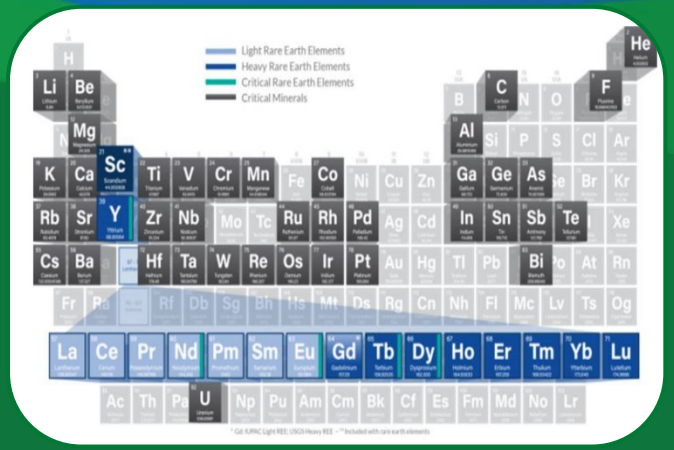
U.S. DEPARTMENT OF ENERGY

Fossil Energy and Carbon Management

Development of Carbon Capture, Utilization and Storage (CCUS) in the United States

Asia CCUS Network Knowledge Sharing Conference

July 28, 2021



Biden Administration: approach to addressing climate change

"We'll take steps towards my goal of achieving 100 percent carbon-pollution-free electric sector by 2035. Transforming the American electric sector to produce power without carbon pollution will be a tremendous spur to job creation and economic competitiveness in the 21st century, not to mention the benefits to our health and to our environment."

President Joseph R. Biden, Jr.

"You can't get to [the] goal of net carbon zero without technologies that are being deployed and researched at the Department of Energy like CCUS…hydrogen solutions…direct air capture… [and other] technologies that the Department of Energy is working on to reduce and manage carbon emissions. And I think that is an important piece of the energy mix to… reach the goal of net zero carbon emissions by 2050."

Jennifer Granholm, Secretary of Energy

"Climate change is an existential threat and one of the dominant forces shaping the world and our economy. Meeting this challenge is an urgent need, and I am committed to doing whatever I can to address this impending crisis. Using the tax code to set incentives for businesses and individuals to adopt climate-friendly policies is a critical tool in this battle."

Janet Yellen, Secretary of the Treasury

Biden Administration: climate priorities

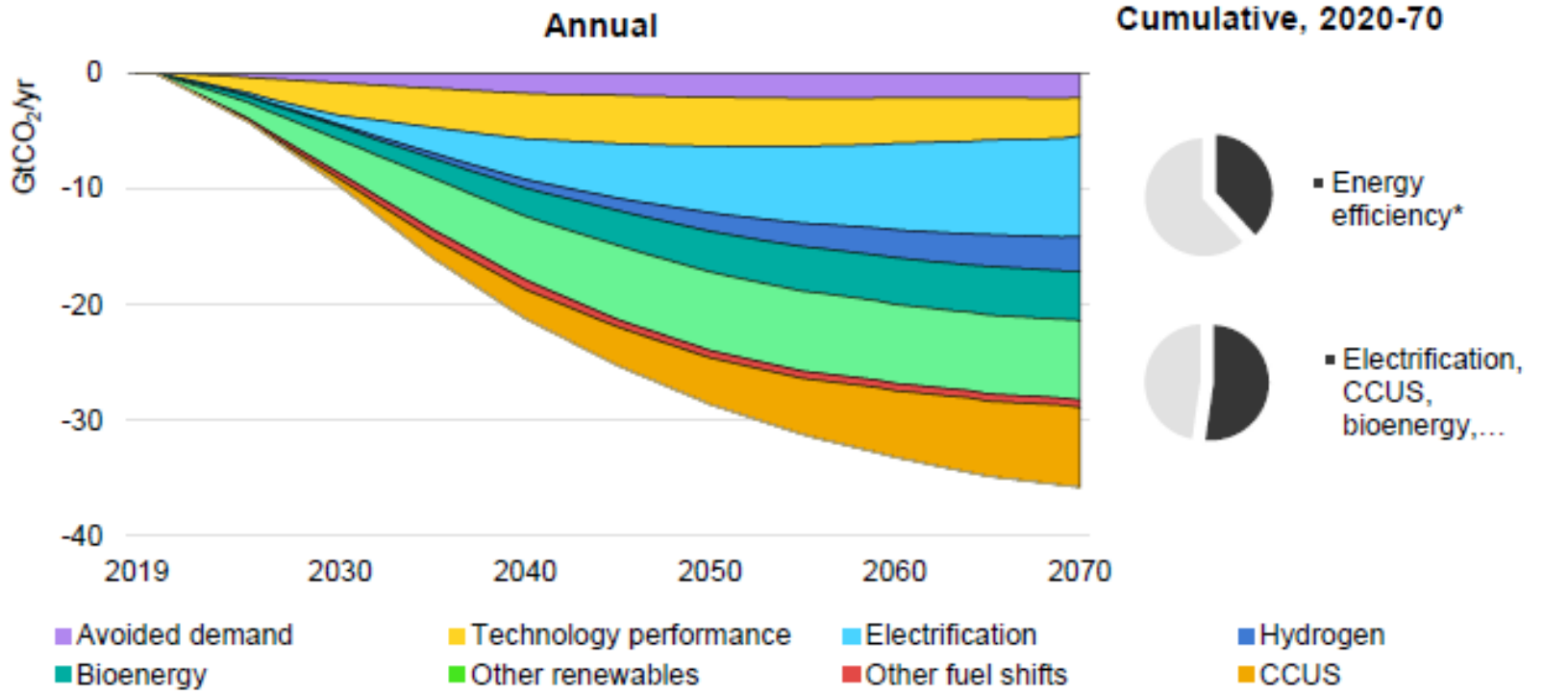
- Re-establishing U.S. leadership in climate: Climate crisis will be central to U.S. foreign policy and national security
  - Rejoined the Paris Agreement
  - Held the Leaders' Climate Summit to raise climate ambition
- Taking a government-wide approach to the climate crisis: National Climate Task Force
- Building a 100% clean energy economy
  - Reaching net-zero emissions by 2050
  - Carbon pollution-free electricity sector no later than 2035
- Developing a climate finance plan
- Modernizing infrastructure towards a sustainable economy
  - "Greening" federal government procurement
  - Ensuring procurement and awards support the use of American-made goods and services in the clean energy supply chain
- Empowering workers and marginalized communities

The role of CCUS – critical to addressing the challenge

- CCUS is a key pillar in efforts to put the world on a path to net zero emissions
- Reaching net zero will be virtually impossible without CCUS
- CCUS tackles emissions from existing infrastructures – power, heavy industry
- CCUS is a pathway to low-carbon hydrogen at scale
- Mid-century net zero targets require a significant scale-up of CCUS

Global energy sector CO_2 emissions reductions

– Sustainable Development Scenario compared to Stated Policies Scenario



* Energy efficiency includes enhanced technology performance as well as shifts in end-use sectors from more energy-intensive to less energy-intensive products (including through fuel shifts).

Notes: CCUS = carbon capture, utilisation and storage. See IEA (2020a) and the ETP model documentation for the definition of each abatement measure. Hydrogen includes low-carbon hydrogen and hydrogen-derived fuels such as ammonia.

