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ELECTRIC POWER RESEARCH INSTITUTE

Applying Large Scale Post Combustion CO_2 Capture: The Implications for New and Existing Power Plants

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US Chamber of Commerce

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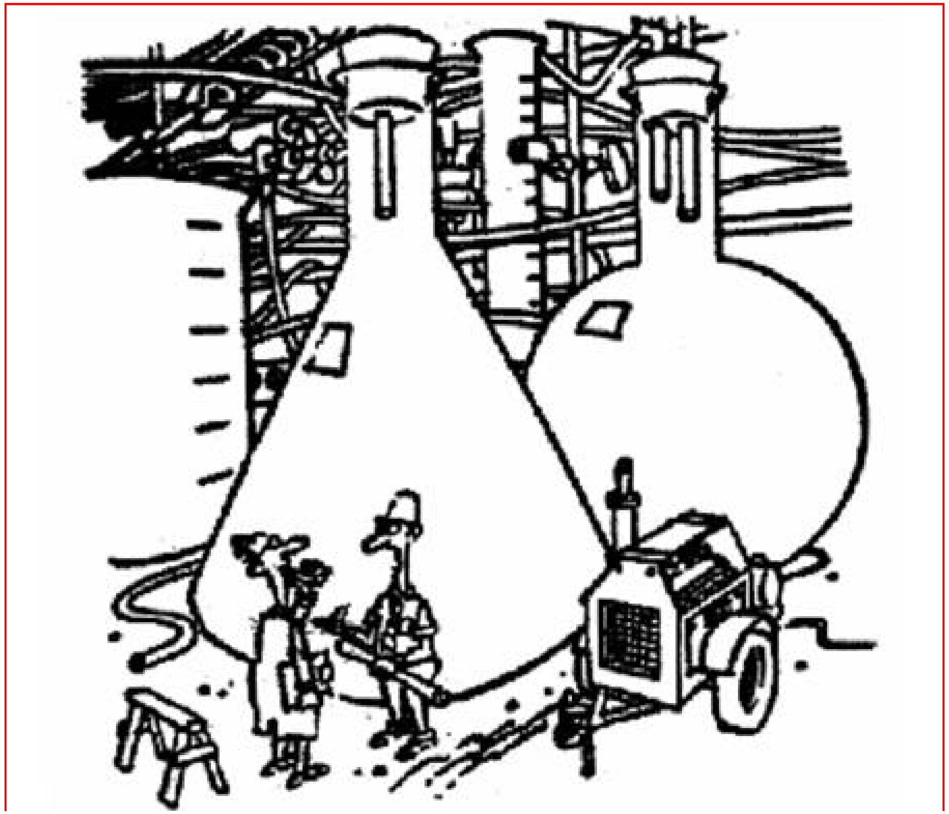
Outline

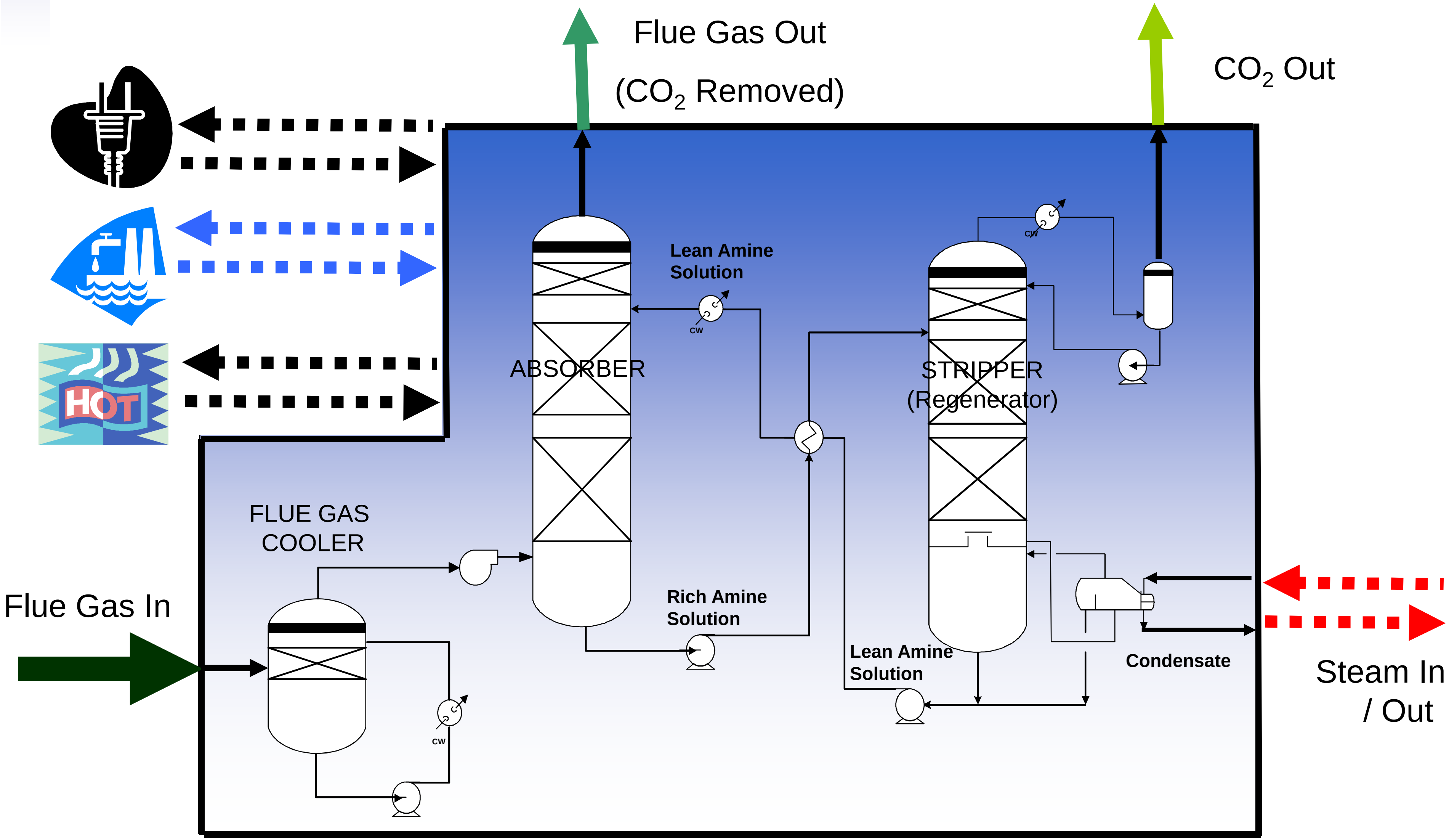
- Focus on Near term Post Combustion Capture Technologies
- Interactions with existing PC plant equipment
  – Power train
  – Heat integration
  – Water requirements
- Space
- Costs
  – Retrofit Vs new build
- EPRI Retrofit Study
- GTCC and CO_2

