

U.S. DEPARTMENT OF
ENERGY

Office of
Fossil Energy

Carbon Capture, Utilization and Storage (CCUS)

*Technology Development,
Incentives, and Multilateral
Initiatives*

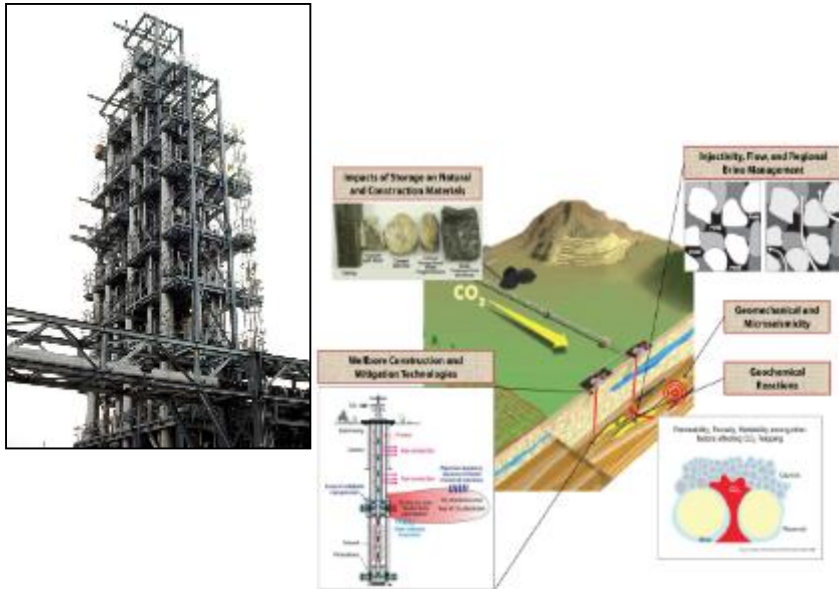
Ari BenAissa

Office of Asian Affairs

Office of International Affairs

CCS Activities in the U.S. – Focused on Technology Development and Market Mechanisms

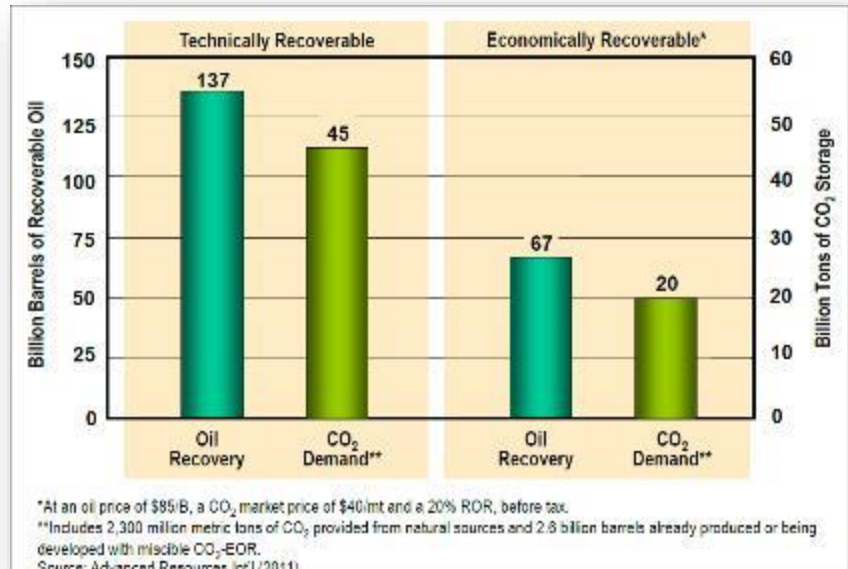
Technology Push



- Government and industry
- R&D focused on cost (capture) and confidence (storage)
- Demos (integration and learning)

Market Pull

Domestic Oil Supplies and CO₂ Demand (Storage) Volumes from “Next Generation” CO₂-EOR Technology**



- Existing Market Mechanisms: Enhanced Oil Recovery (EOR)
 - 65 million tons per year of CO₂ to produce nearly 300,000 barrels of oil per day
- Regulatory Framework
- Financing (Tax Credits and Loan Guarantees)

Commercial CO₂ Enhanced Oil Recovery (EOR)

CCUS Technology's Beginning

- Primary and secondary (water flood) production of conventional light crude oil recovers only about 1/3 of oil in place
- Remaining 1/3 is target for EOR with steam, gas, or chemical injection ultimately producing 30-60% or more of reservoir's original oil in place
- For CO₂ injection, CO₂ is produced alongside the oil but recycled

