Development of Cost Effective Oxy-Combustion for Retrofitting Coal-Fired Boilers

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Annual NETL CO_2 Capture Technology for Existing Plans R&D Meeting – March 24-26, 2009

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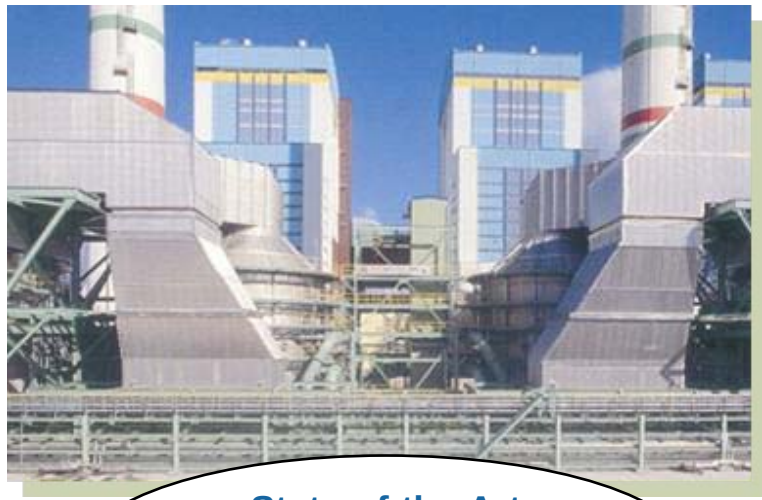
Who We Are: Babcock & Wilcox PGG

State-of-the Art
Steam Generating
Systems



State-of-the Art
Environmental Control
Systems

Since 1867, we are the *original* Babcock & Wilcox with extensive experience in engineering, manufacturing, constructing and servicing steam generating and environmental control systems.

George Babcock

Stephen Wilcox

B&W Oxy/Coal Combustion Experience

- 1979 Numerical Modeling per request of a major oil company
- 2000 Member CANMET

Recent Developments with Air Liquide Collaborations

- 2001-2002 - Oxy-combustion with IL#6 coal performed at 5 million Btu/hr SBS facility, sponsored by the State of Illinois
  - **Substituted secondary air with recycled flue gas & oxygen**
  - **Gained experience with oxygen/flue gas mixing and combustion**
- 2003-2004 - Oxy-combustion with PRB, sponsored by DOE
  - **Demonstrated oxy-combustion at 5-million Btu/hr, achieved stable low-NO_x flame with acceptable heat transfer conditions**
- 2005-2006 - Economic analysis
  - **Working with DOE, Parsons, Air Liquide**
  - **Oxy-combustion compared favorably to amine scrubber**
- 2007-2008 – 30 MW_{th} Demonstration at B&W's CEDF
  - **Near-Full scale burner development fed directly from an on-line pulverizer**

Development of Cost Effective Oxy-Combustion for Retrofitting Coal-Fired Boilers

- **Funding Sponsors**
  - DOE $2,762,643
  - B&W/Air Liquide $690,644
  - Total $3,453,287

