“We are passionate about innovation and technology leadership”

FutureGen 2.0: Power Block Design and Integration.

IEAGHG OCC3 Conference
Ponferrada, Spain

D.K. McDonald, Technical Fellow, Babcock & Wilcox
September 11, 2013

Co Authors: Lyle Falla, James MacInnis, B&W
Presentation Outline

1. Background

2. Project Status
   - Project Structure
   - Current Project Schedule Impact
   - Next Steps

3. Technical Status
   - Power Block Design
   - Performance and Costs
The State of CCS Worldwide
The State of CCS Worldwide
## Current CCS Projects Worldwide

### Largescale Power Plant CCS Projects Worldwide

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Leader</th>
<th>Feedstock</th>
<th>Size MW</th>
<th>Capture Process</th>
<th>CO2 Fate</th>
<th>Start-up</th>
<th>Location</th>
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</table>

**Abbreviations used:**
- Oxy = Oxyfuel Combustion Capture
- Pre = Pre Combustion Capture
- Post = Post Combustion Capture
- EOR = Enhanced Oil Recovery
- EGR = Enhanced Gas Recovery
- Saline = Saline Formation
- Depleted Gas = Depleted Gas Reservoir
- Depleted Oil = Depleted Oil Reservoir
- TBD = To Be Decided

**Source:** Carbon Capture & Sequestration Technologies @ MIT

Current at May 13, 2013
# Current CCS Projects Worldwide

## Largescale Power Plant CCS Projects Worldwide

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Leader</th>
<th>Feedstock</th>
<th>Size MW</th>
<th>Capture Process</th>
<th>CO2 Fate</th>
<th>Start-up</th>
<th>Location</th>
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<td>Saline</td>
<td>Cancelled</td>
<td>Germany</td>
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Current at May 13, 2013
# Current CCS Projects Worldwide

## Large scale Power Plant CCS Projects Worldwide

<table>
<thead>
<tr>
<th>European Union</th>
<th>Project Name</th>
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<th>Feedstock</th>
<th>Size MW</th>
<th>Capture Process</th>
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<th>Start-up</th>
<th>Location</th>
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<td>Coal</td>
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<td>Statoil</td>
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<td>Naturkraft</td>
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<td>On Hold</td>
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## Rest of the World

<table>
<thead>
<tr>
<th></th>
<th>Project Name</th>
<th>Leader</th>
<th>Feedstock</th>
<th>Size MW</th>
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<th>Start-up</th>
<th>Location</th>
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<tr>
<td>China</td>
<td>Daqing</td>
<td>Alstom &amp; Datang</td>
<td>Coal</td>
<td>350 &amp;1000</td>
<td>Oxy</td>
<td>EOR</td>
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<td>China</td>
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<tr>
<td></td>
<td>Taiyuan</td>
<td>B&amp;W and SIEG</td>
<td>Coal</td>
<td>350</td>
<td>Oxy</td>
<td>undecided</td>
<td>planning</td>
<td>China</td>
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<tr>
<td>UAE</td>
<td>HPAD</td>
<td>Masdar</td>
<td>Gas</td>
<td>400</td>
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<td>planning</td>
<td>UAE</td>
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<td>China</td>
<td>GreenGen</td>
<td>GreenGen</td>
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<td>Pre</td>
<td>Saline</td>
<td>planning</td>
<td>China</td>
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Current as of May 13, 2013

Taiyuan added
FutureGen 2.0 History

Meredosia Energy Center

2010
- Awarded $1 billion AARA funding in September
- Began Phase 1 design with Illinois #6 coal

2011
- Redesigned with Illinois-PRB blend to reduce cost
- Storage site in Morgan County selected
- CO$_2$ liability management addressed
FutureGen 2.0 History

2012
- Pre-FEED successfully completed
- Primary PPA terms approved
- Air/water permit modifications filed
- Pipeline permit application filed
- Pore space acquisition nearly completed
- DOE cooperative agreement transferred to FGIA

2013
- Phase II approved by DOE
- Contract executed for sale of a portion of the Meredosia plant to FGIA
- EIS finalized (ROD expected this year)
- Strong community support
FutureGen 2.0 Project Organizational Structure