Developing Post Combustion Capture Technologies

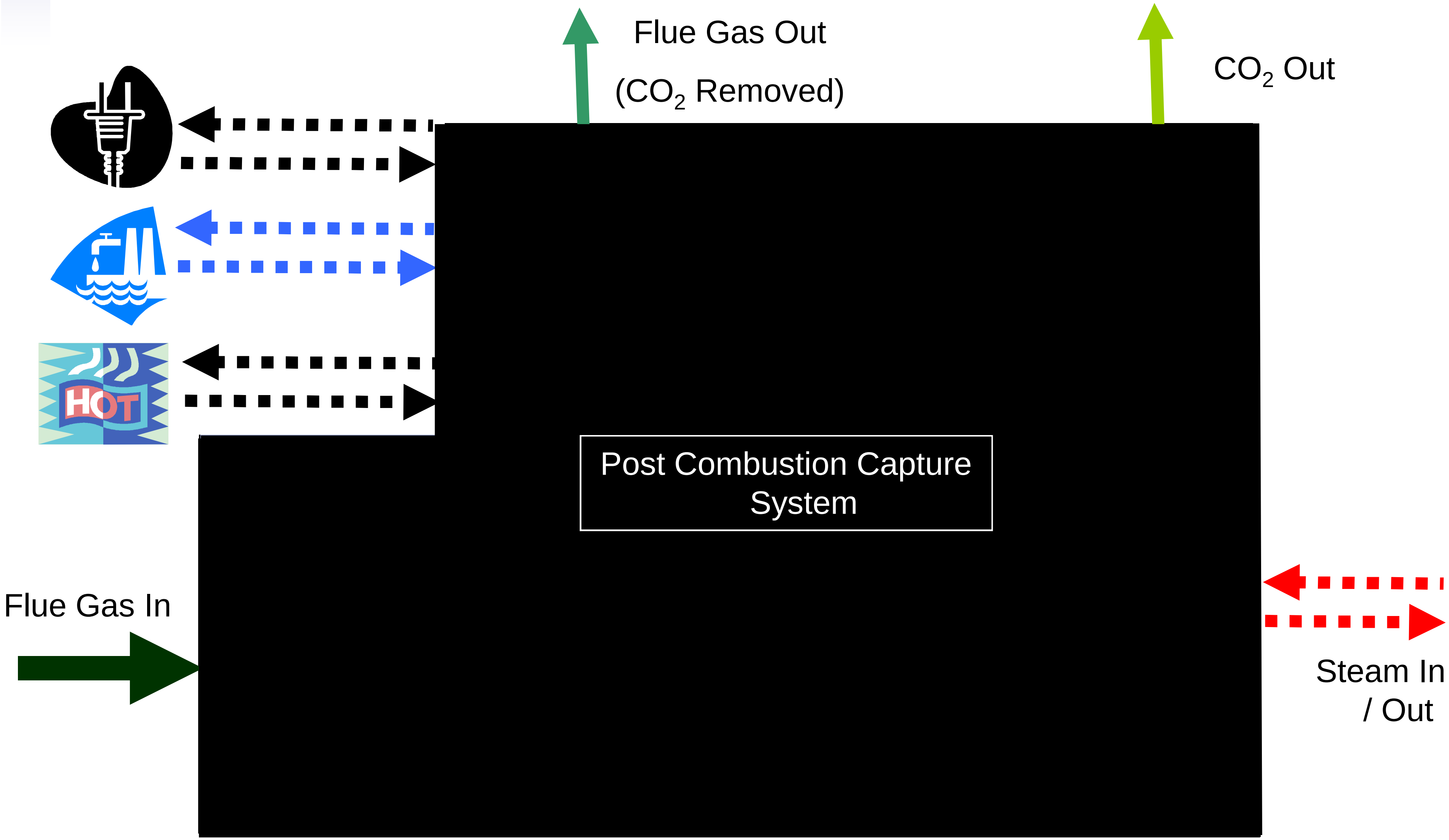


"…We seem to have a few problems going from lab-scale to full-scale production!"

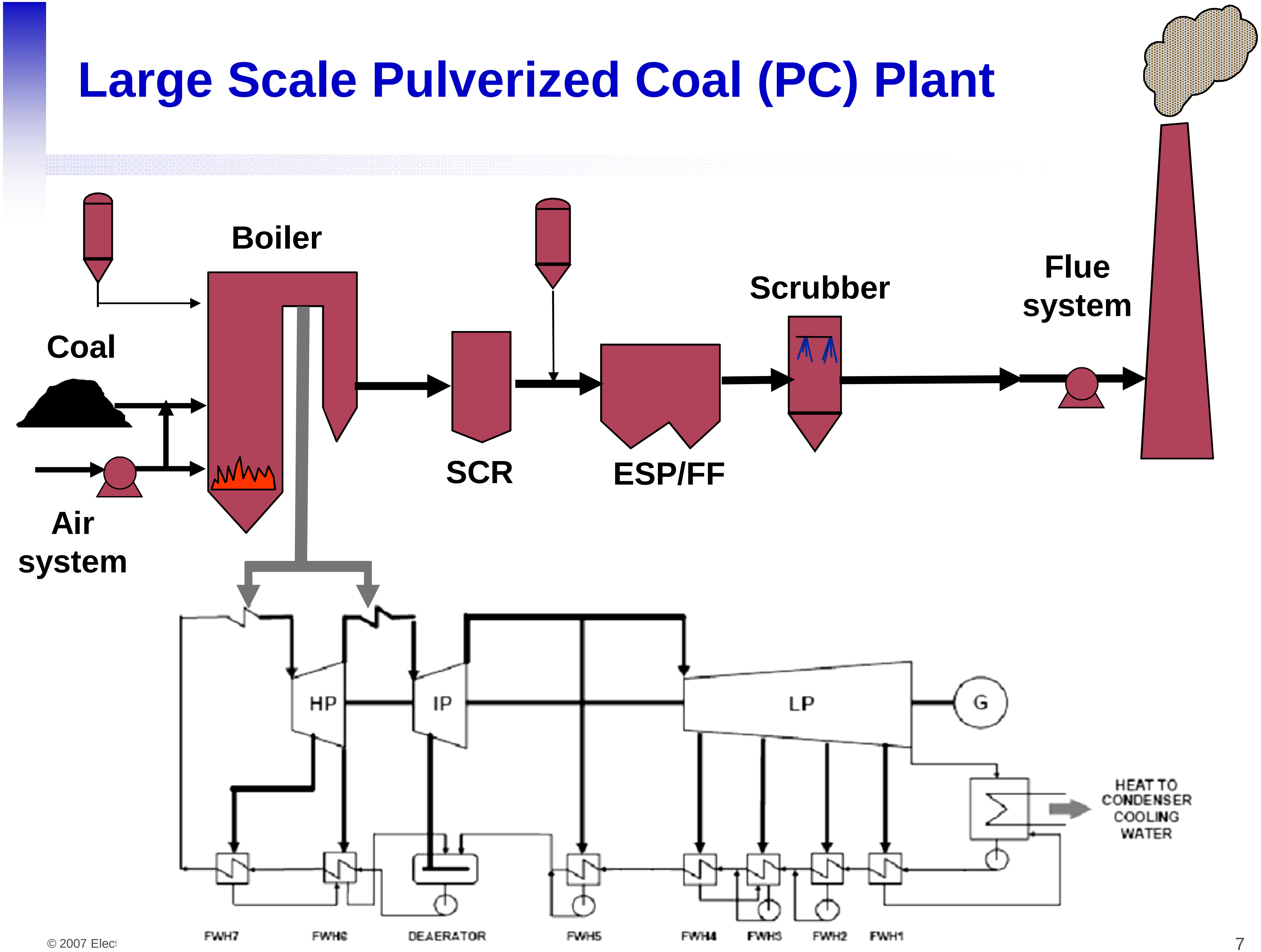
Post Combustion Capture (PCC) Plant Interactions with Power Plant



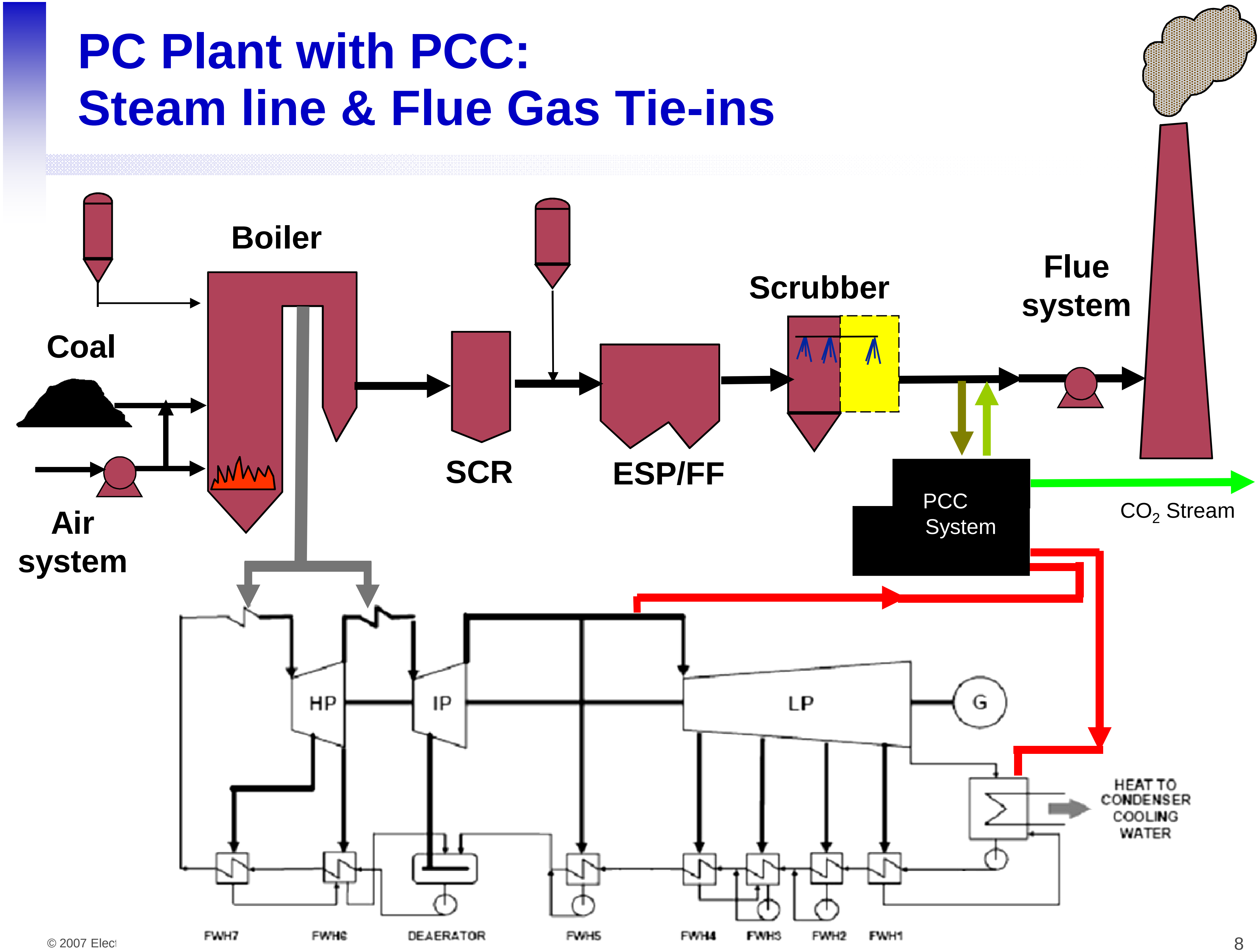
Post Combustion Capture (PCC) Plant Interactions with Power Plant