- **Project Duration**
  - March 2006 to September 2009

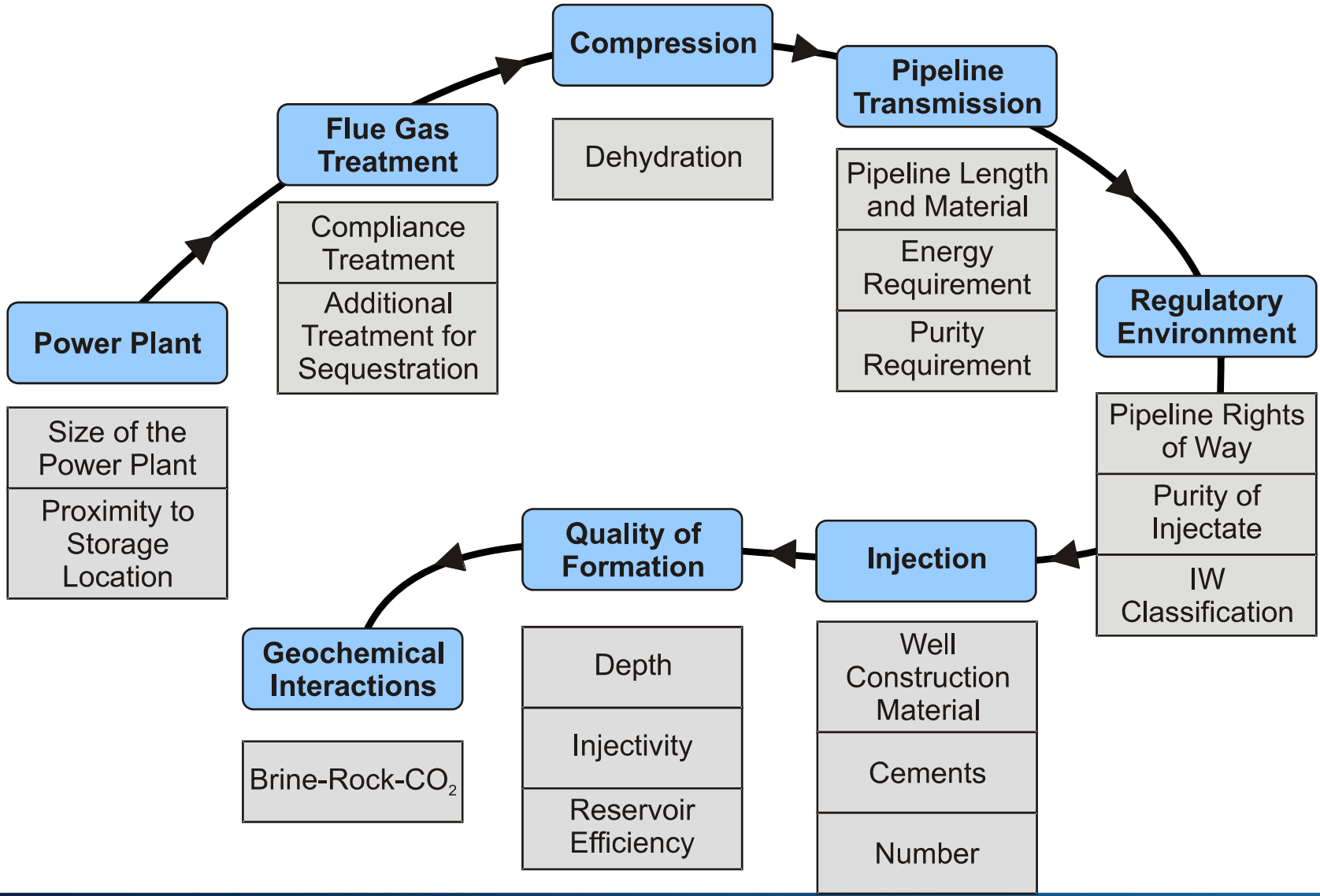
- **Project Team**
  - B&W
  - Air Liquide
  - Battelle Memorial Institute

Project Objectives

To Significantly Expand the Applicability of Oxy-Combustion:

- Evaluate the effect of coal rank that is currently used in existing boilers (i.e., bituminous, sub-bituminous and lignite) in an oxy-combustion design.
- Determine the equipment requirements for the boiler island, flue gas purification, CO_2 compression, transportation, and storage for different coals and combustion systems (cyclone and wall-fired).
- Investigate the potential for multi-pollutant (NO_x, SO_2, and particulate) reduction.
- Validate an existing 3-dimensional computational flow, heat transfer, and combustion model for oxy-combustion scale-up to a commercial size boiler.
- Conduct an engineering and economic assessment of the technology for commercial-scale for cyclone and wall-fired units.

Oxy-Coal Combustion Gas Treatment and Storage



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Process Modeling

- Boiler island: modeling to predict flue gas compositions
- Sequestration: simulations to determine "sequestration-ready" gas specifications
- CO_2 CPU: process design to capture CO_2 from flue gas for sequestration purposes
- 3 coals considered
  - North Dakota Lignite
  - Decker coal (sub-bituminous)
  - Illinois #6 coal (bituminous)

