Oxyfuel Activities in USA & FutureGen Update

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Contents – Some key US projects / initiatives

• Brief overview of CCS projects in the US
• Overview of US Oxyfuel Activities in US
  – B & W and Air Liquide
  – Alstom, US DOE, NETL
  – Air Products & ITM
• EPRI Activities
• FutureGen 2.0 Update
## DOE Large Scale CCS Projects (as of 2011)

<table>
<thead>
<tr>
<th>Project</th>
<th>Location</th>
<th>Capture rate (ts / yr)</th>
<th>Repository</th>
<th>Start</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oxy-Combustion</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>FutureGen 2.0</td>
<td>Meredosia IL</td>
<td>1,150,000</td>
<td>GS</td>
<td>2015</td>
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<tr>
<td><strong>Pre-Combustion Capture (IGCC)</strong></td>
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<tr>
<td>Summit Texas Clean Energy</td>
<td>Odessa, TX</td>
<td>2,700,000</td>
<td>EOR</td>
<td>2014</td>
</tr>
<tr>
<td>Southern Company</td>
<td>Kemper Co, MS</td>
<td>1,800,000</td>
<td>EOR</td>
<td>2014</td>
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<tr>
<td>Hydrogen Energy</td>
<td>Kern Co, CA</td>
<td>1,800,000</td>
<td>EOR/GS</td>
<td>2016</td>
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<tr>
<td><strong>Post Combustion Capture</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Basin Electric</td>
<td>Beulah, ND</td>
<td>450,000 – 1,360,000</td>
<td>EOR/GS</td>
<td>2014</td>
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<tr>
<td>NRG Energy</td>
<td>Thompsons, TX</td>
<td>400,000</td>
<td>EOR</td>
<td>2015</td>
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<tr>
<td>AEP</td>
<td>New Haven, WV</td>
<td>1,500,000</td>
<td>GS</td>
<td>2015</td>
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<tr>
<td><strong>Industrial CCS Solicitation</strong></td>
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<tr>
<td>Leucadia Energy</td>
<td>Lake Charles, LA</td>
<td>4,000,000</td>
<td>EOR</td>
<td>2014</td>
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<tr>
<td>Air Products</td>
<td>Port Arthur, TX</td>
<td>900,000</td>
<td>EOR</td>
<td>2013</td>
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Alstom, US DOE & NETL

- One of 6 R & D Carbon Capture Projects funded by Existing Plants, Emissions & Capture Programme (EPEC)
- Focus on retrofit to T-fired units (500 – 600MWe)
- Optimised demonstration 100 – 200MWe
- Pilot scale tests at 15MWth T-Fired BSF
- Several oxy-combustion system designs to be evaluated
- Will include techno-economic analysis
- Project cost – circa $18m (DOE -$15m)
Babcock & Wilcox and Air Liquide

• B & W and Air Liquide have been developing oxy-combustion retrofit technology at their respective test facilities

• Two-phased approach
  • Phase 1 – Effect of coal rank
  • Phase 2 – Engineering & Economic assessment of technology

• Developing a 700MWe Oxy-Coal Reference Plant with EPRI & URS
  • Sub-bituminous coal
  • Steam – 259bar, 593C
  • Wet Cooling
  • Location – Kenosha, Wisconsin

• Technology suppliers to FutureGen 2.0
ITM Oxygen Membranes – Air Products

- Proprietary ceramic membrane separates oxygen from air
- Single-stage high-purity oxygen
- Extremely selective and fast transport for oxygen
- Very compact

1500-1650°F (800-900°C), 200+ psia (14+ bara)
ITM Oxygen Unit

ITM Modules
- 0.5 tpd
- 1.0 tpd

Options for ITM Oxygen Unit Design:
- Power co-production
- Minimum fuel consumption
- Minimum CO₂ emissions

ITM Oxygen

High-Pressure Air
Heat/Fuel

Nitrogen
Flue Gas to CO₂ Purification

99.5% Oxygen
Electric Power, Steam

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EPRI – Generation Sector Focus

Collaborative Bandwidth

Operations and Maintenance
- I&C & Automation
- Maintenance Management & Technology
- Fossil Maintenance Applications Center
- Operations Management & Technology

Major Component Reliability
- Boiler Life & Availability
- Boiler and Turbine Steam & Cycle Chemistry
- Steam Turbines, Generators, & Auxiliary Systems
- Fossil Materials & Repair

Combustion Performance
- Combustion Performance & NOx Control
- Post-Combustion NOx Control

Generation Planning
- Technology-Based Business Planning Information & Services
- Power & Fuel Markets & Generation Response

Renewables
- Renewable Generation

Combustion Turbines
- Combustion Turbine & Combined Cycle O&M
- New CT/CC Plant Design and Technology Selection
- Heat Recovery Steam Generator (HRSG) Dependability

