U.S. DEPARTMENT OF ENERGY | Office of Fossil Energy

Overview of the CCUS R&D Programs

August 14, 2018

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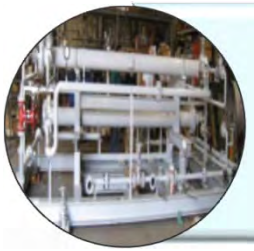
Outline

- Overview (Accomplishments, Drivers, Goals)
- Carbon Capture Program
- Carbon Utilization Program
- Carbon Storage Program

Office of Clean Coal and Carbon Management – What we do

Advanced Energy Systems
Technologies that greatly improve plant efficiencies, reduce CO_2 capture costs, increase plant availability, and maintain the highest environmental standards



Carbon Capture and Utilization
R&D and scale-up technologies for capturing and using CO_2 from new and existing industrial and power-producing plants

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

Cross Cutting Research
Materials, sensors, and advanced computer systems for future power plants and energy systems integrated with CCS

Some accomplishments over the past fiscal year

- **Petra Nova achieves 1 million tons mark; Power Engineering's 2017 Best Coal-Fired Project and 2017 Best Overall Power Project**
- **Air Products reaches 4 million metric tons**
- **National Carbon Capture Center receives Pioneer Award from Peabody**
- **Carbon Capture Projects *are starting to scale-up*; moving beyond the lab**
  - **moving from concept (paper) → lab (lbs/day) → bench (up to 1 tpd) → small pilot (10s of tpd) → large pilot (100s of tpd)**
- **CCSI toolset released as open source**
- **NRAP receives R&D 100 award**
- **Carbon X-Prize: 10 teams announced as finalists (non-DOE)**

Lab-Scale Unit

Bench-Scale Unit

Small Pilot-Scale Unit

National Carbon Capture Center Testing Facilities

Drivers for Adoption of CCUS

- Expansion of 45Q tax incentives for CO_2 storage in saline ($50/tonne), EOR, Utilization and Air Capture ($35/ton)
  - Projects must begin construction by 2024
  - Minimum capture for small generators, air capture, and EGUs
  - Credit can be assigned to capture or disposal facility
  - LCA required – guidelines TBD

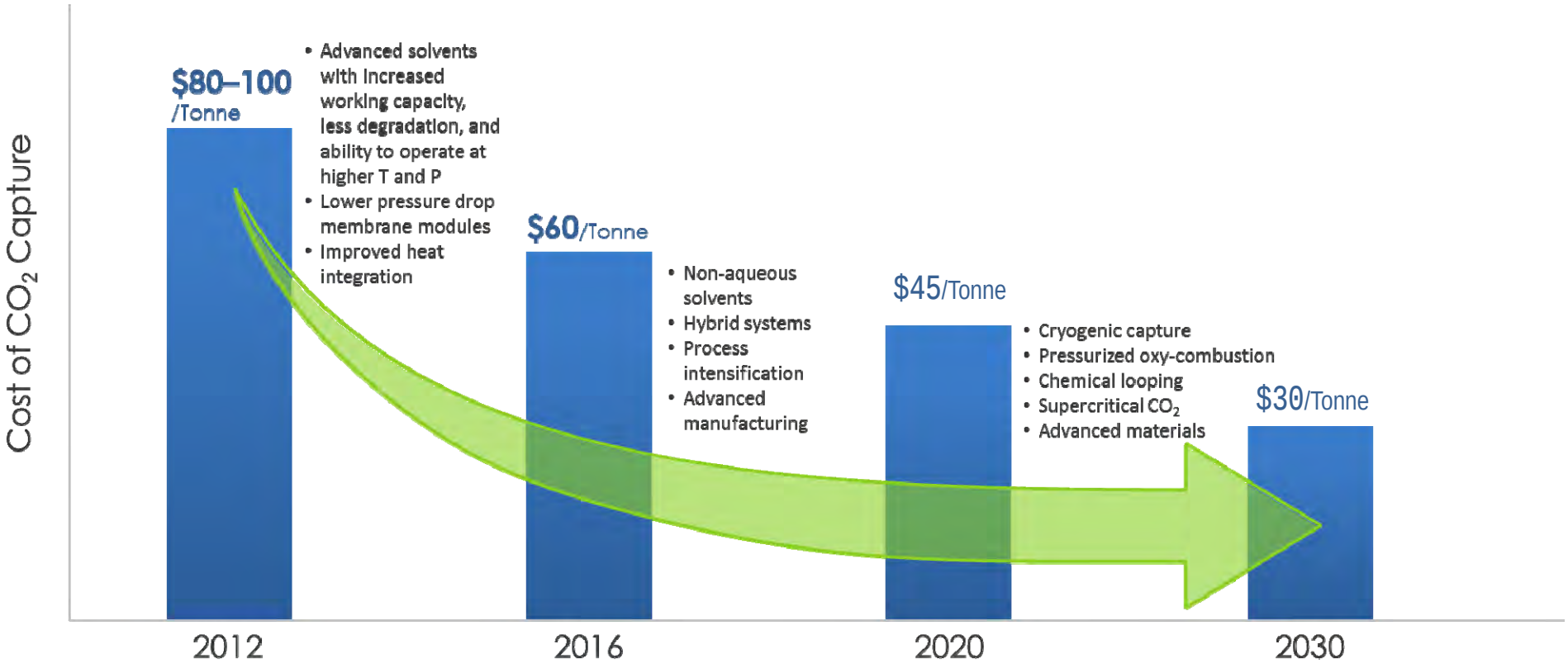
- Other tax and financial incentives under consideration include:
  - Master Limited Partnerships (MLPs)
  - Private Activity Bonds (PABs)
  - Investment tax credits (ITCs)

