



CSLF Technical Working Group Nov. 5th, 2013, Washington DC

Dr. S. Julio Friedmann

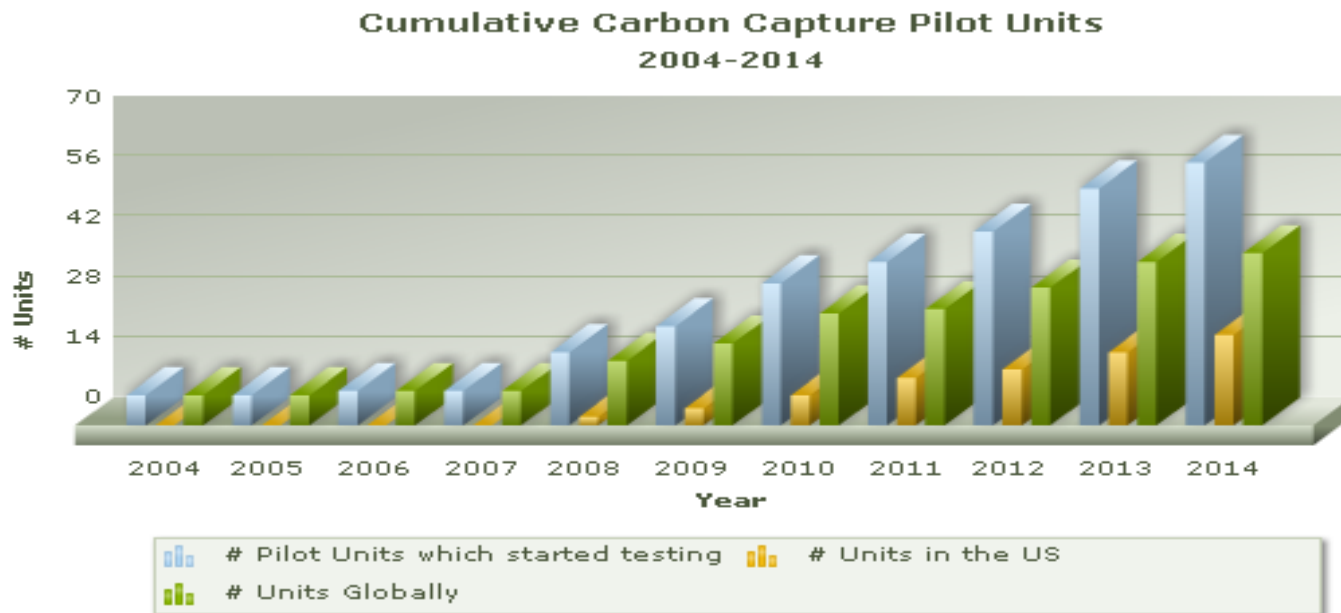
Deputy Assistant Secretary

Office of Clean Coal

November 2013

This has been a good decade for CCUS R&D Advancements

Technology Advancements in Carbon Capture



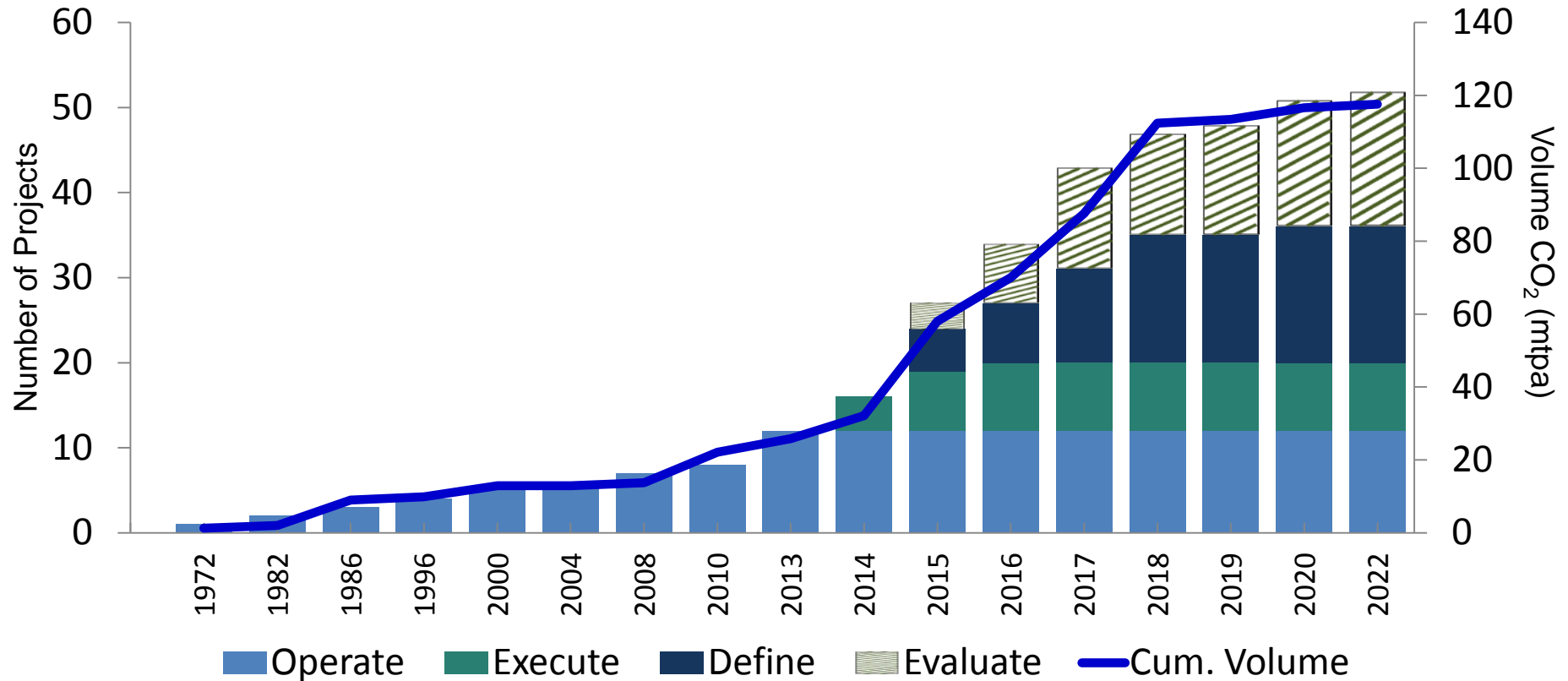
Major technological advancements:

- 14 patents in carbon capture (DOE/NETL) in the past 10 years
- 14 additional patent applications in carbon capture (DOE/NETL) in the past 10 years
- R&D has led to new designs that benefit from larger economies of scale, process enhancements, and process integration that have reduced the cost of capture

Pilot Unit References: CSLF Report Oct 2013,
MIT Oct 2013 -
http://sequestration.mit.edu/tools/projects/index_pilots.html

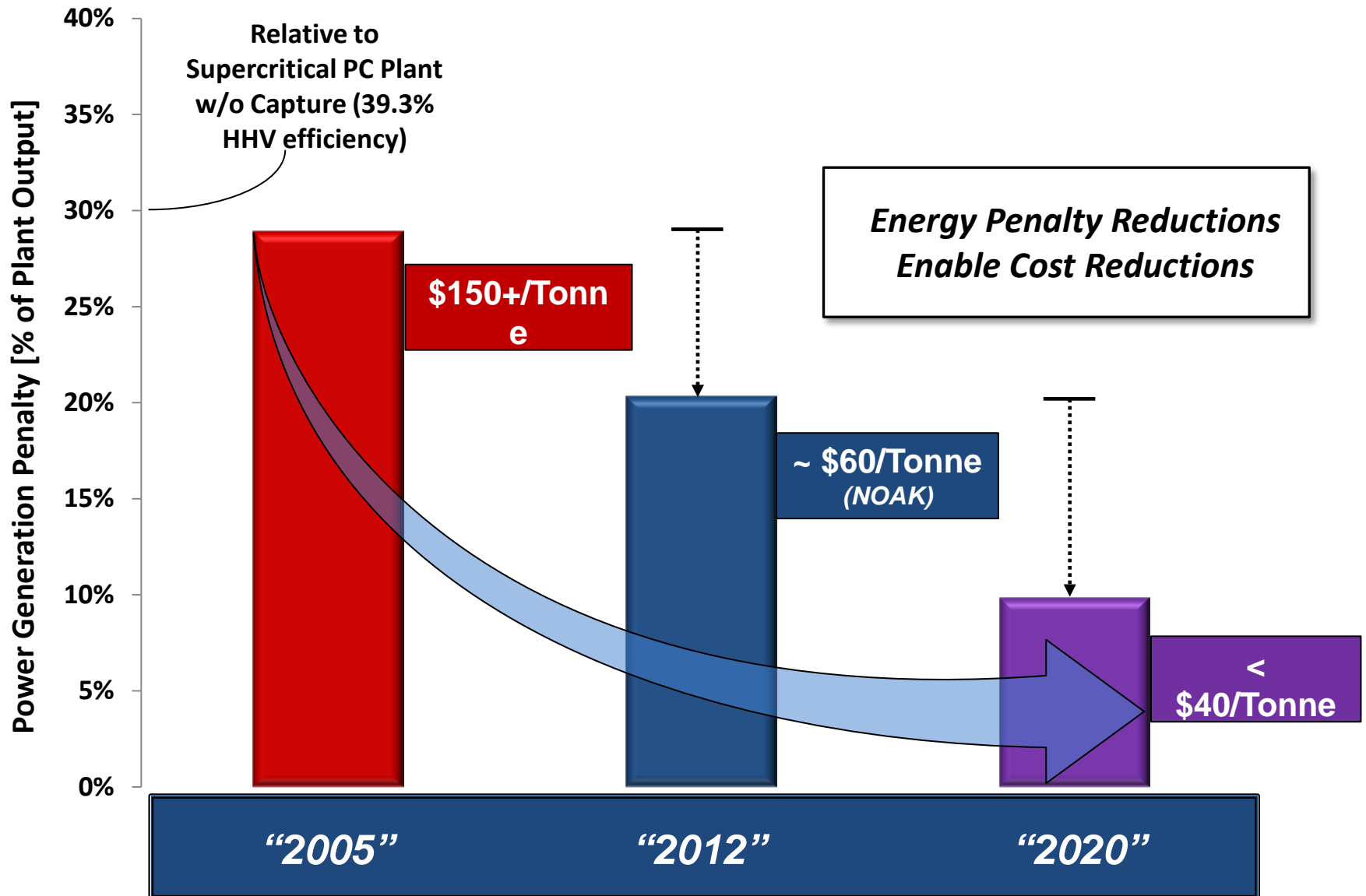


Large Scale Integrated Projects World Wide



Data from Global CCS Institute

Clean Coal R&D Progress *Performance Drives Cost*



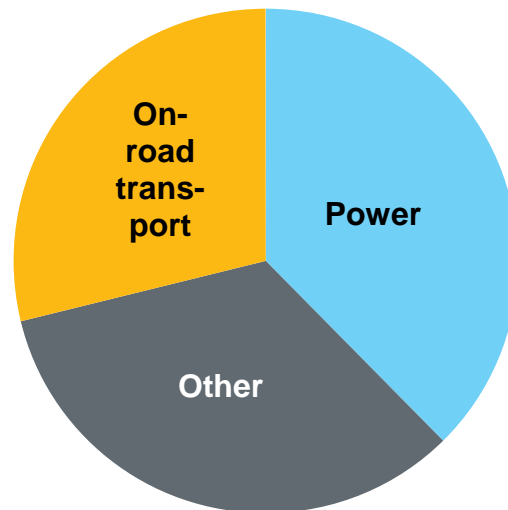
US climate change policy currently consists of a portfolio of federal and state initiatives