Environmental Controls
- Integrated Environmental Controls
- Particulate and Opacity Control
- Continuous Emissions Monitoring
- Coal Combustion Product Use

Advanced Coal Generation
- CoalFleet for Tomorrow
- CO2 Capture and Storage

Demonstrations
- Industry Demonstrations

Operational integrity of existing assets, regulatory compliance, new build decisions
Advanced Coal Generation

**Cost-effective coal-based generation with carbon capture and storage**

- **Economics/Planning**
  - Technology knowledge databases
  - Economic analyses of new and retrofit power generation with CCS

- **Retrofit/Repower Existing Assets**
  - Repowering strategies which maximize use of existing coal assets
  - Quantifying and Optimizing CO\(_2\) capture retrofit strategies

- **Future Assets**
  - High efficiency ultra-supercritical PCs
  - IGCC design/cost improvements
  - Optimization of design and operations with CCS (post-, pre- and oxy-combustion capture)
  - Accelerated development of advanced CO\(_2\) capture technologies

- **All Assets**
  - Supporting the US Dept of Energy’s National Carbon Capture Center
CoalFleet for Tomorrow (66)

Preparing technologies for use in the Coal Power Plant of the 2020s:
Advanced Ultrasupercritical PCs, IGCCs and Oxy-Combustion Power Plants

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2012 R&D focus
Identifying and nurturing technologies which can have a significant impact on the cost of electricity from new coal power plants

- Targeting to have reliable and highly efficient new coal plant designs with near-zero emissions and CO₂ capture available to industry by 2025
- Timely and accurate engineering and economic information about advanced coal technologies to support generators’ decision-making processes
- Shorten the development time for promising CO₂ capture technologies by co-sponsoring the US Dept of Energy’s National Carbon Capture Center
- Validating materials needed for boilers and turbines to operate with steam conditions up to 1400°F (760°C) and 47% HHV efficiency
Carbon Capture & Storage (CCS)

Cost-effective coal-based generation with carbon capture and storage

• Economics/Planning
  – Technology knowledge databases
  – Economic analyses of new and retrofit power generation with CCS
  – Understanding of fully integrated CO$_2$ chain – capture to storage

• Post-Combustion CO$_2$ Capture Technology Development
  – Accelerated development of advanced PC capture technologies
  – Carbon capture technologies testing at pilot and sub-pilot scales
  – Industry technology demonstrations
  – Optimization of design and operations with post-combustion CO$_2$ capture

• CO$_2$ Storage
  – Guidelines for managing storage
  – Advanced reservoir characterization and CO$_2$ monitoring techniques
CO₂ Capture & Storage (165)

Provide confidence that acceptable capture technologies and storage options will be available when needed

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2012 R&D focus
Develop improved post-combustion capture processes and confirm suitability of transport and storage

- Basis for credible asset planning
- Reduced cost-of-electricity (COE) for post-combustion carbon capture
- Reduced parasitic energy demand
- Knowledge to enable CO₂ underground storage to be understood by government bodies and the public.
- Independent information to develop regulations and legal frameworks for underground CO₂ storage.
- Reduce risk and cost of CO₂ product impurities resulting in increased CO₂ removal requirements, additional injection wells, or unacceptable storage sites.
EPRI Oxy-Coal Program Approach

1. Conduct engineering and economic evaluations of oxy-coal with CO₂ capture.
   - Full scale, new-build plant evaluations (published and on-going)
   - Oxy-coal retrofit/repowering evaluations (pending)

2. Monitor worldwide oxy-coal with CO₂ capture research, demonstration, and deployment.
   - Periodic critical reviews of worldwide activities. (published and on-going)
   - Pressurized oxy-coal
   - Chemical looping combustion

3. Conduct CO₂ purification unit technology assessments
   - Achieving the zero-emissions coal-fired power plant. (preliminary assessment published)
   - CPU process optimization (pending)
   - Affect of impurities on transport and storage of product CO₂ (In cooperation with Program 165)

4. Provide a platform to put forth industry (utility and vendor) view of oxy-coal with CO₂ capture RD&D needs.
   - Working group to produce a white paper (in process)

5. Assist in development (and monitoring) of field demonstration projects
Publications Pertinent to Oxy-Combustion CO₂ Capture


- **Oxy-Fired Circulating Fluidized Bed with Carbon Dioxide Capture and Storage at Holland Board of Public Works.** December 2009. 1020277.

- **Summary of Test Results from Babcock and Wilcox’s 30 MWth Oxy-Coal Pilot Plant.** September 2009. 1017508.