U.S. Department of Energy

FutureGen Alliance

Oxy-Combustion Repowering
CO₂ Pipeline & Storage Hub

B&W
Power Generation Group
Oxy-Combustion Boiler and GQCS

AIR LIQUIDE
Technology Providers

ASU & CPU
**FutureGen 2.0 Project Schedule & Status**

<table>
<thead>
<tr>
<th>Phase I</th>
<th>Phase II</th>
<th>Phase III</th>
<th>Phase IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-FEED</strong>&lt;br&gt; (Front End Engineering Design)&lt;br&gt; October 2010 thru June 2012</td>
<td><strong>FEED</strong>&lt;br&gt; February 2013 no later than June 16, 2014</td>
<td><strong>EPC and Startup</strong>&lt;br&gt; No later than June 16, 2014 to June 2017</td>
<td><strong>Test Period</strong>&lt;br&gt; July 2017 to March 2020 (monitoring continues until March 2022)</td>
</tr>
</tbody>
</table>

**Timeline:**
- **Design:** 2010
- **Construction:** 2014
- **Power Production w/ CCS:** 2017
- **Post-closure monitoring:** 2037
- **End of monitoring:** 2087
Capture Plant Scope Split

Oxy-Coal Combustion Plant Configuration

ASU
Nitrogen (N₂) Out
Air In
Air Separation Unit
Oxygen (O₂)

Boiler Island
Recycled Flue Gas
Coal In
CO₂ and Flue Gas

Boiler

Environmental Cleanup Equipment
Ash
H₂O
SO₂
Other Captured Emissions

CPU
Other Gases (NCGs)
CO₂ Compression
CO₂ Capture (liquid)
Transport and Storage Scope

Conservative scale-up with proven technology

B&W

1.5 MWt Demo

30 MWt Demo

Dust Filtration

Lacq

Callide

CIUDEN

FutureGen 2.0

AIR LIQUIIDE

**FutureGen 2.0 Process Configuration**

- **ASU**
  - Burners
  - Coal
  - Boiler
- **Boiler**
  - Steam; 2100psia, 1000F/1000F
- **CDS**
- **PJ FF**
- **ID Fan**
- **DCCPS**
- **CPU**
- **Stack Damper**
- **Vent**
- **CPU Damper**
- **Recycle Damper**
- **Gas Reheater**
- **Secondary Recycle (SR) Fan**
- **Primary Recycle (PR) Fan**
- **Air Intake**
- **Cool Recycle Process**

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FutureGen 2.0 Process Configuration

- ASU
- Burners
- Boiler
- Coal
- Steam; 2100psia, 1000F/1000F
- Recycle Heater
- CDS
- PJ FF
- ID Fan
- DCCPS
- Gas Reheater
- Burners
- Cool Recycle Process
- To Storage
- Vent
- CPU
- ASU
- Burners
- Boiler
- Coal
- Steam; 2100psia, 1000F/1000F
- Recycle Heater
- CDS
- PJ FF
- ID Fan
- DCCPS
- Gas Reheater
- Burners
- Cool Recycle Process
- To Storage
- Vent
- CPU
FutureGen 2.0 Phase II

Planned Activities

Project Level:

- Pipeline easement acquisition
- Complete EPC, commodity and O&M contracts
- Receive Final permits
- Obtain NEPA approval and DOE “Record of Decision” (ROD)
- Financial Close
Planned Activities

Technical:

- Evaluate steam turbine upgrade
- Complete dynamic analysis of gas side
- Confirm CDS stoichiometry
- Complete component engineering in preparation for fabrication
  • • • • • • • • • • • •
- 3-D plant model
- Completion of construction drawings
- Final equipment specifications
- Select key equipment vendors
FutureGen 2.0 Phase II

Gas Side Dynamic Analysis
FutureGen 2.0 Phase II
FutureGen 2.0 Phase II
FutureGen 2.0 – Carbon Capture Plant Arrangement

1. Boiler
2. CDS
3. PJ FF
4. DCCPS
5. Stack
Ash Silo

Circulating Dry Scrubber (CDS)