- Diverse stakeholder support for proposed CCS legislation

High-level Program Goals and Challenges

- **Reduce the cost of capture**
  - Capital cost
  - Energy penalty
  - Integration
- **Develop viable carbon utilization alternatives**
  - Capital cost
  - Energy requirements
  - Lifecycle assessment
- **Reduce the risk of geologic storage**
  - Higher resolution and quantification (e.g., accurate characterization of faults and fractures)
  - Geomechanics (pressure and state of stress)
  - Cost

Carbon Capture Program Goals



Carbon Capture R&D Pathways

Pre-Combustion

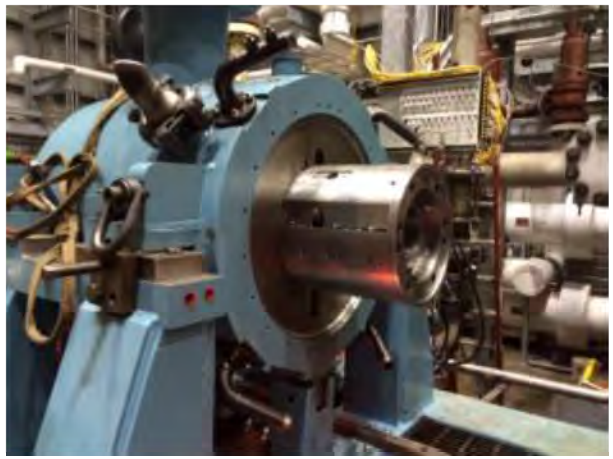
- *Solvents*
- *Sorbents*
- *Membranes*
- *Hybrid processes*
- *Water-gas shift reactor*

Post-Combustion

- *Solvents*
- *Sorbents*
- *Membranes*
- *Hybrid processes*

Advanced Compression

- *Intra-stage cooling*
- *Cryogenic pumping*
- *Supersonic shock wave compression*