Key policies targeting transportation CO₂

(in effect unless noted)

- Federal renewable fuel standard
- Federal vehicle fuel economy standards
- Various alternative vehicle tax credits, rebates, and sales targets
- Infrastructure tax credits
- Fuel tax credits (most expired)
- **California economywide GHG cap-and-trade**
- California Low Carbon Fuel Standard (in effect, but suit pending)

2011 US CO₂ emissions by major sector



Key policies targeting power CO₂

(in effect unless noted)

- Federal renewable tax credits
- Federal appliance standards
- Federal conventional pollutant regulations*
- **Federal CO₂ performance standards** (under development)
- State renewable portfolio standards
- State energy efficiency programs
- **California economywide GHG cap-and-trade**
- **RGGI cap-and-trade**
- Other state programs

*Not explicitly targeting CO₂ emissions, but nonetheless impactful.

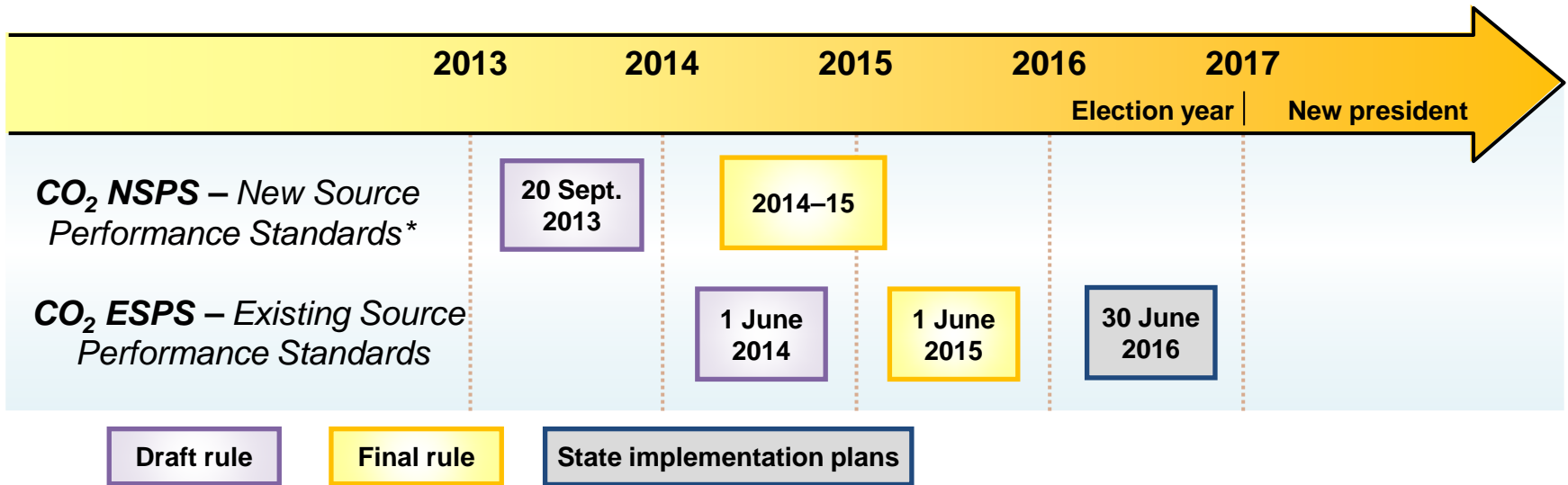
Note: RGGI = Regional Greenhouse Gas Initiative.

Source: US EIA; IHS CERA



President Obama's Climate Action Plan focuses on US power sector CO₂ emissions

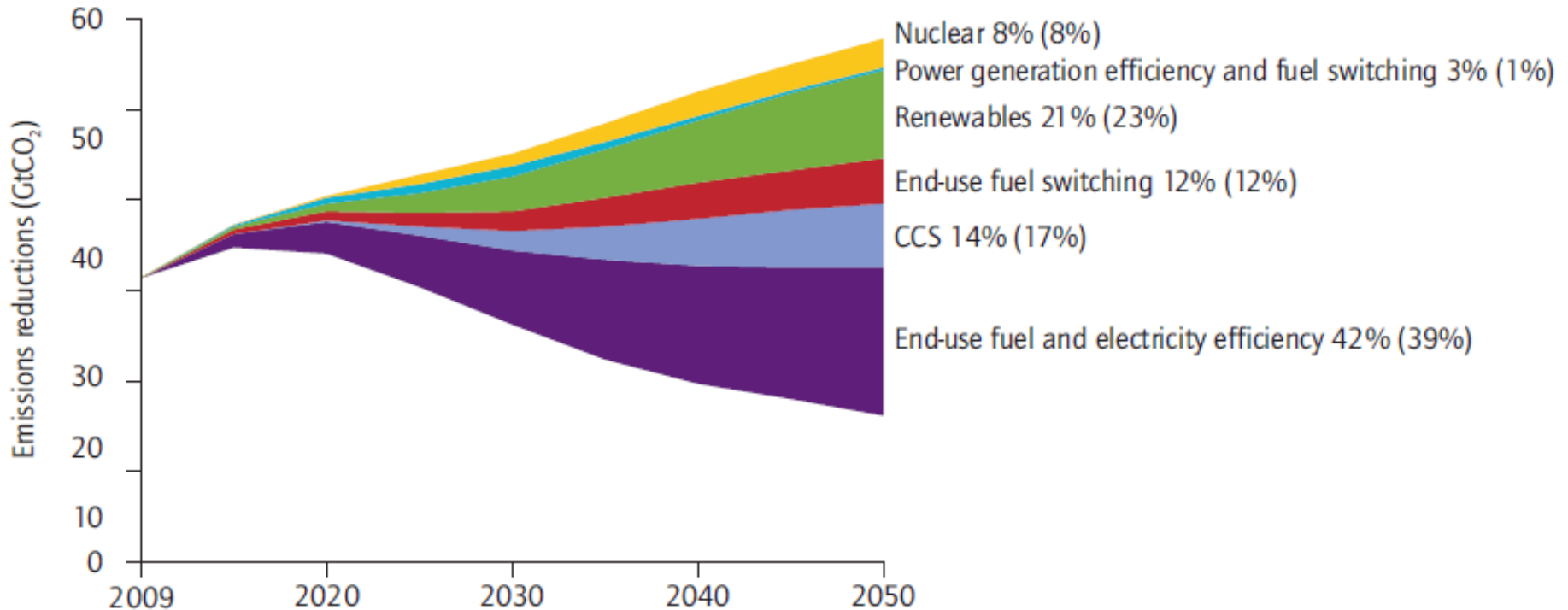
- The President's June 2013 plan included about 20 directives and initiatives that collectively aim to reduce US GHG emissions.
- The most noteworthy element is the directive to EPA to complete CO₂ performance standards for power plants under the Clean Air Act, according to the following timeline:



*The President has instructed EPA to repropose CO₂ NSPS by 20 September 2013 after issuing an earlier draft in April 2012. EPA is directed to finalize the new rule as "expeditiously" as possible.
Source: IHS CERA.

Slide from IHS Forum "International Carbon Policy Trends: Is a role reversal under way", 19 September 2013 • Houston

IEA CCS Roadmap 2013: Key Technologies for Reducing Global CO₂ Emissions



A wide range of technologies will be necessary to reduce energy-related CO₂ emissions substantially.

Source: IEA Roadmap 2013.

Note: Numbers in brackets are shares in 2050. For example, 14% is the share of CCS in cumulative emission reductions through 2050, and 17% is the share of CCS in emission reductions in 2050, compared with the 6DS.



Coal: Critical to Our Energy Supply...

Coal will remain the largest energy source for electricity generation through 2040...

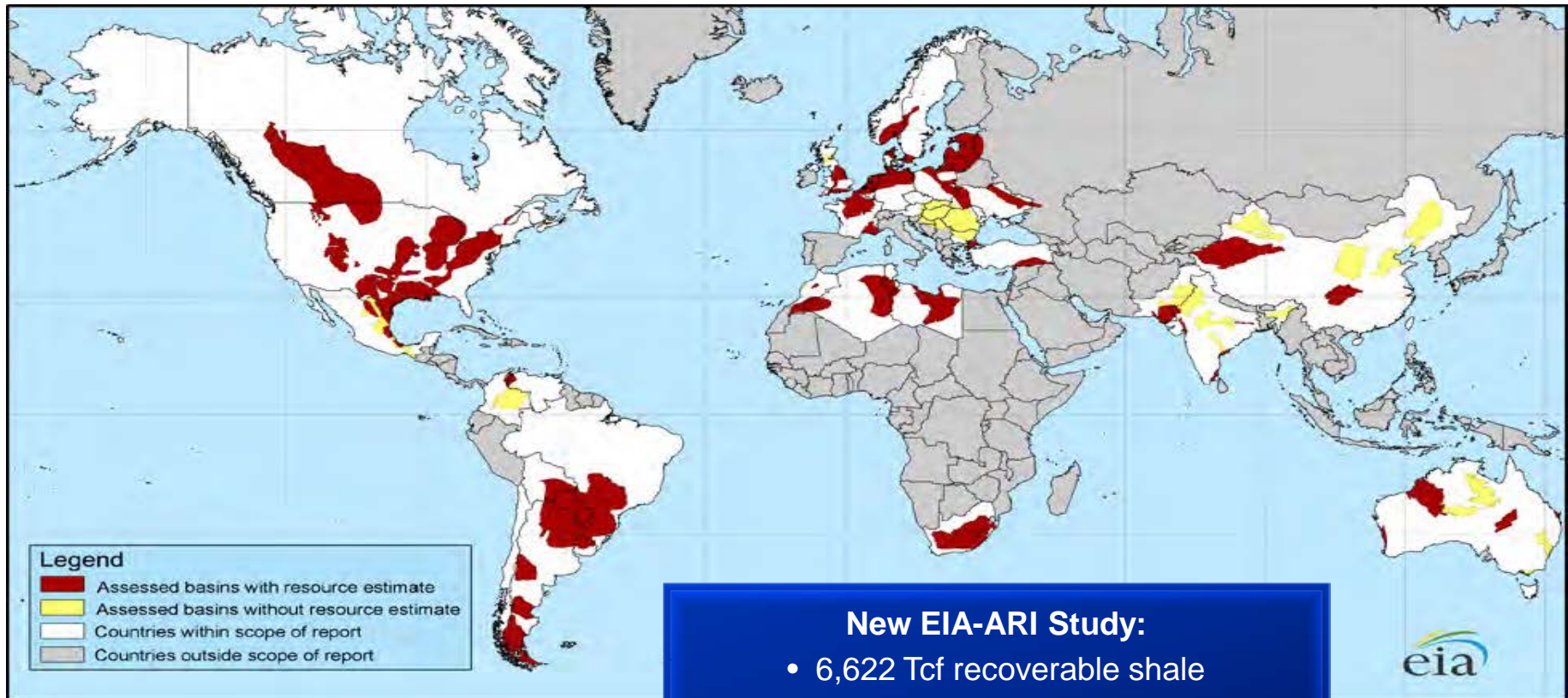
But will be 34% of energy-related CO₂ emissions by 2030

