Pathways for Coal Power Generation in a Low-Carbon World

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National Conference of State Legislatures
20 Nov 2008
Agenda

- Emitting Less and Capturing More
- Carbon Capture
  - Technologies Advancement
  - Demonstration & Deployment
- What this means for new and existing fossil generation
No Single Solution – Multiple Building Blocks

• **Demand Reduction**
  − Consumer behavior
  − Efficient appliances and buildings
  − Energy management

• **Technology Mix**
  − Nuclear
  − Renewables

• **Production Efficiency**
  − Fuel Preparation/Retrofit
  − New Plants

• **Carbon Capture and Storage**
Stabilizing power emissions by 2030 is possible.
EFFICIENCY
Important basis for both operating and new plants

- High efficiency plants
- Biomass co-firing
- Carbon capture and storage

Service and Retrofit
- Retrofit (efficiency improvement)
- Biomass Cofiring/Fuel switch
- Integrated Retrofit Projects

Plant Efficiency_HHV

Existing power plant

New power plant

CO₂ Emissions lbs/MWh

30% 35% 40% 45% 50% 55% 60%

Lignite  Bituminous Coal  Coal +20% Biomass  Natural Gas  SC/USC  NGCC
Biomass and Fuel Preparation

Opportunities
• Up to 20% CO2 avoided
• Retrofittable to existing coal plants
• Flexibility – low incremental cost
• Most efficient use of biomass

Challenges
• Biomass logistics and availability

Biomass Co-firing: - 20% CO2
Lignite drying Retrofit: - 10% CO2
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CO2 CAPTURE SOLUTIONS
Zero emission technology pathways

Power Plant with CO2 Capture

Pre-combustion

Oxy-combustion (New + retrofit)

Post-combustion (New + retrofit)

SOLUTIONS DEVELOPED BY ALSTOM

Pre-combustion: 
- Source: Vattenfall

Oxy-combustion: 
- Source: Vattenfall

Post-combustion: 
- Source: Vattenfall
CO2 CAPTURE SOLUTIONS
Zero emission technology pathways

Pre-combustion with CO2 capture (IGCC with CO2 capture)

Capturing CO2

SHIFT

BURN H2

Source: Vattenfall
CO2 CAPTURE SOLUTIONS
Zero emission technology pathways

Postcombustion capture (absorption process)

Steam turbine
Boiler
Cooling water
Steam condenser
Air
Fuel
Fly ash
Bottom ash

Clean flue gas
Mechanical energy
Low temperature heat
CO₂-rich absorbent
CO₂ lean absorbent
CO₂ stripper
CO₂ compressor

Source: Vattenfall
CO2 CAPTURE SOLUTIONS
Zero emission technology pathways

O₂/CO₂ recycle (oxyfuel) combustion capture

- Pre-combustion
- Post-combustion
- Oxy-combustion

Source: Vattenfall

SOLUTIONS DEVELOPED BY ALSTOM
Post-Combustion
Chilled Ammonia Process
Post-Combustion Field Pilots

**WE Energies Industrial pilot program**

- Project participation through EPRI by over 30 US and international utilities
- Designed to capture up around 15,000 tons/year of CO2 at full capacity
- Parametric testing to commence summer 2008
- Will provide data necessary to establish “proof of concept”

**Eon Pilot Program**

- Designed to capture approximately 15,000 tons/year of CO2 at full capacity
- Project schedule:
  - Commissioning Summer 08
  - Testing Fall 2008
- Testing to continue into late 2009
AEP Demonstration and Validation program

- Designed to capture up to 100,000 tons/year of CO2 at full capacity from coal plant
- Saline aquifers storage
- Commenced engineering Oct 07: commissioning 09

StatoilHydro Norway

- European Test Centre Mongstad for flue gases from natural gas CHP plant and a refinery
- Designed to capture 100,000 tons/year

Transalta Validation Plant Program

- Designed to capture up to Mtons/year of CO2 at full capacity from coal plant
- Project schedule - Engineering 2008
  - Testing expected in 2012
Post Combustion CO2 Capture
Amine based processes

Amine CO2 capture is proven

- Retrofittable
- Installed on a few plants burning coal
- High energy demand for regeneration

