U.S. CCS Policy, Regional Carbon Sequestration Partnerships, and Major Demonstration Projects

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Major Projects Division

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President's Climate Action Plan

- EPA draft rules 111 (b) and 111 (d)

President's Climate Action Plan:
Three overarching themes

Mitigation (Emissions Reduction)

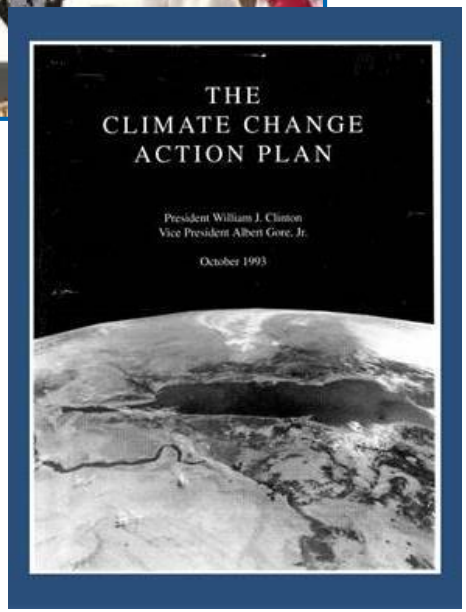
- ***ALL OF THE ABOVE***
- **Efficiency, Renewables, Nuclear, Gas**
- **Coal with CCS/CCUS**

Adaptation & Resilience

- **Smart, reliable grid**
- **Key infrastructure investments**

International Partnerships

- **China and Asia**
- **Coordinated Int'l Efforts**



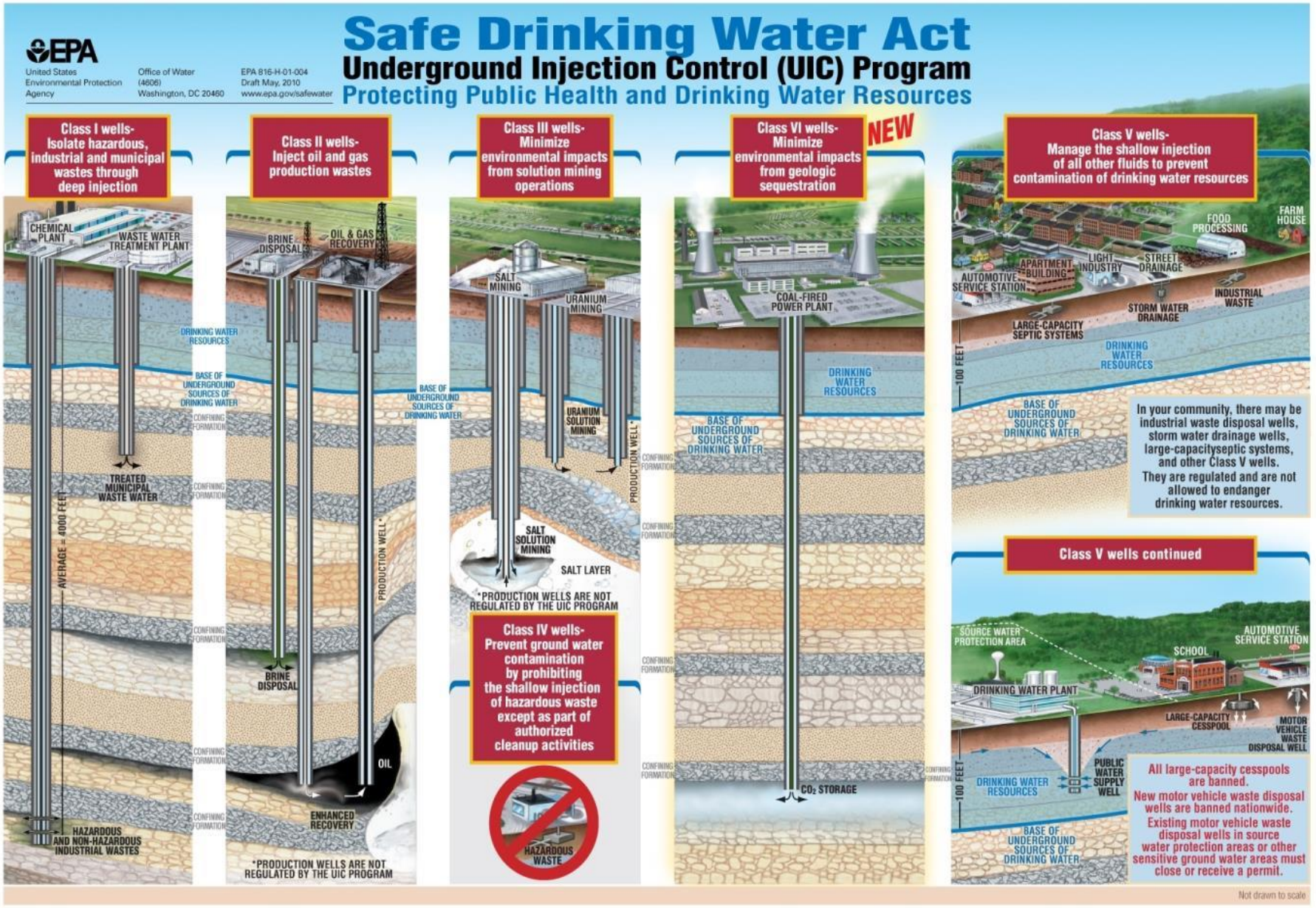
Once in a Generation Opportunity to Build