Accelerating the Rate of RD&D - Transformational

Partnership between national labs, academia, and industry

Accelerate deployment by 50% in TRL 2-5 range

Parallel paths for materials discovery – synthesis – process design

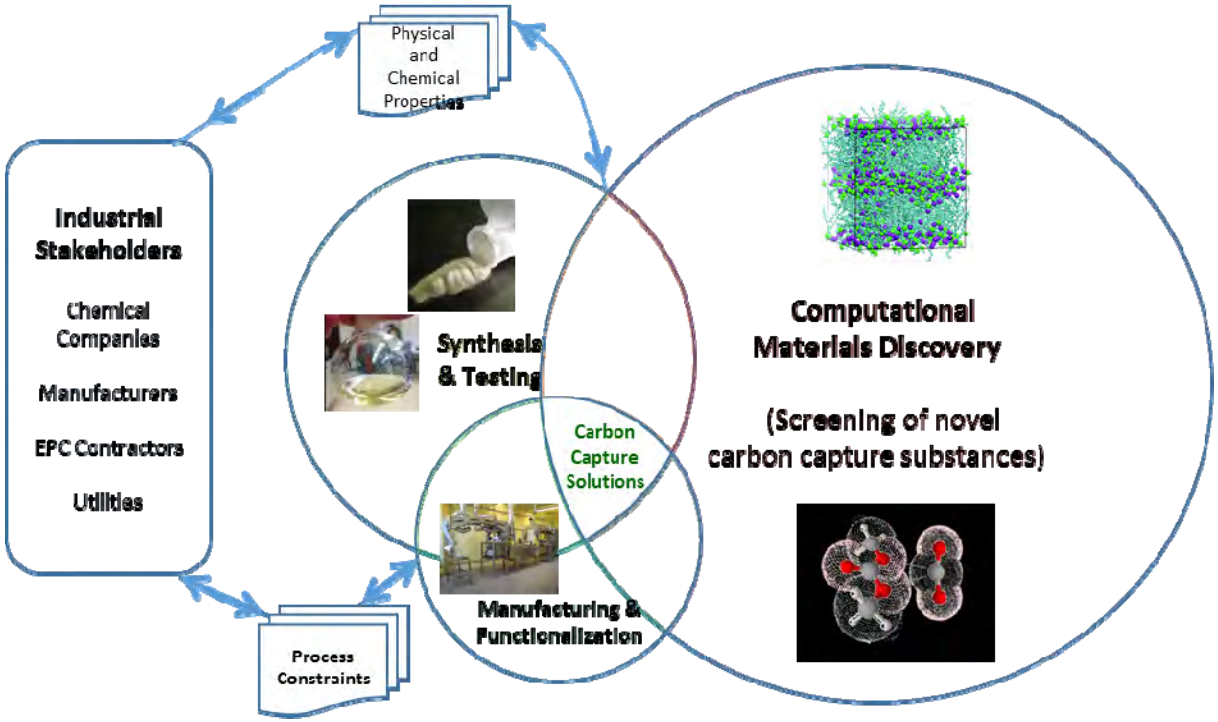
Leverage advanced computing

Robotics for rapid synthesis and analytical capabilities

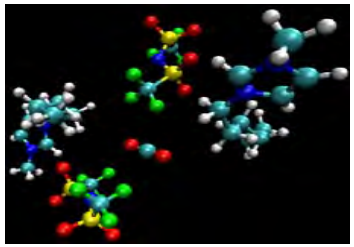
DOCCSS Labs

- **PNNL - Solvents**
- **LBNL – Metal Organic Frameworks**
- **NETL – CCSI2, materials**
- **LLNL – Adv Manufacturing**

"Transformational Technology Development"



Non-aqueous and phase change solvents



Molecular Design

Advanced Manufactinrg

Scaling Up Advanced Capture Technologies

Performer	Project Title	Technology
Topic Area 1: Engineering Scale Testing of Advanced Carbon Capture Technologies		
Research Triangle Institute	Engineering Scale Testing of Transformational Non-Aqueous Solvent-Based CO_2 Capture Process at Technology Centre Mongstad (13MWe)	Non Aqueous Solvent
SRI International	Engineering Scale Demonstration of Mixed-Salt Process for CO_2 Capture (15MWe)	Physical Solvent
Membrane Technology and Research, Inc.	Scale-Up and Testing of Advanced Polaris Membrane CO_2 Capture Technology (1MWe+)	Membrane – Partial Capture
TDA Research, Inc.	Membrane-Sorbent Hybrid System for Post-combustion Carbon Capture (2MWe+)	Membrane / Sorbent – 90% capture
Fluor	Multi-component solvent test (13MWe)	Water lean solvent
Topic Area 2: Initial Engineering, Testing, and Design of a Commercial-Scale, Post-Combustion CO_2 Capture System		
Electric Power Research Institute	Initial Engineering Design of a Post-Combustion CO_2 Capture System for Duke Energy's East Bend Station Using Membrane-Based Technology	Membrane – Partial Capture
ION Engineering LLC	ION Engineering Commercial Carbon Capture Design & Costing (C3DC)	Non Aqueous Solvent
University of North Dakota	Initial Engineering, Testing, and Design of a Commercial-Scale, Post-combustion CO_2 Capture System on an Existing Coal-Fired Generating Unit – Milton R. Young Station	Amine Solvent