- **Program on Technical Innovation: Oxy-Fired CFB with CO₂ Capture and Storage at Jamestown (NY) Board of Public Utilities.** May 2009. 1018709.
Selected Oxy-Coal Engineering and Economic Evaluation Publications

EPRI


USDoE


Consistent conclusions:

• Oxy-Coal power plants (with CO₂ capture) can be built using technologies currently available; a viable technical option to Post-Combustion CO₂ Capture and Pre-combustion CO₂ Capture.

• Oxy-coal LCOE, cost of avoided CO₂ emissions, and cost of CO₂ captured are: at a minimum competitive with Post- and Pre-combustion CO₂ capture and: may have economic advantages over these alternatives.
FutureGen 2.0
Oxy-Combustion w/ CO₂ Sequestration

- Meredosia, IL & Morgan Co., IL
- 200 MWe gross oxy-combustion repowering of Ameren’s Meredosia Unit 4 steam turbine (Start 2016)
- 90% CO₂ capture (cryogenic separation) 1,300,000 tons CO₂/year
- Deep saline sequestration in Mt. Simon formation
- Total Project: $1.3 Billion
  DOE Share: $1.05 Billion (81%)

Key Dates
- Complete FEED: October 2012
- Construction: November 2012
- Operation: May 2016

Information courtesy of NETL

Status
- PreFEED – in progress
- Sequestration site characterization and validation In progress
- NEPA in progress, scoping meetings held, EIS being drafted
FutureGen 2.0 – Project Objectives

To prove the Oxy-combustion process at commercial scale

• Establish a cost and schedule baseline for the technology
• Equipment Design Considerations – Primarily Boiler Reliability – component design, materials of construction
• Maintainability – erosion, corrosion, outage cycles
• Not designed for high efficiency – for flexibility & learning
• Prove basic process and heat transfer parameters – can scale to higher efficiency, larger capacity w/o incremental steps
• Process Design Safety, Functionality, Operability
• Integrated operation of major components
• Understanding Storage Start-up, Shutdown, Load Swing, Capacity Factor, System Dynamics
FutureGen 2.0 – Project Partners

• Ameren (recently decided to pull out)
• Babcock & Wilcox
• Air Liquide
• FutureGen Alliance (non-profit partnership) - includes
  – Anglo American
  – Rio Tinto
  – Peabody Energy
  – Xstrata Coal
  – Consol Energy

• B & W and Air Liquide are the primary contractors

• The FutureGen Alliance is the single entity for the whole project following Ameren’s withdrawal and responsible for Project Mgt
A large-scale integrated test to repower Ameren’s existing Meredosia Unit 4 with oxy-combustion & carbon capture technology

- A purpose-built oxy-combustion system
- Confirmation that oxy-combustion is a viable repowering/new build technology for coal-fueled power plants, incorporating a testing program that will utilize Illinois bituminous coals & other coals
- Basis for industry acceptance: lowers equipt, operational, reliability & financial risks for future commercial deployments to meet U.S. & world energy needs

Benefits of the Meredosia Host Site

- Existing site infrastructure conserves capital cost
- It is the “right size” unit
  - Demonstrates retrofit/repowering potential for existing coal units
  - Large enough test of the technology to support commercial deployment (e.g., 500-800 MWe, supercritical) without another, intermediate, scale-up step
  - Small enough to conserve capital expense for a large-scale integrated test
  - ~3500 tpd CO₂ to storage
FutureGen 2.0: CO₂ Transmission Pipeline

- Pipeline to transport CO₂ from Meredosia to preferred CO₂ storage site in northeastern Morgan County, Illinois
  - ~30 miles of pipeline from Meredosia to Morgan County site
  - 12-inch diameter pipeline; 2000 psi operating pressure
  - 4-mile wide corridor to be studied as part of EIS

Information courtesy of NETL
FutureGen 2.0: Geological CO₂ Storage

- Design, build & operate geologic storage repository capable of safely permanently sequestering anthropogenic CO₂
  - Site characterization for large volumes to be stored
    - Modeling, seismic surveys, drilling of characterization wells, injection well design
  - Visitor, education & research facilities
  - Strong community interest, at preferred site & two alternate sites
  - Characterization well completed to depth of 4826’ on December 4, 2011
  - Core sample analyses & reservoir characterization studies being initiated

1. The FGA will not cost share in the visitor, education and training facilities.

Information courtesy of NETL
FutureGen 2.0 – Progress to date

• Currently 6 – 7 months behind
• Ameren cannot participate as originally envisioned
• Ameren announced plan to close the Meredosia Plant
• Possible FutureGen Alliance may lease the Unit, currently seeking DOE approval
• Preliminary Engineering studies (Pre-FEED) complete
• Test storage well completed
  – Characterisation well indicates suitability of geology
  – Geology data still being analysed
• Project cost estimates up for Federal Review
• The Energy Department remains committed to demonstrating CCS
• Watch this space
Thank you for listening
Happy to take questions

Together…Shaping the Future of Electricity