Department of Energy
Carbon Capture and Storage Program

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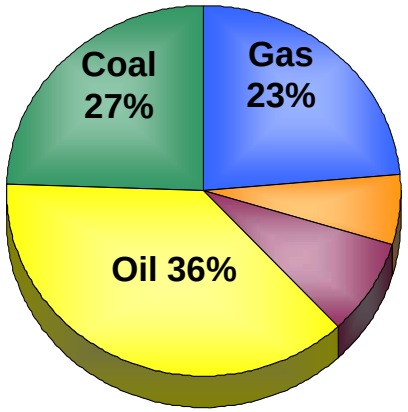
Assistant Secretary for Fossil Energy
February 16, 2010

Growing World Energy Demand

World Energy Consumption 2006

472 QBtu or 498 EJ
86% Fossil Energy



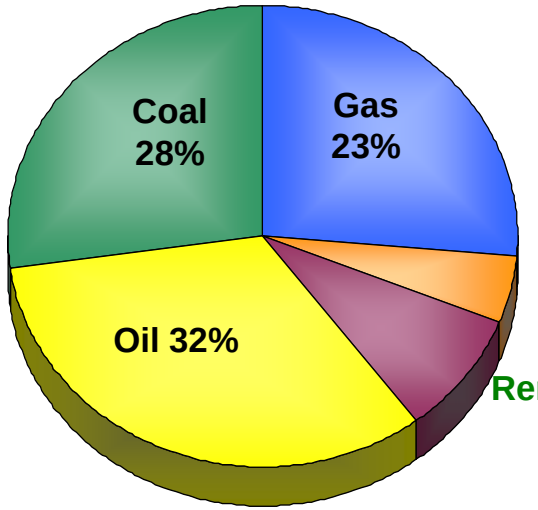
Nuclear
6%

Renewables
8%

44%
World

World Energy Consumption 2030

678 QBtu or 715 EJ
83% Fossil Energy



Nuclear
6%

Renewables
11%

World today and tomorrow data from EIA IEO 2009.

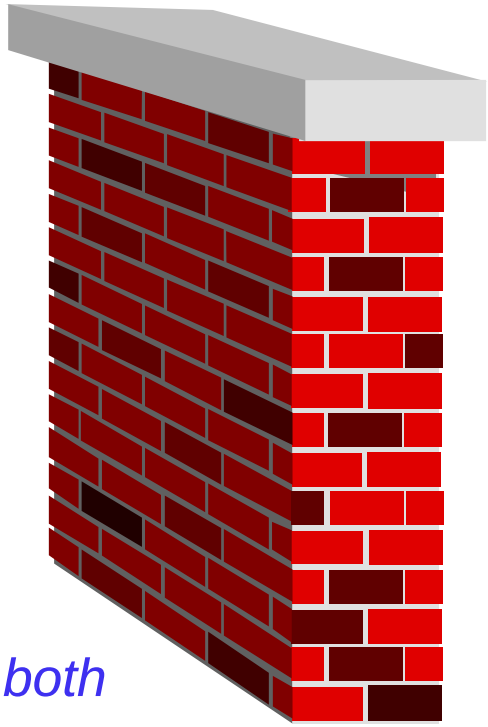
Key Challenges to Carbon Capture and Storage

Technical Issues

- **Capture Technology**
  - Existing Plants
  - New Plants (PC)
  - IGCC
- **Cost of CCS**
- **Sufficient Storage Capacity**
- **Permanence**
- **Best Practices**
  - Storage Site Characterization
  - Monitoring/Verification
  - Site Closure
  - Etc etc …

Legal/Social Issues

- **Regulatory Framework**
  - Permitting
  - Treatment of CO_2
- **Infrastructure**
- **Human Capital**
- **Legal Framework**
  - Liability
  - Ownership
    - pore space
    - CO_2
- **Public Acceptance (NIMBY → NUMBY)**

