Outline

• DOE Organization – Missions
• Fossil Energy Coal Program
• FE RD&D Activities
• Challenges & Opportunities
• Visions
DOE Missions

• To advance the national, economic, and energy security of the United States
• To promote scientific and technological innovation in support of that mission
• To ensure the environmental cleanup of the national nuclear weapons complex
Division of Clean Coal Energy Research

Adv. IGCC
Adv. Turbines
Innovations for Existing Plants
Fuel Cells
Fossil Energy Program Outline

DOE Research Programs

Industry Participation & Cost Sharing Increases

Fossil Energy Core Programs (Gasification, Turbines, Fuel Cells)

Fossil Energy Advanced Research

Office of Science Research

Basic Research

Applied Research

Process & Engineering Development

Demonstration & Commercialization

Energy R&D Portfolio

ICCS, CCPI, Demos

FutureGen

Public Benefits
Fossil Energy Focus

• Reduce penalty of carbon capture

• Prove capability, permanence, & capacity for geologic storage

• Gain public acceptance of storage

• Identify & develop viable beneficial end uses for carbon dioxide

• Deploy cost competitive CCS technology for both existing & new fossil power plants by 2020
Government’s Coal RD&D Investment Strategy

**Approaches**

- Technology Development
- Commercial Readiness
- Market Penetration

**Programs**

- **RESEARCH & DEVELOPMENT**
  - Core Coal and Power Systems R&D
  - DOE – FE – NETL

- **TECHNOLOGY DEMONSTRATION**
  - Clean Coal Power Initiative Stimulus Activities
  - DOE – FE – NETL

- **FINANCIAL INCENTIVES**
  - Tax Credits
  - Loan Guarantees
  - DOE – LGO – IRS

**Goals**

- Technologies & Best Practices
  - < 10% increase COE with CCS (pre-combustion)
  - < 35% increase COE with CCS (post- and oxy-combustion)
  - < $400/kW fuel cell systems (2002 $)
  - > 50% plant efficiency, up to 60% with fuel cells
  - > 90% CO₂ capture
  - > 99% CO₂ storage permanence
  - +/- 30% storage capacity resolution
DOE’s Coal Research is Divided Among Seven Core R&D Programs

- **Innovations for Existing Plants**
  CO₂ capture research for new and existing pulverized coal plants
- **Sequestration**
  CO₂ storage and monitoring
- **Gasification**
  Coal gasification for production of synthetic hydrogen gas
- **Turbines**
  Advanced hydrogen and high efficiency gas turbines
- **Fuels**
  Production of liquid and gaseous fuels from coal
- **Fuel Cells**
  Large scale energy production from fuel cells
- **Advanced Research**
  Materials, sensors and controls, and computational energy science

Total: $404 M (FY11 request)
Total USA Electricity Growth Predicted

2007

- 4159 TWh
- >73% Fossil Energy

2035

- 5259 TWh
- >66% Fossil Energy

28 Yrs.
+0.9%/Yr.
+28.5%

FC relevant to potentially tighter constraints on CO₂, water and NOx as well as greater efficiency requirements to make-up for anticipated CCS parasitic loads.

Source: EIA AEO 2010r.d11809a Spreadsheet
U.S. Coal Plant Size

Source: Electric Power Research Institute
Key Gasification R&D Areas

APCI Oxygen Membrane

Hot Compressed Air

Lean Air

Oxygen

Fuel Gas

Reduces Capital Cost by 1/3 - 5.0% reduction in COE

Low-rank Coal* Alternative Feedstocks*

• Energy security
• Carbon footprint reduction

Improve RAM*

• Refractory durability
• Feed system reliability
• Heat removal/integration
• Temperature measurement & control

Gasification Areas

RTI Warm Gas Cleaning

• Efficiency increases by 2.9 %pt
• COE decreases by 12.0%

Eltron H₂/CO₂ Membrane

H₂ Rich Stream

H₂, H CO₂ H H₂, H CO₂ H

Water-Gas Shift*

Process improvement and intensification

CO₂

3 projects; 45% of budget

* Advanced Gasification
Fossil Energy CO$_2$ Capture Solutions

- **CO$_2$ Capture Targets:**
  - 90% CO$_2$ Capture
  - <10% increase in COE (IGCC)
  - <30% increase in COE (PC)

- **Time to Commercialization:**
  - 2010
  - 2015
  - 2020

- **Cost Reduction Benefit:**
  - Post-combustion (existing, new PC)
  - Pre-combustion (IGCC)
  - Oxycombustion (new PC)
  - CO$_2$ compression (all)