Biden Administration: priorities for CCUS and CDR

- Energy: DOE will be essential to President Biden's climate mission to push the frontiers of science and engineering and catalyze clean energy jobs through research, development, demonstration, and deployment
  - Accelerate technology development and deployment
  - Leverage the expertise of DOE's program offices and national laboratories to pursue innovations
  - Restore evidence-based decisions guided by the best available science and data to combat the climate crisis
- CCUS and CDR
  - Expanding Carbon Dioxide Removal (CDR) technologies such as direct air capture (DAC) and bio-energy with CCS (BECCS)
  - Simultaneously bring new carbon capture technologies to market, continue to fund carbon capture RD&D
  - Enhance tax incentives for CCUS
  - Retrofits for existing power plants
  - Decarbonizing industry, especially in hard-to-abate sectors

Consolidated Appropriations Act (2021): support for CCUS and CDR

- Sets out funding, programs, and reports on CDR, demonstration projects, direct air capture, industrial emissions, and hydrogen
- Requires interagency effort and coordination to support CCUS and CDR
  - Taskforces on CDR and permitting
  - Direct air capture technology board
  - Reports on regulations, storage, demonstration projects, and CO_2 utilization
- Directs agencies to conduct studies on blue hydrogen, commercializing carbon, CO2 utilization

"The Energy Act represents the first modernization of our nation's energy policies in well over a decade. This bipartisan package will foster innovation across the board on a range of technologies that are critical to our energy and national security, our long-term economic competitiveness, and the protection of our environment..."
-Sen. Lisa Murkowski, R-Alaska, Chairman of the Senate Energy and Natural Resources Committee

"The Energy Act of 2020 provides a down payment on the technologies that will be critical to reducing greenhouse gas emissions in the power sector, industry, and buildings and addressing climate change. This focus on research, development, and demonstration will create high quality jobs and ensure the United States continues to lead the world in the clean energy future..."
-Senator Joe Manchin, D-W.Va., Ranking Member of the Senate Energy and Natural Resources Committee

Section 45Q tax credits

- Tax benefits have been available since 2008 for qualified CCUS projects in the United States
- In 2018, benefits were significantly expanded and extended to include:
  - Increased credit amount:
    Saline storage: $50/tonne; utilization: $35/tonne
  - Expanded qualified carbon oxides to include carbon monoxide (CO)
  - Expanded qualified uses to include CO_2 utilization other than enhanced oil or natural gas recovery
- Congress recently approved a two-year extension of credit (Consolidated Appropriations Act, 2021)
  - Construction must begin by January 1, 2026
- The Internal Revenue Service (IRS), in consultation with EPA, DOE, and other agencies, finalized the rule in January 2021, providing clarified guidance to stakeholders on areas such as:
  - Monitoring and verification for geologic storage
  - Life cycle analysis provisions for utilization
  - Recapture of carbon dioxide
  - Definition of carbon capture equipment
  - Qualified facility (ex: industrial or DAC)
- 36 projects are in initial planning stages, having been inspired by 45Q updates and state level incentives such as the California Low Carbon Fuel Standard (LCFS)

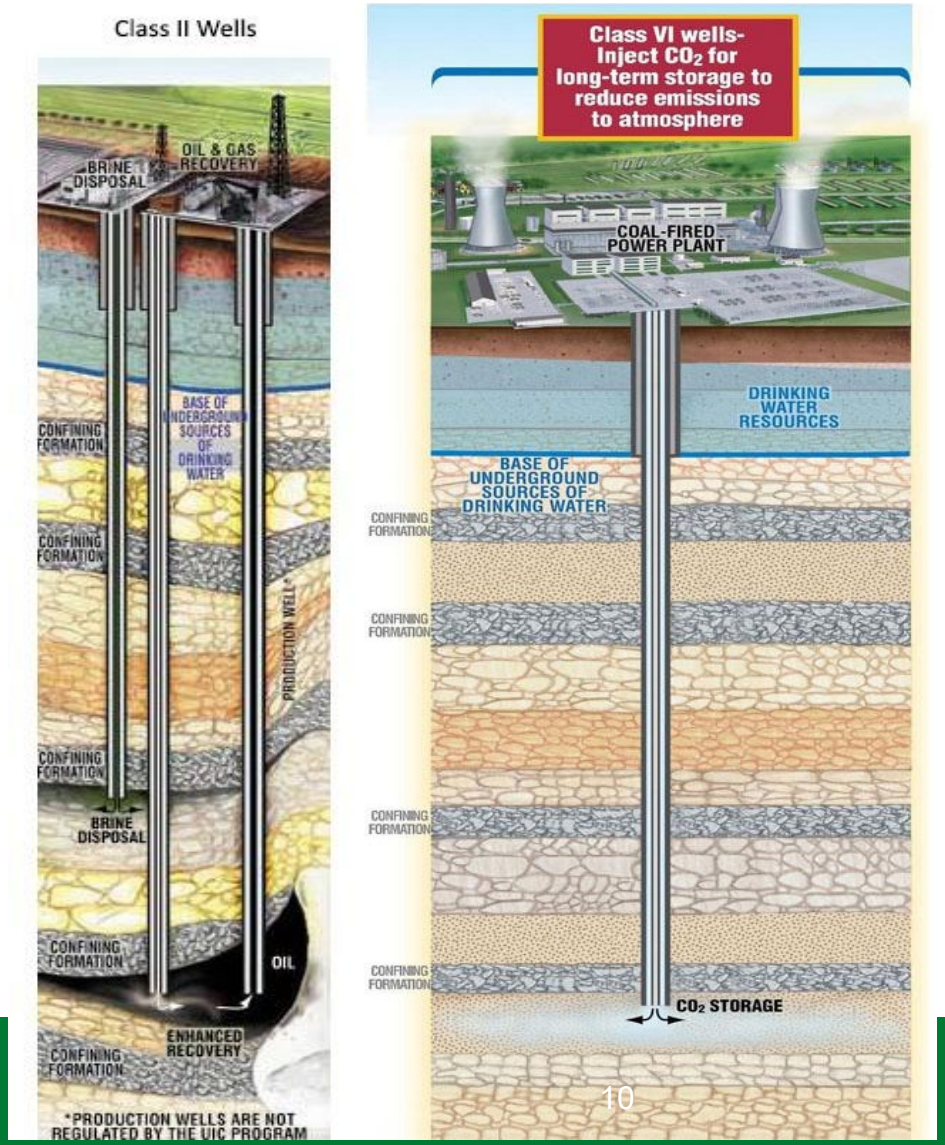
State policies and incentives for CCUS

- Financial Assistance for CCS Projects and CO_2 Pipelines, often as grants or loans.
- Off-Take Agreements, which provide a guaranteed buyer for the electricity or output from a CCS project.
- Utility Cost Recovery Mechanism, which offer timely reimbursement of costs incurred during construction and operation or favorable rates of return for regulated utilities' investments. Some states have explicitly included CCS as an eligible technology for cost recovery mechanisms.
- Eligibility of CCS in Electricity Generation Portfolio Standards or Voluntary Goals. When CCS is included in these standards, utilities can earn saleable compliance credits by generating electricity using CCS. Additionally, inclusion of CCS in portfolio standards or goals could facilitate utility cost recovery approval of CCS power projects, which is critical for financing.
- State Assumption of Long-Term Liability for Sequestered CO_2 reduces the long-term costs of CO_2 injection for private project developers.
- Low Carbon Fuel Standards or other energy market credits (case dependent)

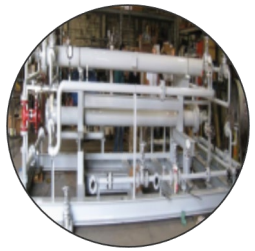
Environmental regulations governing CO_2 storage

U.S. Environmental Protection Agency (EPA) regulates the construction, operation, permitting, and closure of injection wells used to place fluids underground for storage or disposal.

- Class II wells are used only to inject fluids associated with oil and natural gas production, - permits required for CO_2-Enhanced Oil Recovery
- Class VI wells are used to inject CO_2 into deep rock formations – permits required for CO_2 long-term underground storage