Flue Gas Composition from Boiler

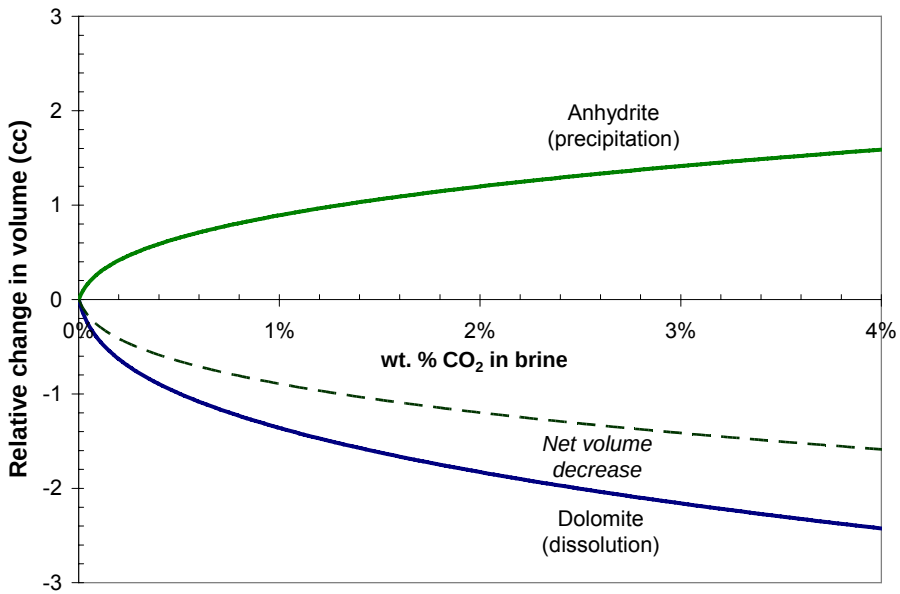
- Flue gas compositions predicted assuming high air infiltration rate & minimal SO_2 removal with bituminous coal

	ND Lignite		Decker		Illinois # 6	
	Wet	Dry	Wet	Dry	Wet	Dry
Item	mol%	mol%	mol%	mol%	mol%	mol%
H2O	17.41	0.00	17.42	0.00	17.43	0.00
CO_2	**59.63**	**72.20**	**59.57**	**72.14**	**58.18**	**70.46**
N_2	16.01	**19.38**	16.32	**19.76**	17.63	**21.35**
O_2	4.10	4.96	4.00	4.85	4.11	4.97
SO_2	0.3797	0.46	0.1350	0.16	0.1004	0.12
Ar	2.40	2.90	2.50	3.03	2.50	3.03
NO_2	0.0619	0.075	0.0248	0.030	0.0380	0.046
CO	0.0165	0.020	0.0165	0.020	0.0165	0.020

- Low air infiltration case also considered
  - N_2 reduced to 10%

Reservoir and Geochemical Interactions

- Co-sequestration of CO_2 and SO_2 appears to be technically feasible in many deep saline reservoirs, but the injection lifetime of these reservoirs could be reduced if precipitation reactions take place.
- In carbonate-rich formations, sulfate could be a problem. Geochemical modeling results indicate that screening must be done to identify potential precipitation of sulfate minerals, such as anhydrite, which could reduce injectivity.
- To maintain supercritical state in a mixture of CO_2 and noncondensable gases, the flue gas will need to be injected in formations with higher pressure than would be needed for pure CO_2.
- In some reservoirs, storage space may be so limited that it is necessary to remove N_2 and O_2 to maximize the storage capacity.