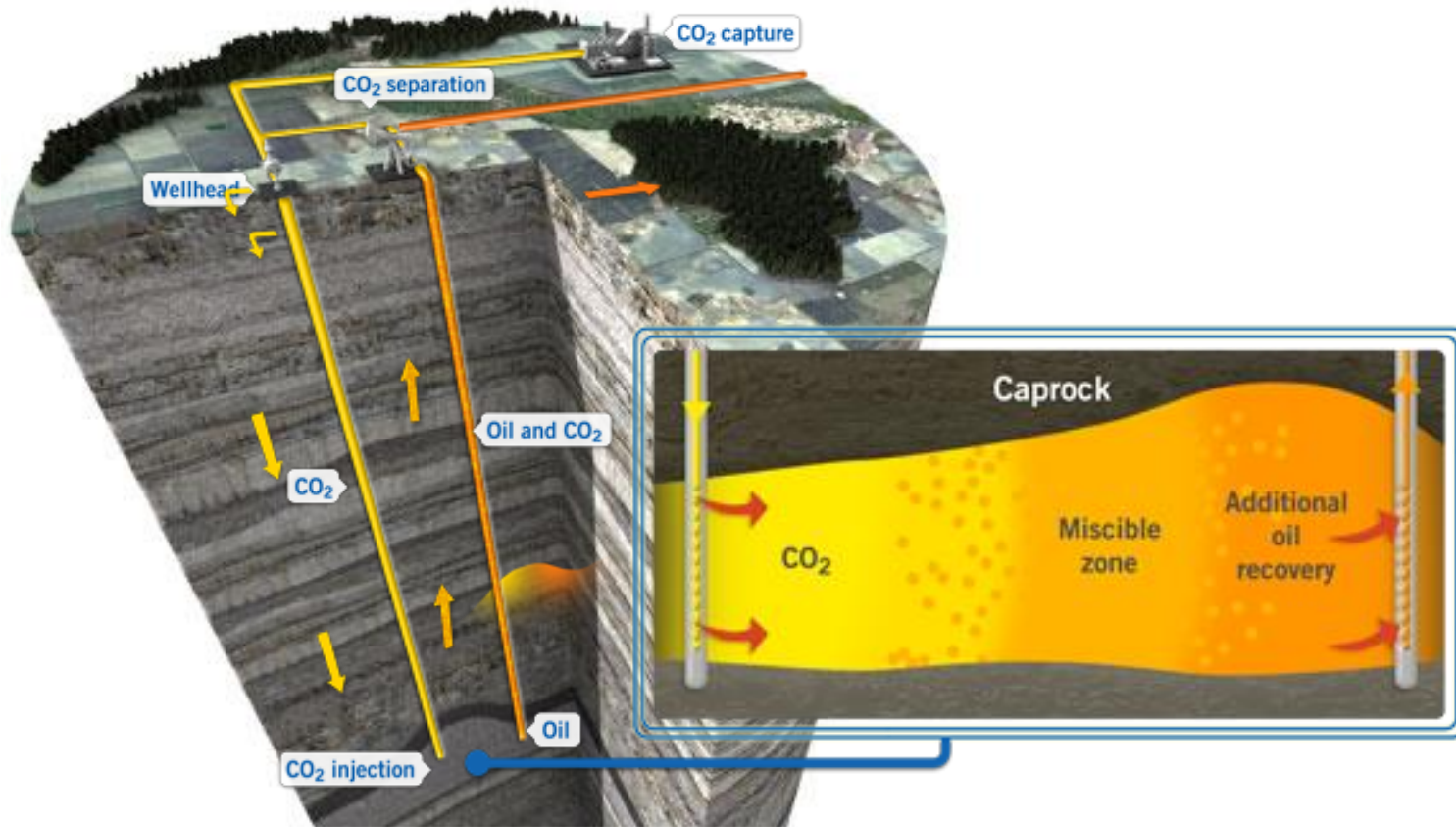