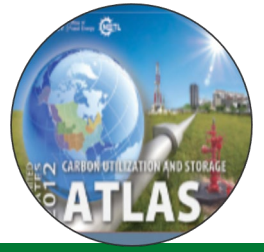


U.S. federal investment in CCUS R&D has been strong and steady

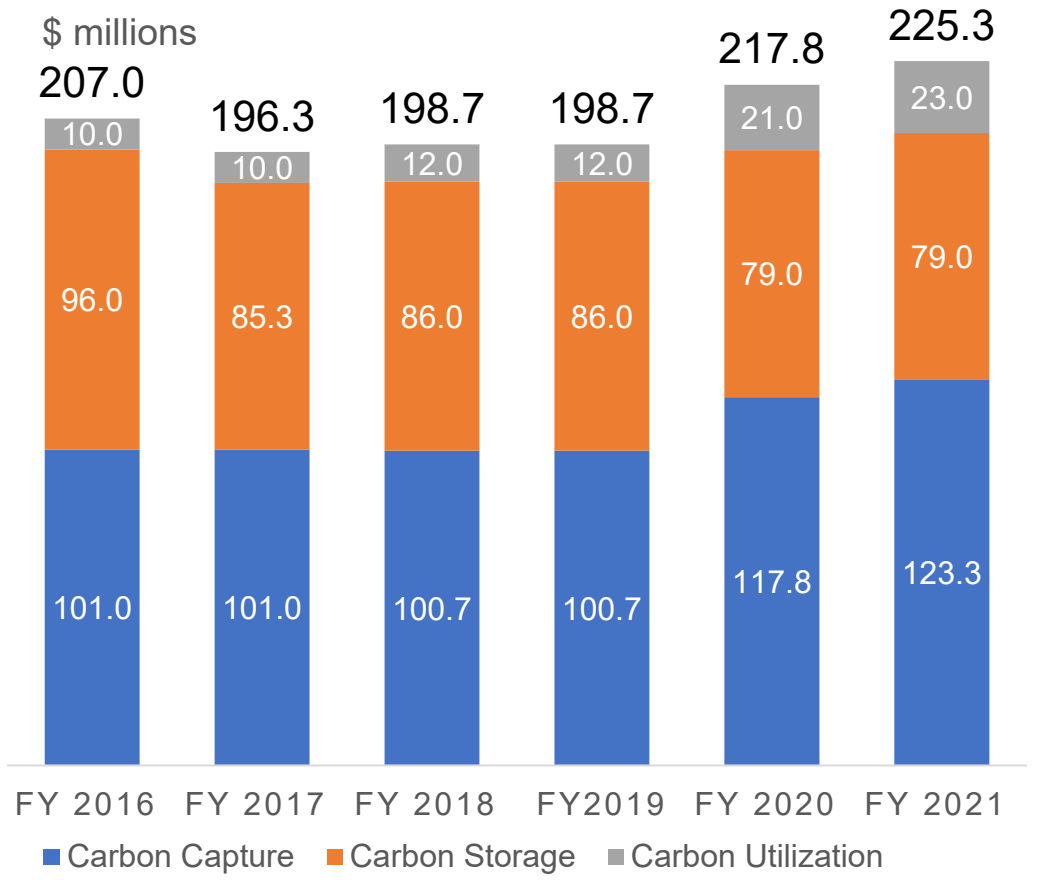


Carbon capture
R&D and scale-up technologies for capturing CO_2 from new and existing industrial and power plants, and direct air capture

CO_2 utilization
R&D and technologies to convert CO_2 to value-added products



Carbon storage
Safe, cost- effective, and permanent geologic storage of CO_2

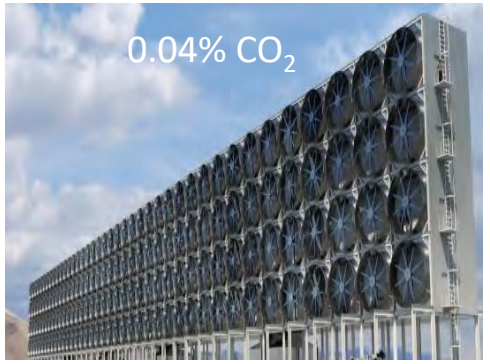


Carbon Capture Program - evolving and expanding

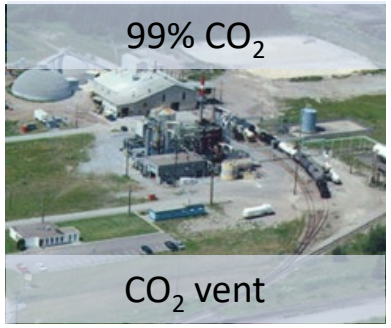
Coal Power Plant

Gas Power Plant

Direct Air Capture

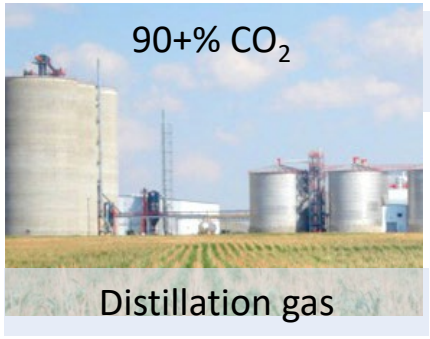


NG Processing Plant



Ammonia Plant

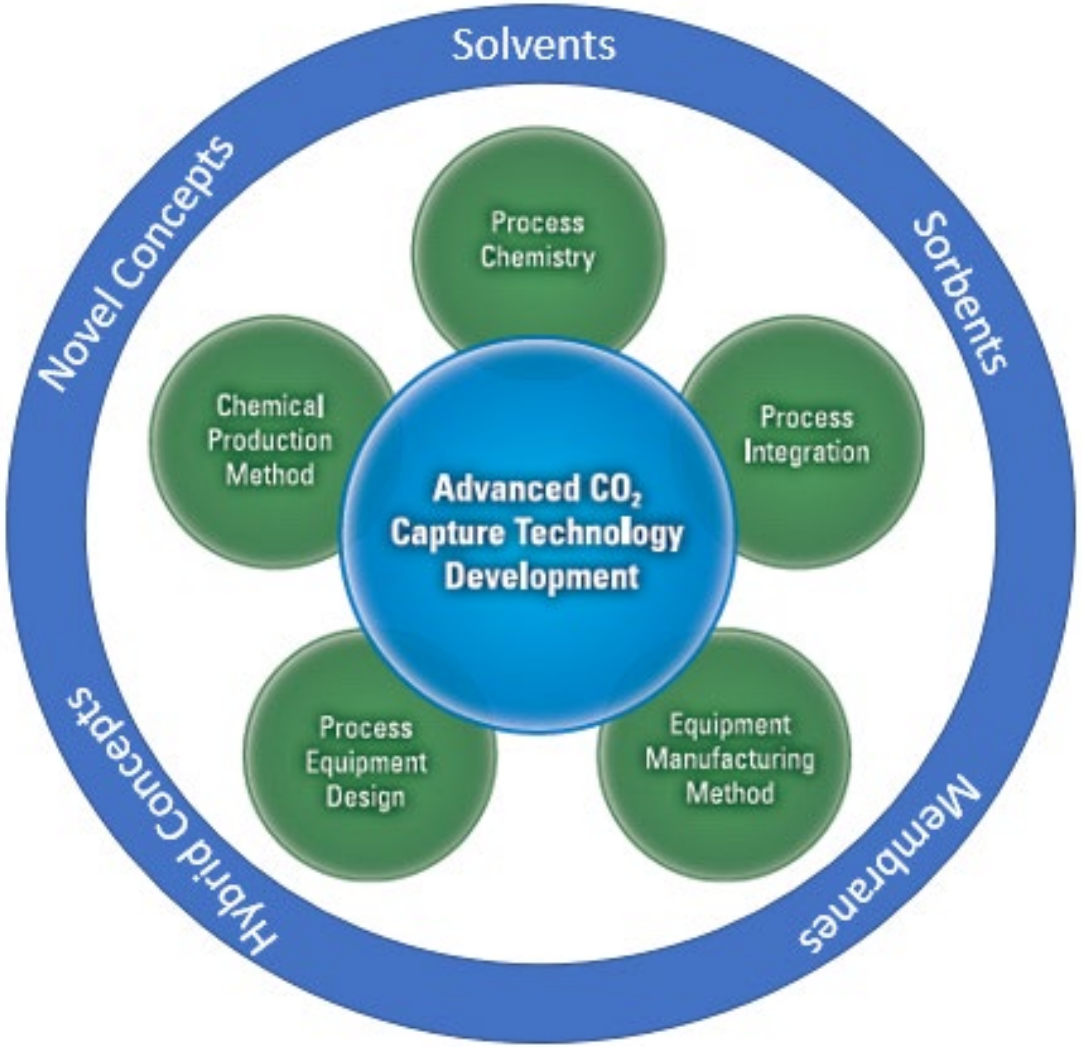
Ethanol Plant



Steel Plant

Cement Plant

Carbon capture pathways and areas of improvement



National Carbon Capture Center

- Operated by Southern Co. Services
- Hosted at Plant Gaston, AL
- Facility capable of testing on coal and natural gas streams – capture and utilization technologies, incl. DAC
- DOE funds 80% of operations
- Over 100,000 test hours (10+ years)
- Technologies from U.S. and six other countries since 2008 founding of NCCC
- More than 50 carbon capture technologies tested
  - 30+ Post combustion
  - 20+ Pre-combustion
- Dedicated staff of plant engineers
- Standard design guidelines
- Slipstream (0.05 MWe) and Pilot (0.5 MWe) Solvent Test Units
- International partners – Total (France)

Lab-Scale Unit

Bench-Scale Unit

Small Pilot-Scale Unit

First-generation CCUS technologies have been successfully demonstrated

Air Products Facility (Port Arthur, TX) - 2013

- Built and operated by Air Products and Chemicals Inc.; located at Valero Oil Refinery in Port Arthur, TX
- State-of-the-art system to capture the CO_2 emitted from two large steam methane reformers
- 6.7 million metric tons (MT) of CO_2 captured and transported via pipeline to oil fields in eastern Texas for enhanced oil recovery (EOR) since March 2013