Source: EIA AEO2013

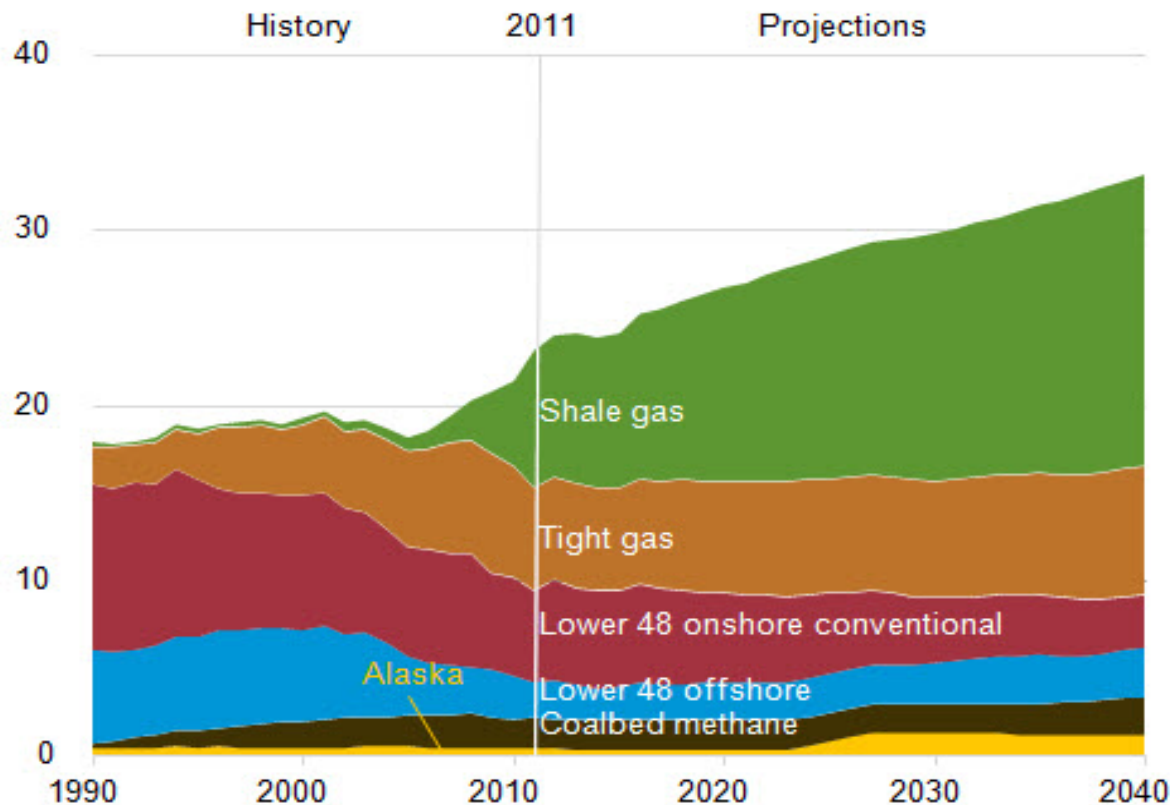
President Obama has proposed an 83 percent reduction in U.S. carbon emissions by 2050



A global resource, changing the world



Shale gas provides the largest source of growth in U.S. natural gas supply (Source: EIA AEO2013)



Most 2050 climate budgets require CCUS from natural gas power



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DOE Office of Fossil Energy Clean Coal Program

Integrated Fossil Energy Solutions

Advanced Combustion

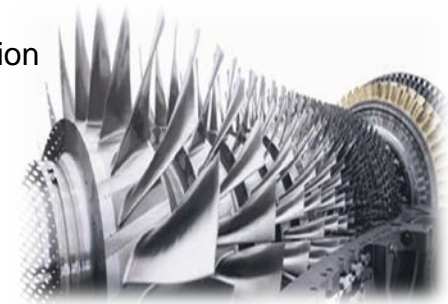


5 MWE Oxycombustion Pilot

- Pressurized
- O₂ membrane
- Chemical looping
- USC Materials

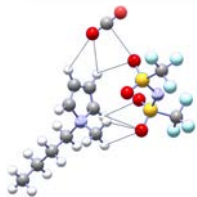
- Gasification
- Turbines
- Supercritical CO₂
- Direct Power Extraction

Advanced Energy Systems



Advanced Turbines

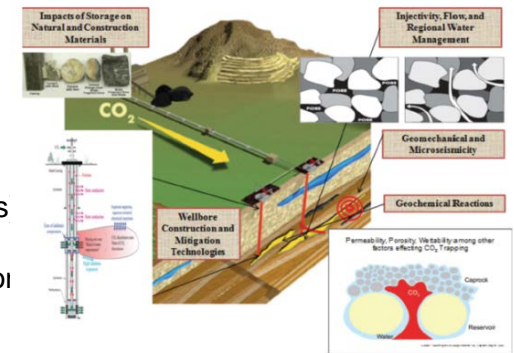
Advanced CO₂ Capture and Compression



- Solvents
- Sorbents
- Membranes
- Hybrid
- Process Intensification
- Cryogenic Capture

- Carbon Utilization (EOR)
- Infrastructure (RCSPs)
- Geological Storage
- Monitoring, Verification and Accounting