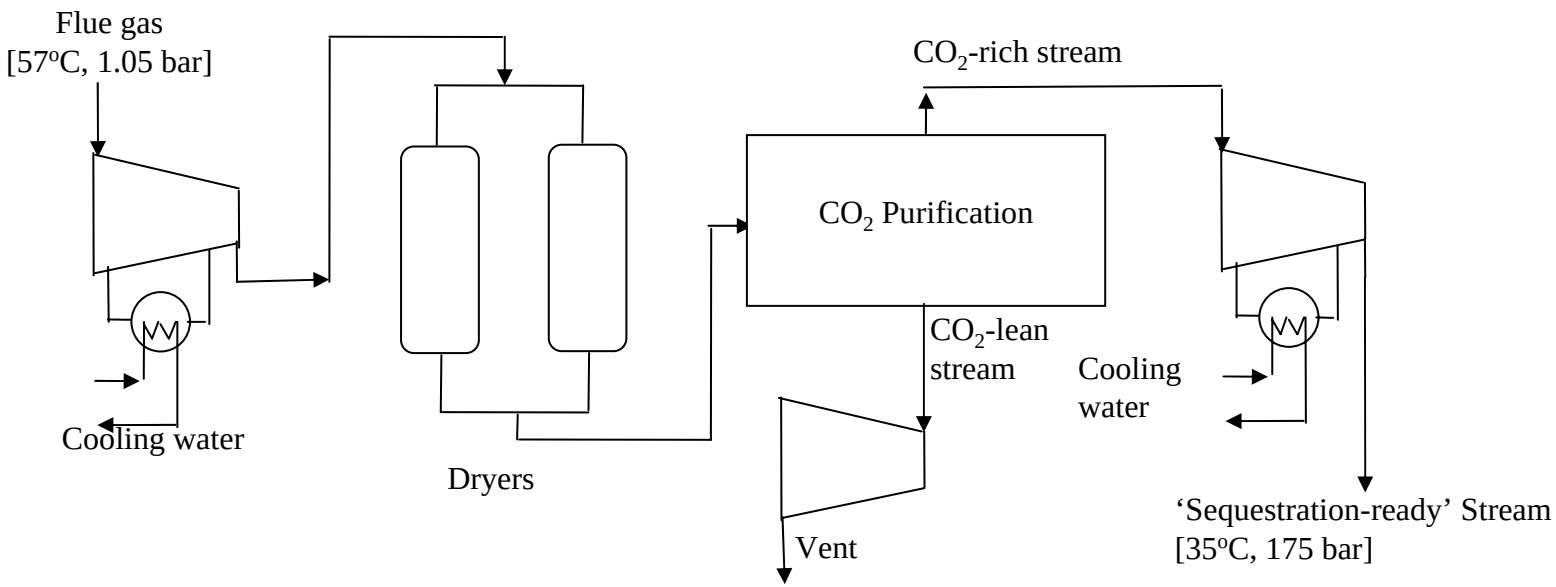


Development of Cost Effective Oxy-Combustion for Retrofitting Coal-Fired Boilers

- Existing CO_2 pipeline specifications are mainly for gasification units
  - No NO_x guidelines
  - Limited SO_x guidelines
  - Significant variation in other specifications
    - H_2O: -5°C to -40°C dew point
    - O_2: 10 to 100 ppmv

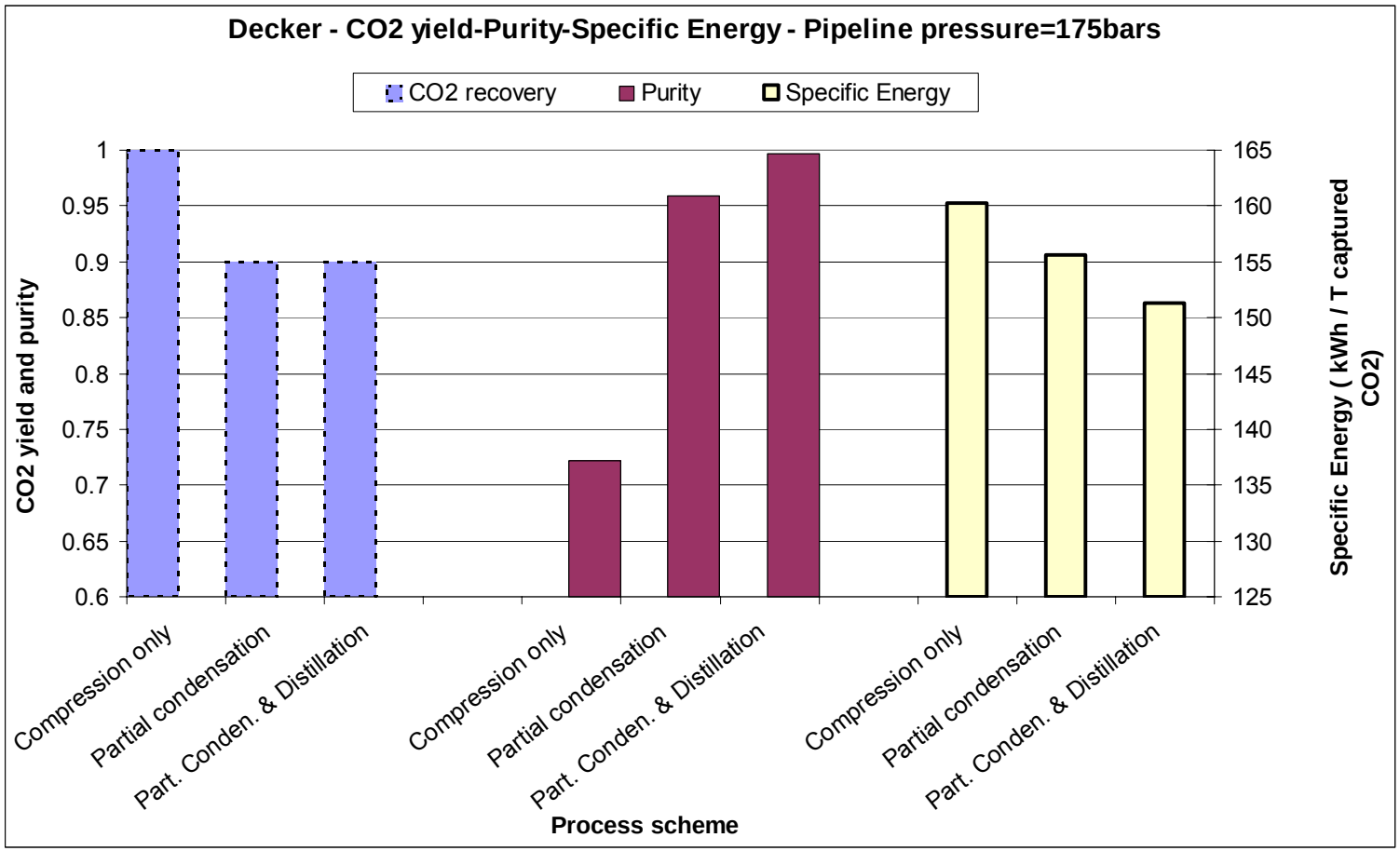
- Specifications assumed for this study:
  - 175 bara
  - 90% CO_2 capture (DOE target)
  - H_2O reduced to 30lb/MMSCF (~600ppmv)
    - existing Kinder Morgan specification
  - No restriction on other gas components
    - Possibility of co-sequestration
    - Chance to assess tradeoff between purification cost and sequestration cost