Petra Nova CCS (Thompsons, TX) - 2017

- Joint venture by NRG Energy, Inc. and JX Nippon Oil and Gas Exploration
- Demonstrate the ability of Mitsubishi Heavy Industries' CO_2 capture technology to capture 90% of the CO_2 emitted from a 240-megawatt flue gas stream (designed to capture/store 1.4 MT of CO_2 per year)
- 3.5 MT of CO_2 used for EOR and sequestered in West Ranch Oil Field
- Successfully achieved project objectives; operation suspended indefinitely due to market conditions

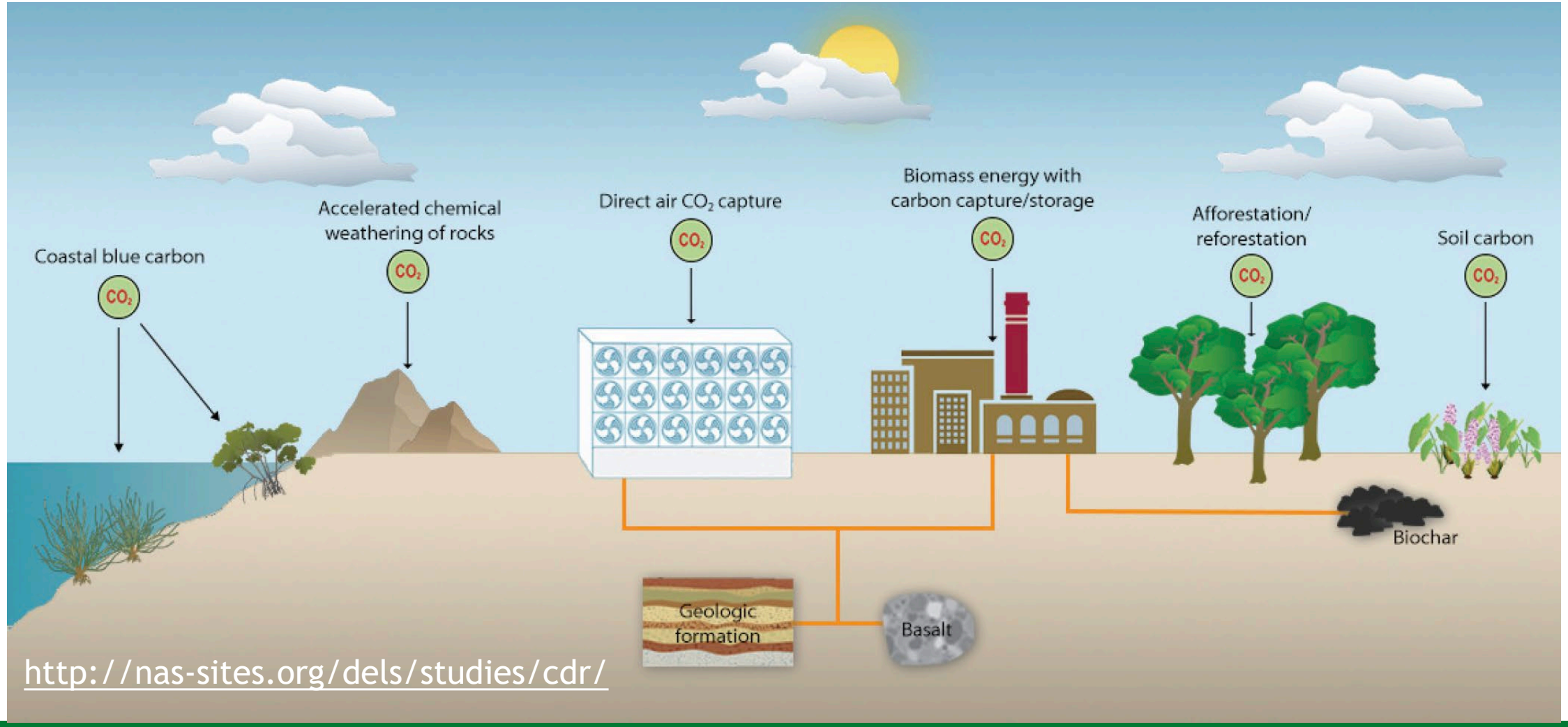
ADM Ethanol Facility (Decatur, IL) - 2017

- Built and operated by Archer Daniels Midland (ADM) at its existing biofuel plant
- CO_2 from ethanol biofuels production captured and stored in deep saline reservoir
- First CCS project to use new U.S. Environmental Protection Agency (EPA) Underground Injection Class VI well permit, specifically for CO_2 storage
- 2.1 MT of CO_2 stored since April 2017

Initial Engineering Design or Engineering Scale Testing

Applicant	Project Title
ArcelorMittal USA LLC	Enabling Production of Low Carbon Emissions Steel Through CO_2 Capture From Blast Furnace (BF) Gases At Arcelormittal's 5 Mtpa Steel Plant At Burns Harbor, Indiana
Praxair Inc.	Engineering Design of a Linde-BASF Advanced Post-Combustion CO_2 Capture Technology at a Linde Steam Methane Reforming H_2 Plant
Electricore, Inc.	LH CO2MENT Colorado Project
Membrane Technology and Research, Inc.	Engineering Design of a Polaris Membrane CO_2 Capture System at a Cement Plant
University of North Dakota EERC	Initial Engineering and Design for CO_2 Capture from Ethanol Facilities
Ion Clean Energy, Inc.	Engineering-scale Demonstration of Transformational Solvent on NGCC Flue Gas
Chevron U.S.A. Inc.	Chevron Natural Gas Carbon Capture Technology Testing Project
Gas Technology Institute	Engineering Scale Design and Testing of Transformational Membrane Technology for CO_2 Capture
Electric Power Research Institute, Inc.	Engineering-Scale Test of a Water-Lean Solvent for Post-Combustion Capture

