Applying Large Scale Post Combustion CO$_2$ Capture: The Implications for New and Existing Power Plants

Bryan Hannegan, Ph.D.
Vice President, Environment & Renewables

US Chamber of Commerce
November 13, 2009
Outline

• Focus on Near term Post Combustion Capture Technologies
• Interactions with existing PC plant equipment
  – Power train
  – Heat integration
  – Water requirements
• Space
• Costs
  – Retrofit Vs new build
• EPRI Retrofit Study
• GTCC and CO₂
“…We seem to have a few problems going from lab-scale to full-scale production!”
Post Combustion Capture (PCC) Plant Interactions with Power Plant
Post Combustion Capture (PCC) Plant Interactions with Power Plant

Flue Gas Out
(CO₂ Removed)

CO₂ Out

Flue Gas In

Steam In / Out

Post Combustion Capture System
Large Scale Pulverized Coal (PC) Plant

- **Boiler**
- **SCR**
- **ESP/FF**
- **Flue system**

**System Components:**
- **Coal**
- **Air system**

Diagram showing the flow of coal and air through the system, ending with emissions reported as a stack or flue gas.
PC Plant with PCC: Steam line & Flue Gas Tie-ins

Boiler → SCR → ESP/FF → Scrubber → Flue system

Coal → Air system

CO₂ Stream

PCC System

HEAT TO CONDENSER COOLING WATER
Steam Turbine Generator and Auxiliaries

- Advanced amines require ~25% of IP/LP steam for solvent regeneration
- IP/LP pipe should have required valves and tie-ins
- Turbine building should have space to route the large LP steam pipe
  - Build pipe racks and support structure to enable routing
  - Provisions in drain system to handle additional pipe work drains

Source: Imperial College London
LP Turbine Issues

- Approach to resolving LP turbine issues depends on the amount of steam extracted and type of extraction as well as the design of the existing unit
  - Replacement of the LP blade path with a smaller annulus
  - Adjust cooling water flow to optimize backpressure
  - If the extraction is relatively small (10-15%) no change to the LP turbines may be needed

Note: Some existing coal plants designed to maximize output not efficiency are operating to the far right on the exhaust loss curve. They may see an improvement in LP efficiency with reduced LP flow
• Thrust forces resulting from steady state flow through the blade path are balanced at one point on the turbine and a thrust bearing is used to control transients or off-normal operating conditions.

• Extraction flow changes the flow “balance” resulting in uncompensated steady-state thrust increasing the load on the thrust bearing.

Modifications may need to be made to the balance diaphragms and thrust bearings to accommodate the revised thrust loads.
PCC Retrofit to Existing Coal Plants
Implementation Suggestions

• PCC retrofit will affect significantly more plant systems and components than a typical scrubber or SCR back-fit due to the PCC steam demand

• PCC operational profile should be defined early
  • Partial CO$_2$ Removal / Maximum CO$_2$ Removal
  • Full time operation / Seasonal operation

• The steam-water cycle should be included in plant specific PCC retrofit evaluations to select the optimum approach and identify related impacts

• Steam-water cycle upgrades should be evaluated as a part of detailed PCC retrofit studies
  • Blade path upgrades
  • Integration of PCC heat recovery
  • Potential for increased main steam flow

Detailed engineering analyses, that include the steam-water cycle, will be needed to make the best PCC retrofit decisions.
PC Plant with PCC: Let Down Turbine and Condensate Return
PC Plant with PCC: Heat Integration

HEAT INPUT FROM BOILER

PCC System

HEAT TO CONDENSER COOLING WATER

HEAT FROM COMPRESSOR INTERCOOLERS

HEAT FROM CO2 REFLUX CONDENSERS
PC Plant with PCC: Water Requirements

- PCC will increase cooling duty
- For closed-cycle cooling towers
  - Allow for space to add cooling tower modules and tie-in to existing water systems
- For seawater or freshwater cooling, the temperature increase may be acceptable; however, a new cooling tower may be required
PCC Process Improvements and the Effect on Water Usage

Assuming Process Improvements Are Additive

Raw Water Usage (gpm/MWnet)

IGCC  IGCC w/CO2  USCPC  USCPC w/CO2  NGCC  NGCC w/CO2

6.1  8.3  9.9  22.3  9.7

9.16  19.2  14.5  4.5

© 2007 Electric Power Research Institute, Inc. All rights reserved.
Minimum Space Requirements

• Generally space will be required for the following:
  – CO₂ capture equipment
    • Scrubbing columns / stripper columns CO₂ Compressors
  – Boiler island additions and modifications
    • Space for routing flue gas ductwork
  – Steam turbine island additions and modifications
    • Low-pressure steam pipe to amine scrubber
  – Extension of balance-of-plant systems
  – Additional vehicle movement and safe storage and handling of amines
Other Essential Space and Sizing Considerations

- Compressed air system
- Raw water pre-treatment
- Wastewater treatment plant
- Electrical loads
  - Cable trenches
- Control and instrumentation
  - Control room extension
Retrofits Require a Lot of Space: First Come, First Served

CO$_2$ capture plant for 500-MW unit occupies 6 acres (i.e., 510 ft x 510 ft)
EPRI PC Net Power Output with and without CO$_2$ Capture (PRB Coal)

Ultra Supercritical PC

Net Power Output, MWe

New Plant No Capture

Retrofit Capture to New Plant

~ 30% reduction in power
EPRI PC Capital Cost Estimates with and without CO₂ Capture (PRB Coal)