Large Scale Pulverized Coal (PC) Plant

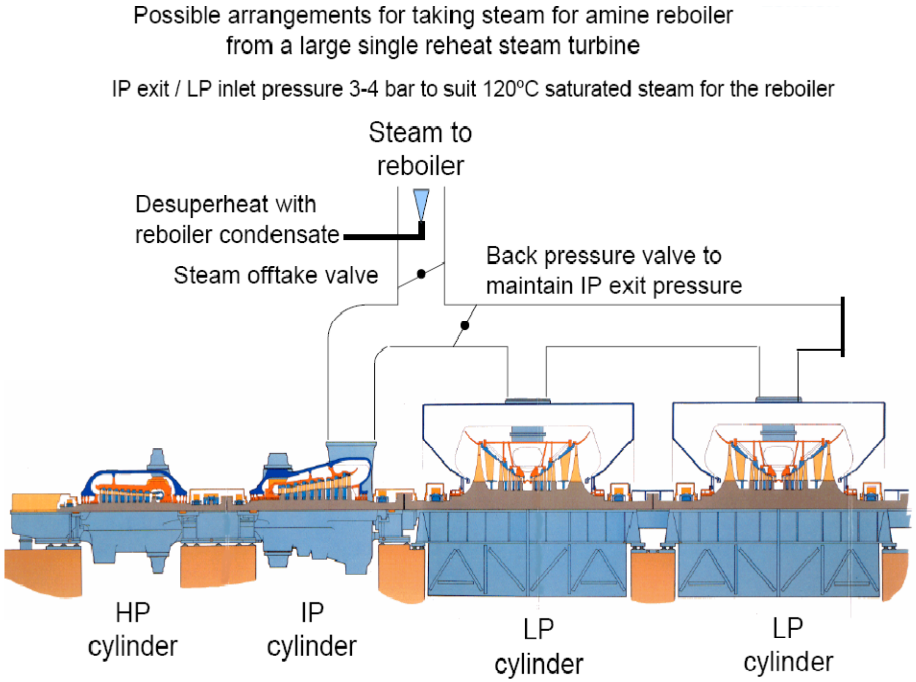


PC Plant with PCC:
Steam line & Flue Gas Tie-ins



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



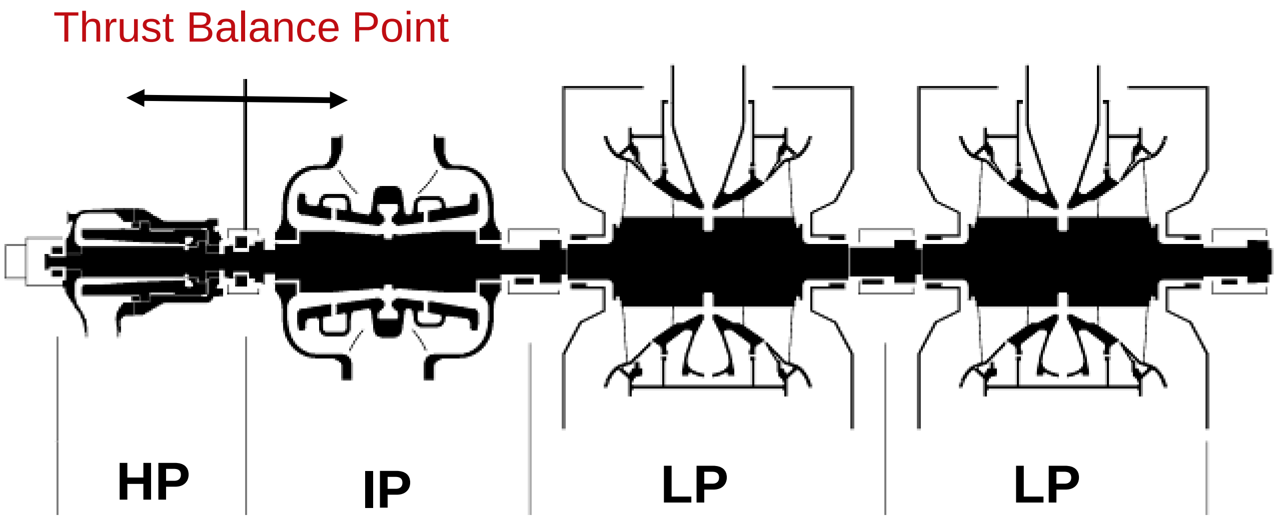
Source: Imperial College London

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

Rotor Thrust Balance Issues



•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

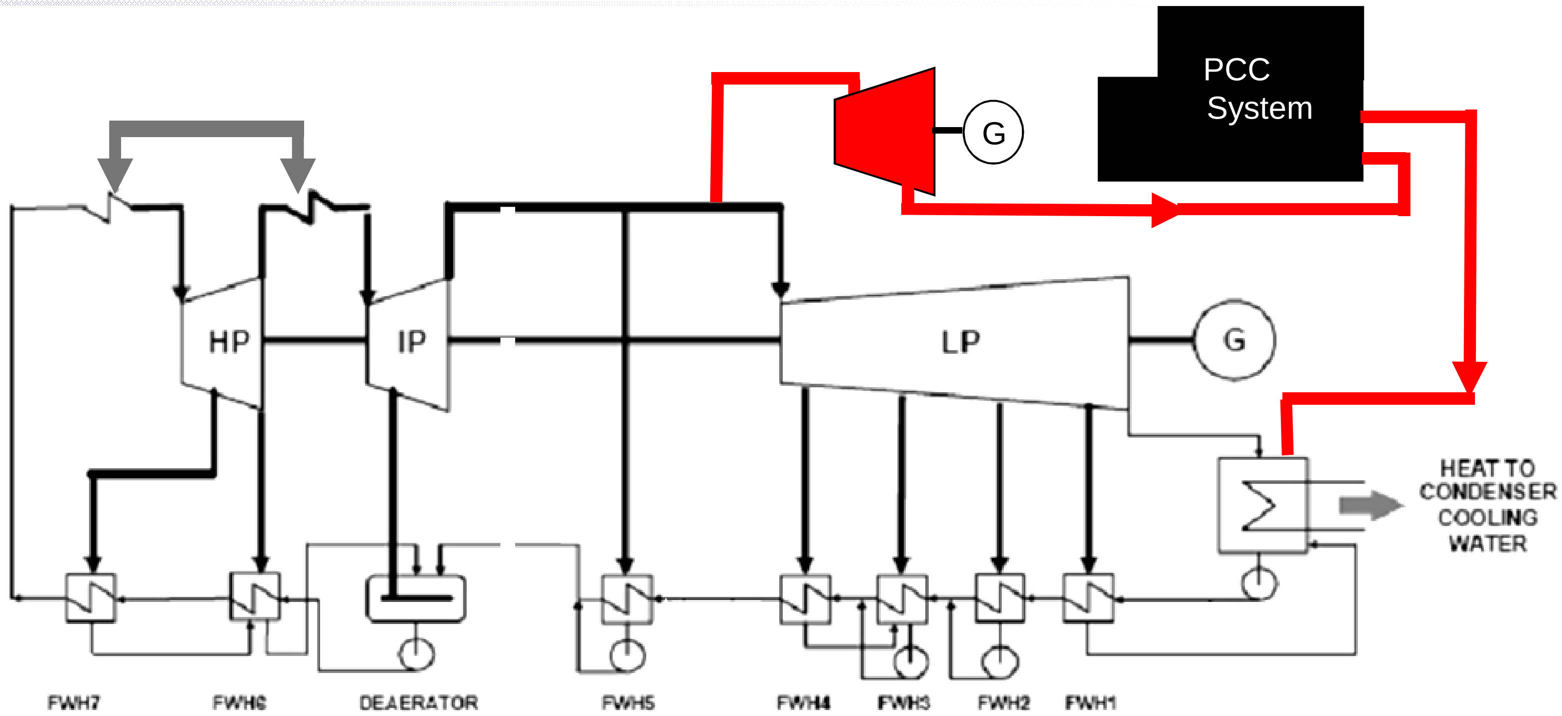
Modifications may need to be made to the balance diaphragms and thrust bearings to accommodate the revised thrust loads.