CDR – help offset hard-to-avoid emissions

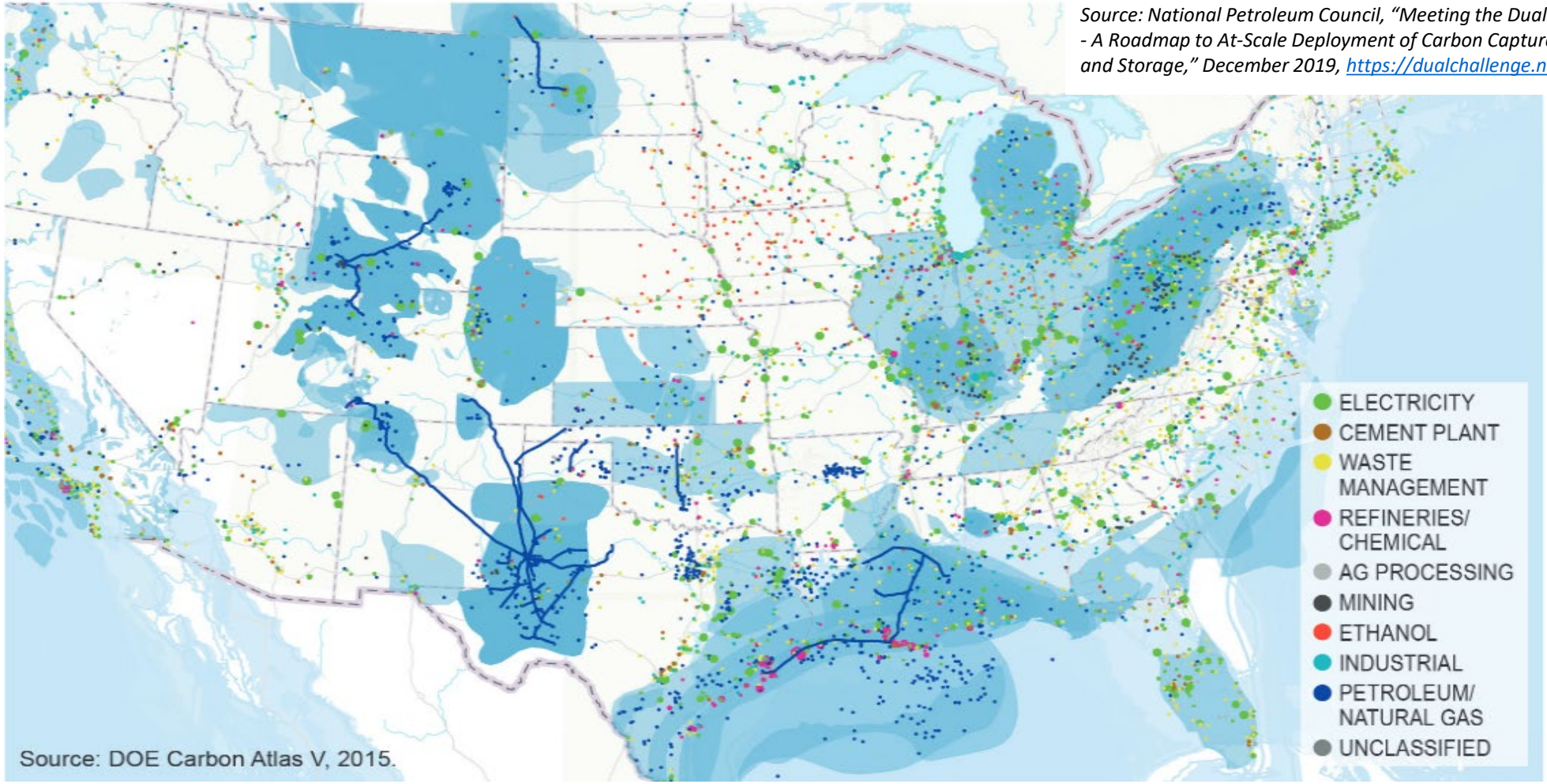


CDR Interagency Working Group

- Charged with preparing a Report to Congress that:
  - Estimates the magnitude of excess carbon dioxide in the atmosphere that will need to be removed by 2050 to achieve net-zero emissions
  - Inventories current and emerging approaches of CDR and evaluates advantages/disadvantages of each approach
  - Identifies recommendations for legislation, funding, rules, revisions to rules, financing mechanisms or other policy tools that the Federal Government can use to advance deployment of CDR projects
- Proposed workplan and schedule:
  - Given the tight timelines we strongly recommend using existing literature and interagency expertise to prepare this first report
  - The findings and recommendations will be evaluated every 2 years and the report will be updated, as necessary
- The Interagency Working Group will also:
  - Help establish criteria for expanding the CDR Task Force to include non-government experts
  - Help evaluate, develop, and improve accounting frameworks and tools to accurately measure CDR

U.S. stationary sources of CO_2 emissions, saline formations, and existing CO_2 pipelines

Source: National Petroleum Council, "Meeting the Dual Challenge - A Roadmap to At-Scale Deployment of Carbon Capture, Use, and Storage," December 2019, https://dualchallenge.npc.org/

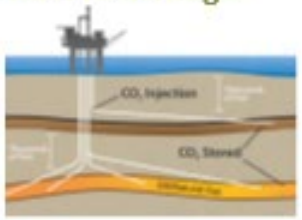


Carbon Storage Program - improving and optimizing performance

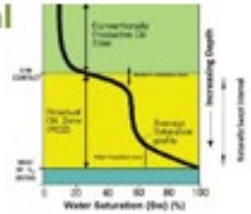
Regional Carbon Sequestration Partnerships (RCSPs)

CarbonSAFE

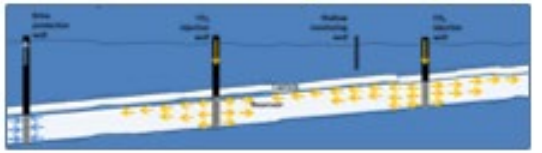
Offshore Storage



Unconventional EOR



Brine Extraction Storage Tests (BEST)



CARBON STORAGE PROGRAM

ADVANCED STORAGE R&D

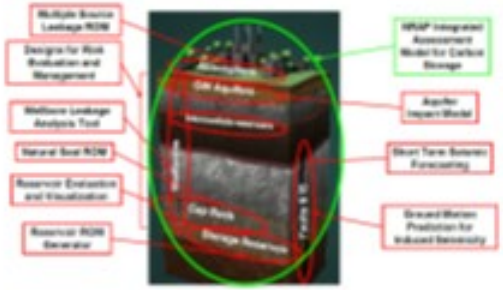
- Plume Detection and Storage Efficiency
- Secure Storage
- Subsurface Stress
- Wellbore Integrity
- Risk Assessment

STORAGE INFRASTRUCTURE

Advancing monitoring and measurement tools: improving characterization and reducing the uncertainty about the CO_2 and pressure fronts.

Fiber Optic Distributed Acoustic Sensing (DAS)

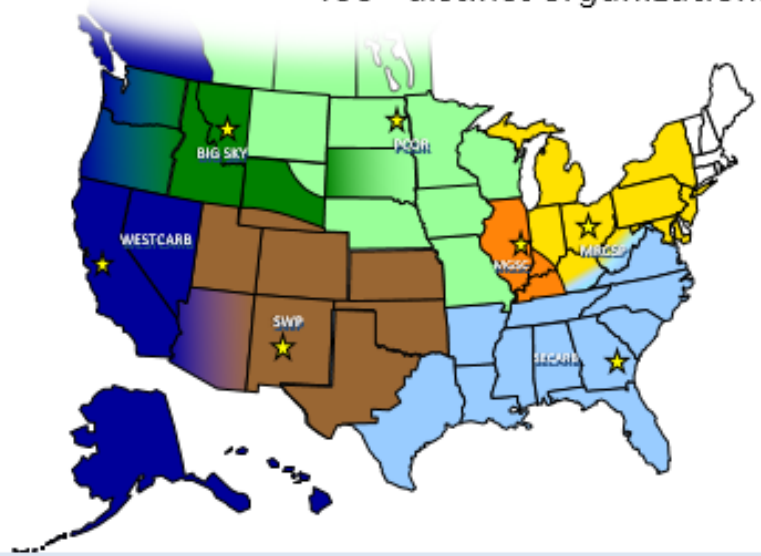
National Risk Assessment Partnership (NRAP) is developing toolsets to reduce uncertainty and quantify potential impacts related to release of CO_2 and induced seismicity



Regional Carbon Sequestration Partnerships (RCSPs)
- Nearly two decades of success

Seven Regional Partnerships

400+ distinct organizations, 43 states, 4 Canadian Provinces



- Engage regional, state, and local governments
- Determine regional sequestration benefits
- Baseline region for sources and sinks
- Establish monitoring and verification protocols
- Validate sequestration technology and infrastructure

Characterization Phase (2003-2005)

Search of potential storage locations and CO_2 sources	Found potential for 100s of years of storage

Validation Phase (2005-2011)

20 injection tests in saline formations, depleted oil, unmineable coal seams, and basalt

Development Phase (2008-2018+)

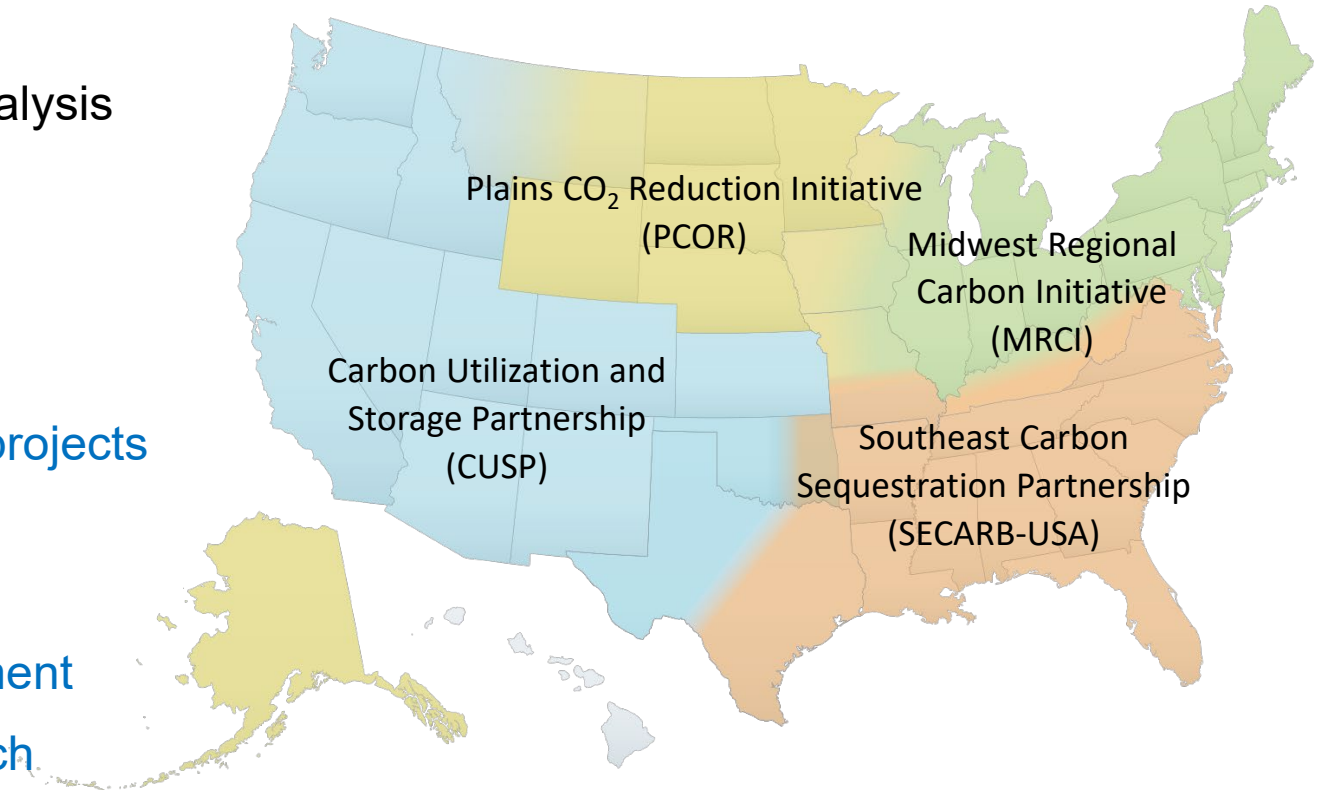
6 large scale injections (over 10 million tons injected)	Commercial scale understanding and validation