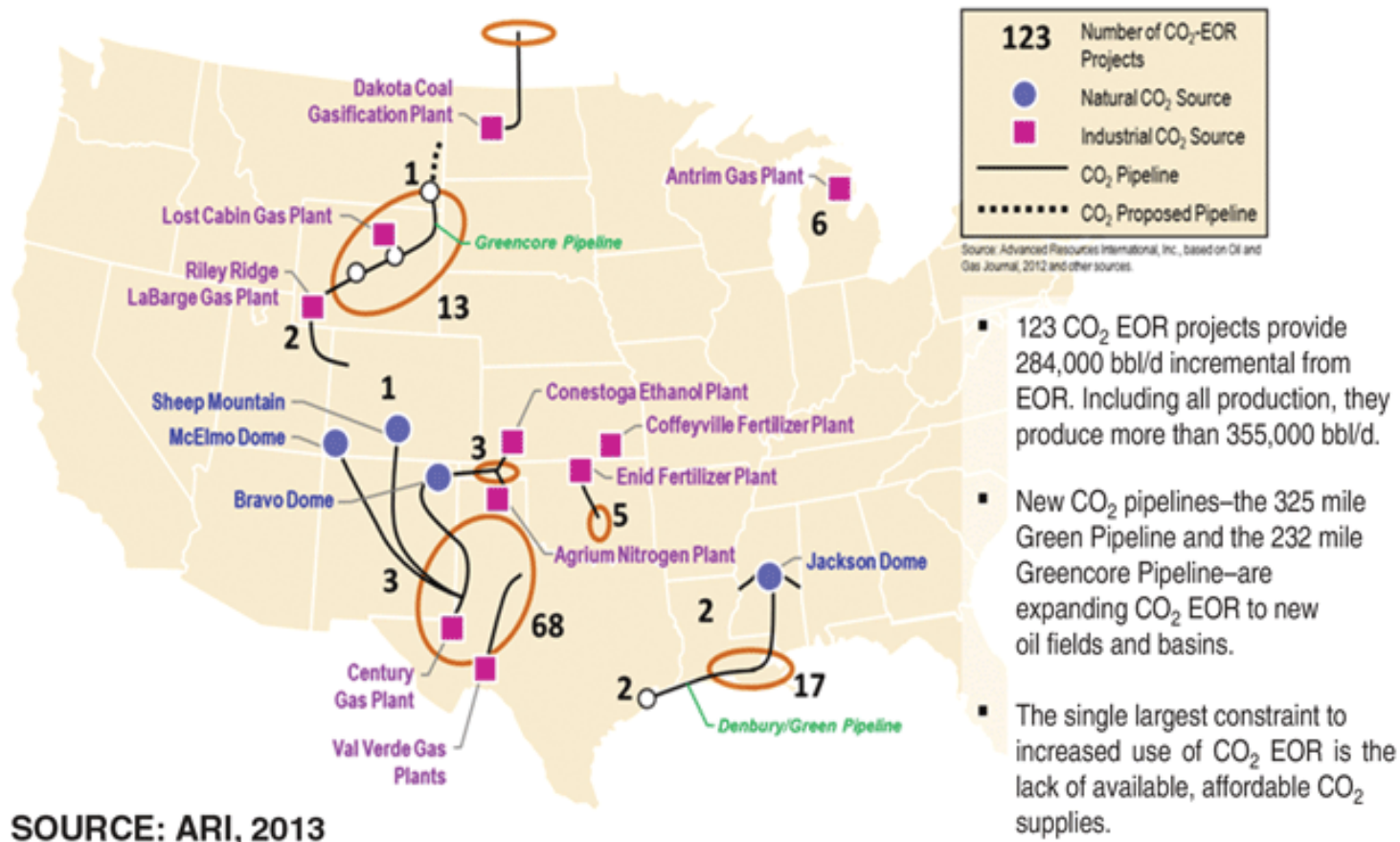