PCC Retrofit to Existing Coal Plants Implementation Suggestions

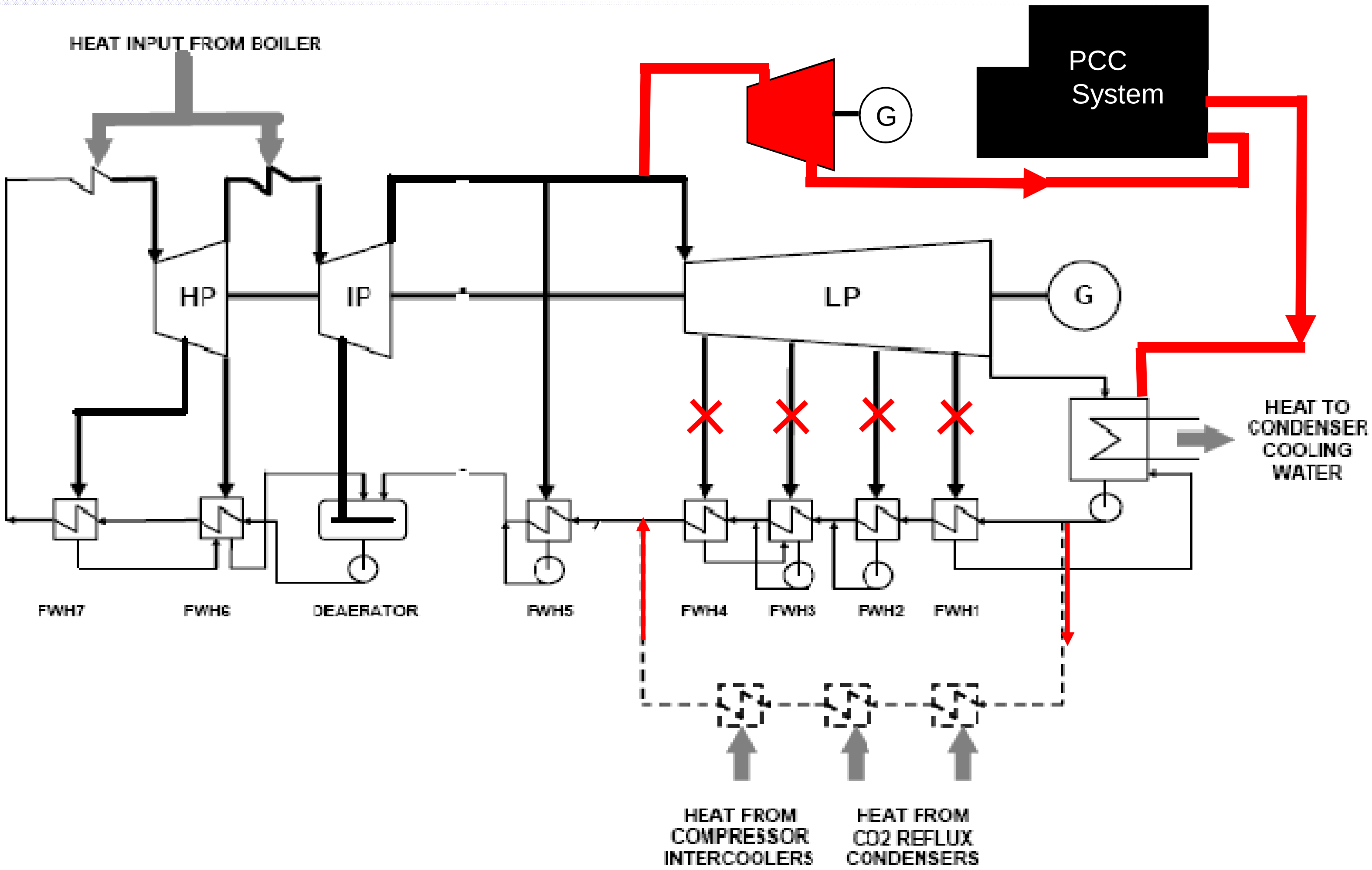
- PCC retrofit will affect significantly more plant systems and components than a typical scrubber or SCR back-fit due to the PCC steam demand
- PCC operational profile should be defined early
  - Partial CO_2 Removal / Maximum CO_2 Removal
  - Full time operation / Seasonal operation
- The steam-water 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.

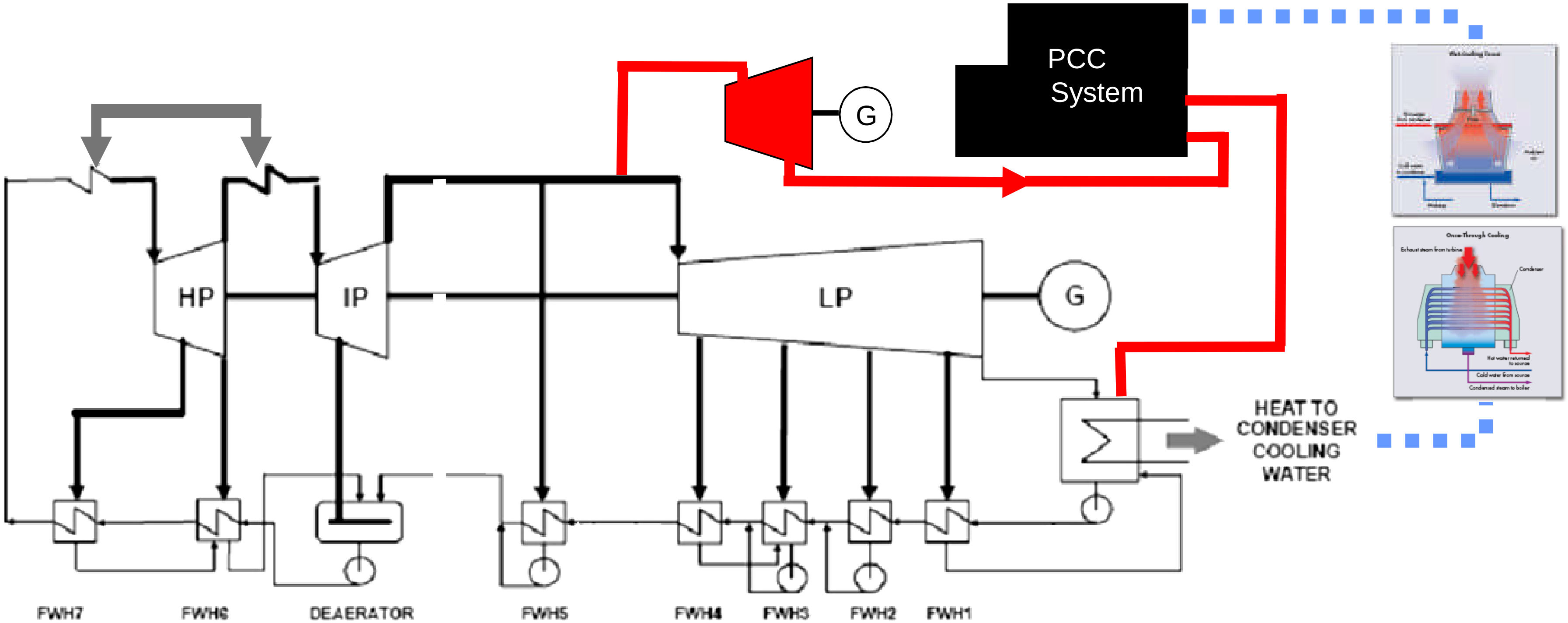
PC Plant with PCC: Let Down Turbine and Condensate Return