Regional CCUS Deployment Initiative projects: successors of RCSPs

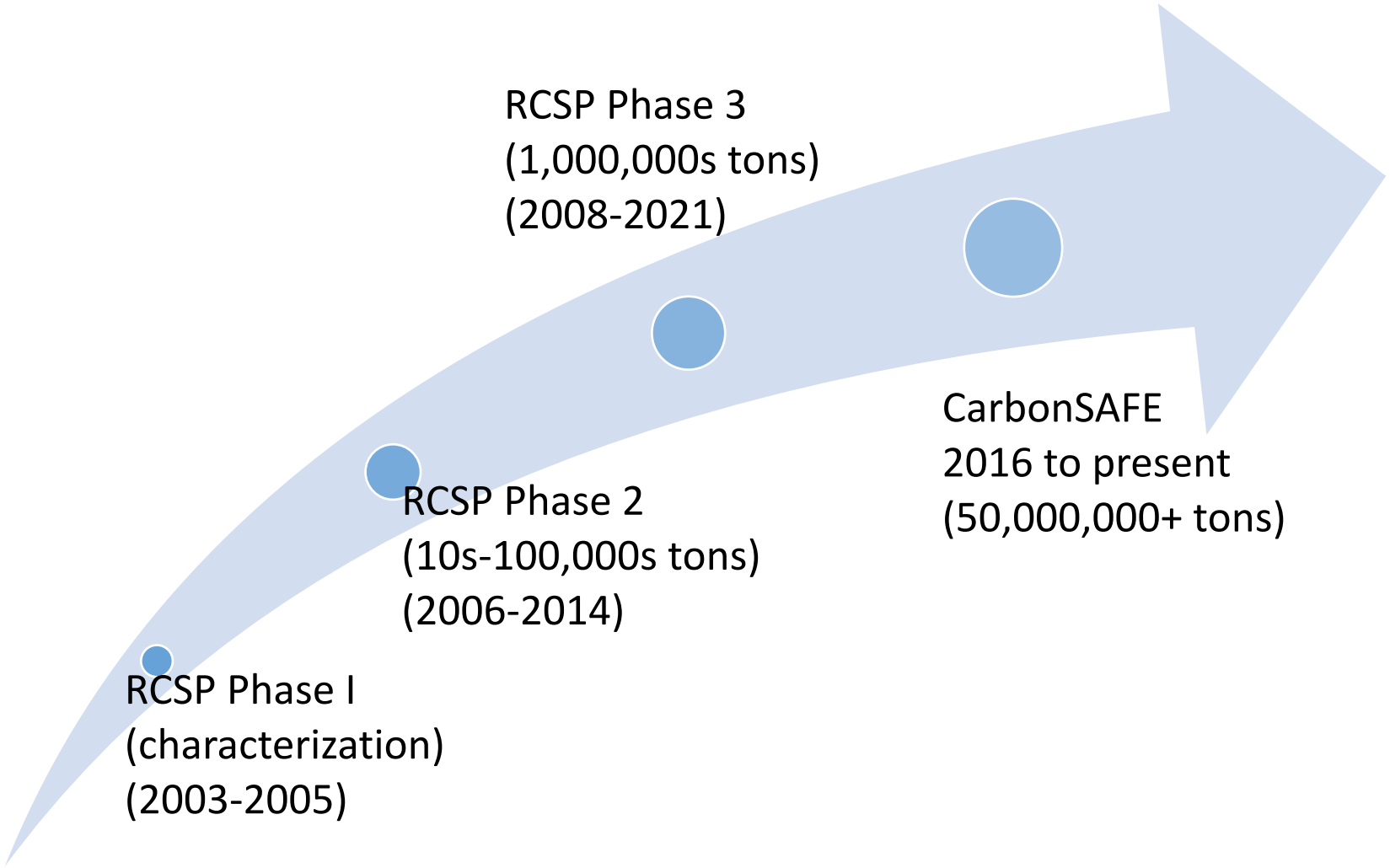
- Addressing key technical challenges
- Facilitating data collection, sharing, and analysis
- Evaluating regional infrastructure
- Promoting regional technology transfer

As RCSP successors, the Regional Initiative projects bring with them:

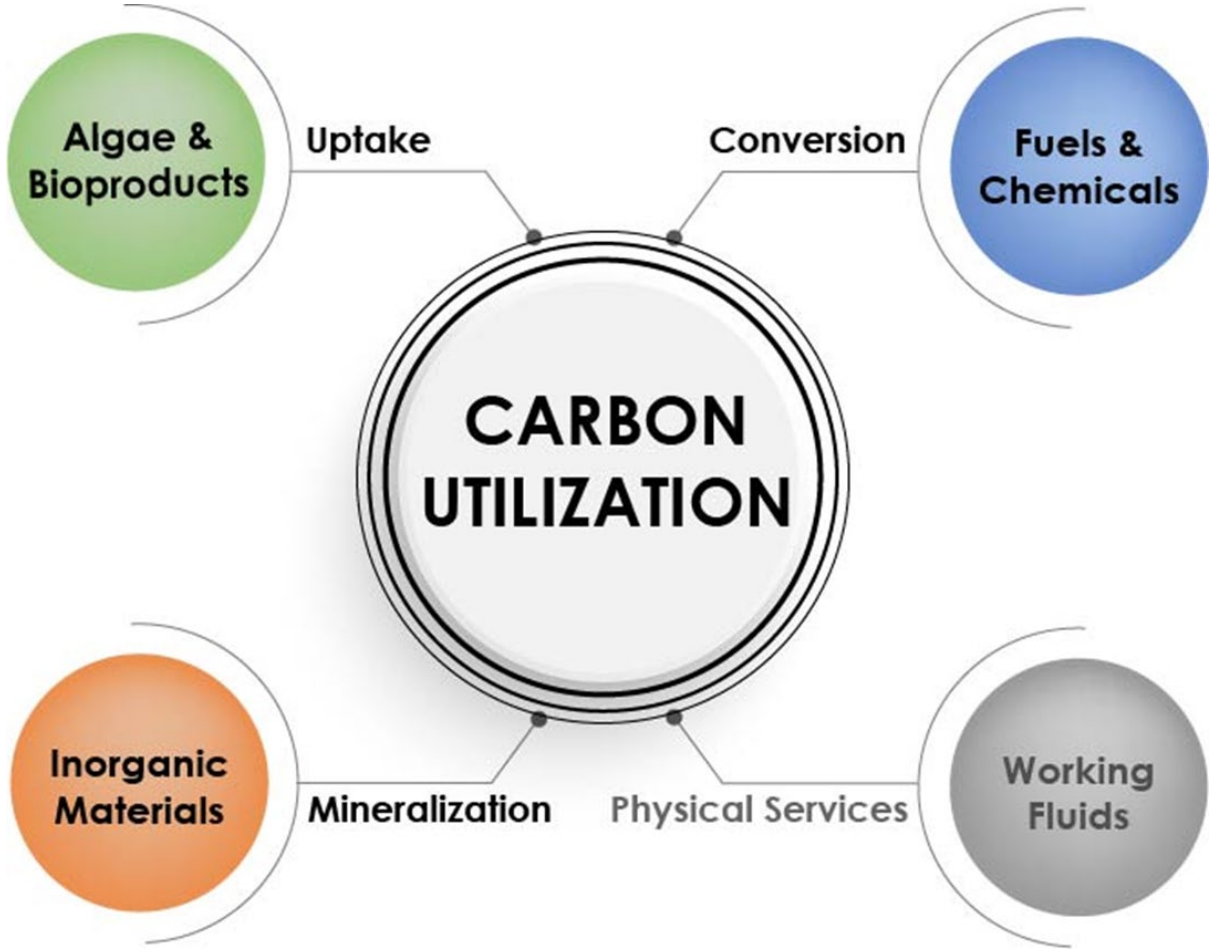
- ➢ Established stakeholder network
- ➢ Long history on best practices development
- ➢ Wealth of data to support further research
- ➢ Experienced in public outreach and education