Image: Global CCS Institute

EOR in the United States

Decades of experience and thousands of miles of pipelines



USDOE Office of Clean Coal & Carbon Management

Advancing Clean Coal Technology Development



**Making Coal Plants
More Efficient**

**Gasification, Advanced
Turbines, Advanced
Combustion, and Fuel Cells**



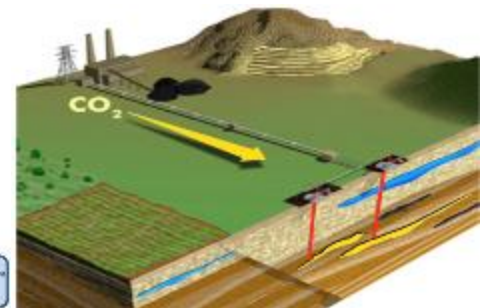
Capturing More CO₂

**Cost-effective carbon
capture for new and
existing power plants**



**Turning CO₂
into Valuable Products**

**New pathways to utilize
captured CO₂**



CO₂ Utilization

**Safe use and permanent
storage of CO₂ from power
generation and industry**



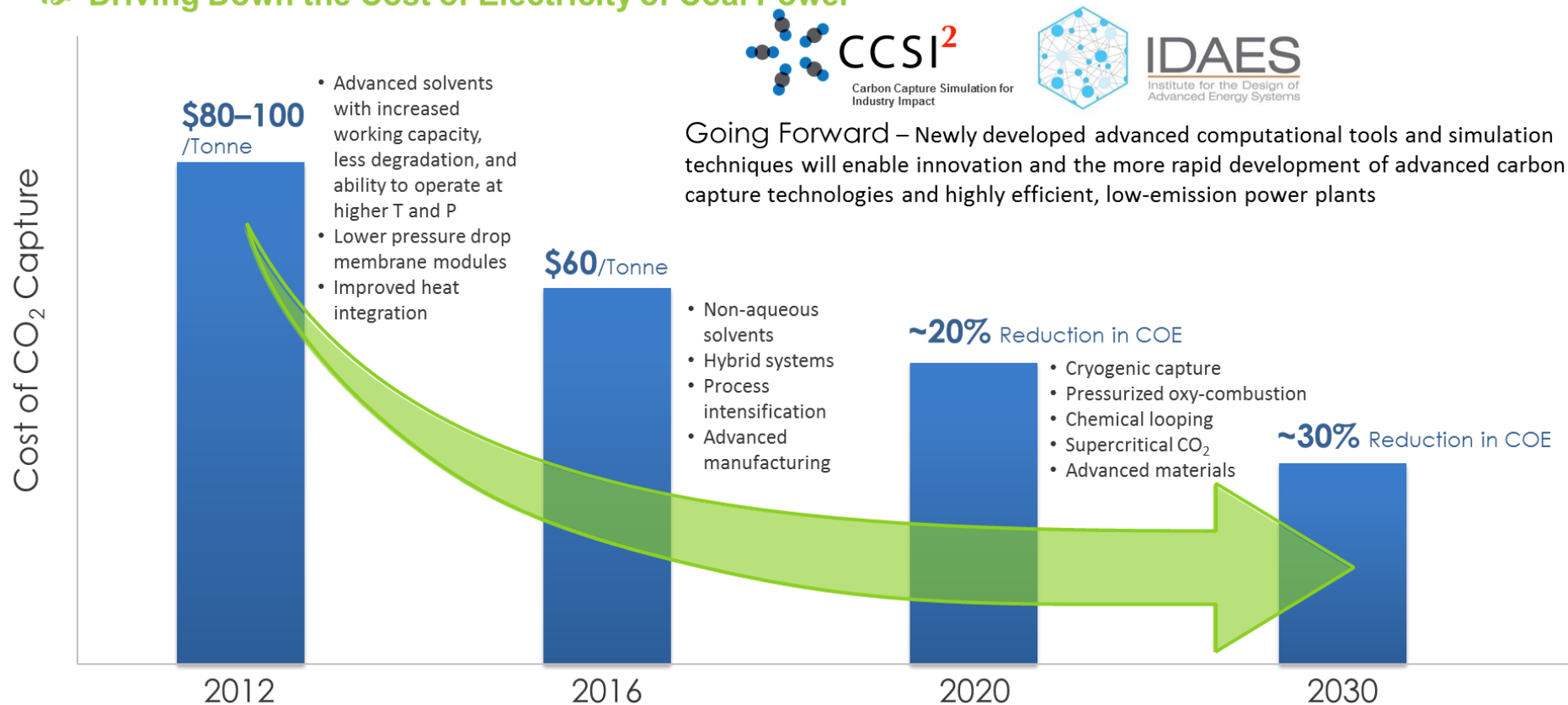
Bringing it All Together

**Crosscutting technology
development program**

USDOE's CCUS Program

Investing in RD&D to drive down costs and increase performance

➤ Driving Down the Cost of Electricity of Coal Power

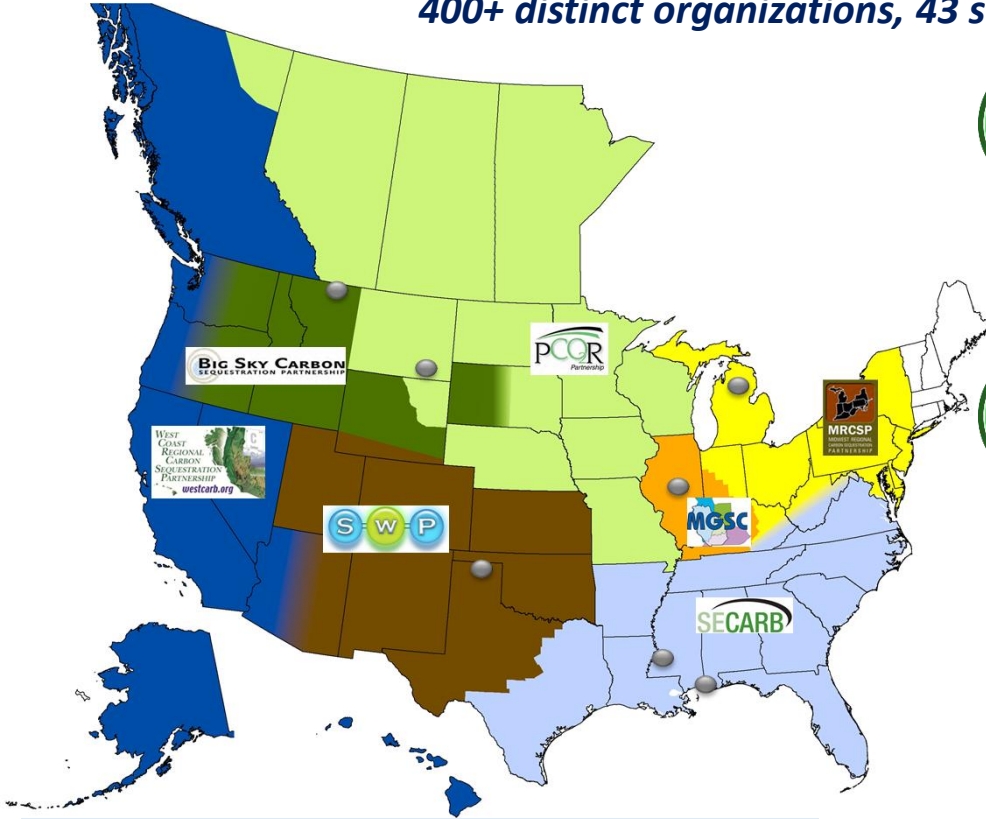


USDOE FE's Carbon Storage Program

Proving capacity, storage permanence, and public acceptance

Seven Regional Carbon Sequestration 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 CO₂ 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 1 million tons each)

Commercial scale understanding and validation

>16 million metric tons stored to date

Post-Combustion Capture

National Carbon Capture Center – Moving from Lab to Market

- Operated by Southern Co. Services
- Hosted at Plant Gaston, AL