To PR Fans and then Recycle Heater

To Recycle Heater

From Recycle Heater

Lime Prep System

Fabric Filter

ID Fan

Stack

Water Tank

DCCPS

Trona Tank

To CPU

Gas Reheaters

Secondary Recycle Flue

Primary Recycle Flue

CDS Recirculation Flue

SR Fan
## FutureGen 2.0 Current Performance

<table>
<thead>
<tr>
<th>Oxy-PC Plant Predicted Thermal Performance</th>
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<tbody>
<tr>
<td>Steam Turbine Generator Output (gross)</td>
<td>168,400 kW</td>
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<tr>
<td>Generator Step-Up Transformer Losses</td>
<td>674 kW</td>
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<tr>
<td>Steam Turbine Gross Generation to 138 kV Grid</td>
<td>167,726 kW</td>
</tr>
<tr>
<td><strong>Plant Net Generation</strong></td>
<td>99,005 kW</td>
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<tr>
<td>Boiler Heat Output</td>
<td>1,369.5 MBtu/hr</td>
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<tr>
<td>Boiler Fuel Efficiency (HHV)</td>
<td>87.25%</td>
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<tr>
<td>Fuel Heat Input (HHV)</td>
<td>1569.6 MBtu/hr</td>
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<tr>
<td>Coal Consumption</td>
<td>159,610 lb/hr</td>
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<tr>
<td><strong>Plant Net Heat Rate, HHV</strong></td>
<td>15,854 Btu/kWh</td>
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<tr>
<td><strong>Net Plant Efficiency, HHV</strong></td>
<td>21.50%</td>
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## FutureGen 2.0 CO₂ Production

<table>
<thead>
<tr>
<th>CO₂ Recovery and Quality Predictions</th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>CO₂ Recovery (mass basis)</strong></td>
<td><strong>98%</strong></td>
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<tr>
<td><strong>Mass flow (CO₂)</strong></td>
<td>319 klbs/hr, 3,828 tpd</td>
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<tr>
<td></td>
<td>1.08 million metric tons/year (based on 85% capacity factor)</td>
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<tr>
<td><strong>Pressure</strong></td>
<td>2,100 psig</td>
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<tr>
<td><strong>Temperature</strong></td>
<td>71 F</td>
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<tr>
<td><strong>CO₂ content</strong></td>
<td><strong>99.8%</strong> (by mass, dry basis)</td>
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<tr>
<td><strong>Inerts (Ar, N₂)</strong></td>
<td>? 0.04% (by mass, dry basis)</td>
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<tr>
<td><strong>Water (H₂O)</strong></td>
<td>? 1 ppmw</td>
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<tr>
<td><strong>Oxygen (O₂)</strong></td>
<td>? 110 ppmw (dry basis)</td>
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<tr>
<td><strong>Total Sulfur (SOₓ)</strong></td>
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<td><strong>Hydrogen Sulfide (H₂S)</strong></td>
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<tr>
<td><strong>Nitrous Oxides (NQₓ)</strong></td>
<td>? 1,600 ppmw (dry basis)</td>
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<tr>
<td><strong>Mercury (Hg)</strong></td>
<td>? 1 ppbw (dry basis)</td>
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# FutureGen 2.0 Predicted Air Emissions

<table>
<thead>
<tr>
<th>Emissions Constituent</th>
<th>lb/hr (lb/Mbtu), HHV Basis</th>
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<td>4.8 (0.0031)</td>
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<tr>
<td>NO\textsubscript{x}</td>
<td>33 (0.0206)</td>
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<tr>
<td>VOM</td>
<td>1.8 (0.0011)</td>
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<tr>
<td>PM (Total)</td>
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<tr>
<td>SO\textsubscript{2}</td>
<td>0.02 (0.000013)</td>
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<tr>
<td>Sulfuric Acid Mist</td>
<td>Negligible</td>
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<tr>
<td>HCl</td>
<td>Negligible</td>
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<tr>
<td>HF</td>
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<tr>
<td>Hg</td>
<td>Negligible</td>
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