Basic CO_2 CPU Process



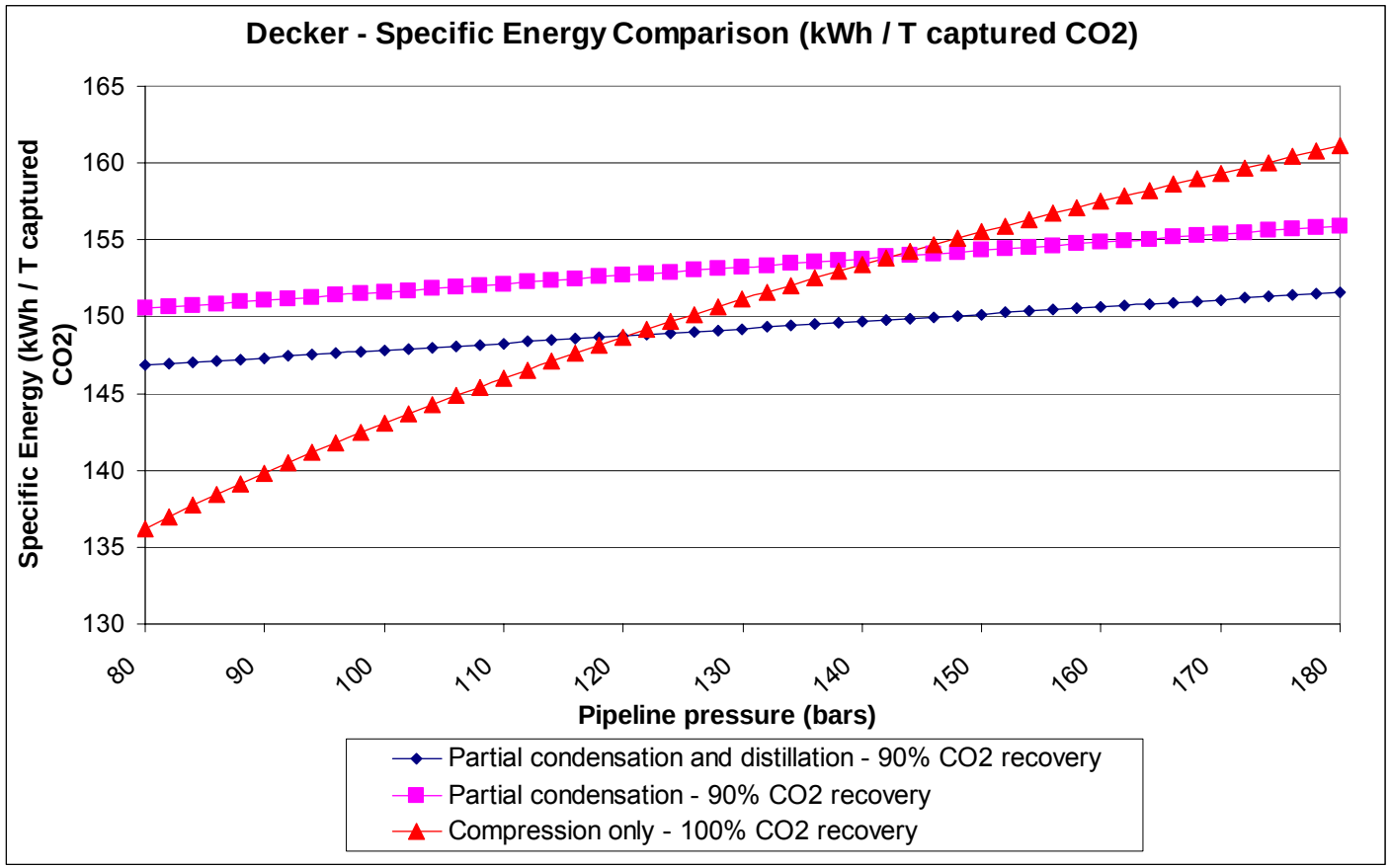
- 3 processes
  - No purification
    - » *only drying to Kinder Morgan specifications*
  - Partial condensation at cryogenic conditions (cold box)
    - » *95% CO_2 purity target*
  - Cold box, including distillation
    - » *1ppm O_2 target*