- 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 40 carbon capture technologies tested
 - 20+ Post combustion
 - 20+ Pre-combustion
- Dedicated staff of plant engineers
- Standard design guidelines
- Small (0.05 MWe) and Large (0.5 MWe) Solvent Test Units
- 90+% of US developers opt for NCCC
- Natural Gas Combined Cycle and Utilization Capabilities

Lab-Scale Unit



Bench-Scale Unit



TRIG - Gasifier



Small Pilot-Scale Unit

USDOE Supported Major CCUS Demonstration Projects

AIR PRODUCTS FACILITY (PORT ARTHUR, TX) - 2013



- State-of-the-art system to capture the CO₂ emitted from two large steam methane reformers
- Captured gas transported via pipeline to oil fields in eastern Texas where it is used for EOR. Since 2013, the project has **captured over 3 million metric tons of CO₂**

PETRA NOVA CCS (THOMPSONS, TX) - 2017



- Demonstrate Mitsubishi Heavy Industries' CO₂ capture technology **ability to capture 90% of CO₂ emitted** from a 240-MW flue gas stream. (designed to **capture/store 1.4 million tonnes of CO₂ per year**)
- Captured CO₂ being used for EOR in West Ranch Oil Field in Jackson County, TX

ADM ETHANOL FACILITY (DECATUR, IL) - 2017



- Planned to **capture 1 million metric tons of CO₂ per year** as by-product of ethanol biofuels production and stored in deep saline reservoir
- First CCS project to use new USEPA Underground Injection Class VI well permit specifically for CO₂ storage