Electric Utility Sector & EPA Regulations

	Issue	Federal Regulation/Compliance
Air	SO_x & NO_x crossing state lines	**Cross-State Air Pollution Rule (CSAPR)** Finalized 7.7.2011; 12.30.2011, DC Circuit stay of CSAPR (CAIR in effect); 8.21.2012, DC Circuit decision vacating CSAPR; SCOTUS overturned, EPA Review Pending ***Compliance: Unknown***
	Mercury and Hazardous Air Pollutants (HAPs)	**Mercury and Air Toxics Standards (MATS) Rule for Electric Generation Units** Finalized 12.16.2011 – Pending SCOTUS Review ***Compliance: ~2015***
	GHG emissions	**GHG New Source Performance Standards (NSPS)** New rule proposed 9.20.2013; Final rule expected Mid-summer 2015 **Existing Source GHG Regulation** Proposed rule delivered 6.2014 Final rule expected Mid-summer 2015
Waste	Coal Combustion Residuals (e.g., coal ash, boiler slag)	**Coal Combustion Residuals (CCR) Rule** Proposed rule 6.10.2010; Final rule issued 12.19.2014 ***Compliance: Rolling Basis***
Water	Cooling Water Intake Structures – impact on aquatic life	**CWA §316(b) Rule** Final rule delivered 5.2014 (settlement agreement) ***Compliance: Within 8 Years***
	Surface water discharges; Surface impoundments	**Steam Electric Effluent Limitations Guidelines** Proposed rule 11.2012; final rule expected 9.2015 (settlement agreement) ***Compliance: Unknown***

- Near-term (through 2015-2016) Compliance Horizon for EPA regulations may create potential localized reliability issues
- Local reliability issues can be managed with timely notice and coordination on retirement and retrofit decisions
- States and regions will play a valuable role in addressing EPA regulation impacts
- Non-transmission alternatives can help alleviate reliability impacts when/where available
- EPA regulations are only one aspect impacting the future of our electricity system

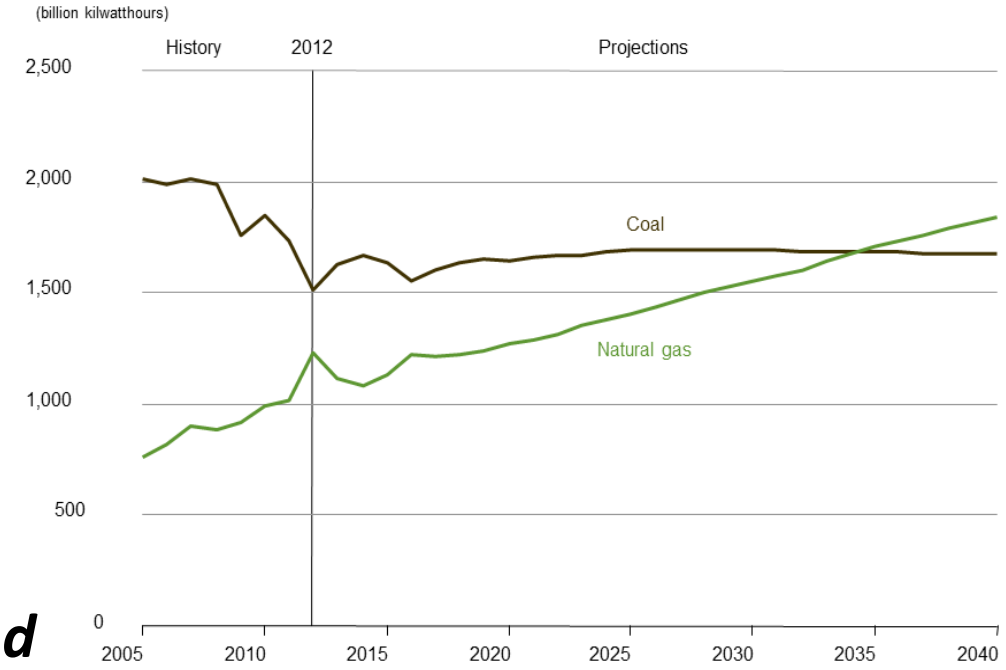
Underground Injection Control (UIC) Well Classes



Future of Fossil Energy Demand & Generation

- Even with robust natural gas growth, coal is still a major source of global energy demand and domestic electricity generation
- Fossil Energy remains dominant share (68%) of United States electricity generation in 2040
- ***With this continued use and growth is a need to address CO_2 emissions***