Operating Energy Requirement of CPU



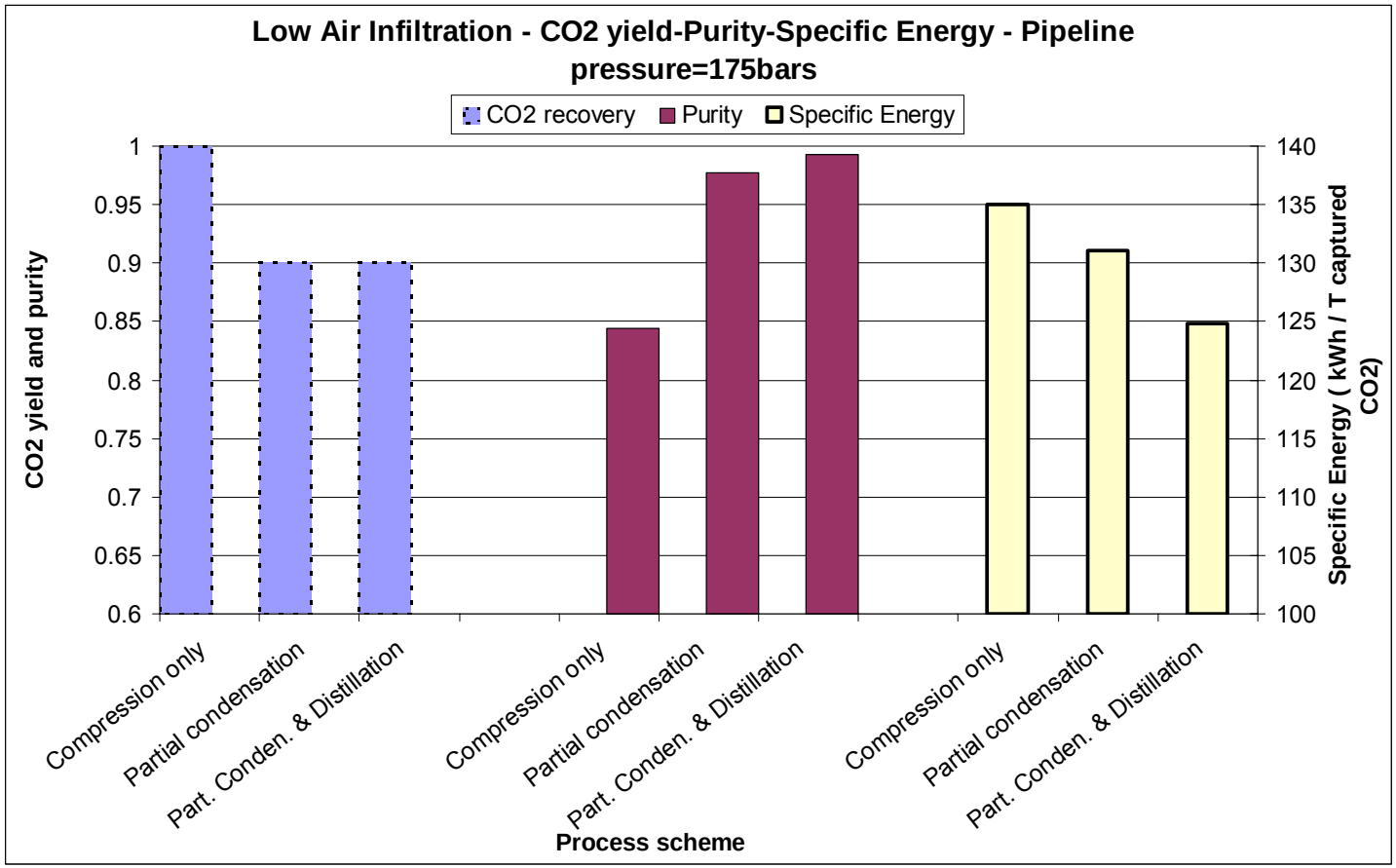
- Addition of a cold box REDUCES specific energy requirement!
  - Will a different pipeline pressure requirement give different results?