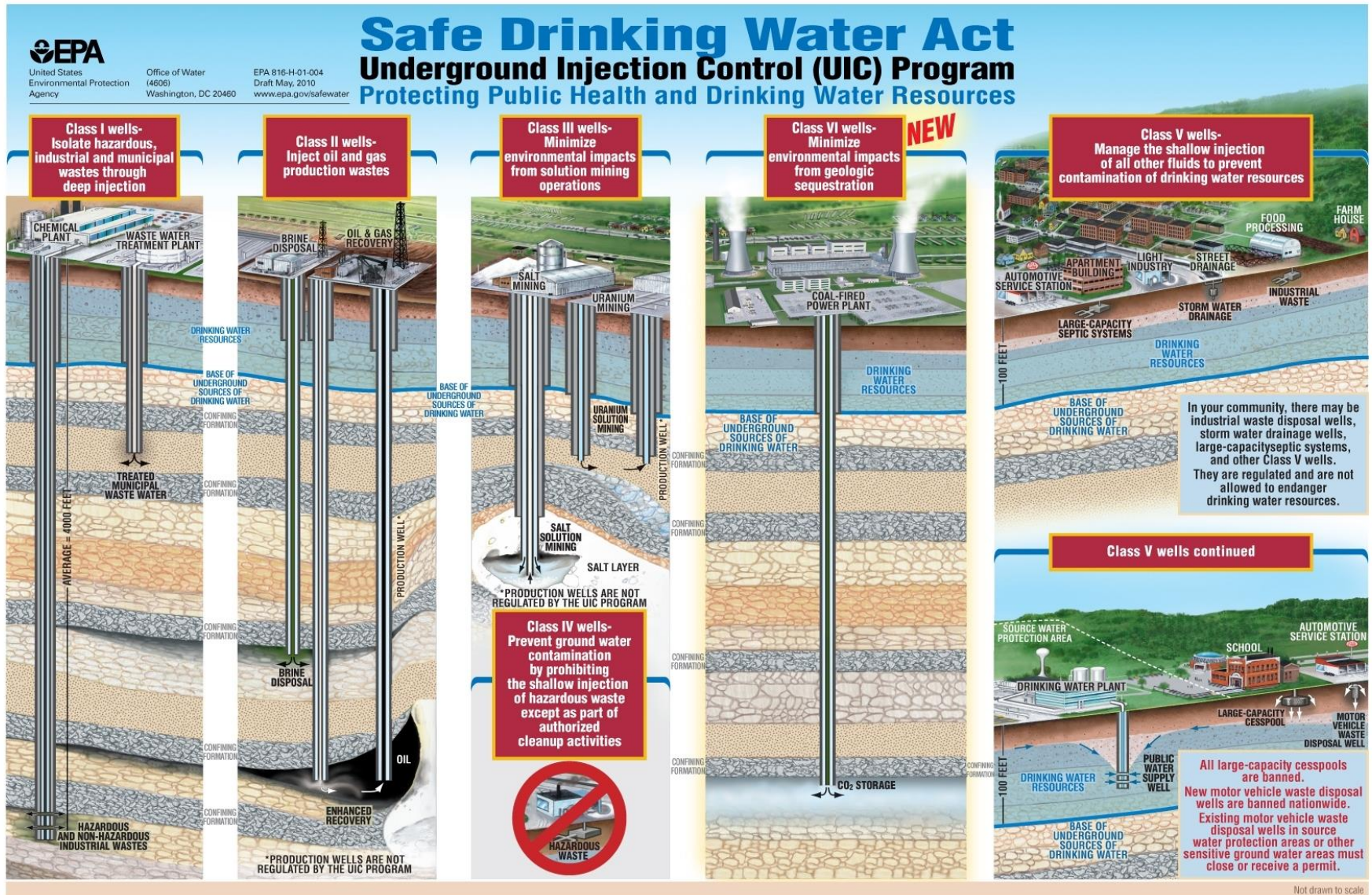
KEMPER CCS PROJECT (KEMPER COUNTY MS) - *SUSPENDED*



- 65% of plant's CO₂ emissions (around 3 million metric tons per year) were to have been captured and shipped to depleted oil fields in Gulf coast region
- Transport Integrated Gasification (TRIG) technology developed jointly by DOE, Southern Company, and KBR

Stable Regulatory Environment Needed for CCUS Deployment

New USEPA Class VI Permits for CO₂ Injection



U.S. Incentives for CCUS Deployment

45Q Tax Credit Update

- Credit available for 12 years
- Applicable Amounts
 - \$50 per metric ton for secure geologic storage*
 - \$35 per metric ton for enhanced oil recovery (EOR), enhanced gas recovery (EGR), or utilization*

Adds qualification for Carbon Oxides (CO or CO₂) from Industrial sources

- Excludes gases recaptured during EOR process

Qualified facilities:

- Construction begins by January 1, 2024
- Electricity Generating Units (EGUs): at least 500,000 tons captured
- Other Industrial Facilities: 100,000 tons
- Air Capture: at least 100,000 tons
- Utilization, including Photo- or chemo-synthesis, chemical conversion, other purposes for which commercial markets exist
- Credit can be claimed by owner of capture equipment or transferred to disposal/use entity
- Treasury, EPA, Interior, and DOE to establish regulations to determine adequate security measures; Treasury may prescribe regulations to ensure proper allocation