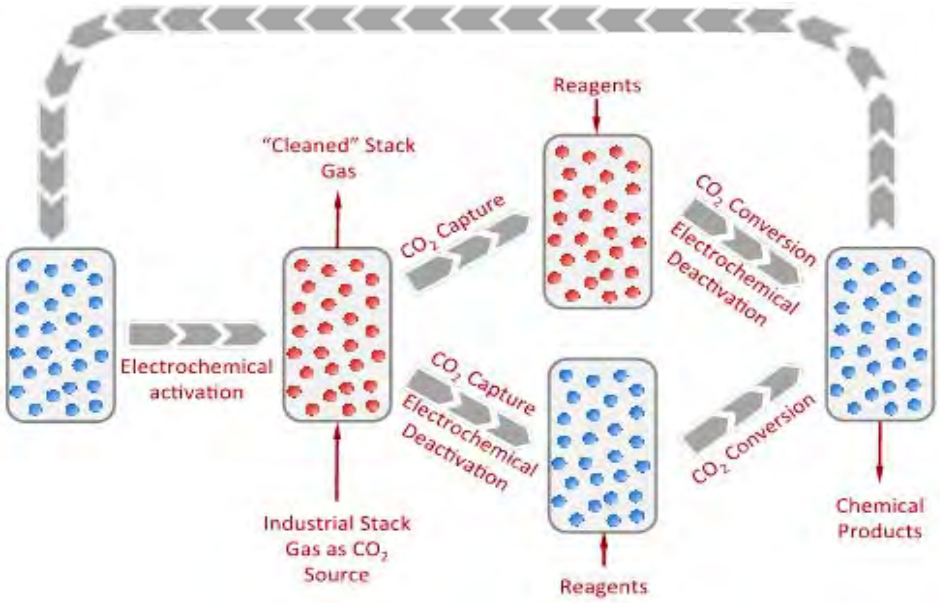
Carbon Utilization

Carbon Use & Reuse

Offset CO_2 capture costs + Fix CO_2 in stable products

Biological Capture & Conversion

Fuels & Chemicals



Mineralization & Cements

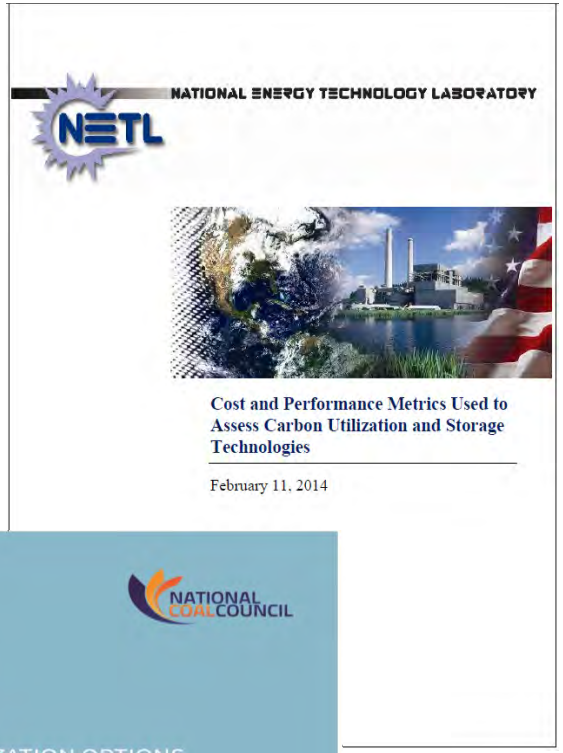
Carbon Use and Reuse

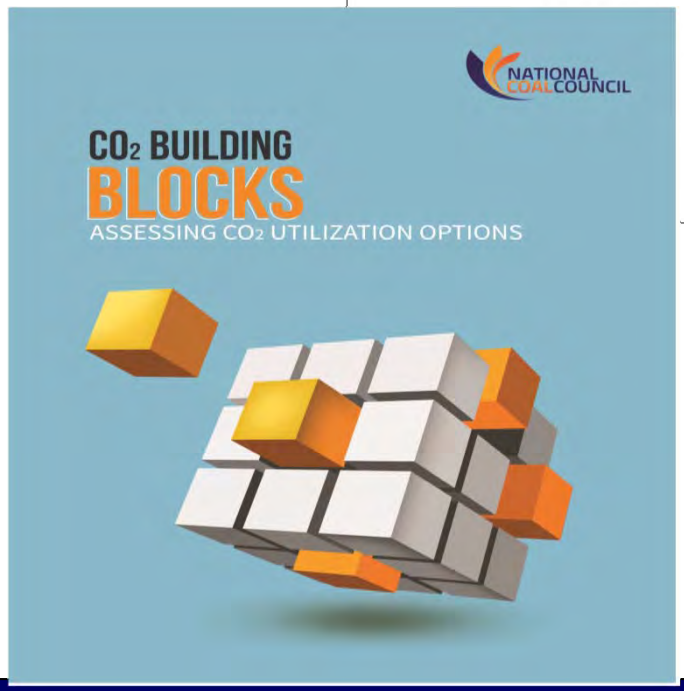
Accelerate a Commercial Pathway to CCUS

- Carbon Utilization Reports
  - National Coal Council
  - National Academies of Science
  - Secretary's Advisory Board

- Novel Methods for Making Products from Carbon Dioxide or Coal FOA ($7M):
  - AOI 1: Lab-scale CO2 Conversion (Abiotic only
  - AOI 2: Field-scale CO2 Conversion (Biotic or Abiotic)