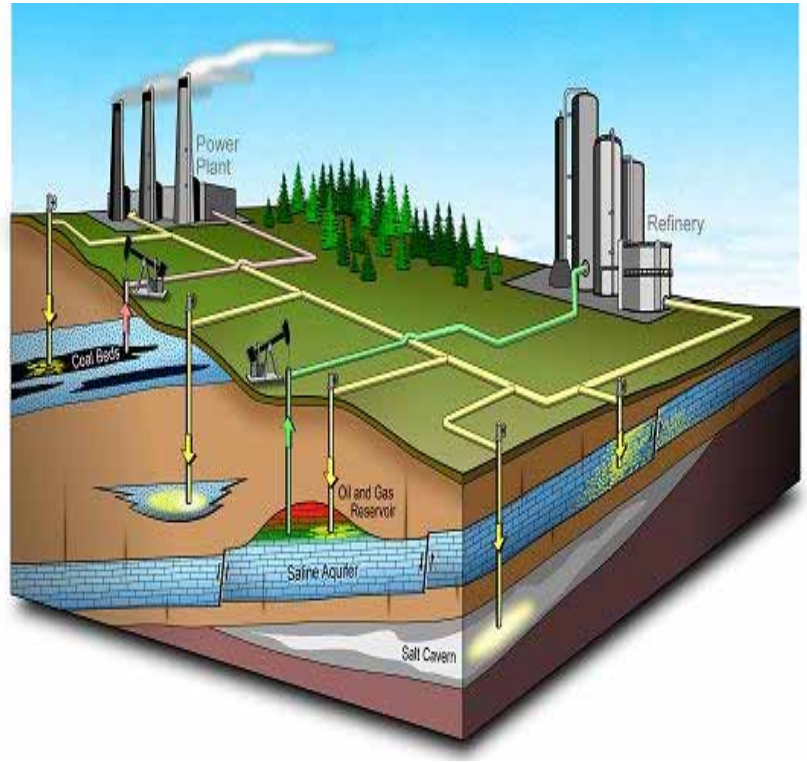


Projects helping to address both categories of issues

Carbon Sequestration Program Goals

Develop Technology Options That...

- **Deliver technologies & best practices that provide Carbon Capture and <u>Safe</u> Storage (CCSS) with:**
  - 90% CO_2 capture at source
  - 99% storage permanence
  - < 10% increase in COE
    - Pre-combustion capture (IGCC)
  - < 35% increase in COE
    - Post-combustion capture
    - Oxy-combustion
  - Coal based power generation w/CCS will need to be able to dispatch against natural gas combined cycle



CCS Program Objectives

1) **Develop and demonstrate advanced, increasingly cost-effective capture (separation and compression) technologies, enabling commercial deployment beginning in 2020.**

   - **Must be applicable to situations in developing economies,**
   - **Must be retrofittable to existing facilities, i.e. cost effective, low energy penalty, compact physical footprint.**

2) **Characterize U.S. geologic source and sink potentials and infrastructure configurations for CCS by 2020 for the majority of U.S. stationary source CO_2 emissions. (including offshore sub-seabed formations)**

3) **Validate scientifically and technically-based tools and practices to determine safe, effective long-term geologic storage by 2020.**

4) **Demonstrate large-scale integrated next generation game-changing technologies for stack capture while improving efficiency, capacity and minimizing water impacts associated with capture.**

5) **Enable early, broad-scale CCS opportunities for beneficial use of CO_2 via demonstrations.**

6) **Collaborate on and leverage international CCS RD&D activities.**

The American Recovery and Reinvestment Act of 2009 (ARRA)