~ 80% Increase in Capital
EPRI PC Cost of Electricity with and without CO$_2$ Capture (PRB Coal)

- COE includes $10/tonne for CO$_2$ Transportation and Sequestration

Graph showing the 30-Yr levelized COE, $/MWh (Constant 2007$)

- Ultra Supercritical PC

- New Plant No Capture
- Retrofit Capture to New Plant

70 - 100% Increase in COE
Consider CO₂ Capture Retrofit Costs for an existing 600 MW Plant

Capital cost for adding CO₂ capture and compression equipment $540 million (in 3rd quarter 2007 dollars)

= $66 million per year if financed

CO₂ transportation, measurement, and monitoring for 20 years at $10/metric ton (levelized value)

= $33 million per year

The levelized annual incremental cost for CCS (including capture plant capital recovery)

= $99 million per year

If the plant’s capital cost has been recovered a representative LCOE value is $20/MWh. Thus “breakeven” annual revenue (levelized basis) for operation at an 80% capacity factor

= $84 million per year

The new “with CCS” breakeven revenue requirement

= $183 million

Assuming the CCS retrofit reduces net plant output to 425 MW, breakeven LCOE value

= $61/MWh

Plant obligated to purchase replacement power for the 175 MW of lost output, assuming the purchase was from a new PC plant with CCS at a levelized cost of $110/MWh

The breakeven requirement for 600 MW of output with CCS

= $75/MWh
EPRI PC Capital Requirement with and without CO\textsubscript{2} Capture (PRB Coal)
EPRI Retrofit Study

EPRI Retrofit Study Considers:
• 5 different sites
• 5 separate owners
• Different designs of plant and emission control technologies
• Focus on establishing several different data points
Proposed Retrofit Study Strategy

- Collect Site Info from Hosts
- Model Each Base Power Plant
- Establish Power Plant Retrofit Based on Optimized MEA Process and Determine Costs

Builds on Knowledge from EPRI State-of-the-Art Plant CO₂ Study
Funding and Contracts Update

Total funding >$1 million and growing

• Contracts with all hosts are in place and funding from non-hosts has been secured
• Both US and International Funders
• Power Companies, Suppliers, Government Offices
• DOE participation
• Aim to work with the same Nexant and Bechtel team currently focused on EPRI ultra-supercritical capture studies
• To formally announce the project, an EPRI press release was issued in early 2009

We welcome any additional participants
In a Carbon-Constrained Economy, What Does the Future Hold for Combustion Turbine Plants?

• Many technologies proposed to capture CO$_2$ from coal-coal-fired plants are targeted at levels of greater than 90%

• These capture technologies are aggressively being developed for full commercial application within the next 10–15 years

• CO$_2$ storage know-how is also being developed within this timescale

How long before new-build or existing natural gas combined cycle plants are challenged to reduce their level of CO$_2$ emissions?

– What capture technologies should be considered?
– What costs are applicable?
California’s “De Facto” Coal Moratorium

• In January 2007, California became first state to place “de facto moratorium” on new coal plants
  – Set the standard for CO₂ emissions at 1100 lb-CO₂/MWh (500 kg-CO₂/MWh)
  – Washington state has followed a similar approach

| Pulverized Coal Plant = 1760 lb/MWh (800 kg/MWh) |
| California Standard = 1100 lb/MWh (500 kg/MWh) |
| CTCC = 800 lb/MWh (360 kg/MWh) |
| Pulverized Coal at 90% CO₂ Capture = 180 lb/MWh (80 kg/MWh) |

~80% capture required on CTCC?
CO₂ Capture…What Plant Modifications Are Required?

• For a USC PC plant to accommodate CO₂ capture from an amine process, the modified plant must be able to:
  – Extract significant quantities of LP steam
  – Extract IP steam intermittently for solvent reclaiming
    • Ion exchange processes are an alternative approach
  – Polish significant quantities of hot condensate return
  – Increase cooling water load to meet PCC demands
    • Utilize heat from CO₂ compressors
    • Adopt heat rate improvements and water conservation technologies
  – Increase electrical distribution capacity to meet PCC power demands
  – Re-route flue gas ducting to transfer flue gas to, and from, the PCC unit

CO₂ capture from gas combined cycle plant very similar
Supplemental Project: CO₂ Capture for Combustion Turbine Combined Cycle Plants: An Engineering/ Economic Study

Summary

• Based on a host participant offering an existing or planned CTCC power plant, two cases will be investigated:
  – A retrofit to the offered host plant
  – A new build plant, purpose built for capture, at the same host location

• The study will highlight the technical and economic issues associated with applying advanced amine post-combustion capture technology.

Value

• Determine performance, economic impacts and technical barriers to CTCC plants with CO₂ capture
  – Incorporate the latest in process design improvements
  – Assess the economics of retrofit versus new build CTCC with CO₂ capture
  – Highlight potential CO₂ capture-ready design considerations for CTCC plants

Details

• The estimated total cost to complete both the retrofit and new plant cases is $450,000.

• Price: $150,000 for host site;
• $50,000 all other participants
• Tailored Collaboration eligible
• Supplemental Project Notice 1018789

Contacts

• Des Dillon, 650-855-2036, ddillon@epri.com
• Dale Grace, 650-855-2527, dgrace@epri.com
Together…Shaping the Future of Electricity