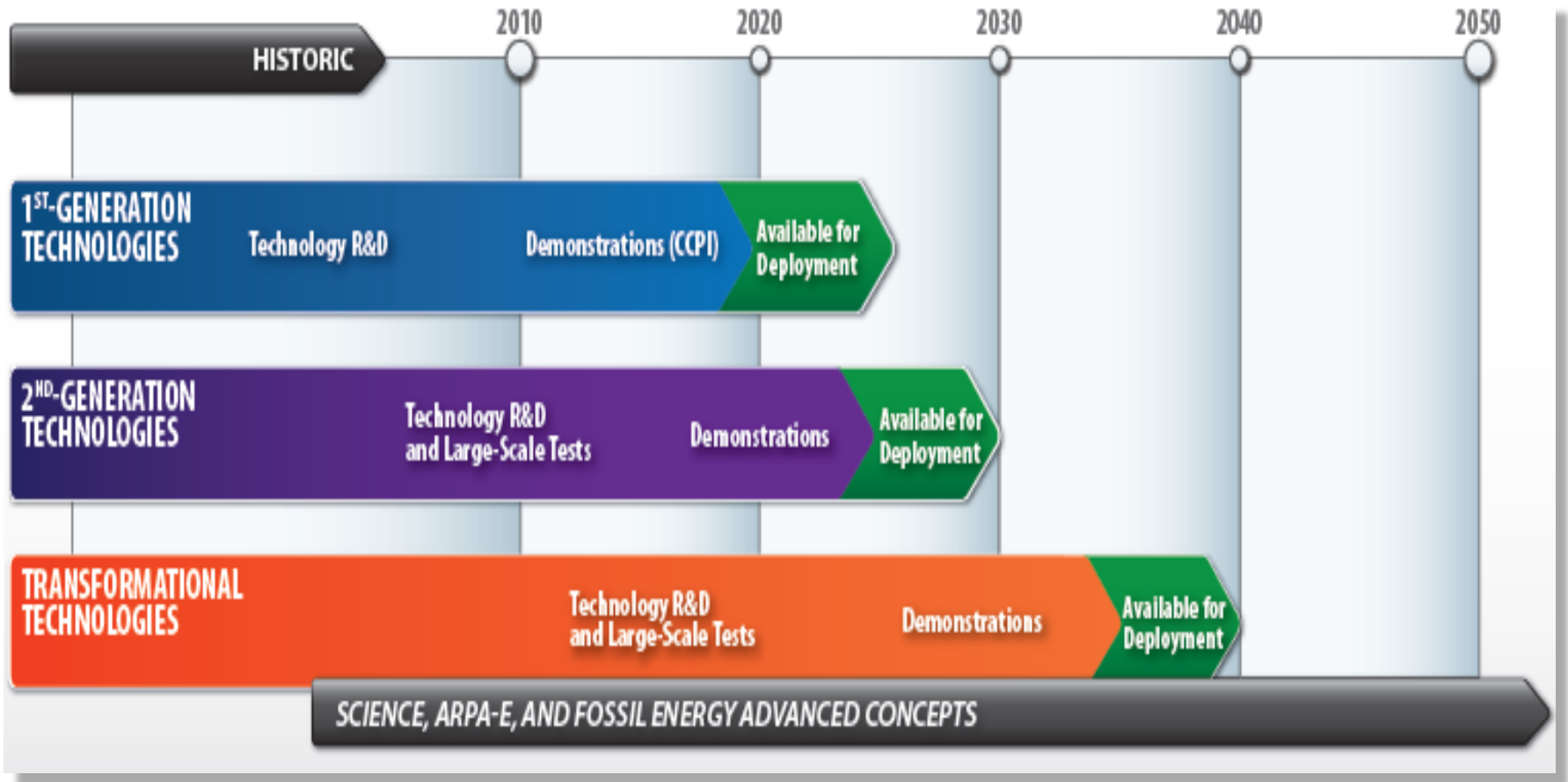
CO₂ Storage



Efficiencies > 45%
↓ Capital Cost by 50%
\$40/tonne CO₂ Captured
Near-zero GHGs
Near-zero criteria pollutants
Near-zero water usage