Effect of Product Pressure on Specific Energy



- Above 125 bar (1815 psi) pipeline pressure, cold box + distillation has lowest specific energy requirement

Operating Energy Requirement of CPU



Compare with 150-160 kWh/ton

- Low air infiltration reduces power need by 15-18%

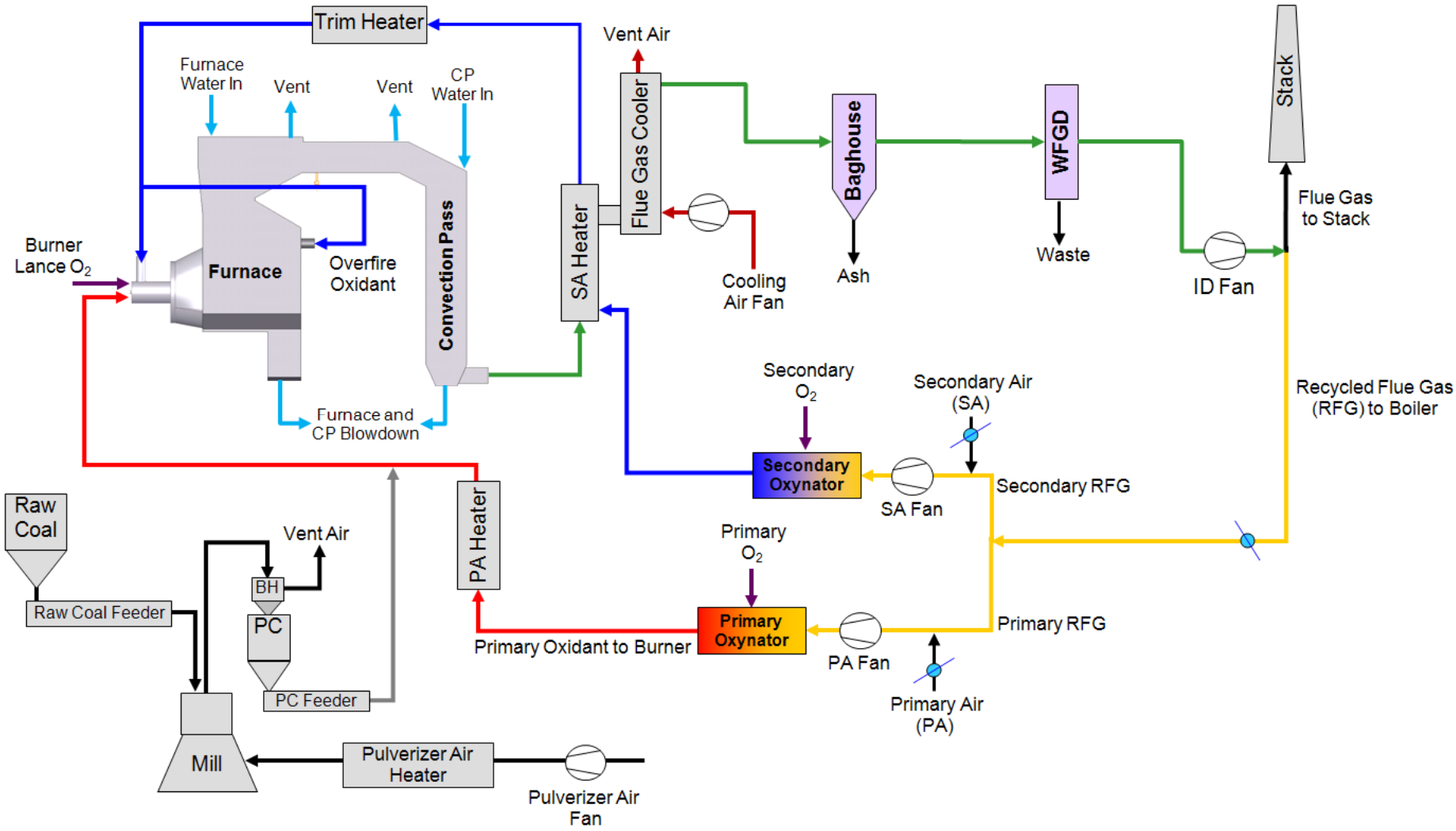
CPU Conclusions/Summary

- Due to high pipeline pressure requirement, CO_2 purification reduces specific energy (Compare to compression only case)

- Air Infiltration has a significant effect on overall energy requirement of oxy-coal combustion

- It has to be evaluated (experimentally) whether the wet compressors can handle the SO_x and NO_x levels in the wet flue gas from the boiler island
  - Not in the scope of this project

