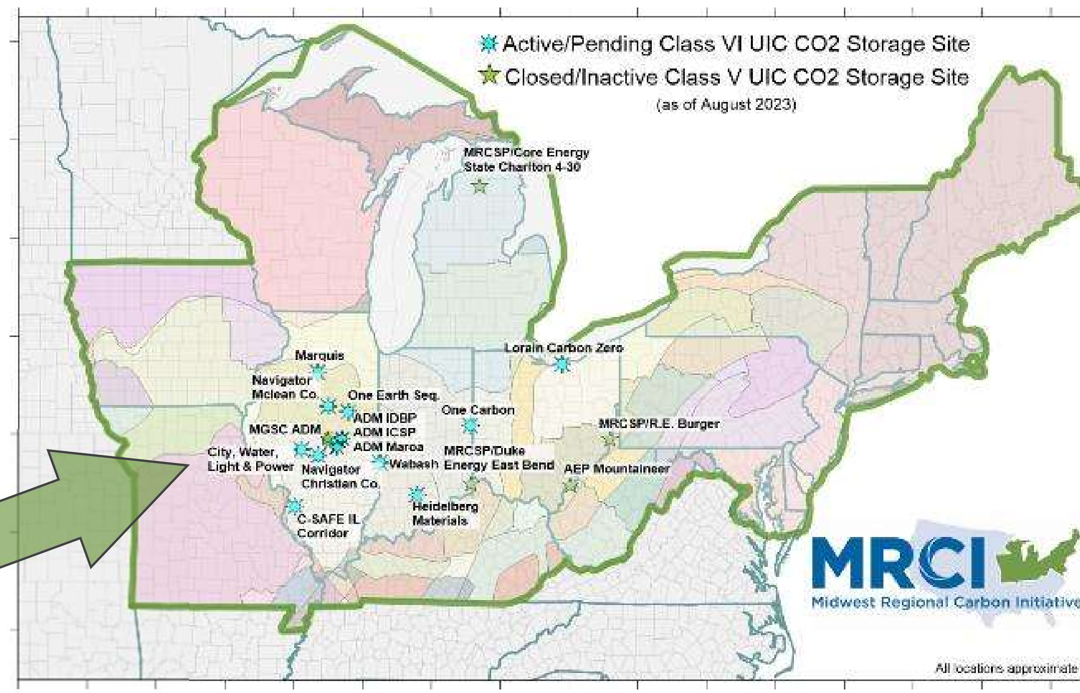
MRCI: Previous Testing and Research
A foundation for CCS Development

- CCS projects span major sedimentary basins in the MRCI.
- 30+ site characterization wells, piggyback drilling efforts, geological studies completed.

Current/Pending CCS Projects



Previous Testing & Research

Many non-public projects not shown above

MRCI: CO_2 Storage Reservoirs in the MRCI Region

This map identifies the 28 key storage formations within each of the 48 onshore sub-regions and the 4 off-shore sub-regions.