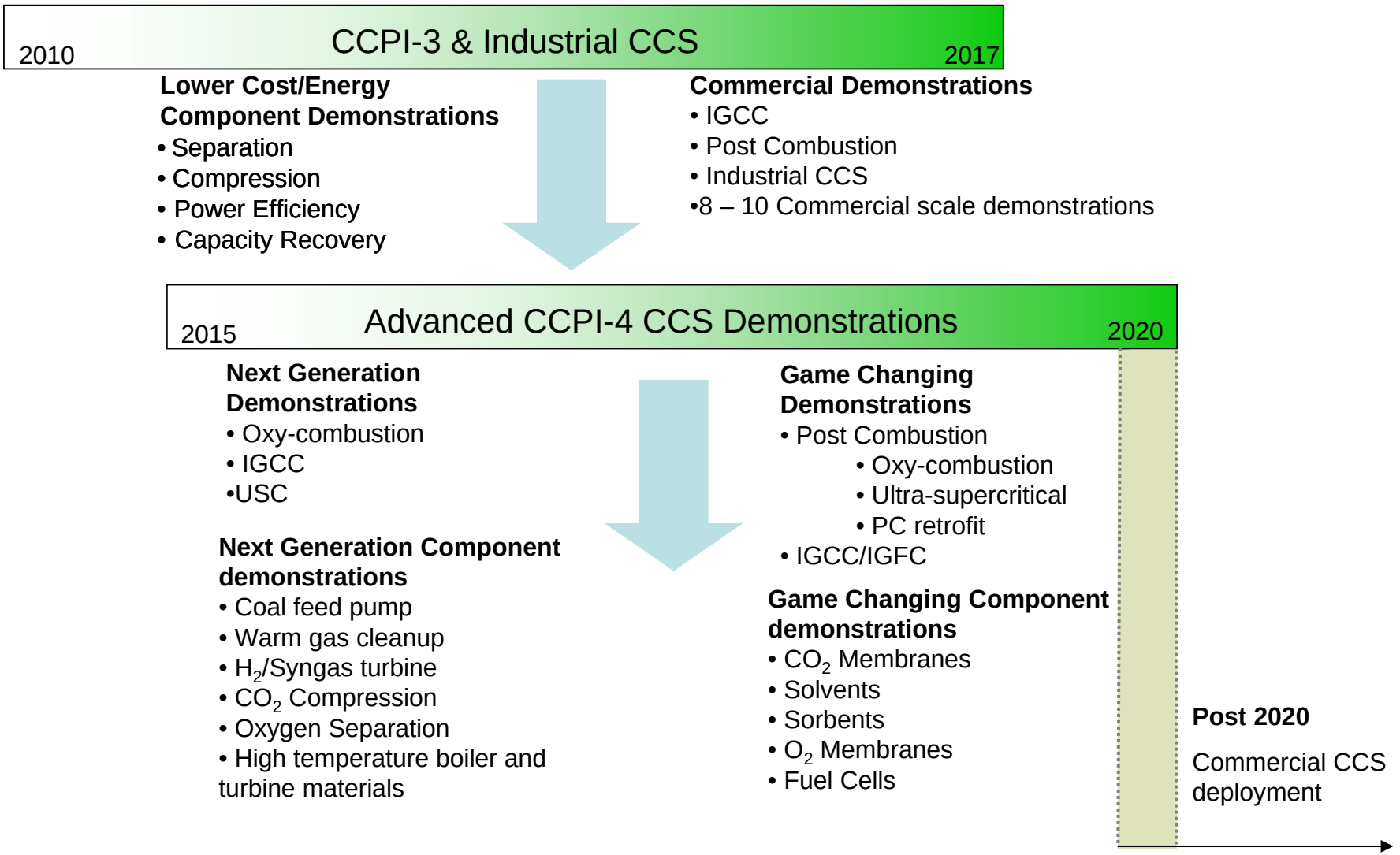
- **Provides and Additional $3.4 Billion for Fossil Energy Research and development to:**
  - Develop and Demonstrate CCS Technology in partnership with Industry
  - Transition this technology to Industry for their Deployment and Commercialization
- **Objectives of FE's Portion of ARRA are:**
  - Demonstrate CCS technology to reduce Greenhouse gas emissions from the Electric Power and Industrial sectors of the economy
  - Become the World's Leader in Science and Technology
  - Implement Projects to Support Economic Recovery