A technology pipeline for affordable CCS

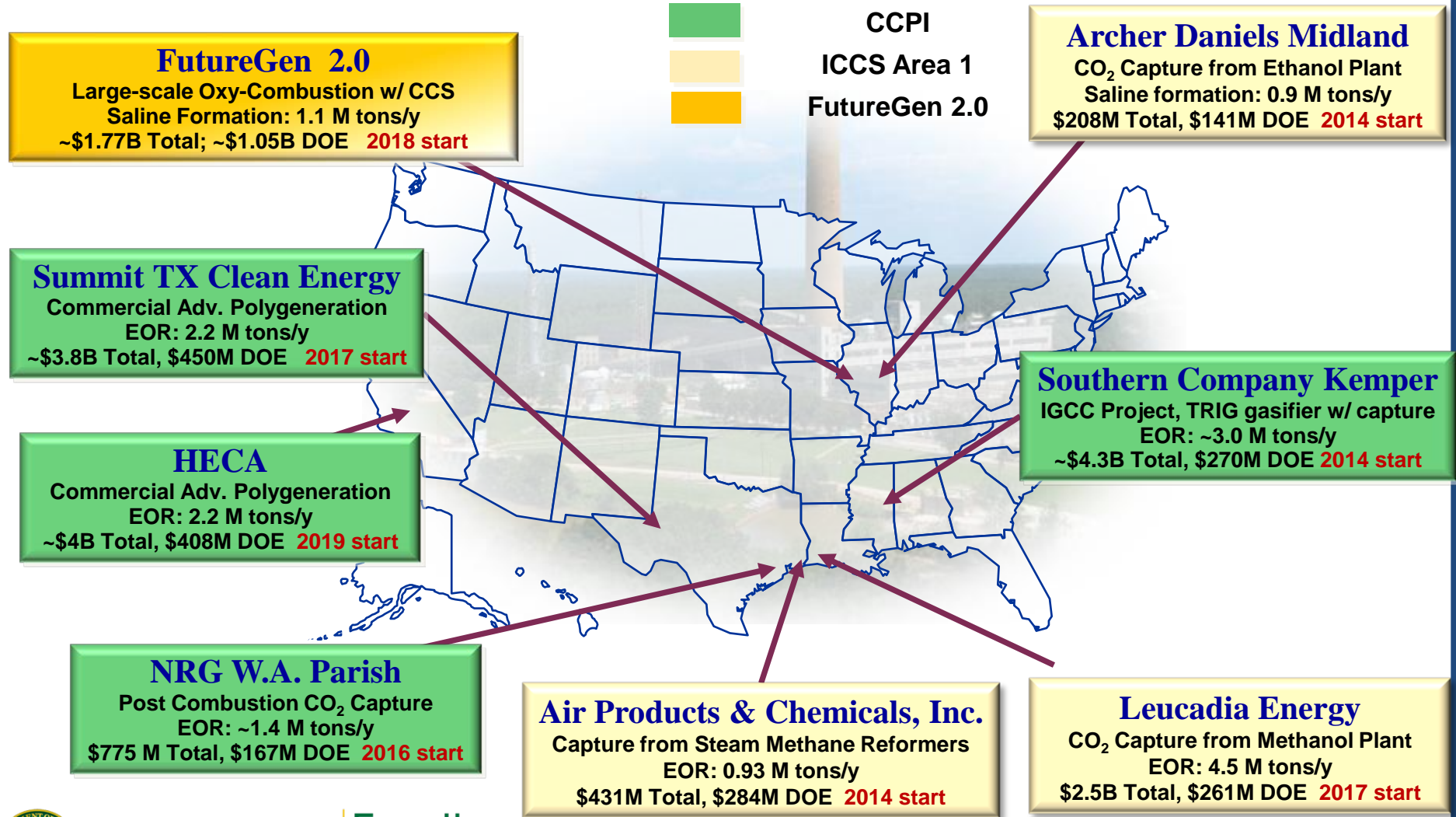


We need more 2nd generation demos!



Major CCS Demonstration Projects

Engines of Discovery, Foundation of Deployment



Southern Company Services

Advanced IGCC with CO₂ Capture



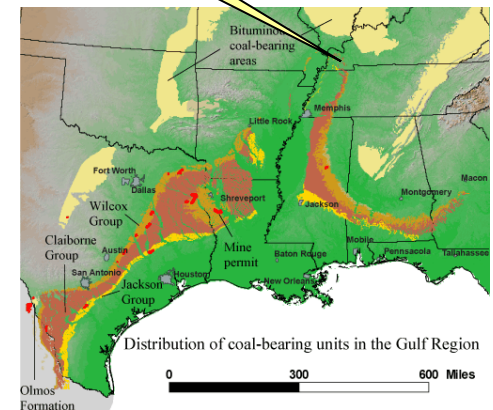
- Kemper County, MS
- 582 MWe (net) IGCC: 2 Gasifiers, 2 Siemens Combustion Turbines, 1 Toshiba Steam Turbine
- Mississippi Lignite Fuel
- ~67% CO₂ capture (Selexol® process)
3,000,000 tons CO₂/year
- EOR Denbury Onshore LLC, Treetop Midstream Services LLC
- Total Project: \$4.12 Billion
DOE Share: \$270 Million (7%)

Key Dates

- Project Awarded: January 2006
- Project moved to MS: December 2008
 - Construction: July 2010
 - NEPA ROD: August 2010
 - Operations: May 2014



Plant Site



Status

- Plant construction >74% complete; >6,100 construction workers on site
 - CO₂ off-take agreements signed
 - Lignite mine under development
- Subsystems (water treatment, cooling towers) to begin pre-commissioning
- Combustion turbine startup: Aug 2013
 - Gasifier heat-up: Dec 2013



Liberty Mine

Treated Effluent Reservoir

Water Treatment Area

Gasification Area

Lignite Storage Dome

Combined Cycle Area

Gas Cleanup Area

Ash Management Area



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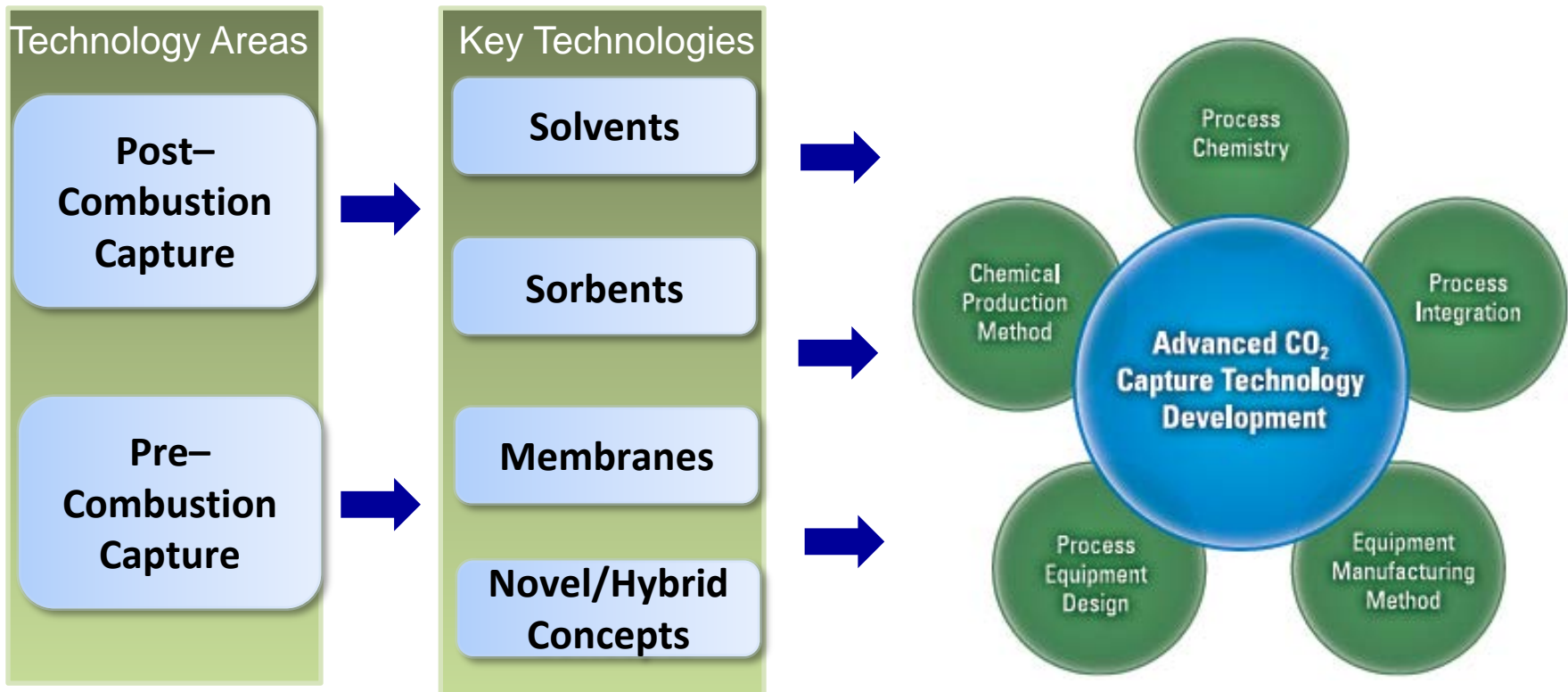
Major CCS Demonstration Projects