Pilot-Scale Process



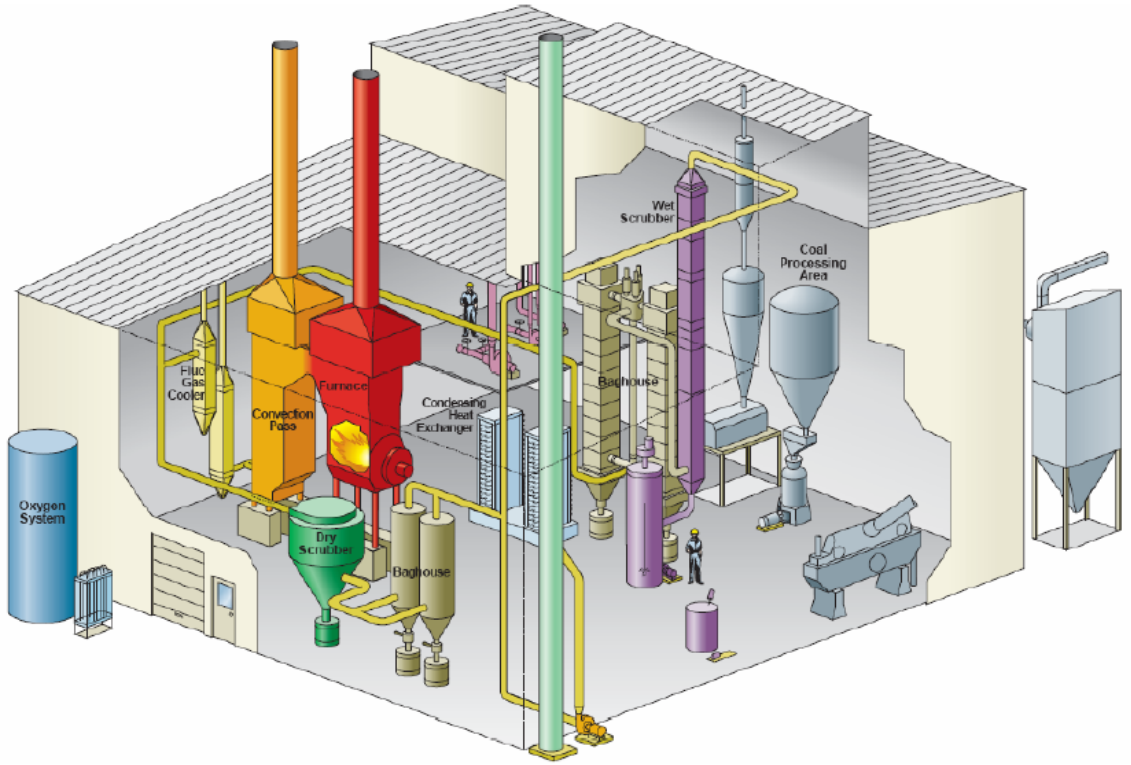
Pilot-Scale Evaluation

Significantly Expand Applicability
- Bituminous, PRB, lignite
- Cyclone firing

New Oxy-Combustion ready Facility
- 6 million Btu/hr – SBS- II
- Cyclone and Wall-firing
- Dry/Wet Scrubber
- Construction Completed
- Just passed EPA performance

Currently Planning for:
- DOE Oxy-cyclone
- USC Materials Oxy-combustion

2nd to 4rd Quarter 2009 Testing



Engineering & Economic Evaluations

U.S. State	Vint-age	MW_e	Eff. (HHR)	Coal Type	SOx (ppm)	SO2 Control	NOx Control	Selection
Illinois	1967, 1968	2x 660	33%	Sub-bituminous	200-300	No	OFA/-SCR	Good Location (primary and secondary targets)
Indiana	1974	521	32%	Sub-bituminous	200-300	No	OFA/-SCR	Marginal Location (locally shallow; needs long pipeline)
North Dakota	1977	440	30%	Lignite	700-800	Yes	OFA	Satisfactory
Missouri	1972, 1977	2x 600	33%	Sub-bituminous	200-300	No	SCR	Near seismic zone
Kentucky	1963	2x 650	35%	Bituminous	2000	Yes	OFA/-SCR	Near fault zone

Path to Commercialization

B&W & Air Liquide have performed the following activities:

- Pilot-scale proof of concept – Sponsored by DOE and State of Illinois
- Near-full scale demonstration at B&W's 30 MW_{th} CEDF
- Engineering and System integration studies
- **Significantly expand the applicability of the technology – this project**
- We are currently planning for a commercial demonstration of the technology

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LEGAL NOTICE

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