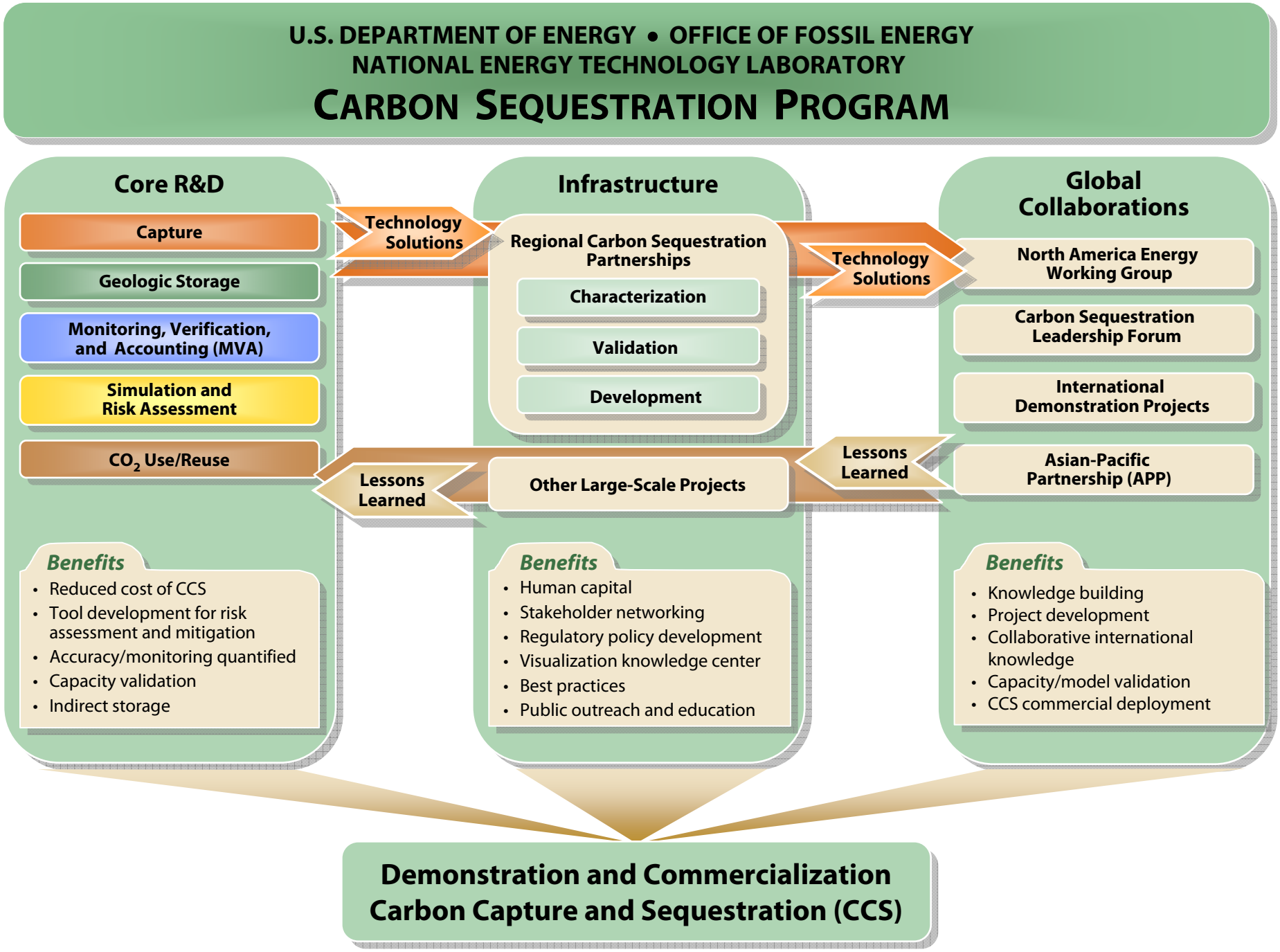
Fossil Energy R&D - ARRA

Program Name	Amount ($M)
Clean Coal Power Initiative	800
Industrial Carbon Capture and Storage	1,520
Fossil Energy (CCS) R&D	1,000
Geologic Sequestration Site Characterization	50
Geologic Sequestration Training and Research Grants	20
FE Program Direction	10

- **Cost-sharing Requirements**
  - A minimum of 30% Non-federal cost share will be applied to Industrial CCS, Geologic Site Characterization, and Carbon Capture and Storage projects
  - Cost sharing will be waived for Geologic Sequestration Training and Research projects
  - CCPI projects require a minimum 50% Non-federal cost share
  - Funds will be obligated by September 2010 and Expensed by September 2015

Coal: CCS Technology Deployment




U.S. DEPARTMENT OF ENERGY • OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY
CARBON SEQUESTRATION PROGRAM
Core R&D
Capture
Geologic Storage
Monitoring, Verification, and Accounting (MVA)
Simulation and Risk Assessment
CO_2 Use/Reuse
Technology Solutions
Infrastructure
Regional Carbon Sequestration Partnerships
Characterization
Validation
Development
Technology Solutions
Global Collaborations
North America Energy Working Group
Carbon Sequestration Leadership Forum
International Demonstration Projects
Asian-Pacific Partnership (APP)
Lessons Learned
Other Large-Scale Projects
Lessons Learned
Benefits
• Reduced cost of CCS
• Tool development for risk assessment and mitigation
• Accuracy/monitoring quantified
• Capacity validation
• Indirect storage
Benefits
• Human capital
• Stakeholder networking
• Regulatory policy development
• Visualization knowledge center
• Best practices
• Public outreach and education
Benefits
• Knowledge building
• Project development
• Collaborative international knowledge
• Capacity/model validation
• CCS commercial deployment
Demonstration and Commercialization
Carbon Capture and Sequestration (CCS)