PC Plant with PCC: Heat Integration

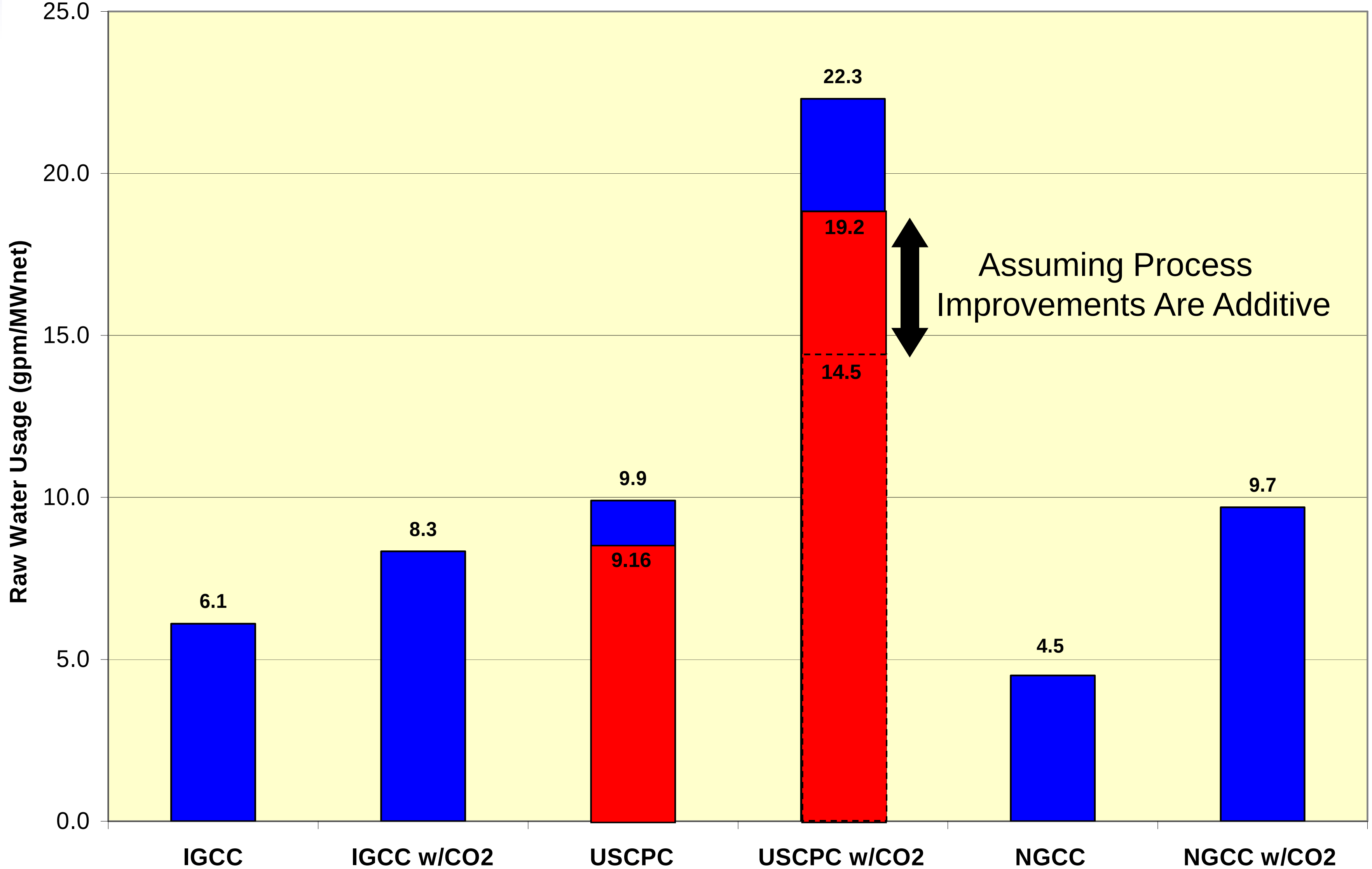


PC Plant with PCC: Water Requirements



- 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

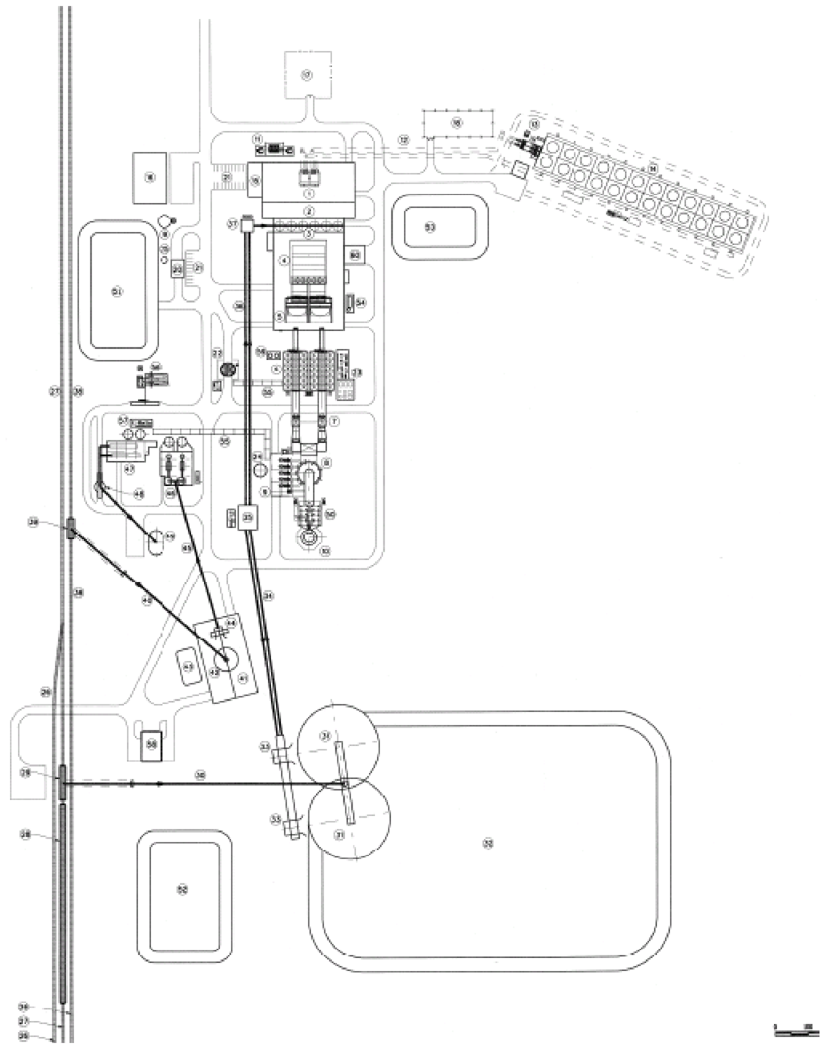


Minimum Space Requirements

- Generally space will be required for the following:
  - CO_2 capture equipment
    - Scrubbing columns / stripper columns CO_2 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



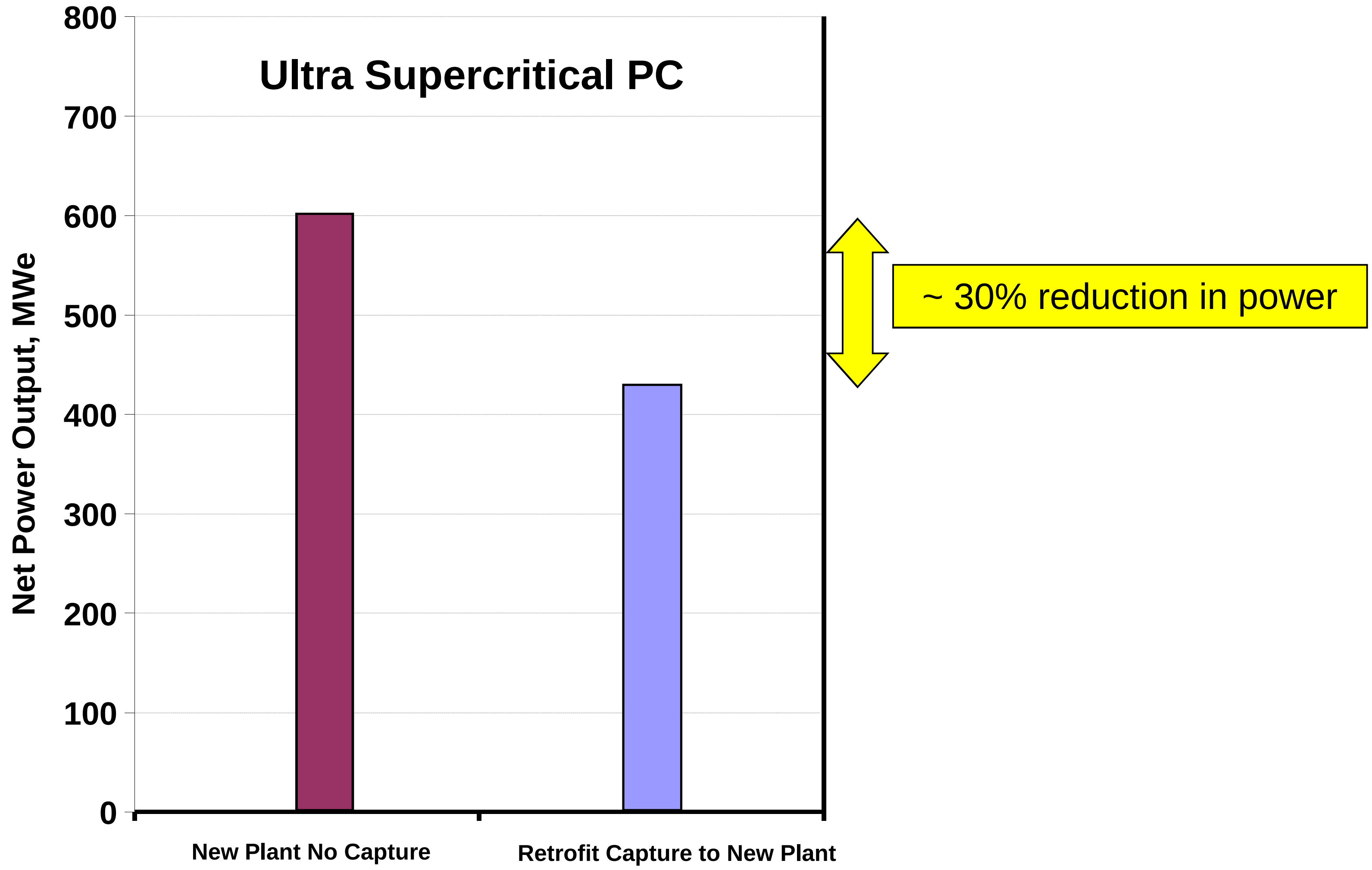
Retrofits Require a Lot of Space: First Come, First Served