- **Chemical looping
  - OTM boiler
  - Biological processes

- **Solvents and Membranes:**
  - Amine solvents
  - Physical solvents
  - Advanced chemical solvents
  - PBI membranes
  - Solid sorbents
  - Membrane systems
  - ITMs
  - Ionic liquids
  - Metal organic frameworks
  - Enzymatic membranes

- **Other Technologies:**
  - Cryogenic oxygen
  - Cryogenic compression
  - Advanced physical solvents
  - Ammonia
  - Advanced physical solvents
  - Biomass co-firing

- **Abbreviations:**
  - OTM – O$_2$ Transport Membrane (PC)
  - ITM – O$_2$ Ion Transport Membrane (PC or IGCC)
Active CCPI Demonstration Projects
Locations & Cost Share

- **Excelsior Energy**
  - Mesaba Energy IGCC
  - $2.16B – Total
  - $36M – DOE

- **Basin Electric**
  - Postcombustion CO₂ Capture
  - $287M – Total
  - $100M – DOE

- **Summit TX Clean Energy**
  - Commercial Demo of Advanced IGCC w/ Full Carbon Capture
  - ~$1.9B – Total
  - $350M – DOE

- **NRG**
  - Post-Combustion CO₂ Capture
  - $308M – Total
  - $154M – DOE

- **Southern Company**
  - IGCC-Transport Gasifier w/Carbon Capture
  - $2B – Total
  - $294M – DOE

- **NeuCo (NRG Limestone)**
  - Mercury Specie & Multi-pollutant Control
  - $15.6M – Total
  - $6.1M – DOE

- **AEP**
  - Post Combustion CO₂ Capture
  - $668M – Total
  - $334M – DOE

Awarded
In Negotiation
<table>
<thead>
<tr>
<th>Project Location</th>
<th>Industry Type / Product</th>
<th>Sequestration Type</th>
<th>CO₂ Capture Technology</th>
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<td>Wolverine, CFB Power; EOR, Hitachi Amine, Rogers City, MI</td>
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<td>Archer Daniels Midland; Industrial Power &amp; Ethanol; Saline, DOW Alstom Amine, Decatur, IL</td>
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<td>Cemex; Cement; EOR &amp; Saline, RTI Dry Carbonate Odessa, TX</td>
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<td>Leucadia Energy; SNG from pet coke; EOR, Rectisol, Mississippi</td>
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<td>Leucadia Energy; Methanol; EOR, Rectisol, Lake Charles, LA</td>
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<td>Air Products, H₂ Production; EOR, BASF’s aMDEA Port Arthur, TX;</td>
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<td>Praxair; H₂ for Refinery; EOR, VPSA, Texas City, TX</td>
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Fossil Energy Coal R&D Program
A History of Innovative Solutions

1970’s
- Clean Air Act
- National response to address air quality concerns
- Profound impact on existing (and future) coal burning power plants

1980’s
- Oil Embargo
- Exposed the Nation’s vulnerability to oil supply disruptions
- U.S. imposes price controls on domestic oil – search for alternatives

1990’s
- Acid Rain
- National trans-boundary response to natural resource preservation
- Identifies SO2 and NOX from fossil energy use as principal culprits

2000’s
- Utility Deregulation
- Changed utility business model
- Competitive pricing drives investment efficiency - private sector investment in R&D reduced

- Climate Change
- A global issue
- President targets 80% reduction in CO2 by 2050
- Congress considers cap-and-trade

New power system technology (CFBC)
✓ Emission control technologies for existing plants target NOX, SO2, and Particulates
  - Installed on 75% of U.S. coal plants; 1/2 to 1/10 cost of older systems

Coal processing technology advances - but markets fail to develop
✓ Successful demonstrations (coal liquids, SNG, chemicals)
✓ First gasification-based pioneer plants – Dakota Gasification

Integrated CCS energy systems (highly efficient, zero emission, affordable)
✓ CCS (pre & post-combustion capture, site characterization, MVA, Best Practices)
✓ Fuel processing & separation (gasifiers, O2/H2 membranes, feed-pump, gas cleaning)
✓ Power generation (H2 turbines, SECA-SOFC, oxy-combustion, chemical looping)

...fossil’s programs made a significant contribution to the well-being of the United States, lead to realized economic benefits, energy options for the future, and significant knowledge gained...


...the Regional Partnerships is an excellent program that will achieve significant results for CCS in the United States, Canada and internationally... the Partnerships Programme will significantly advance and accelerate the CCS field... The individual projects will together build a comprehensive and expansive research programme, the size and scope of which is unique throughout the world...

Vision

• A new round of advanced CCS demonstration in the 2016 timeframe
• Accelerate R&D on 2nd generation technologies that can be ready demonstration by 2020
• A 250-MW SOFC stationary power plant by 20XX??