Coal Funding Cross-Cut

($ in Thousands)	FY09 Enacted	FY 2010 Enacted	FY2011 Request	Areas Targeted
Capture	66,000	66,500	81,200	Pre- and Post- combustion capture, with emphasis on Post-combustion. Technologies will reduce capture cost and energy penalties.
Storage	134,000	139,500	126,800	Regional Partnerships, MVA, Simulations, Risk Assesment
Efficiency Improvements	176,236	170,000	148,000	ITM - O_2 Separation; H_2 Turbines; Materials for USC Systems;Gas cleaning, Advanced CO_2 compression; MW-scale Fuel Cells
Cross Cutting Research	28,000	28,000	47,850	FY2011, new multi-year national laboratory partnership for physics-based computer modeling and simulation from the molecular level to the integrated plant level, and geologic reservoir modeling
CCS Demos	288,174	0	0	Large scale CCS demonstrations are currently funded by Recovery Act and prior year approps.
TOTAL COAL	**692,410**	**404,000**	**403,850**	

NB: Bottom line FY2011 Coal request is nearly identical to FY2010 enacted level, with budget shifts to focus on post-combustion carbon capture and a new laboratory modeling and computer simulation effort.

Efficiency Improvements

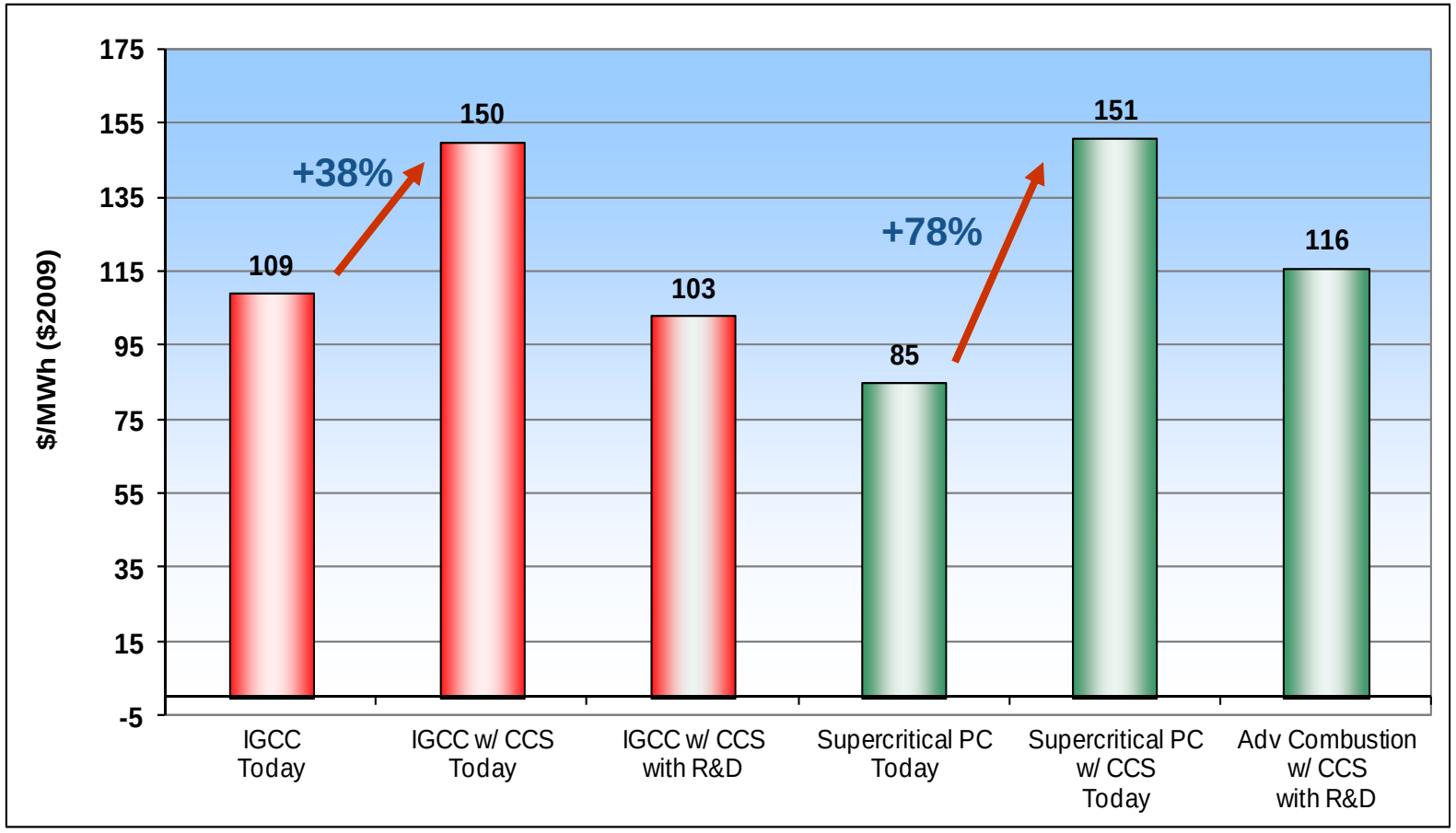
- **Scale-up of Ion Transport Membrane (ITM) Air Separation Unit (ASU) for low-cost oxygen production**
- **Scale up Eltron H_2/CO_2 separation membrane technology to ~220 lb/day hydrogen and begin integrated testing with high temperature desulfurization.**
- **Modify existing F and G class turbines for high H_2 firing, and continue development of low swirl combustion technology.**
- **Design, engineer and initiate manufacture of 1 MWe Solid State Energy Conversion Alliance (SECA) fuel cell power block**
- **Develop computational control intelligence for power, fuel, and carbon capture systems**
- **Design and develop advanced sensor networks for harsh environment power, fuel, and carbon capture systems including the development of sensors capable of verifying CO_2 plant emissions**
- **Continue R&D for advanced Ultra Super Critical Materials (A-USC)**