- NETL Guidelines for Evaluation of Utilization Pathways; Released 2014





Carbon Storage

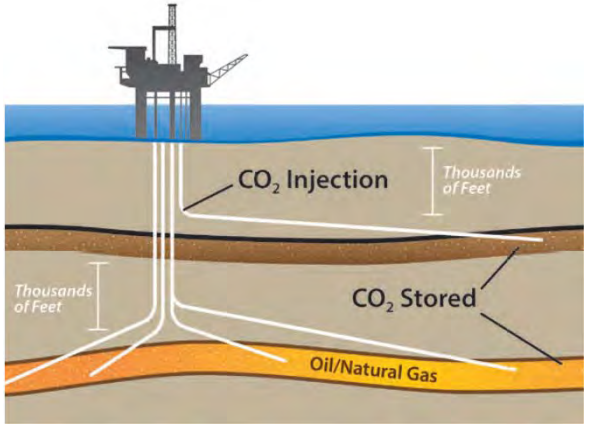
Carbon Storage Infrastructure

Addressing Large-Scale Challenges

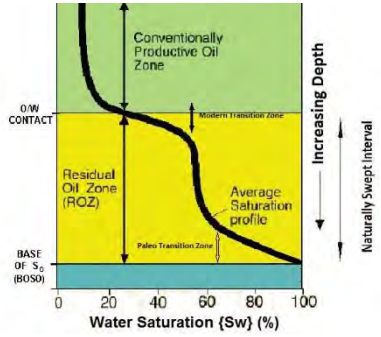
Regional Carbon Sequestration Partnerships (RCSPs)