Carbon storage onshore field activity progression



Carbon utilization: DOE R&D program directions



PROGRAM HIGHLIGHTS

55+ active research projects averaging 1.08M/award

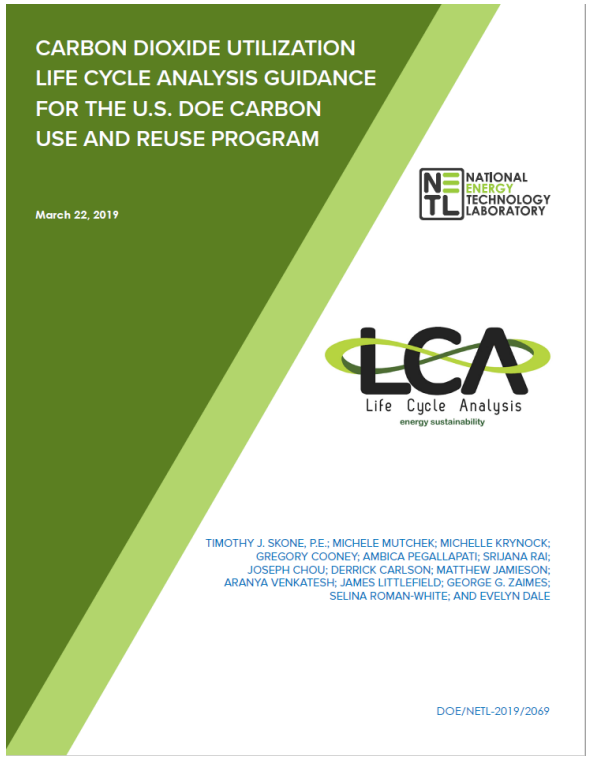
Over 30 different research partners

Lifecycle analysis & techno-economic analysis tools

Technology testing facilities

Carbon utilization: Life Cycle Analysis (LCA) project guidelines

DOE FE/NETL Life Cycle Analysis work and templates, best practices, baseline studies
netl.doe.gov/LCA/CO2U

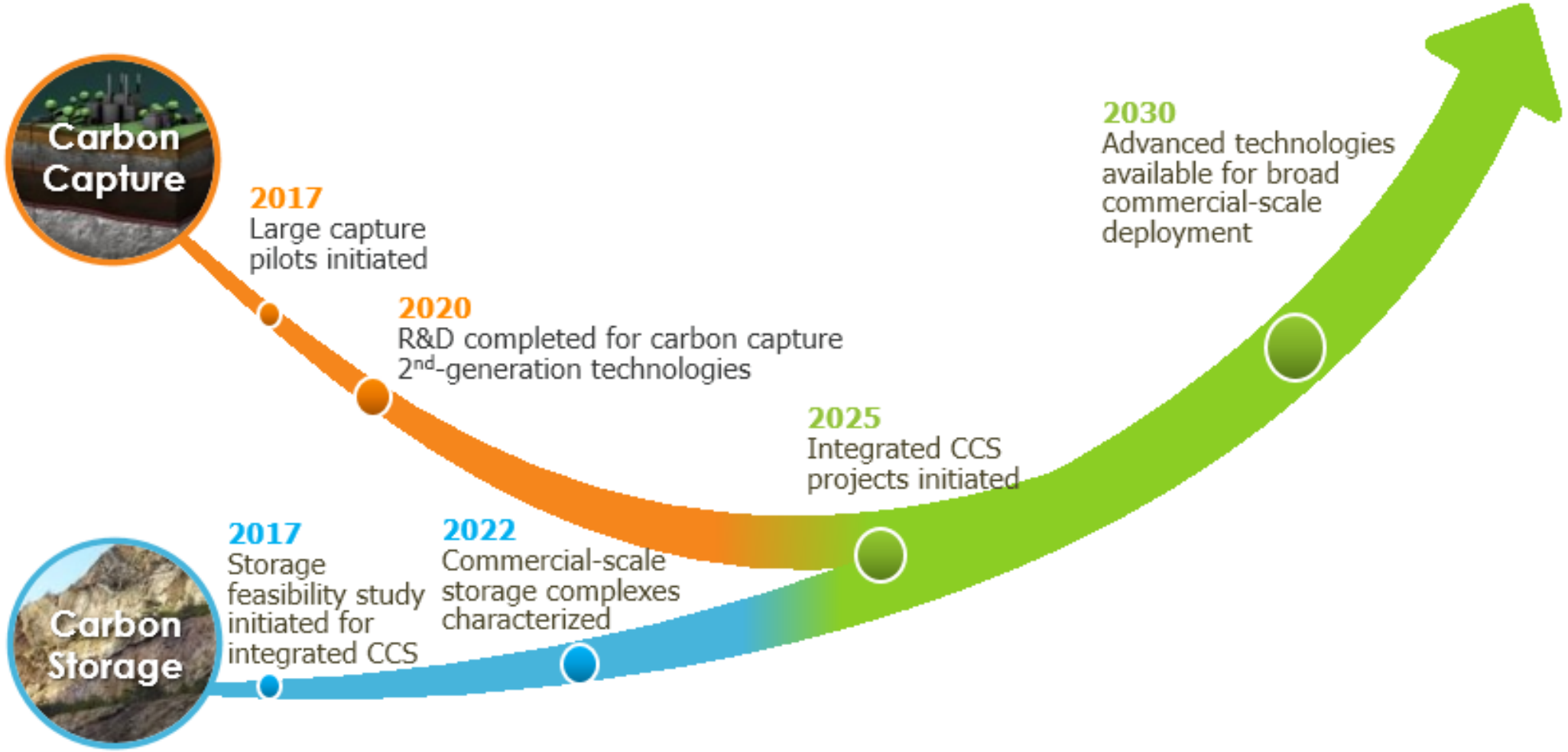


COLLABORATION

Harmonization data and LCA / TEA (techno-economic analysis) methodologies

Increase dialogue with our TEA and LCA teams. We engage international partners through work with Global CO_2 Initiative

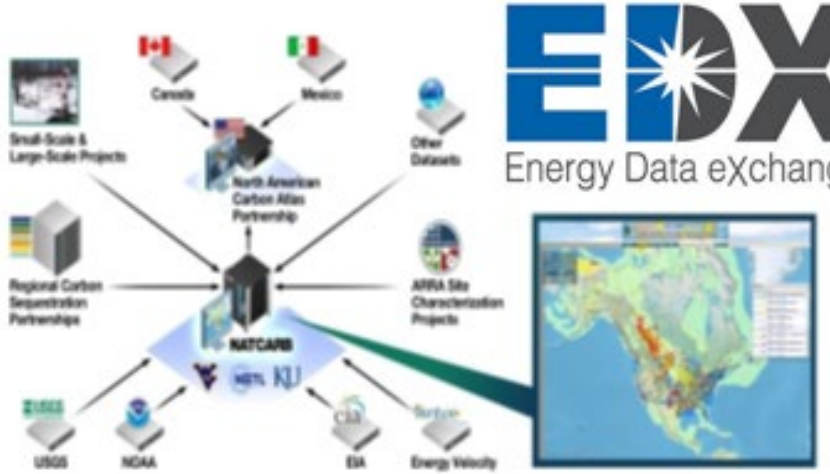
Integrated R&D approach for future commercial-scale deployment



Knowledge sharing products

https://netl.doe.gov/coal/carbon-storage/strategic-program-support/natcarb-atlas

- Annual Carbon Storage Meeting
- RCSP Working Groups
- Domestic Collaborations
- International Collaborations
- Technical Workshops