Capture Research

- **A new multi-year national laboratory partnership for physics-based computer modeling and simulation from the molecular level to the integrated plant level, and similar sub-surface Geologic reservoir modeling will be initiated in FY2011.**
- **Test promising post-combustion including solvents, sorbents, membranes, oxygen separation, flue gas purification, and advanced compression technologies) at bench and pilot scale (FOA in FY2009).**
- **Test promising Oxy-combustion and Chemical looping technologies at bench and pilot scale (FOA in FY 2010)**
- **Scale-up 5 to 10 technologies to the 1 – 5 MWe scale using actual PC power plant flue gas.**
- **Conduct system studies, simulations, NETL in-house R&D. In concert with Office of Science, will begin reaching out to other organizations listed above.**
- **Pilot-scale test reactive barrier filters, sorbents for gas clean-up, water-gas shift catalysts, CO_2 capture technologies, and coal/biomass co-feeding with the transport gasifier at the National Carbon Capture Center operated by Southern Company. Subscale subsystem integration testing (anchor point) and scaling components to prepare for slip/test streams at plants before full size demos.**

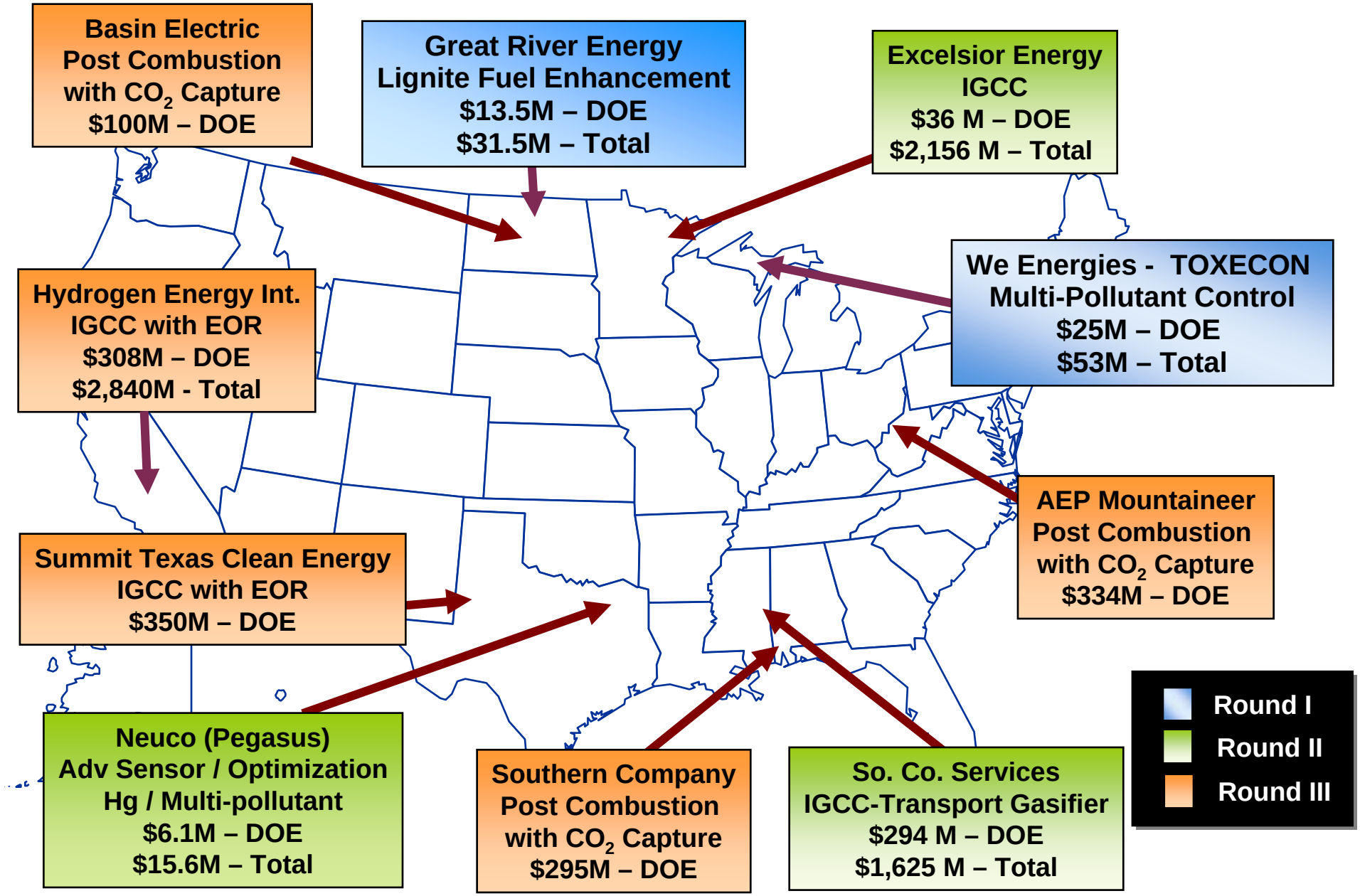
Levelized Cost of Electricity Comparison -- New Plants