June 1990

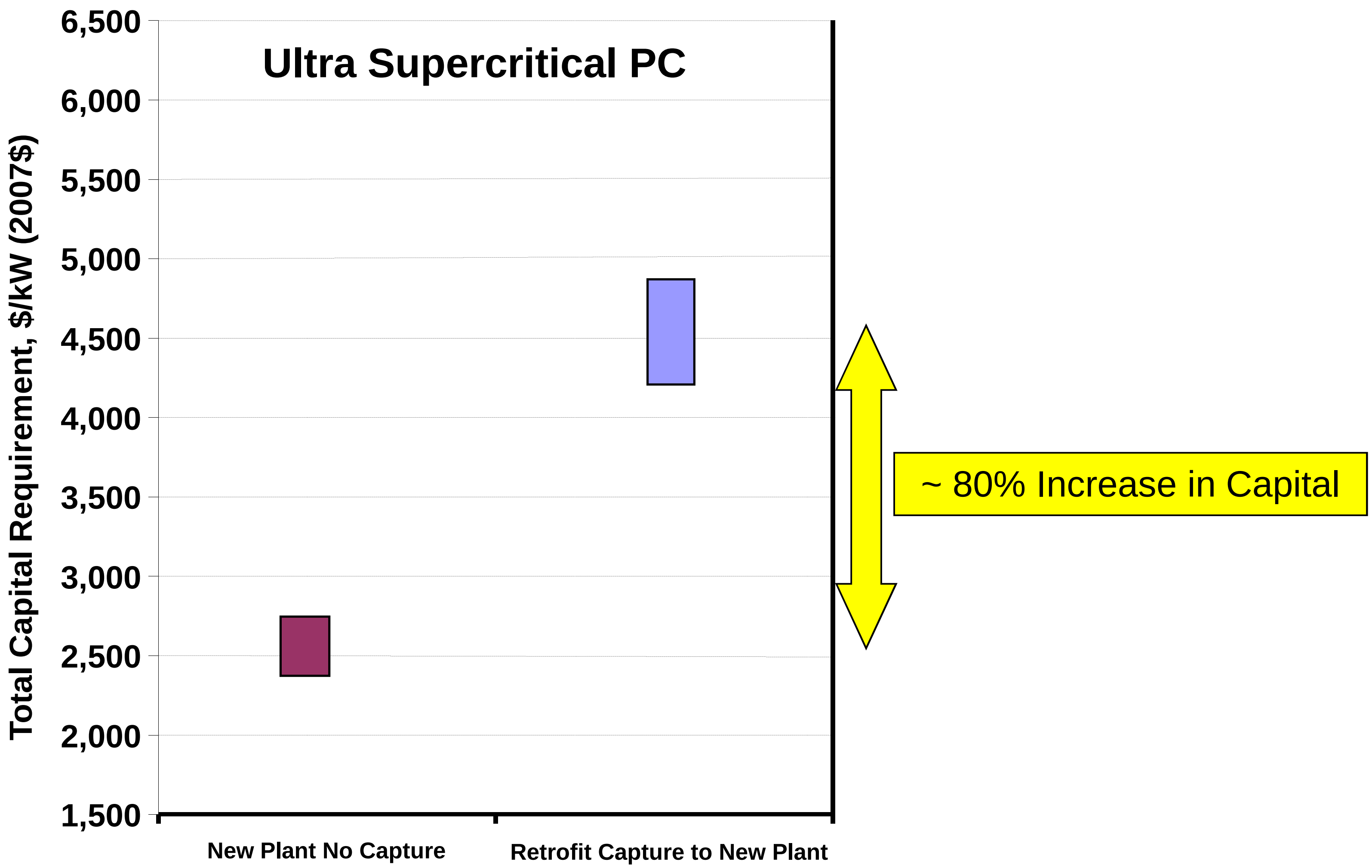
December 2006

CO_2 capture plant for 500-MW unit occupies 6 acres (i.e., 510 ft x 510 ft)

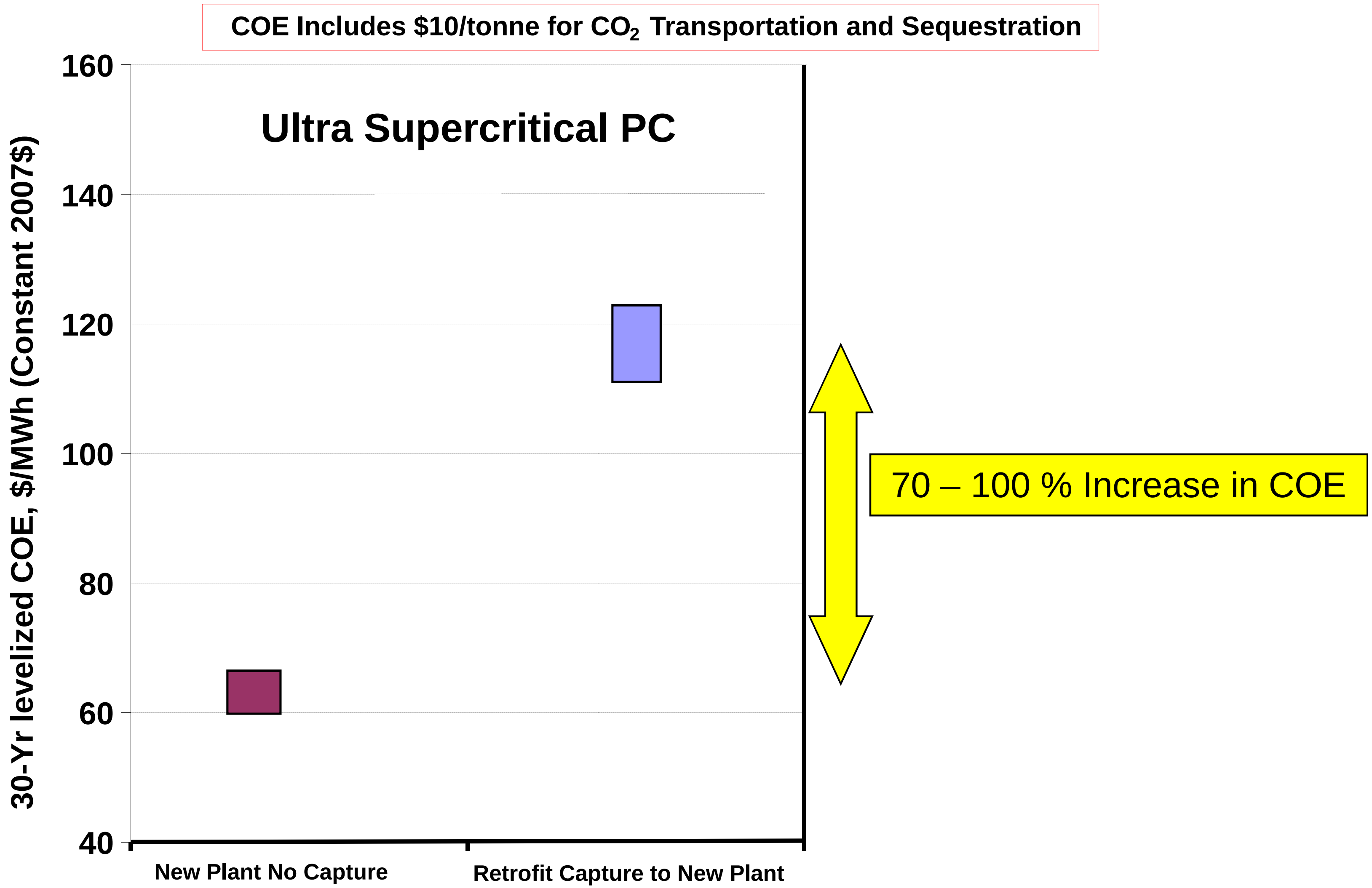
EPRI PC Net Power Output with and without CO_2 Capture (PRB Coal)