Figure 3. Electricity generation from natural gas and coal, 2005-2040



Source: EIA 2014 Annual Energy Outlook

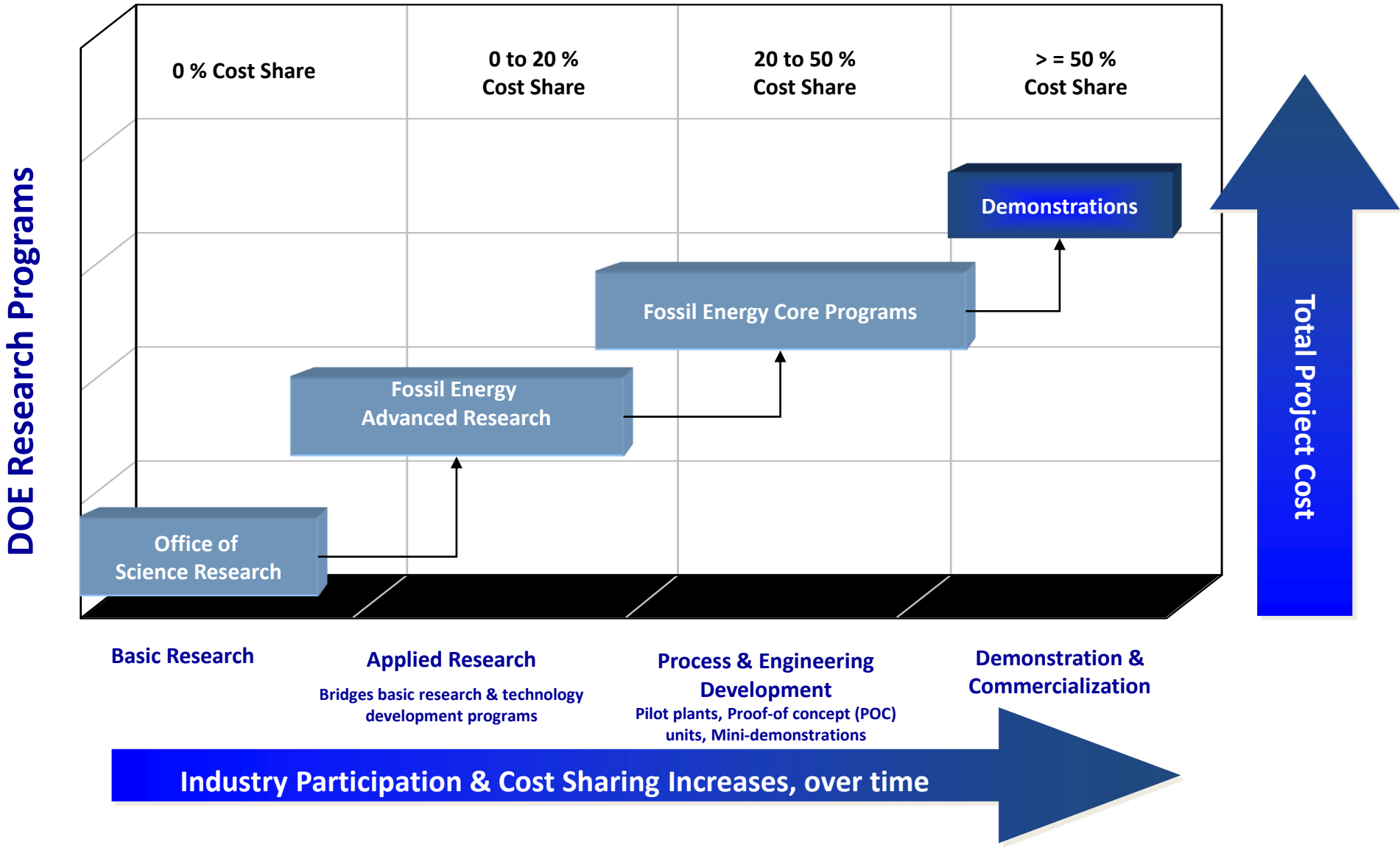
eia

Carbon Sequestration Leadership Forum (CSLF)

The CSLF aims to:

- Share information on CCS projects, policy initiatives and legal and regulatory developments in member countries
- Build the capacity for CCS in the developing country CSLF members
- Explore methods for financing CCS projects, including in developing countries
- Develop global roadmaps for research, development and demonstration of CCS technologies

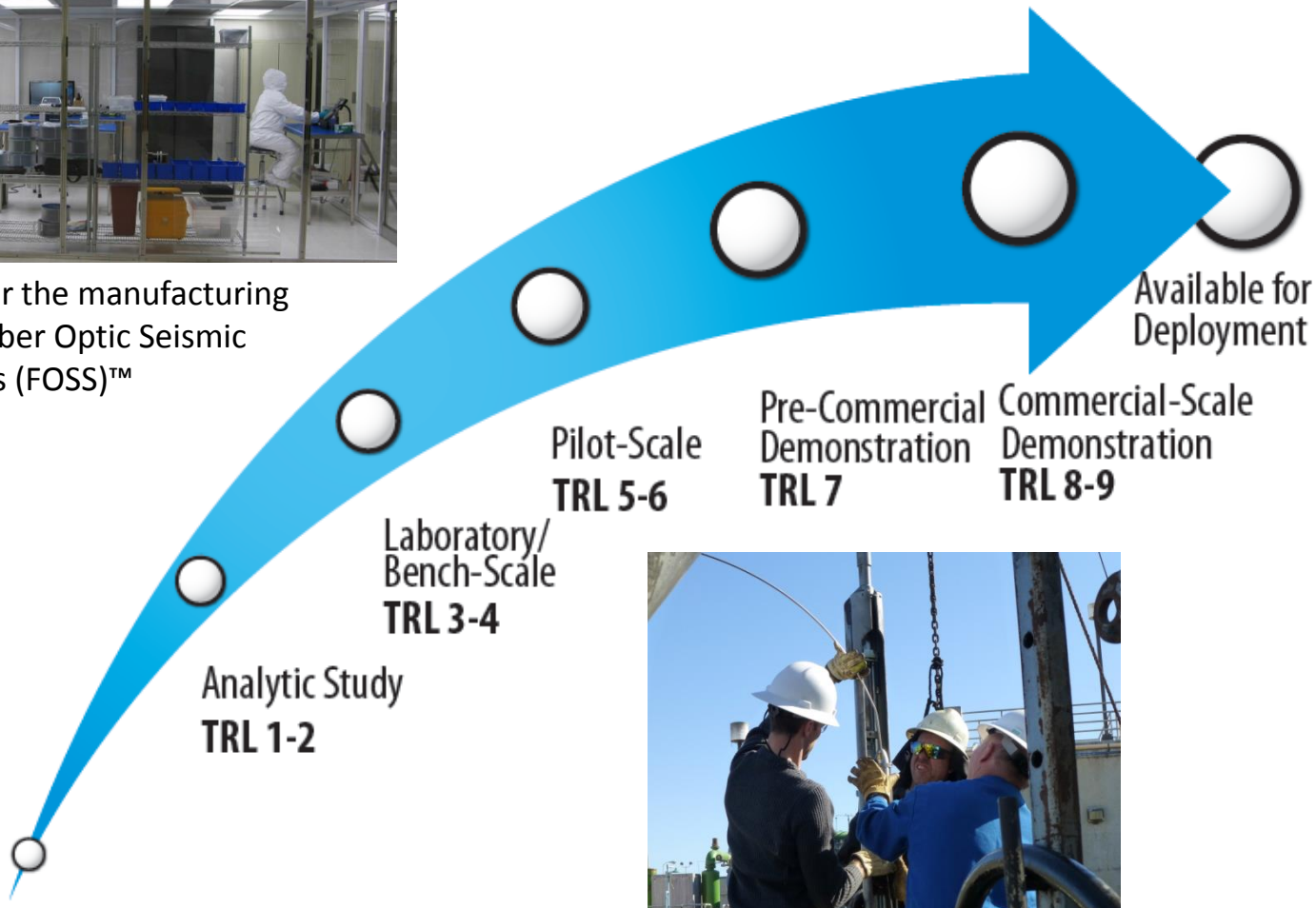
Cost Share Ensures Commercial Relevance



Carbon Storage Program

Technology Readiness Levels (TRLs)

The clean room for the manufacturing of the 300ºC Fiber Optic Seismic Sensors (FOSS)™