Exclusive partnership with DOW
- Advanced Amines
- Improved Process
- Plant Integration
Oxy-Combustion
Oxy-PC: Demonstrations

30 MW_{th}: Vattenfall

Main features
• 9 t/h CO2

30 MW_{th}: TOTAL Lacq

Main features
• 150,000 tons CO2 will be stored in a depleted gas field
• Retrofit of an existing boiler
• Goal: validation and improvement of oxyfuel process starting 2008
Oxy and Post Combustion: Overview of all Technologies

<table>
<thead>
<tr>
<th>Oxy technologies</th>
<th>Post combustion</th>
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<tbody>
<tr>
<td>Time to Market</td>
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<tr>
<td>&gt;15 years</td>
<td>&gt;15 years</td>
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<tr>
<td>OTM, CAR</td>
<td>High surface solids, membranes, enzyme, algae, solid absorbent</td>
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<tr>
<td>10-15 years</td>
<td>10-15 years</td>
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<tr>
<td>Sargas</td>
<td>Anti-sublimination</td>
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<tr>
<td>Oxy CFB</td>
<td>5-10 years</td>
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<tr>
<td>Oxy PC</td>
<td>Ammonia Scrubbing</td>
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<tr>
<td>5-10 years</td>
<td>&lt; 5 years</td>
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<td>Long Term Research</td>
<td>Advanced Amines</td>
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<td>Prototype Stage</td>
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<tr>
<td>Demo stage</td>
<td></td>
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<tr>
<td>Commercial</td>
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- Alstom involved
- Alstom not involved
### CO2 Capture and Storage Deployment time-line

#### Roadmap

<table>
<thead>
<tr>
<th>Capture</th>
<th>2007</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
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<tbody>
<tr>
<td>Post-comb.</td>
<td>Pilot / Demo</td>
<td>Pre-commercial</td>
<td>Commercialisation</td>
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#### Transport

- **EU, US, Australia**: Local, limited EOR projects + Demo
- **EU, US, Australia**: Progressive pipeline deployment, depending on validated storage sites

#### Storage

- **EU, US, Australia**: EOR + validation of storage sites
- **EU, US, Australia**: Ramp-up to full scale saline aquifer storage

*Source: Power Systems analysis* 

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Near term new: CO2 ready power plant concept

<table>
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<th>The need</th>
<th>The response</th>
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<tbody>
<tr>
<td>Address today the issues raised by future stringent CO2 regulations</td>
<td><strong>The need</strong></td>
</tr>
<tr>
<td><strong>CO2 ready power plant concept</strong></td>
<td><strong>The response</strong></td>
</tr>
<tr>
<td></td>
<td>• Definition:</td>
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</table>
| | − A CO2 capture-ready power plant is a plant which can include CO2 capture when the necessary regulatory or economic drivers are in place. The aim of building plants that are capture-ready is to avoid the risk of stranded assets or “carbon lock-in“.
| | • Answer: |
| | − Inclusion of sufficient space and access for the additional facilities that would be required |
| | − Identification of reasonable route(s) to storage of CO2 |
| | − A study of options for CO2 capture retrofit and potential pre-investments |

Insure CO2 readiness of current power plants

Source: ALSTOM analysis

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Capture ready CO₂ “Capture Ready” concept for a coal power plant

- Control system adaptation
- Optimization of the cooling system
- Recovery of heat in the CO₂ capture and compression
- Preparation for increased low pressure steam demand from steam turbine
- Provision for auxiliary Power consumption
- Optimization of the Boiler surfaces
- Improvement of flue gas cleaning and potentially addition of components
- Arrangement planning

An integrated approach is key
Amine – Commercial Scale
After implementation
Conclusions

- A portfolio approach is needed: Demand reduction, Renewables, Nuclear, Efficiency, CCS.

- Driving technologies to higher efficiency is a solid strategy for lower CO2 in the near and longer term.

- US and Europe must show leadership: fund early large-scale CCS demonstration plants and change behavior.

- Retrofittable CCS technologies are a must to have.

- Post-Combustion should be given a higher priority in funded programs.

- CCS deployment will be a major industrial challenge and Post-Combustion can provide for progressive ramp-up.

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**This is URGENT!**

*We are moving beyond paper... Only demonstration will determine the “real”, lowest cost solution*