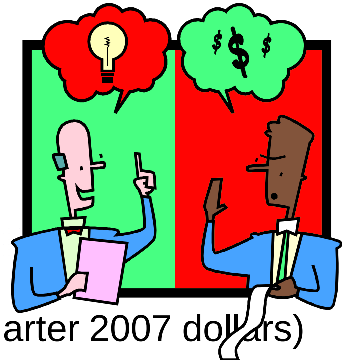
EPRI PC Capital Cost Estimates with and without CO_2 Capture (PRB Coal)



EPRI PC Cost of Electricity with and without CO_2 Capture (PRB Coal)



Consider CO_2 Capture Retrofit Costs for an existing 600 MW Plant



Capital cost for adding CO_2 capture and compression equipment $540 million (in 3rd quarter 2007 dollars)

= $66 million per year if financed

CO_2 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

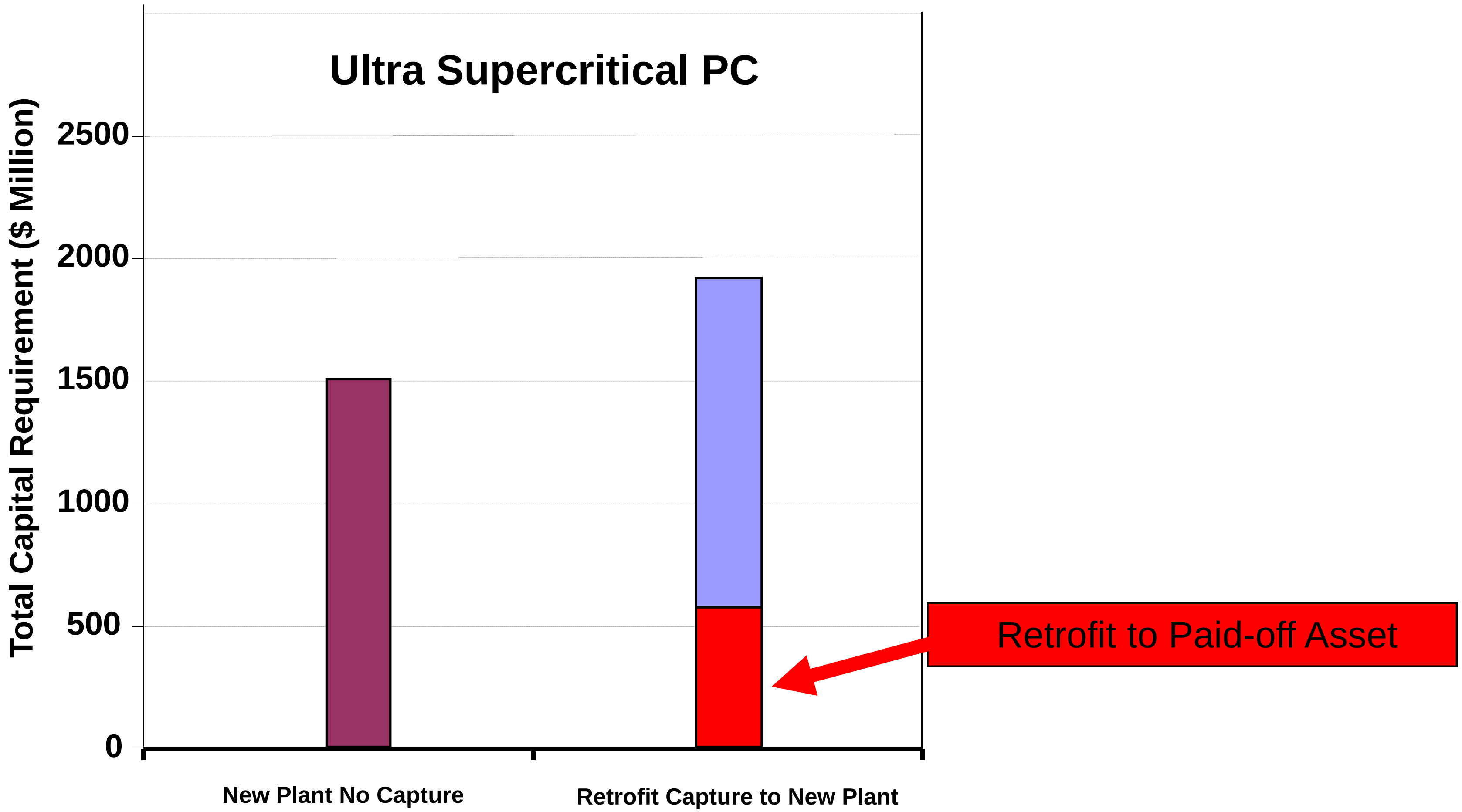
= $61/MWh

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

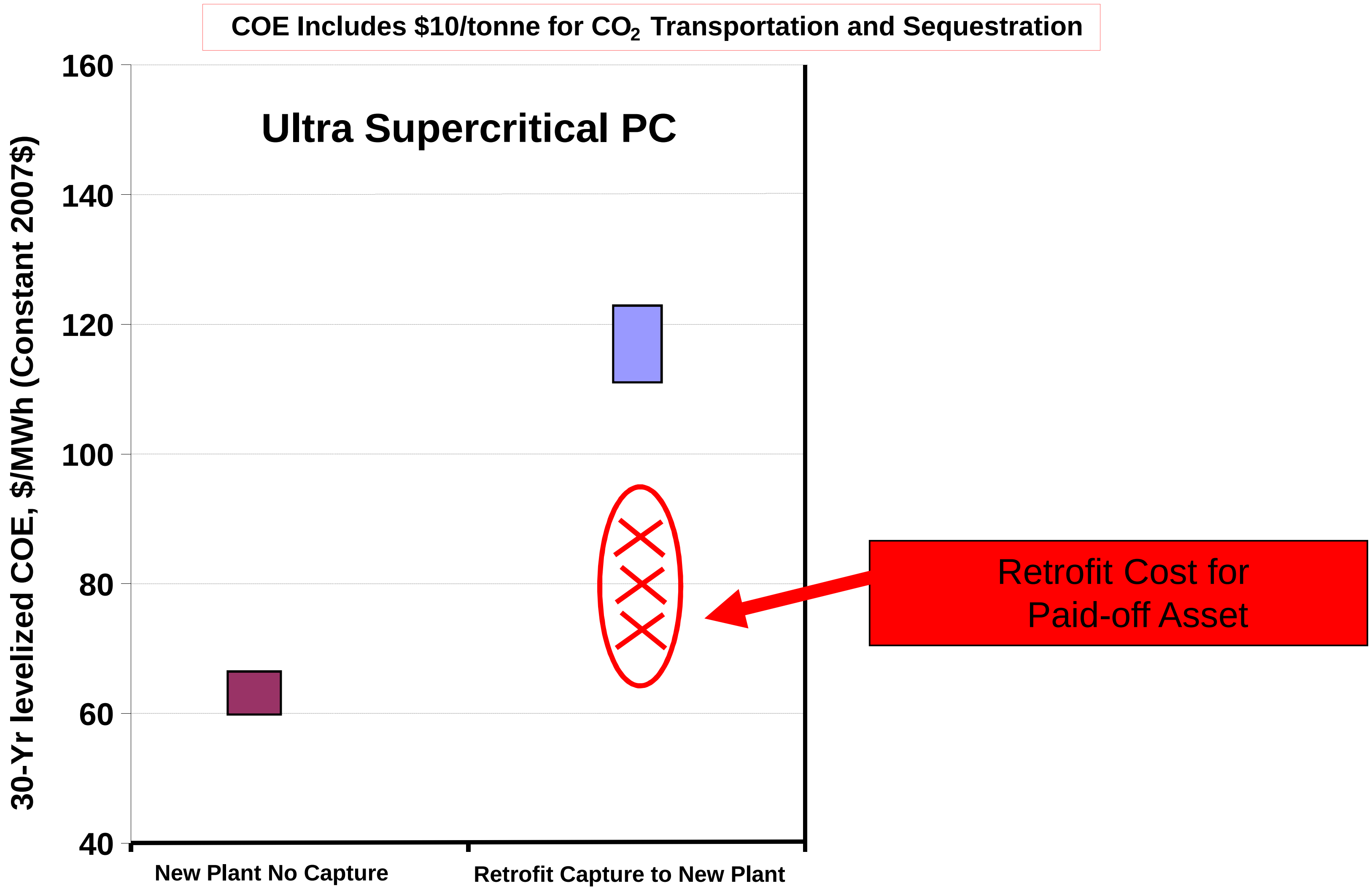
The breakeven requirement for 600 MW of output with CCS

= <u>$75/MWh</u>

EPRI PC Capital Requirement with and without CO_2 Capture (PRB Coal)



EPRI PC Cost of Electricity with and without CO_2 Capture (PRB Coal)