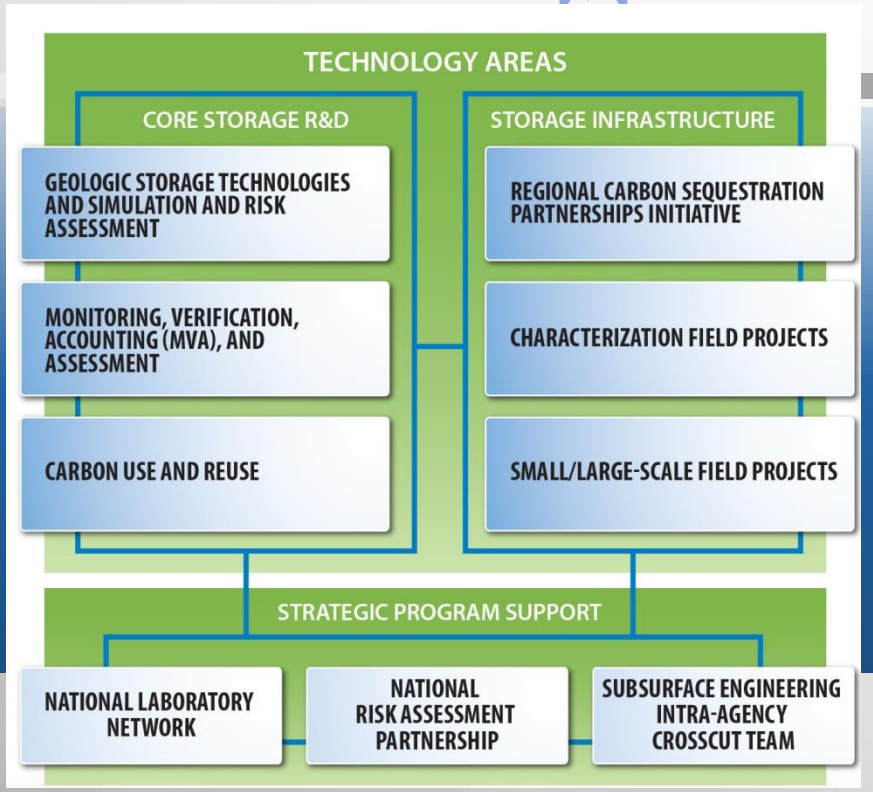


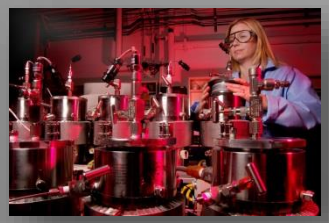
Field deployment and testing of the 5 level 3C array prototype at an industrial well in California

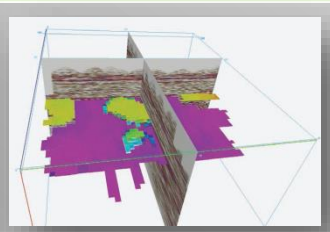
Carbon Storage R&D Program

Current Program Goals

- Develop & validate technologies to ensure 99% storage permanence.
- Support industry's ability to predict CO_2 storage capacity in geologic formations to within ± 30%.
- Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness.
- Develop Best Practice Manuals.



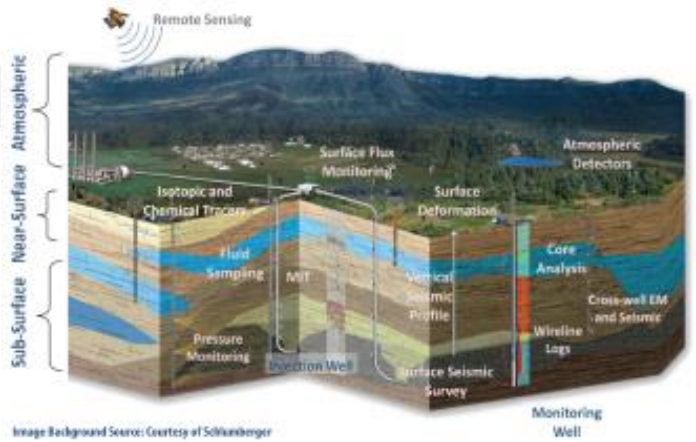


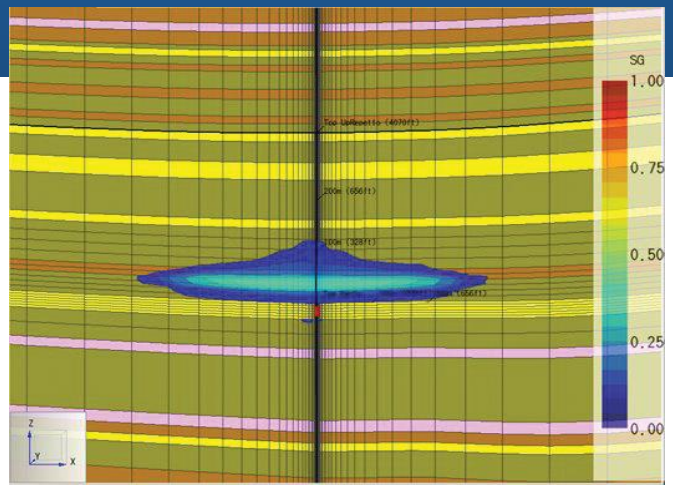




Carbon Storage R&D Program

Technical Priorities to "Master the Subsurface"

- Predicting & monitoring CO_2 plume & brine pressure front movement, stabilization & impacts
- Optimization of reservoirs for CO_2 storage capacity
- Developing & validating risk assessment strategies
- Mitigating risks such as the risk of leakage from old wells & induced seismicity
- Carrying out (large-volume & fit-for-purpose) field tests for different storage types & depositional environments