(Baseline Study – Bituminous Coal)



February 2009 Dollars, Coal cost $1.65/MMBtu

Current Projects in CCPI



Subsurface Storage R&D

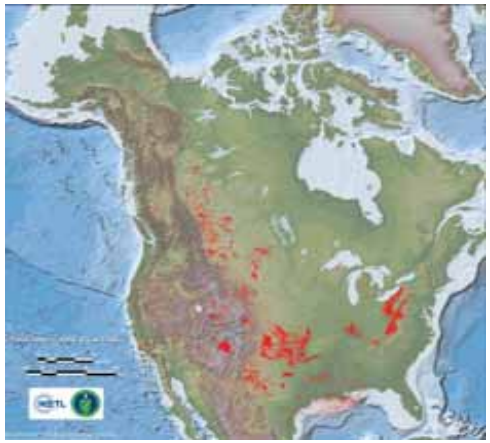
Regional Partnership Large Volume Testing - initiate injection profiles at 5 additional sites (3 already started)

- **Risk Assessment/Modeling - target risk reduction of large-scale storage projects and support National Laboratory Partnership on National CCS Risk Assessment**
- **Monitoring, Verification, and Accounting (MVA)**
  - Target achieving 99+% safe storage permanence;
  - Investigate improved methods to monitor movement of CO_2 into, through, and out of targeted geologic storage areas;
  - Verify location of CO_2 placed in geologic storage; account for the entire quantity of CO_2 that has been transported to geologic storage sites

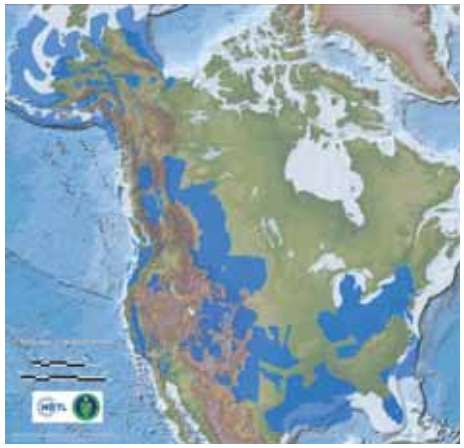
UPDATED: National Atlas Highlights (Atlas II)

Adequate Storage Projected

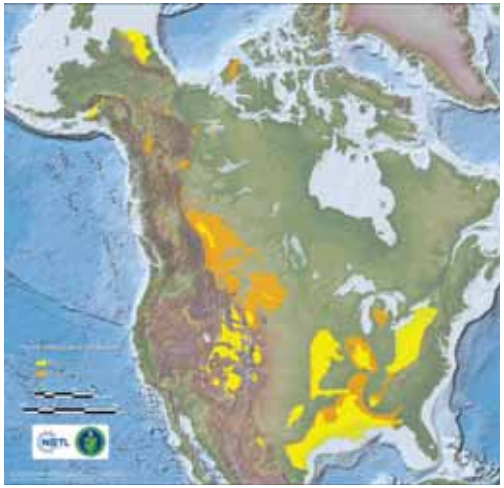
Emissions ~ 3.8 GT CO_2/yr point sources