CarbonSAFE

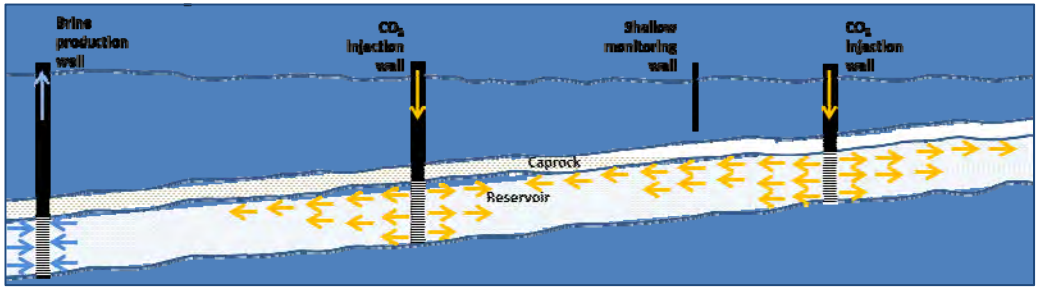
Offshore Storage



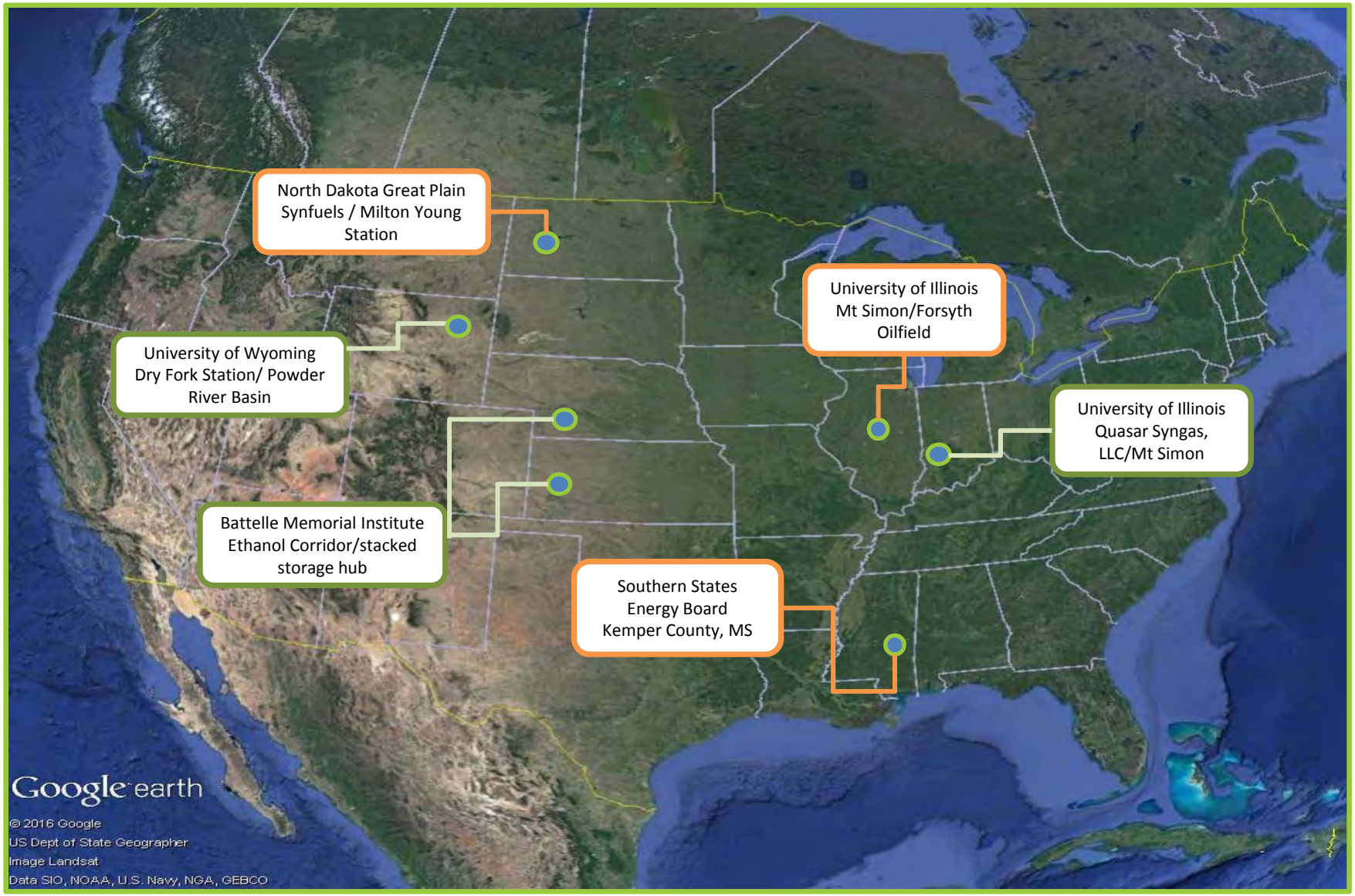
Unconventional EOR



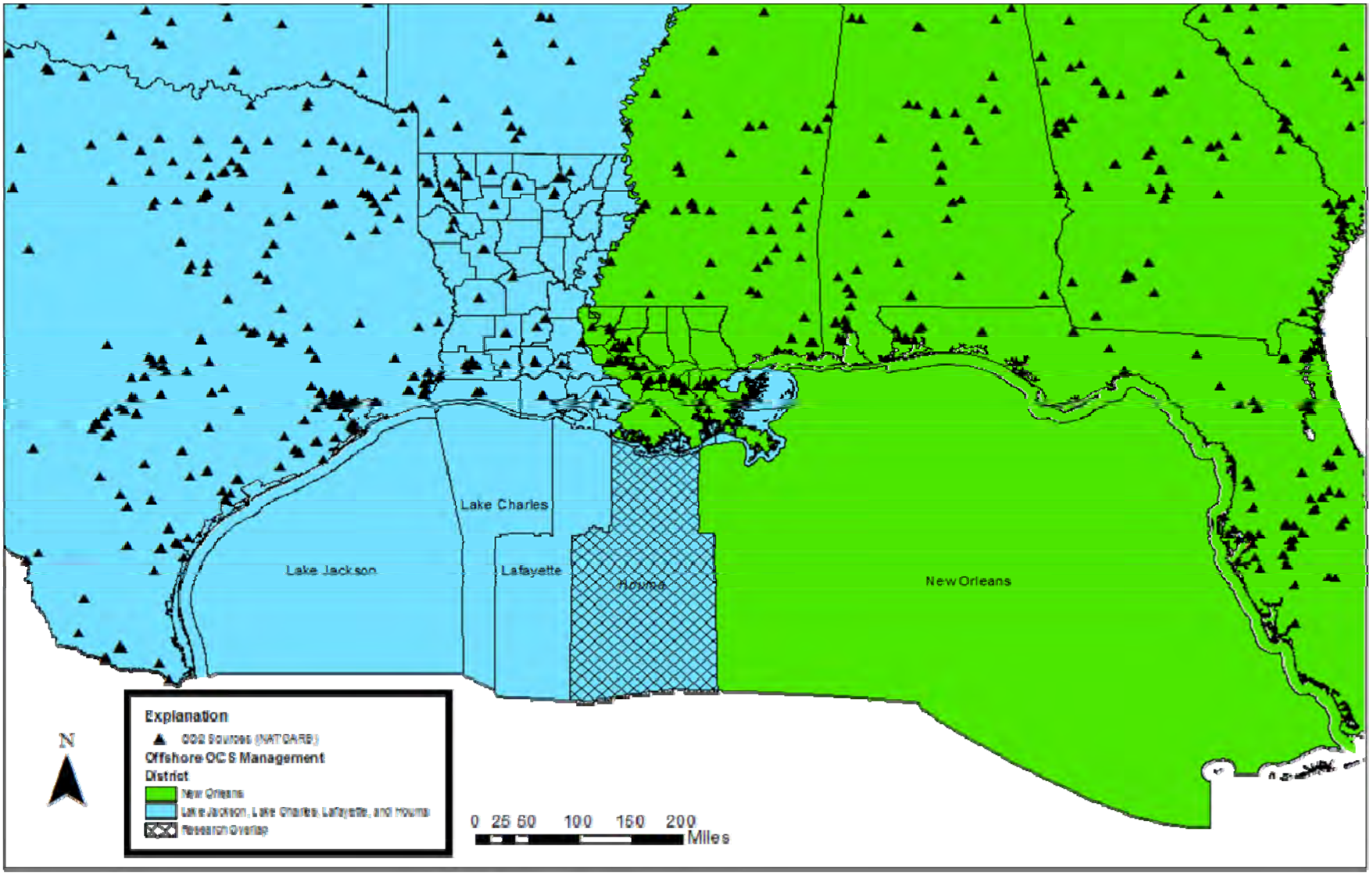
Brine Extraction Storage Tests (BEST)