U.S. Incentives for CCUS Deployment

45Q Tax Credit Update

Level of credit available for different combinations of CO₂ sources and uses
IEA Analysis

Type of CO ₂ storage/use	Minimum size of eligible carbon capture plant by type (ktCO ₂ /yr)			Relevant level of tax credit in a given operational year (USD/tCO ₂)										
				2018	2019	2020	2021	2022	2023	2024	2025	2026	Later	
	Power plant	Other industrial facility	Direct air capture											
	Dedicated geological storage	500	100	100	28	31	34	36	39	42	45	47	50	Index linked
	Storage via EOR	500	100	100	17	19	22	24	26	28	31	33	35	
Other utilisation processes ¹	25	25	25	17 ²	19	22	24	26	28	31	33	35		

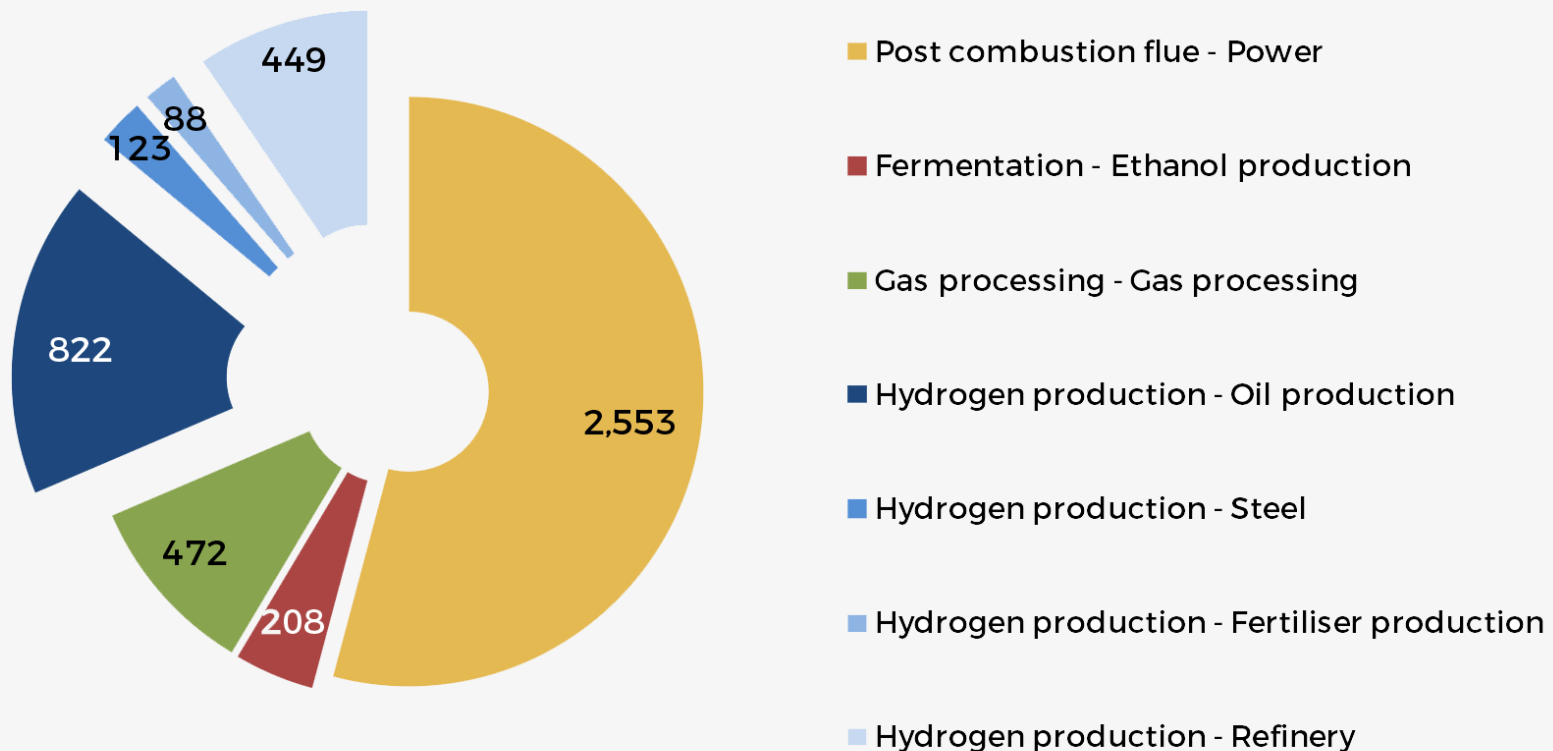
¹ each CO₂ source cannot be greater than 500 ktCO₂/yr