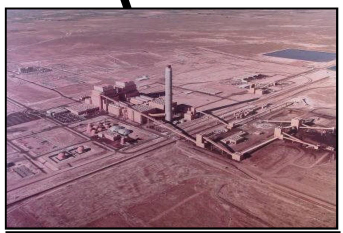
EPRI Retrofit Study

- Owner: **MidWest Generation**
- Location: **Illinois**

- Owner: **Nova Scotia Power**
- Location: **Nova Scotia**

- Owner: **Great River Energy**
- Location: **North Dakota**

- Owner: **FirstEnergy**
- Location: **Ohio**

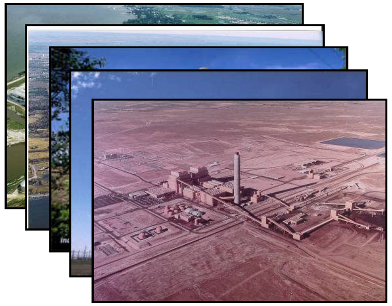


- Owner: **Intermountain Power**
- Location: **Utah**

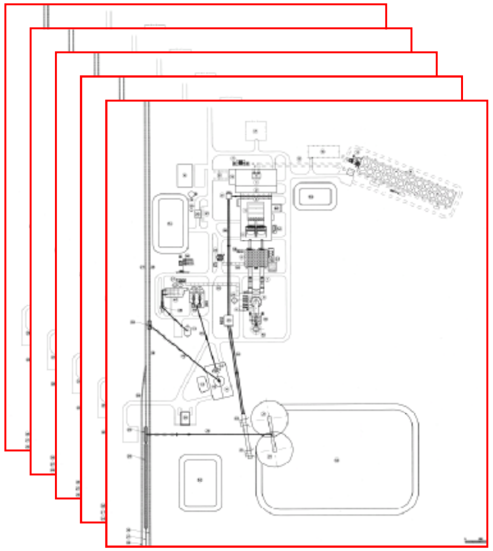
EPRI Retrofit Study Considers:

- 5 different sites
- 5 separate owners
- Different designs of plant and emission control technologies
- Focus on establishing several different data points

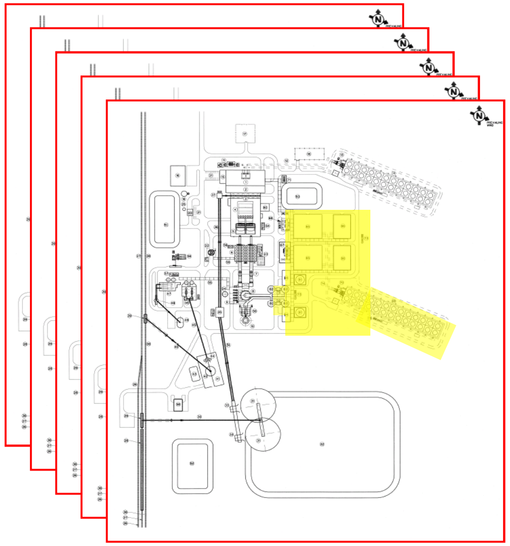
Proposed Retrofit Study Strategy



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 CO_2 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?

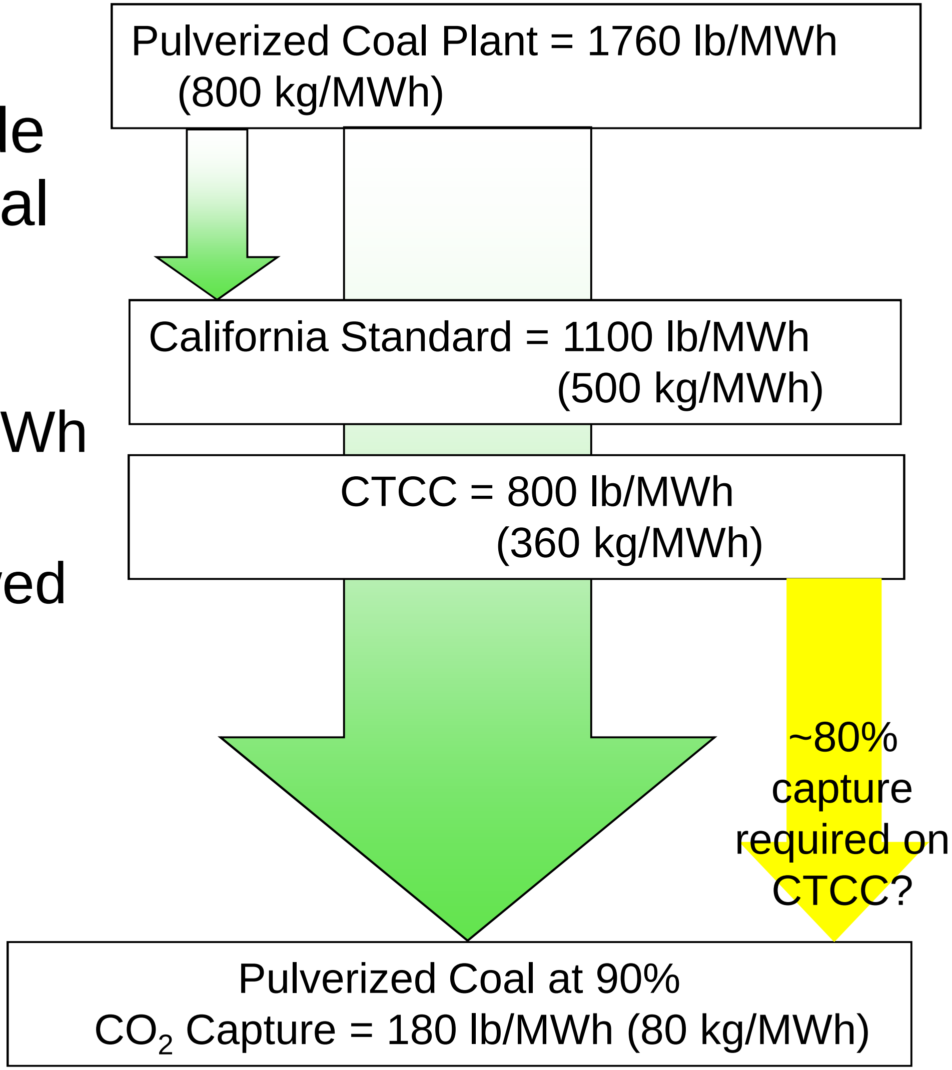
- Many technologies proposed to capture CO_2 from coal-coal-fired plants are targeted at levels of greater than 90%
- These capture technologies are aggressively being developed for full commercial application within the next 10–15 years
- CO_2 storage know-how is also being developed within this timescale

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?

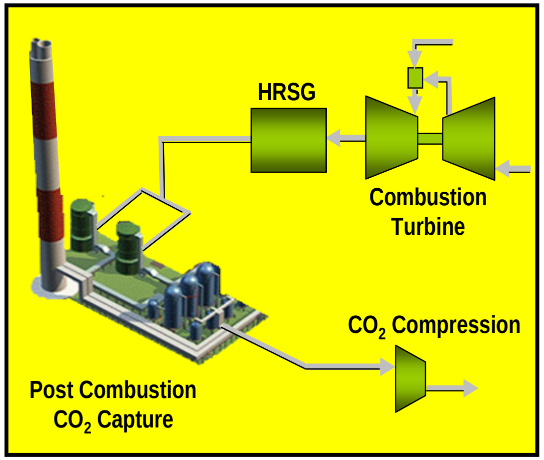
California's "De Facto" Coal Moratorium

- In January 2007, California became first state to place "de facto moratorium" on new coal plants
  - Set the standard for CO_2 emissions at 1100 lb-CO_2/MWh (500 kg-CO_2/MWh)
  - Washington state has followed a similar approach



CO_2 Capture…What Plant Modifications Are Required?

- For a USC PC plant to accommodate CO_2 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 CO_2 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

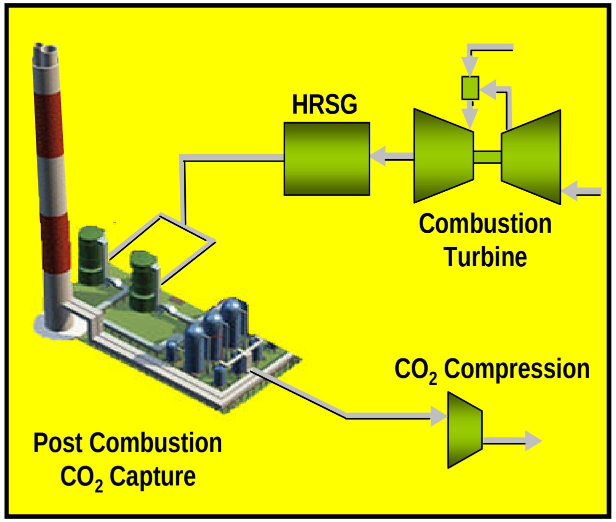


CO_2 capture from gas combined cycle plant very similar

Supplemental Project: CO_2 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 CO_2 capture
  - Incorporate the latest in process design improvements
  - Assess the economics of retrofit versus new build CTCC with CO_2 capture
  - Highlight potential CO_2 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

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