Phase II: Storage Complex Feasibility



Offshore Projects

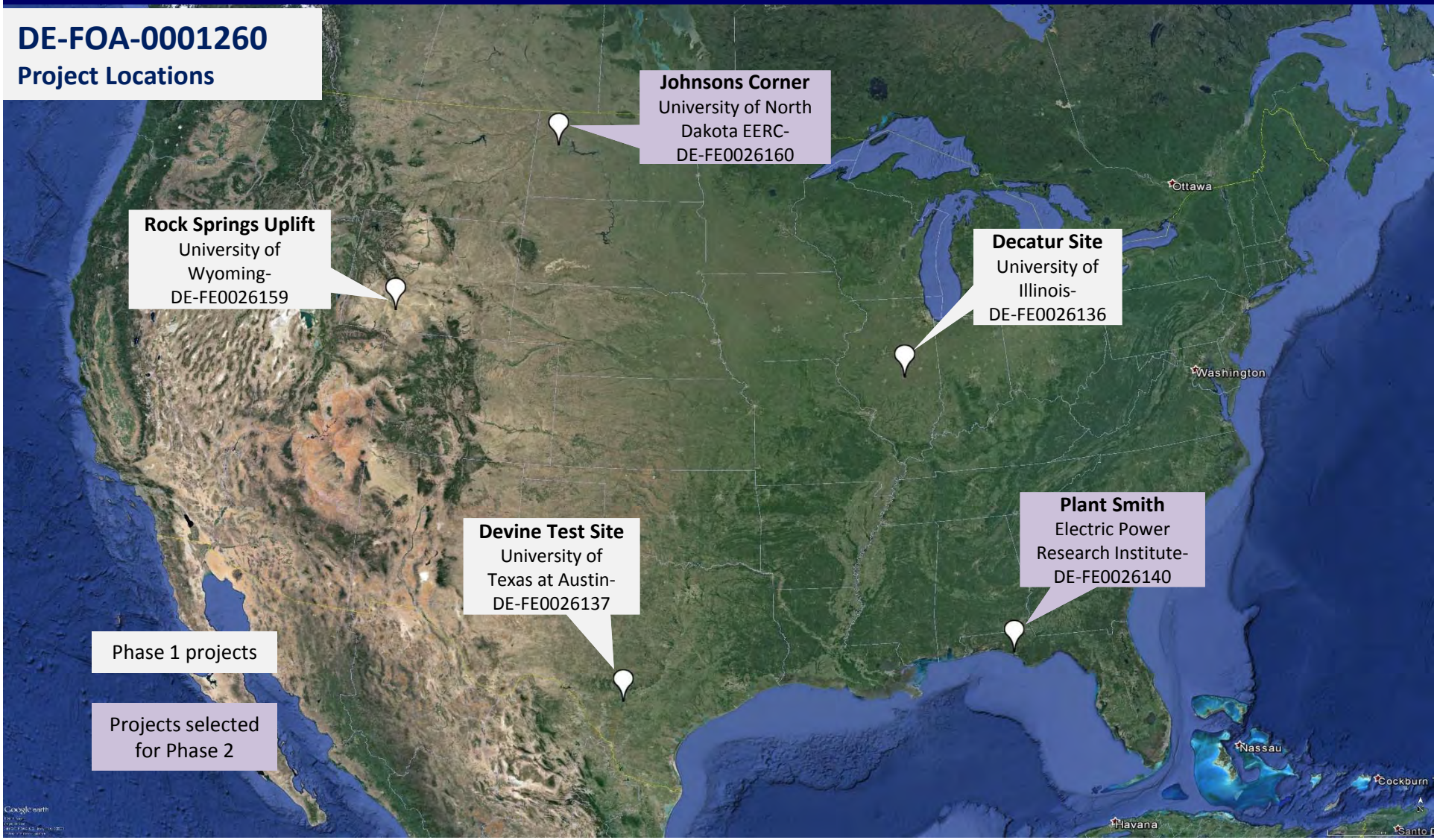


Brine Extraction Storage Test (BEST) Projects

Research objectives:

- R&D projects for managing formation pressure plumes as well as measuring/monitoring the movement of the differential pressure and CO_2 plumes in the subsurface for future saline CO_2 storage projects.
- Brines extracted shall be utilized as a part of a test-bed for brine treatment technologies (coordinated with Crosscutting R&D/Water Management Program)
- Projects completed in two phases:
  - **Phase I** – Gap analysis and water LCA for brine technologies and develop plans for field project
  - **Phase II** – Validation testing employing water/brine injection
- Phase I: 5 projects were awarded, with a total budget of $9.35 million (Cost share = $2.15 million)
- Phase 2: 2 projects awarded:
  - **University of North Dakota Energy & Environmental Research Center.** Total budget (Phases I and II) DOE share $17,366,809; Recipient share $4,915,165. End date 08/31/2020. Status: Initiated construction of wells.
  - **Electric Power Research Institute.** Total budget (Phases I and II) DOE share $17,642,791; Recipient share $4,812,798. End date 08/31/2020. Status: Well construction complete. Initiated equipment procurement and commissioning.