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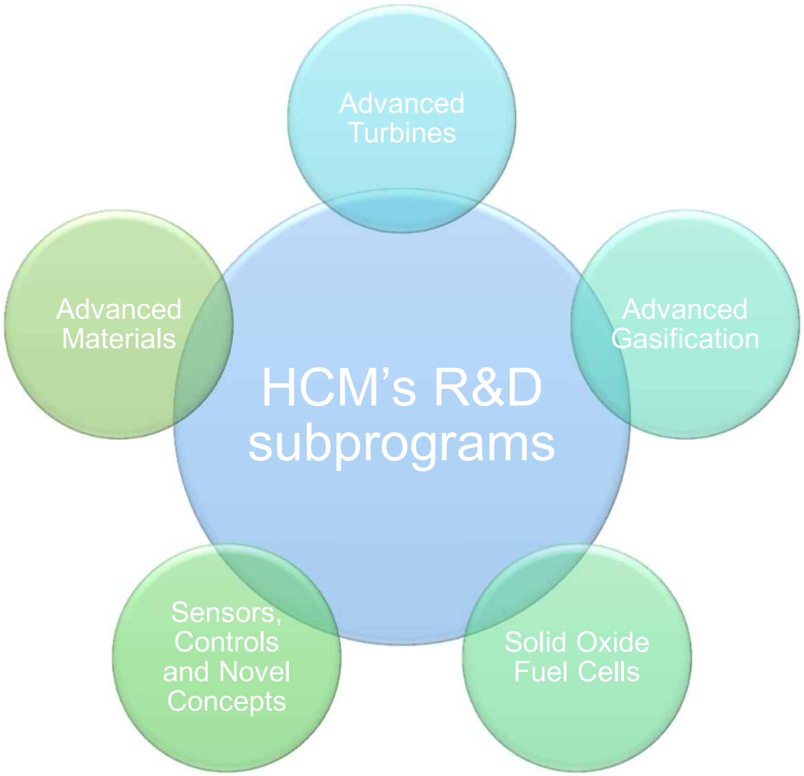
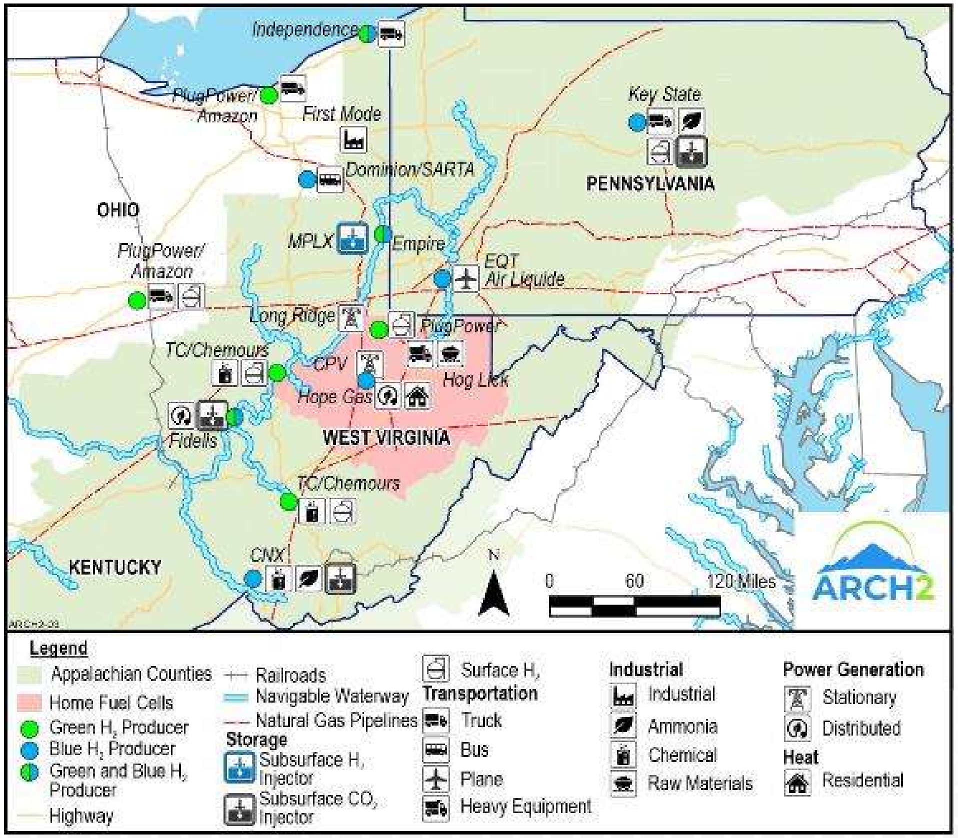
CCS Trends: Hydrogen Hubs

- U.S. DOE Hydrogen with Carbon Management Program- $8 billion for at least four projects, including at least one using fossil fuels with carbon management.
- Goal- reduce cost of clean hydrogen by 80% to $1 per 1 kilogram in 1 decade.
- H_2 hubs aligned with key industrial corridors with CO_2 storage and H_2 storage resources.



fecm.energy.gov

Appalachian Regional Clean Hydrogen Hub (ARCH2)



Note: Proposed project locations based on preliminary siting are subject to change during the detailed planning phase (phase 1).

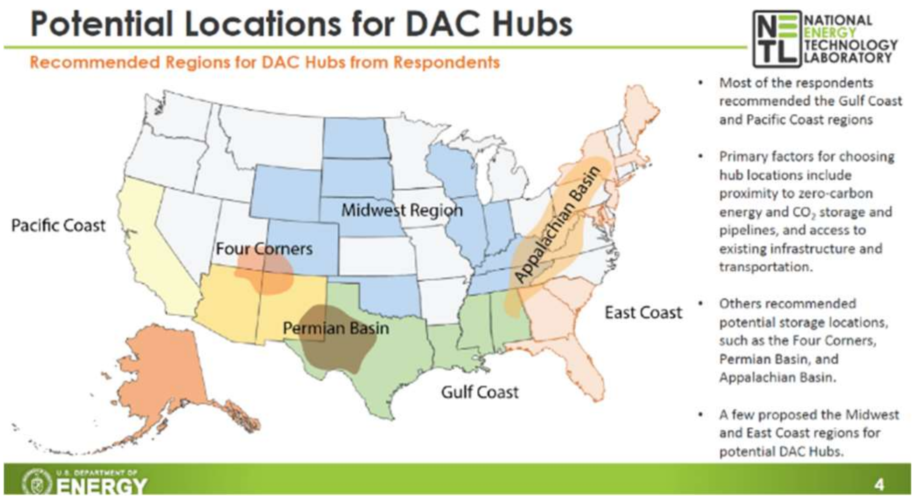
Re-energizing Appalachia
Economically • Socially • Environmentally

CCS Trends: Direct Air Capture Hubs

- $3.5B for Regional DAC Hubs in the US IIJA
- 50/50 funding split with awardees

DAC HUB Selection Criteria

- 1 Mt/y stored capacity
- Cluster of DAC technologies
- Shared carrier, storage, energy infrastructure
- Benefit to economically distressed areas



Conclusions

- CCS projects are progressing in U.S.
- MRCI research and previous CCS tests provide foundation for developing CCS in the Midwest-Northeast U.S.
- Infrastructure buildout and policies are in place and/or in progress.
- Hydrogen, CDR, DAC, projects will require CO_2 storage resources.

Energy

Power Generation
EPC
CO2 Capture
DAC, BECCS
Compression
Dehydration
Pipeline transport
Drilling

(UIC permitting
45Q
Liability
pore space)