Oil and Gas Fields



Saline Formations



Unmineable Coal Seams

North American CO_2 Storage Potential (Giga Tons)

Sink Type	Low	High
Saline Formations	3,300	12,600
Unmineable Coal Seams	160	180
Oil and Gas Fields	140	140

Conservative Resource Assessment

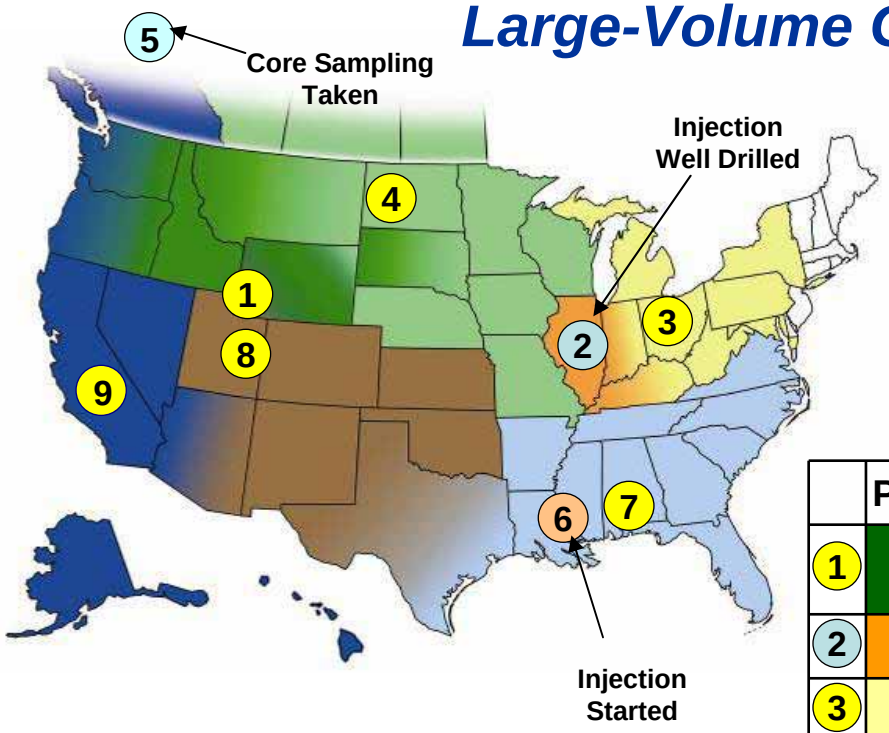
Increases from Atlas I

Hundreds of Years of Storage Potential

Available for download at http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasII/atlasII.pdf

RCSP Phase III: Development

Large-Volume Geologic Field Tests



- 2009 Injection
- 2010/2011 Injection Scheduled
- 2011/2012 Injection Scheduled

- ✓ *Nine large-volume tests*
- ✓ *Injections initiated 2009 – 2012*

	Partnership	Geologic Province	Type
1	Big Sky	Triassic Nugget Sandstone / Moxa Arch	Saline
2	MGSC	Deep Mt. Simon Sandstone	Saline
3	MRCSP	Shallow Mt. Simon Sandstone	Saline
4	PCOR	Williston Basin Carbonates	Oil Bearing
5		Devonian Age Carbonate Rock	Saline
6	SECARB	Lower Tuscaloosa Formation Massive Sand Unit	Saline
7			
8	SWP	Regional Jurassic & Older Formations	Saline
9	WESTCARB	Central Valley	Saline

CCS Best Practice 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	2017	2020
Site Characterization	2009	2016	2020
Simulation and Risk Assessment	2010	2017	2020
Well Construction and Closure	2010	2017	2020
Regulatory Compliance	2010	2016	2020
Public Outreach and Education	2009	2016	2020
Terrestrial	2010	**2016 – Post MVA Phase III**	

Final Observations

- **CCS technology is available today, however:**
  - It is very expensive, energy intensive, and not fully proven
- **Sequestration needs to be more widely demonstrated, especially in deep saline reservoirs with large-volume CO_2 injection**
- **DOE RD&D program is targeting the key issues**
- **Regulatory certainty is a prerequisite for commercial action.**