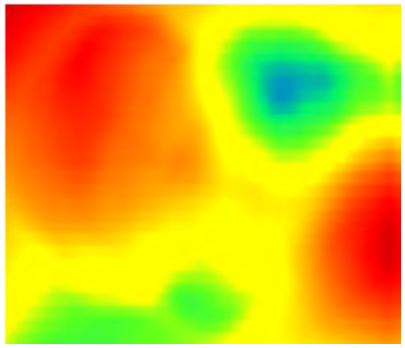
Project Locations



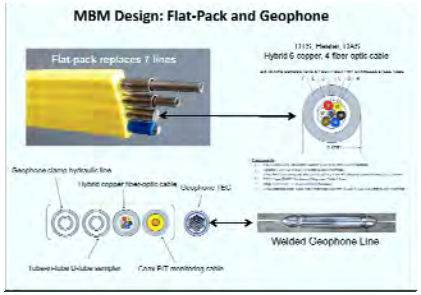
Advanced Carbon Storage Technology Development

Early-Stage Storage R&D

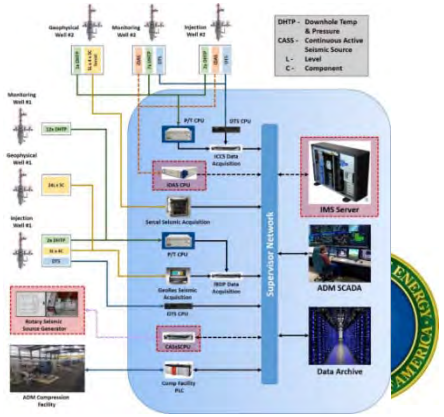
- **Monitoring and measurement tools:** advancing modeling and monitoring methods, technologies, and tools to improve characterization and reduce the uncertainty about the CO_2 and pressure fronts.
- **Monitoring wellbore integrity:** advancing materials and autonomous wellbore monitoring systems for long-term integrity assessment.
- **Advanced simulation tools for coupled processes:** advancing modeling of fluid flow, mechanical deformation/failure, and geochemistry in complex storage reservoirs.
- **National Risk Assessment Partnership:** developing science-based methodology and platform for quantifying risk profiles, which are being used to develop risk-based, integrated monitoring and mitigation protocols.



LLNL Toolset for Fault Detection and Seismicity Mitigation -



Modular Borehole Monitoring (MBM) Flat-Pack

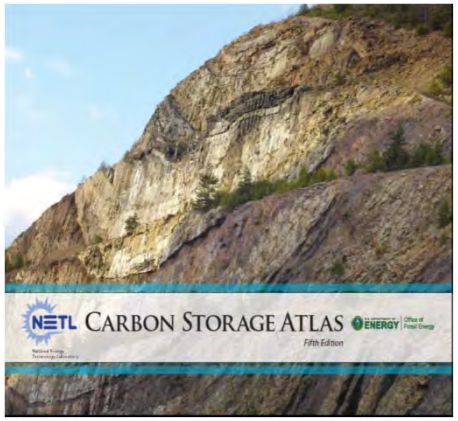


International Activities

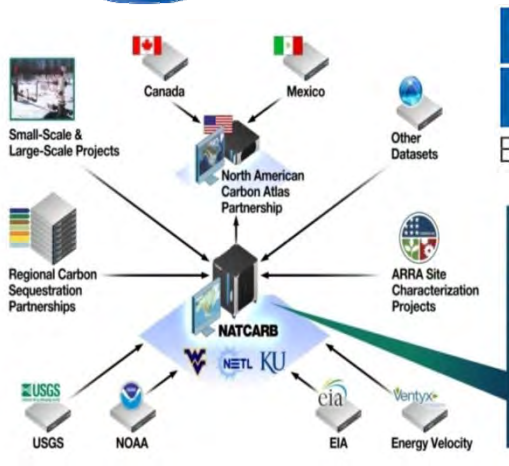
- **Bilaterals**
  - US-Norway
  - US-China Clean Energy Research Center (CERC)

- **Multilaterals**
  - North American trilateral
  - Clean Energy Ministerial/Mission Innovation
    - MI CCUS Report
    - Accelerating CCUS Technologies (ACT) initiative
  - Carbon Sequestration Leadership Forum (CSLF)
  - International Energy Agency Greenhouse Gas (IEAGHG) R&D Program

Knowledge Sharing Products



Worldwide CCS Project Database



EDX
Energy Data eXchange