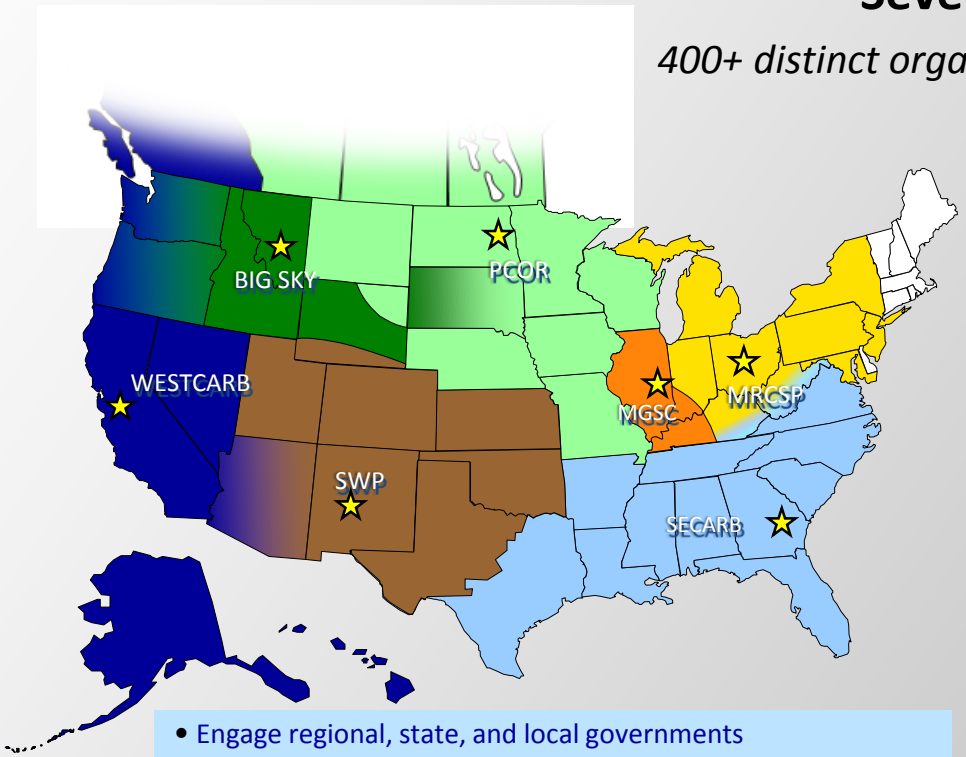


Storage Infrastructure

Regional Carbon Sequestration Partnerships

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 & verification protocols
- Address regulatory, environmental & outreach issues
- Validate sequestration technology & infrastructure

Characterization Phase (2003-2005)

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

Validation Phase (2005-2013)

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

Development Phase (2008-2018+)

8 large scale injections (over 1 million tons each)	Commercial scale understanding	Regulatory, liability, ownership issues

Regional Carbon Sequestration Partnerships

DOE Field Activities in different reservoir classes

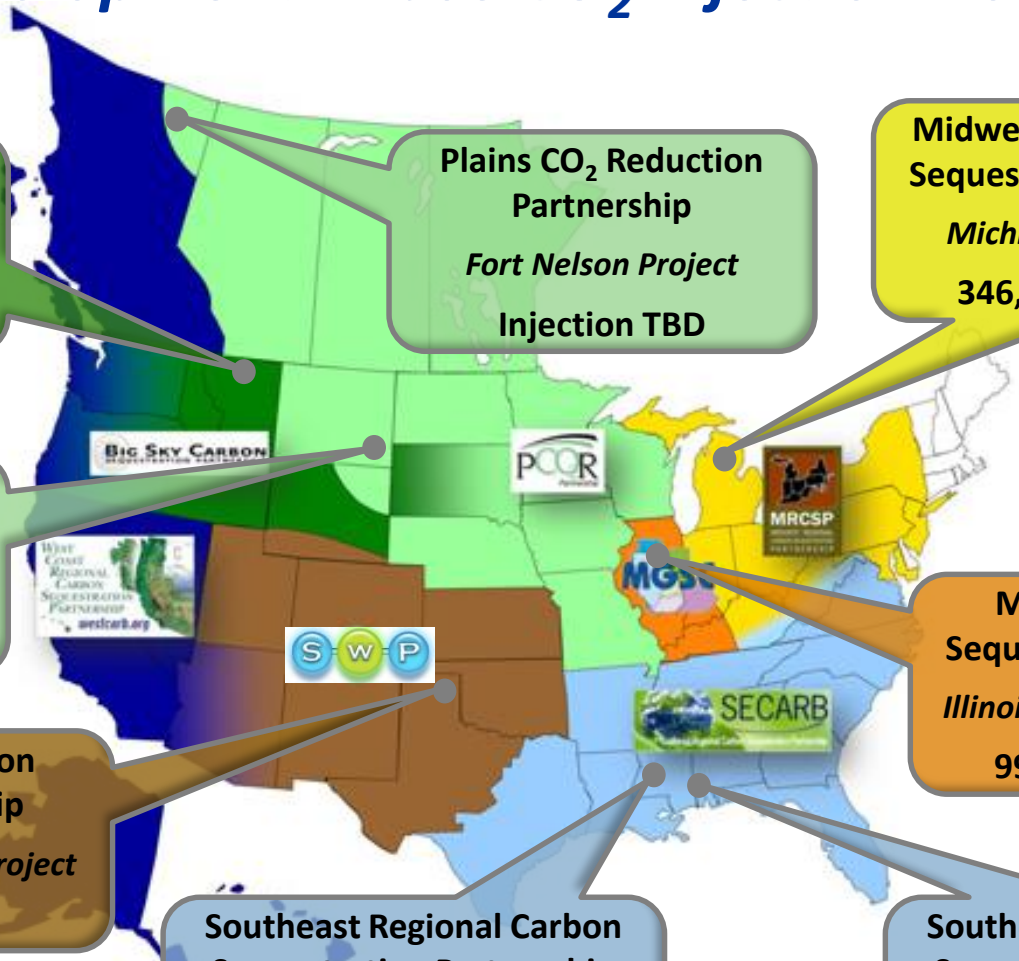
- **Depositional environment impacts storage efficiency and capacity as well as MVA**
- **DOE is studying the potential for CO_2 storage in 11 reservoir classes representing different depositional environments**

Geologic Storage Formation Classification: Reservoir Class		Deltaic	Shelf Clastic	Strandplain	Lacustrine	Eolian	Fluvial and Alluvial	Turbidite	Shelf Carbonate	Reef	Coal/Shale	Basalt (large igneous provinces)
Large-Scale Field Projects[2]	Saline						3		1			
	EOR			1			2[4]			1		
Small-Scale Field Projects[3]	Saline	1	1	1					2			1
	EOR	2	2				1		3	2	7	

NOTES:
(1) The number in the cell is the number of investigations by NETL per geologic storage formation classification.
(2) Large-scale field projects: injection of more than 1,000,000 metric tons of CO_2.
(3) Small-scale field projects: injection of less than 500,000 metric tons of CO_2 for EOR and 100,000 metric tons for saline formations.
Site characterization: characterize the subsurface at a location with the potential to inject at least 30,000,000 metric tons of CO_2.
(4) One large-scale project involves both EOR and saline storage.