- 8 active projects
- 1 in operation, 2 under construction, 5 in engineering/finance
- 5 electricity generation, 3 industrial
- 3 IGCC, 4 post-processing, 1 oxycombustion
- Feedstock: 4 coal, 1 petroleum coke, 1 coal/coke, 1 natural gas, 1 ethanol
- 2 polygeneration
- Storage: 6 EOR, 2 saline formations



CO₂ Capture

Requires Multiple Technologies and Multiple Scientific and Engineering Disciplines



This is the primary pathway to steep cost reductions

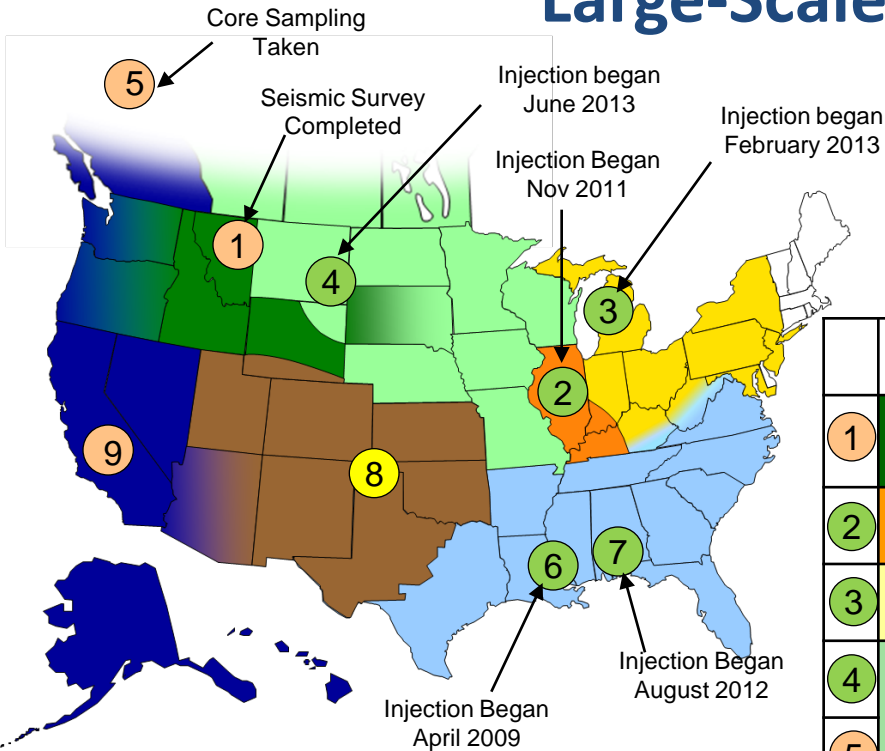


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RCSP Phase III: Development Phase

Large-Scale Geologic Tests



- Injection Ongoing
- 2013 Injection Scheduled
- Injection Scheduled 2014-2015

Note: Some locations presented on map may differ from final injection location

- ✓ Five projects currently injecting CO₂
- ✓ One additional scheduled for 2013
- ✓ Remaining injections scheduled 2014-2015

	RCSP	Geologic Province	Injection Volume (metric tons)
1	BIG SKY	Kevin Dome-Duperow Formation	TBD
2	MGSC	Illinois Basin-Mt. Simon Sandstone	>600,000
3	MRCSP	Michigan Basin-Niagaran Reef	March 2013
4	PCOR	Powder River Basin-Muddy Sandstone	April 2013
5		Horn River Basin-Carbonates	TBD
6	SECARB	Gulf Coast - Tuscaloosa Formation	>3,000,000
7		Gulf Coast - Paluxy Formation	>80,000
8	SWP	Anadarko Basin-Morrow Sandstone	Late 2013
9	WESTCARB	Regional Characterization	



Large-Scale CO₂ Storage Tests

- 8 large scale tests ongoing/planned for 6 of 7 Regional Partnerships
- Tests based on strong core R&D program and 20 smaller field tests.
- Schedule: 5 injecting now, 1 starting 2013, 2 starting 2014-2015
- Storage: 5 EOR, 3 saline formations
- 7 of the 8 will inject between 1 M – 2.9 M tonnes CO₂
- CO₂ sources: NG processing plants, coal power plants, ethanol production plant, natural CO₂ source
- All tests have extensive MVA and will inform Best Practice Manuals

CCS 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 Activities	2011	2016	2020
Terrestrial	2010	2016 – Post MVA Phase III	

The future looks bright – we should pursue important new opportunities

WATER: Both challenge and opportunity

- Water co-production: 8M m³ water for 6M tons CO₂.
- Water reclamation: lignite drying
- Water integration: upgrading municipal water with waste heat

UTILIZATION: Part of the work and value

- EOR already common; ROZ advancing
- CO₂-Algae: small volumes, tough economics; improving
- Cement and mineralization: small volumes, tough economics; improving

Entering commercial realm; now it gets exciting