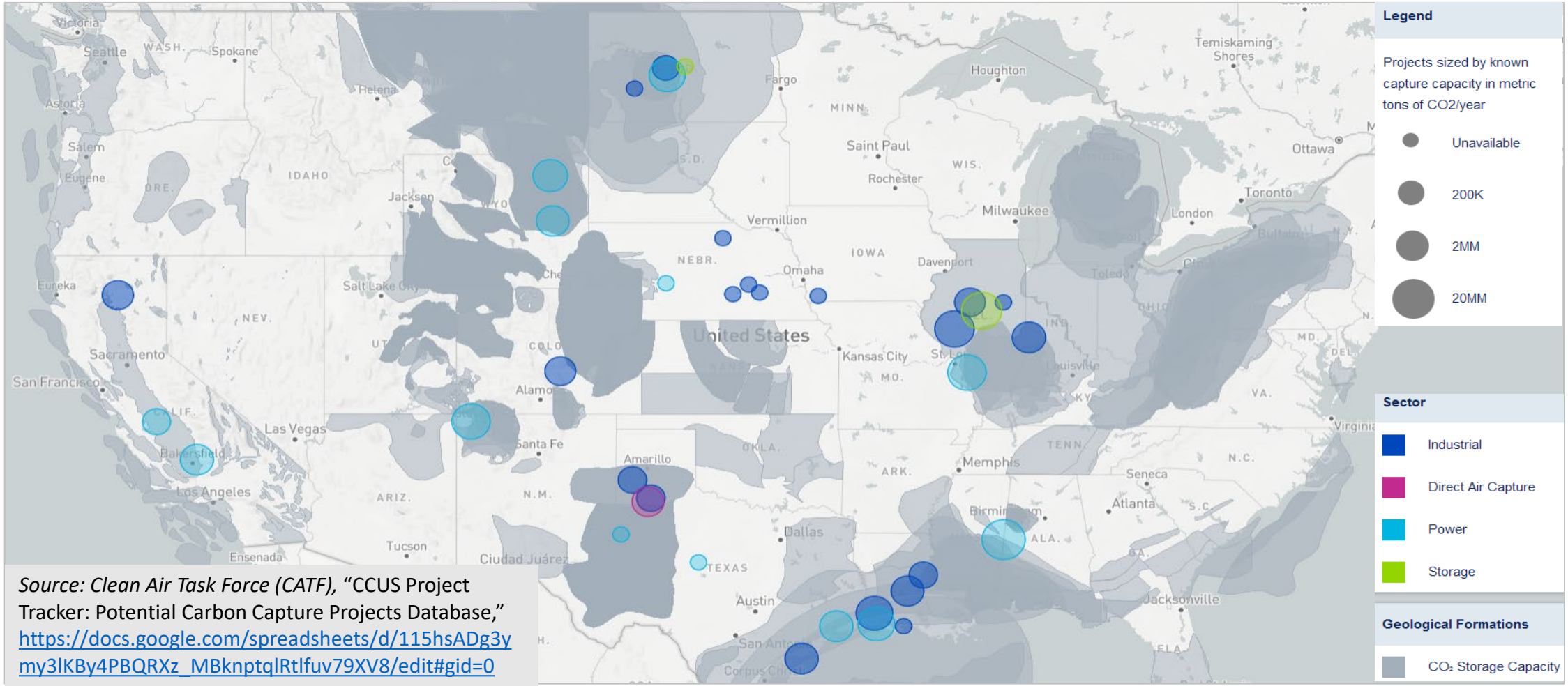
EDX
Energy Data eXchange

NRAP
National Risk Assessment Partnership

CCSI²

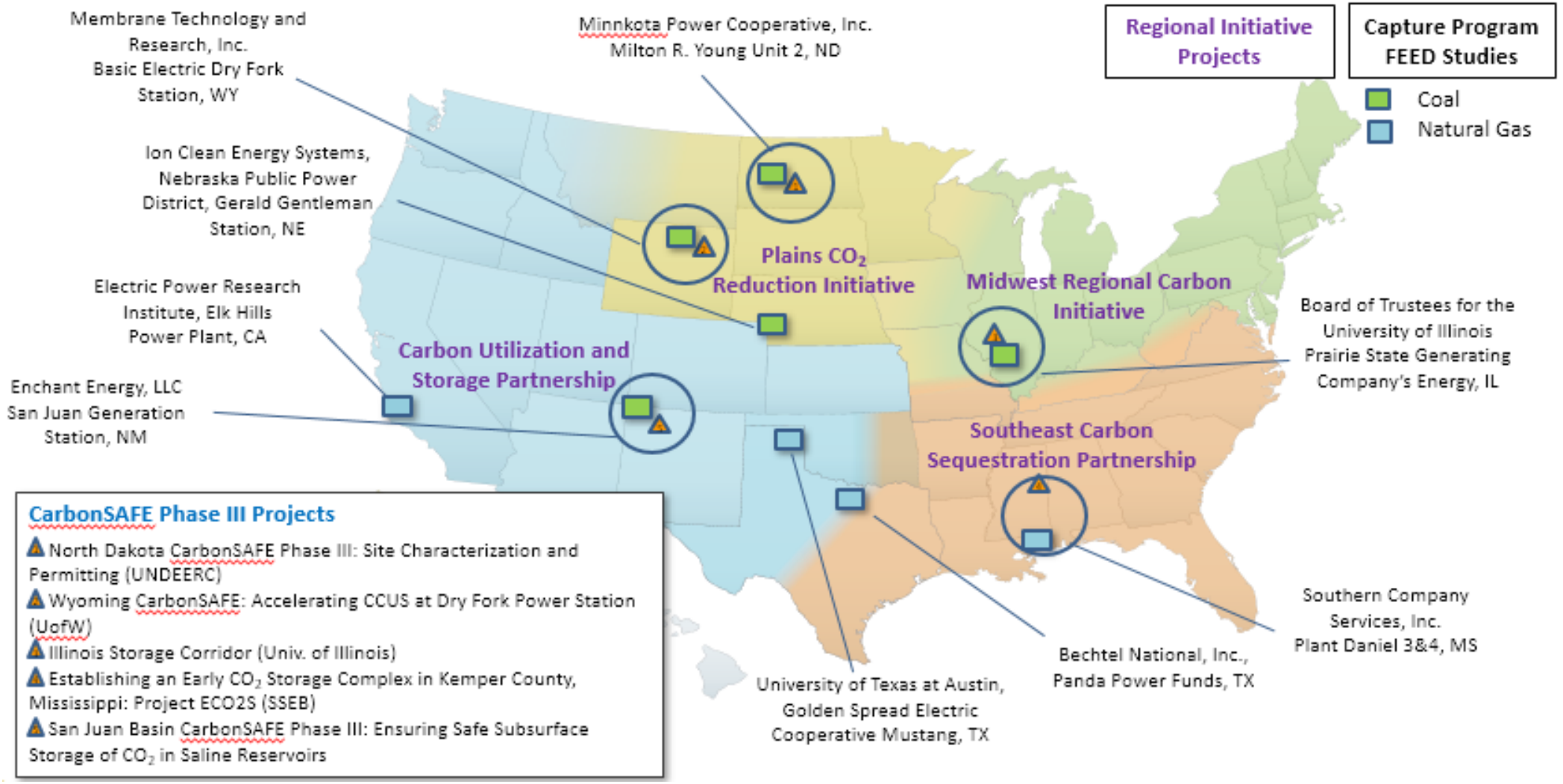
SimCCS

Active CCUS projects developing in the United States



Source: Clean Air Task Force (CATF), "CCUS Project Tracker: Potential Carbon Capture Projects Database," https://docs.google.com/spreadsheets/d/115hsADg3ymy3lKBy4PBQRXz_MBknptqlRtlfuv79XV8/edit#gid=0

Capture Program FEED studies and Storage Program field initiatives



International partnerships

Multilateral Partnerships

International Energy Agency (IEA)

- Working Party on Fossil Energy (WPFE)
- CCUS Unit – CCUS Roadmap and International CCUS Regulatory Network

Technology Cooperation Programmes (TCP):

- Greenhouse Gas R&D Programme (GHG)
- Clean Coal Centre (proposed new name: Centre for Sustainable Carbon)
- Hydrogen

Clean Energy Ministerial (CEM) CCUS Initiative

Carbon Sequestration Leadership Forum (CSLF)

Mission Innovation Carbon Capture Challenge

APEC Expert Group on Clean Fossil Energy (APEC EGCFE)

UN Economic Commission for Europe (UNECE)

Accelerating CCS Technologies (ACT) initiative

+ Asia CCUS Network !!

Bilateral Partnerships

(with over a dozen of countries)