Regional Carbon Sequestration Partnerships

RCSP Development Phase CO_2 Injection Volumes



Big Sky Carbon Sequestration Partnership

Kevin Dome Project

Injection 2016

Plains CO_2 Reduction Partnership

Fort Nelson Project

Injection TBD

Midwest Regional Carbon Sequestration Partnership

Michigan Basin Project

346,243 metric tons

Plains CO_2 Reduction Partnership

Bell Creek Field Project

1,660,570 metric tons

Midwest Geological Sequestration Consortium

Illinois Basin Decatur Project

999,215 metric tons

Southwest Regional Carbon Sequestration Partnership

Farnsworth Unit – Ochiltree Project

259,739 metric tons

Southeast Regional Carbon Sequestration Partnership

Cranfield Project

4,743,898 metric tons

Southeast Regional Carbon Sequestration Partnership

Citronelle Project

114,104 metric tons

Injection volumes updated as of March 2015

Regional Carbon Sequestration Partnerships

Large-Scale Geologic Tests/Key industry Partners

RCSP	Performer	Key Industry Partners	Injection Location	Reservoir/Geologic Province	CO_2 Source	Status
Big Sky	Montana State U.	- Vector Oil & Gas Ltd - Schlumberger - Bison Eng.	Kevin, MN	Saline/Kevin Dome – Duperow Formation	Naturally occurring CO_2 produced from Kevin Dome	Drilling of first well to start September 2016.
MGSC	Illinois State Geologic Service	- Archer Daniels Midland Co. - Schlumberger	Decatur, IL	Saline/Illinois Basin – Mt. Simon Sandstone	ADM ethanol fermentation facility	CO_2 injection started Nov. 15, 2011; 999,215 metric tons injected to date.
MRCSP	Battelle Memorial Institute	- Core Energy, LLC	Otsego County, MI	EOR/Michigan Basin – Niagaran Reef	Core Energy Natural Gas Processing Plant	CO_2 injection started Feb. 2013; 346,243 metric tons injected to date.
PCOR	UNDEERC	- Denbury Resources, Inc. - Ramgen Power Systems	Bell Creek, MN	EOR/Powder River Basin – Muddy Sandstone	ConocoPhilips Lost Cabin Natural Gas Processing Facility, WY	CO_2 injection started May 2013; 1,660,570 metric tons injected to date
PCOR	UNDEERC	- Spectra Energy - RPS Group. Plc - Alberta Innovates	Fort Nelson, BC	Saline/Horn River Basin - Carbonates	Spectra Energy's Fort Nelson Gas – Processing Facility	Reservoir data being collected.
SECARB	SSEB	- Denbury Onshore LLC - Schlumberger - BEG, U. of Texas - Sandia Technologies	Cranfield, MS	Saline/Gulf Coast – Tuscaloosa Formation	Naturally occurring CO_2 produced from Jackson Dome	4.7 million metric tons injected to date
SECARB	SSEB	- EPRI - Denbury Onshore LLC - Alabama Power - Southern Co.	Citronelle, AL	Saline/Gulf Coast – Paluxy Formation	Southern Company's Plant Barry Power Station	CO_2 injection started August 20, 2012; 114,104 metric tons injected to date.
SWP	New Mexico Institute of Mining & Technology	- Chaparral Energy LLC - Schlumberger - ARI	Farnsworth, TX	EOR/Anadarko Basin – Morrow Sandstone	Fertilizer Plant - Borger, TX and Ethanol Plant – Liberal, KS	Monitoring of injected CO_2 in the west Farnsworth Unit 259,739 metric tons injected to date.

Carbon Storage Best Practices Manuals

Critical Requirement for Significant Wide-Scale Deployment: Capturing Lessons Learned

Best Practices Manual	Version 1 (Phase II)	Version 2 (Phase III)	Final Guidelines (Post Injection)
Monitoring, Verification and Accounting	2009/**2012**	2016	2020
Public Outreach and Education	2009	2016	2020
Site Characterization	2010	2016	2020
Geologic Storage Formation Classification	2010	2016	2020
**Simulation and Risk Assessment	2010	2016	2020
**Carbon Storage Systems and Well Management	2011	2016	2020
Terrestrial	2010	**2016 – Post MVA Phase III**	

***Regulatory Issues are addressed within various Manuals*

http://www.netl.doe.gov/technologies/carbon_seq/refshelf/refshelf.html

Strategic Program Support

Global Collaborations Leveraging International R&D

International Demonstrations

Sponsor multi-national R&D internally through the National Laboratory Network

Carbon Sequestration Leadership Forum

International ministerial-level organization focused on improved CCS technologies

Bilateral Agreements (Specific Countries)

DOE has MOUs with UK, Canada, Norway and China

Other Research Activities

Partnerships re: US/China Clean Energy Research Center, work with IEAGHG R&D Programme, and participate on ISO/TC265 CCS

DOE Support to International CCS Projects	
1	DOE is a lead support sponsor and U.S. scientists test multiple monitoring and simulation technologies.
2	Supporting the Plains CO_2 Reduction Partnership to conduct monitoring and reservoir modeling of CO_2 injection into pinnacle reefs.
3	Supporting Plains CO_2 Reduction Partnership to conduct monitoring and reservoir modeling studies.
4	Supporting Indiana University to perform reservoir simulations, and recently supported the Scripps Institute of Oceanography to conduct time-lapse gravity surveys.
5	Supporting the Lawrence Livermore National Laboratory to simulate geomechanical conditions of the reservoir and caprock.
6	Supported Lawrence Berkeley National Laboratory to deploy downhole monitoring technology based on thermal perturbation sensors.
7	Supporting Columbia University Lamont-Doherty Earth Observatory - tracer methods to assess trapping mechanisms in basalts.
8	Supporting the Lawrence Livermore National Laboratory and Lawrence Berkeley National Laboratory to test field and remote sensing monitoring technologies and modeling geomechanical and geochemical reservoir processes.
9	Supporting scientists at Lawrence Berkeley National Laboratory to test multiple monitoring technologies (depleted gas field and saline).
10	Supporting West Virginia University and Lawrence Livermore National Laboratory to assess capacity for storage, and simulating hydrogeologic and geochemical reservoir conditions.
11	Supporting the Petroleum Technology Research Centre and Plains CO_2 Reduction Partnership to conduct site characterization monitoring, modeling, and public outreach efforts for CO_2 storage in a saline formation.