² Any credit will only apply to the portion of the converted CO₂ that can be shown to reduce overall emissions



Global 10-Year CCUS Historical Investment Profile

Investment by capture process and sector 2007 - 2017 (USD million)
IEA Analysis



Carbon Sequestration Leadership Forum



Australia



Brazil



Canada



China



Czech
Republic



European
Commission



France



Germany



Greece



India



Japan



Mexico



New Zealand



Poland



Romania



Russia



Saudi
Arabia



Serbia



South
Africa



United Arab
Emirates



United
Kingdom



United
States

International Ministerial-level initiative focused on developing improved cost-effective technologies for CCS. It also promotes awareness and champions legal, regulatory, financial, and institutional environments conducive to such technologies.



Mission to facilitate development of CCS technologies
via collaborative efforts that address
key technical, economic, and environmental obstacles.



Italy



Korea



Netherlands



Norway

- Last forum hosted by Minister Suhail Al Mazrouei, Minister of Energy and Industry (UAE)
- Focused on advancing CCUS business case
- Ministerial Communique key points:
 - Support inclusion of CCUS as part of suite of clean energy technologies
 - Leverage success of operational CCUS projects and emphasize the need for greater project development
 - Encourage development of regional strategies to support CCUS deployment
 - Explore utilization options beyond CO₂-EOR
 - Support collaborative research and development on innovative CCUS technologies
 - Expand stakeholder engagement and strengthen links with other clean energy efforts
 - Increase global shared learnings on CCUS through best practices and lessons learned
 - Continue engagement with the public on CCUS



- ❑ **Expand spectrum of clean energy technologies actively considered under CEM to include CCUS**
- ❑ **Create sustained platform for private sector, governments, and investment community to engage and accelerate CCUS deployment**
- ❑ **Facilitate identification of both near and longer-term investment opportunities to improve business case for CCUS**
- ❑ **Disseminate emerging CCUS policy, regulatory, and investment best practices as part of integrated clean energy systems**

- **Provide expert assistance and sharing of best practices to support in-country work**
 - “Ask an Expert” service
 - CEM website
- **Establish industry advisory body to provide regular dialogue with key energy ministers on CCUS progress and priorities**
- **Conduct workshops with industry and policymakers to identify promising CCUS opportunities**
- **Support feasibility studies and assessments**

**Minster-level initiative, with participation
from 23 member governments (22 countries plus EC)**

Goal

**Double clean energy R&D investment
from \$15B to \$30B over 5 years (2015-2020)**

- ❑ [Encourage mutually beneficial engagement](#) with other partner countries in international collaborations
- ❑ [Share information](#) on national clean energy needs, plans, priorities, and supporting policies and programs for clean energy innovation
- ❑ [Work closely with the private sector](#) as it increases its investment in the earlier-stage clean energy companies that emerge from government R&D programs

Mission Innovation: Carbon Capture Challenge

Co-Leads: Saudi Arabia, Mexico, and United Kingdom

Work to date:

- Expert's Workshop in September 2017, focused on early-stage CCUS R&D
 - Over 250 experts from 17 countries developed 30 Priority Research Directions
 - <https://www.energy.gov/fe/downloads/accelerating-breakthrough-innovation-carbon-capture-utilization-and-storage>

Ongoing work:

- Forming collaborative platform to organize R&D investments multilaterally
- Aligning work through multilateral funding initiatives, such as Accelerating CCUS Technology (ACT) Programme
- Developing methods to reach out to private industry and create public-private linkages

CCS is Available Today!

Global efforts focusing on reducing costs and deployment

Operating Facilities

Air Products, Port Arthur, TX – Since 2012, over 4 million tonnes CO₂ stored with EOR

Archer Daniels Midland Company, Decatur, IL – Full-capacity operation first quarter 2017; 900,000 tonnes CO₂/yr for sequestration in saline formation

Petra Nova, Thompsons, TX – Full capacity operation January 2017; to capture ~1.6 million tonnes CO₂/yr via post-combustion capture for EOR

Boundary Dam, Saskpower, Saskatchewan – Since October 2014, capturing 1.1 million tonnes CO₂/yr for EOR and geologic storage

Sleipner CO₂ Storage, Offshore Norway – 0.85 million tonnes of CO₂/yr since 1996; over 17 million tonnes CO₂ injected