Overview of the Fossil Energy \( \text{sCO}_2 \) Program

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Administration Energy Goals

President’s *America First Energy Plan*:  
- Strong domestic energy production  
- Energy security at home  
- Commitment to revitalizing coal  
- Expanded global markets for U.S. energy.

Strong support from DOE Office of Fossil Energy’s *Clean Coal R&D* program, emphasizing:  
- Advanced Coal Energy Systems  
- Technologies to increase the *reliability and efficiency* of new and existing coal-fired plants that support and help stabilize the grid.
Next-Generation Coal Plants

Improved Existing Coal Fleet

- Advance and demonstrate technologies to enhance economics, e.g.,
  - Topping cycles to boost efficiencies (5%)
  - Cycling capabilities
- Apply advanced materials and processes to maximize efficiency and minimize emissions.

Coal Plants of the Future

- Modular design (50-200 MW) and capable of distributed generation
- Uses advanced materials and processes to maximize its efficiency and minimize emissions
- Provides stable power that can also be flexibly dispatched to meet the needs of the grid
Why sCO₂ Brayton Cycle: Benefits

• **Smaller Footprint:** High fluid density enables order-of–magnitude smaller turbo machinery and components

• **Higher Efficiency:** Cycle offers up to 4% efficiency points > advanced Ultra supercritical coal-fired steam with 90% capture and compression

• **Reduced Water Use:** Indirectly heated sCO₂ cycle reduces water withdrawals ~ 8%. Preliminary studies indicate condensing sCO₂ cycles lower cost and efficiency penalties for dry cooling.

• **Lower CO₂ Emissions:** Direct-fire configuration provides intrinsic separation and compression.

• **Scalability:** sCO₂ turbomachinery is projected to maintain high efficiency at smaller scales (<10 MWe), lowering capital costs and diversifying energy sources for distributed generation.
Why \( \text{sCO}_2 \): Thermodynamics

**Cycle Efficiency vs. Turbine Inlet Temperature**

- Thermal Efficiency vs. Temperature (C)
- 75% of Carnot
- \( \text{sCO}_2 \)
- Helium Brayton Cycle
- Supercritical Steam
- Toluene (NETL)
- Pentane (NETL)

Source: Dostal MIT thesis
FE Investments in sCO₂ Power Cycle Technology

- FE R&D: $22.3 Million cumulative
- FE STEP: $39.3 Million cumulative
- Used for R&D: $10 Million

Investment ($ Million)
International and Domestic Developments

- **ARPA-E:** exploring high efficiency/temperature/pressure modular systems for stationary and mobile applications

- **DOE Large-Scale Pilot Program Selections:** University of North Dakota EERC/NetPower, Echogen – Fossil proviso Phase 1 Feasibility study.

- **STEP status:** EA issued for public review March 19. Public review will conclude on April 18 after which facility clearing can begin. Selected main heater vendor, majority of equipment out for bid. PFD and P&IDs completed and frozen. Turbine design head for CDR.

- **International:**
  - **Saudi Arabia.** Secretary Perry and Prince Abdulaziz signed MOU on Dec. 4th re: cooperation on sCO₂ and other technologies. Discussions on going.
  - **Korea:** R&D related to turbomachinery, recuperators, systems modeling, pilot projects, collaboration with Saudi Aramco sCO₂ power cycles.

Source: Saudi Press Agency
Opportunities and Challenges

Technology Benefits:

- Small foot print/scalability
- Fuel flexible, low water requirement
- Direct-fire provides zero-cost, pure CO₂ stream as byproduct

Applications & Impacts

- Load centers
- Intermittent sources
- Reduced siting restrictions
- EOR
- Food processing
- Other value-added use

Challenges:

- Affordable extreme-environment materials
- Understanding combustion in sCO₂ environment
- Improved component designs that offer better performance at reduced cost
Pilot test:
- STEP 10MW testing 550–700°C

R&D:
- Improve cost and performance of turbomachinery, recuperators, sensors, control strategy
- Enable sCO₂/O₂ and syngas combustion at 300bar
- Develop material for severe, high-temperature environments

Pilot test:
- Higher temperature indirect cycles
- Directly fired cycle

R&D:
- Develop hi-temp. corrosion-resistant material (focus on water and other syngas contaminants)
- Design components (e.g., combustor, recuperator) to address syngas contaminants challenges
- Enhance sCO₂/O₂ and syngas combustion in off-design conditions
- Develop ultra-high temperature recuperators (indirect and direct)
Thank You
Clean Coal and Carbon Management: R&D Overview

Discover and develop advanced coal technologies that ensure America’s access to and use of secure, affordable, and reliable fossil energy resources.

**Advanced Energy Systems***
- High performance materials
- Solid oxide fuel cells
- Modular design
- Gasification
- Advanced cycles, e.g., sCO₂
- Advanced turbines
- Advanced combustion
- Transformational power

**Crosscutting Research***
- Water management
- Critical mineral extraction from coal and coal byproducts
- Sensors and controls

**CO₂ Capture***
- Post-combustion capture
- Pre-combustion capture

**CO₂ Utilization and Storage***
- New pathways to utilize captured CO₂
- Safe use & permanent storage of CO₂ from power generation and industry

* Programmatic not necessarily budgetary groupings