National Carbon Capture Center (NCCC)

Goal

Test technologies under realistic conditions to reduce the cost of CO_2 capture

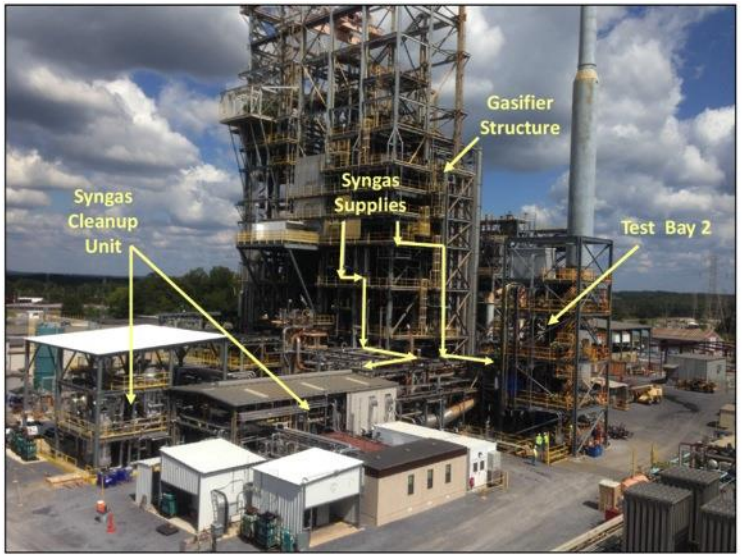
Advantages

- National resource to validate performance & operations
- Consistent testing procedures & data
- Very good safety & environmental record
- Platform for international partnership & sharing

Status

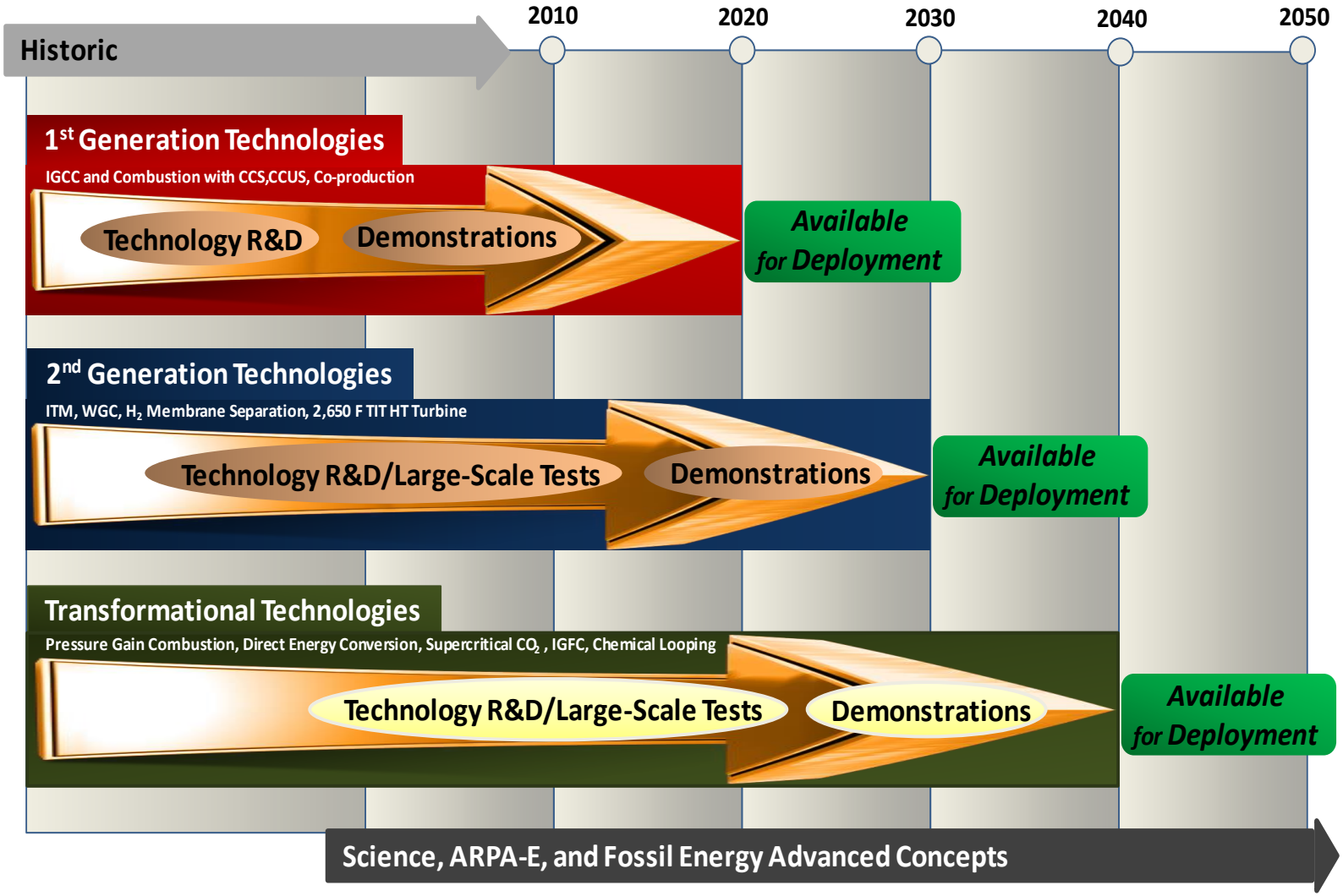
- New 5 year commitment to operator (Southern Company)
- >20 technologies tested
- 100's of technologies screened

Pilot Solvent Test Unit (PSTU)



Pre-combustion Capture Center

CCRP Technology Development Timeline



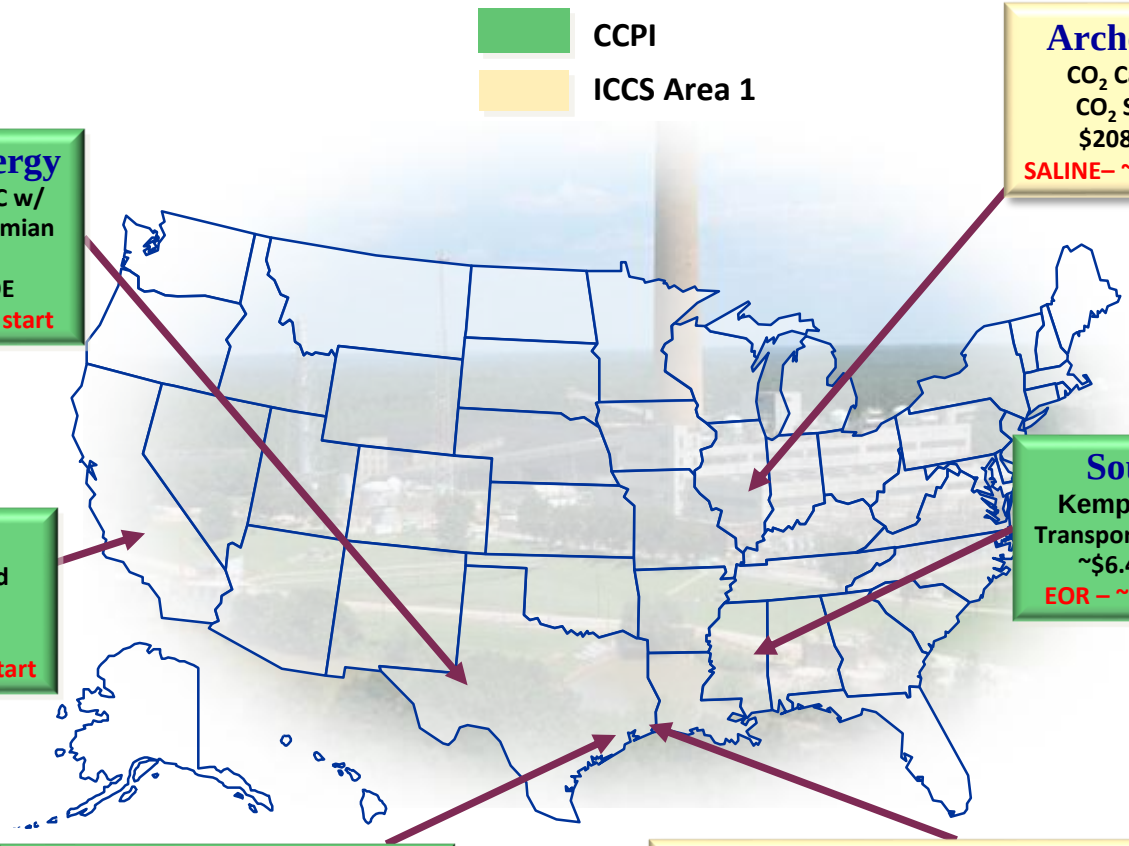
Advanced Coal Power Technologies

Aspects Applicable to Natural Gas

State-of-the-Art	2nd-Generation	Transformational
Today's IGCC	Advanced H_2 Turbines	Integrated Gasification Fuel Cells (IGFC)
	Syngas Cleanup	Pulse Combustion; 3100°F H_2 Turbine
	Advanced Pre-combustion Capture	Chemical Looping Gasification; Transformational H2 Production
Today's Supercritical PC	Advanced Ultra-Supercritical (AUSC) PC	Transformational CO_2 Separation
	Advanced Post-combustion Capture	Chemical Looping Combustion; Direct Power Extraction
		Supercritical CO_2 Cycles
	AUSC Oxycombustion	Pressurized Oxycombustion

Major CCS Demonstration Projects

Project Locations & Cost Share



Archer Daniels Midland
CO_2 Capture from Ethanol Plant
CO_2 Stored in Saline Reservoir
$208M – Total; $141M – DOE
SALINE– ~0.9 MM TPY; Sept. 2015 start

Summit TX Clean Energy
Commercial Demo of Adv. IGCC w/ Full Carbon Capture; EOR in Permian Basin
~$3.5B – Total; $450M – DOE
EOR – ~1.84 MMTPY; late 2018 start

Southern Company
Kemper County IGCC Project
Transport Gasifier w/ Carbon Capture
~$6.4 B – Total; $270M – DOE
EOR – ~3.0 MM TPY; mid-2016 start

HECA
Commercial Demo of Advanced IGCC w/ Full Carbon Capture
~$5B – Total; $408M – DOE
EOR – ~2.6 MM TPY; mid-2020 start

Petra Nova
W.A. Parish Generating Station
Post Combustion CO_2 Capture
$1B – Total; $167M – DOE
EOR – ~1.4 MM TPY; early 2017 start

Air Products & Chemicals, Inc.
CO_2 Capture from Steam Methane Reformers
EOR in Eastern TX Oilfields
$431M – Total; $284M – DOE
EOR – ~0.93 MM TPY; started December 2012; 1.9 MMT stored as of April 2015

Major Demo Capture & Storage Approaches

	Plant Type		Sequestration			Feedstock
	Power	Industrial	Saline	EOR	Rate*	
Pre-combustion						
HECA (IGCC-Polygen)	X	X		X	2.57	NM Sub-bituminous Coal/Petcoke Blend
Southern-Kemper Co. (IGCC)	X			X	3.0	MS Lignite
Summit Texas (IGCC-Polygen)	X	X		X	1.84	WY Sub-bituminous Coal
Air Products and Chemicals, Inc. (SMR)		X		X	0.925	Natural Gas
ADM (Ethanol Production)		X	X		0.900	Corn Fermentation
Post-combustion						
Petra Nova	X			X	1.4	WY Sub-bituminous Coal

Clean Coal Power Initiative (CCPI)

Industrial Carbon Capture & Storage (ICCS, Area 1)

*Rate in million metric tons per year

For Additional Information

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