



WESTCARB Annual Business Meeting

Economics of Site-Specific Retrofit CO₂ Capture

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PRELIMINARY



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Objective & Focus of the Study

- **Objective**
 - Evaluate Impacts of Adding a CO₂ Capture Plant on Existing Site-Specific Power Plants
 - ❖ Plant Performance, Economics, and Physical Impacts
- **Focus**
 - Impacts on Coal Fired and Natural Gas Fired Combined Cycle Power Plants

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Performance and Economic Impacts

- **Performance Impacts On:**
 - Plant Net Output
 - Net Plant Efficiency
 - Additional Cooling Water Consumption
- **Economic Impact**
 - Additional Capital Expenditure
 - Additional O&M Expenditure
 - Increased Cost of Electricity (\$/MWh)
 - ❖ With and w/o Replacement of Lost Power
- **Physical Impact on Site**
 - Additional Land Requirement



Approach and Methodology

- **Site Selection**
 - EPRI Identified a Coal Plant Site Within WestCarb Region
 - Plant Operator Agreed to participate
 - ✓ Provide Required Plant Data
 - ✓ Review Study Results
 - ✓ ** Stay Anonymous **
- **Evaluate Plant Performance**
 - Preliminary Design of Capture Process
 - Estimate Interfaces with the Existing Plant
 - Integrate the Systems



Approach and Methodology (Cont'd)

- **CO₂ Capture Process Design**
 - Assume Mono-Ethanol-Amine (MEA) Capture
 - Use ASPEN Code to Design the Process Plant
 - Use GateCycle Code to Evaluate Overall Performance (Systems Integration)
- **Develop Plant Arrangement**
 - Develop Capture plant Layout including New Cooling Tower
 - Integrate with the Power Plant Layout



Approach and Methodology (Cont'd)

- **Develop Cost Estimate**
 - Use Nexant Internal Cost Code for Capture plant Cost
 - Plant Modifications Cost – Extrapolate from Earlier Studies (Nexant/Bechtel)
 - Estimated Costs
 - Additional Capital Cost
 - Additional Operational and Maintenance Costs
 - Incremental Cost of Electricity (COE)
 - Sensitivity Analysis – Effect of Varying (on COE)
 - Capacity Factor, Capital Cost, Financing Cost, Replacement Power Cost



Existing Plant Features

- **Located in One of the Seven WestCarb States**
- **Sub-Critical Pulverized Coal Fired**
 - **2,400 psig/1,000°F/1,000°F**
 - **Gross Generation – 431 Mwe**
 - **Net Generation – 372 Mwe**
 - **Net Plant Efficiency – 33.9%**
 - **Coal – Bituminous**
 - **Cooling System – Wet Cooling Tower**
 - **Flue Gas Cleanup – Low Nox Burners, SCR, ESP, FGD**
 - **Flue Gas: SO₂ – 20 ppm; CO₂ – 10.4%**

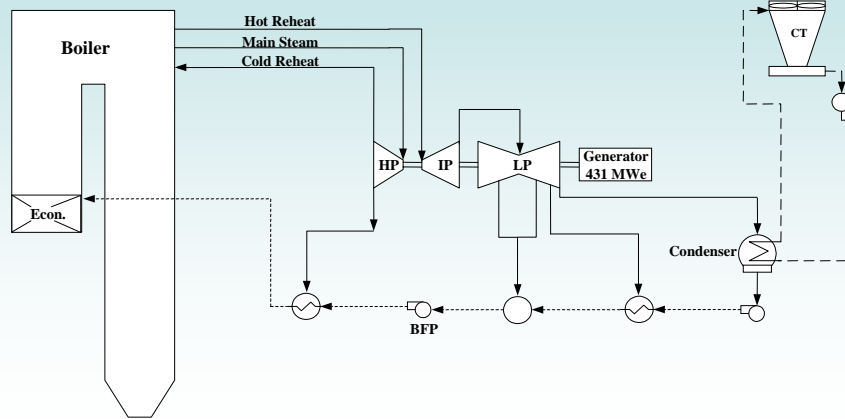


Capture Plant Design Criteria

- **Maximum SO₂ in Flue Gas - <10 ppmv**
- **CO₂ Removal from Flue Gas – 90%**
- **CO₂ Concentration at Plant Discharge – Min. 99%**
- **CO₂ Pressure at Plant Discharge – 2,200 psig.**



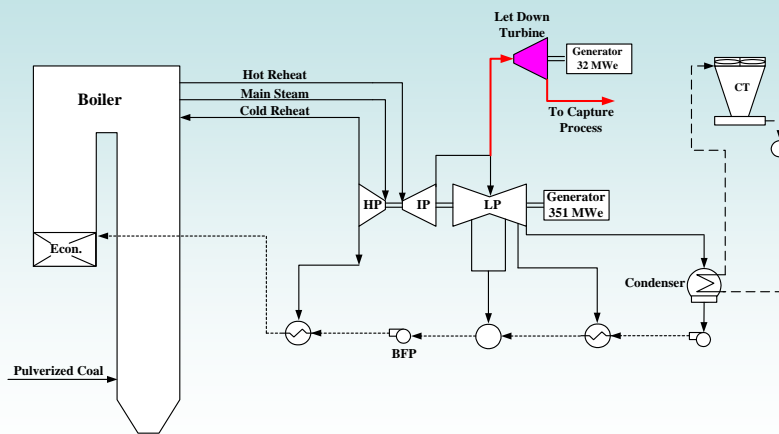
Existing Plant – Process Flow



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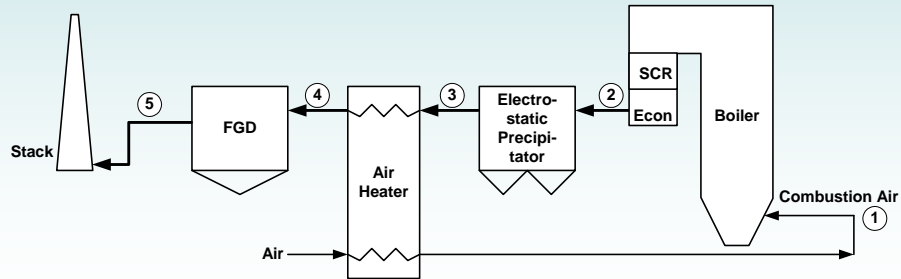
Retrofit Plant – Process Flow



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Existing Plant – Flue Gas Process Flow



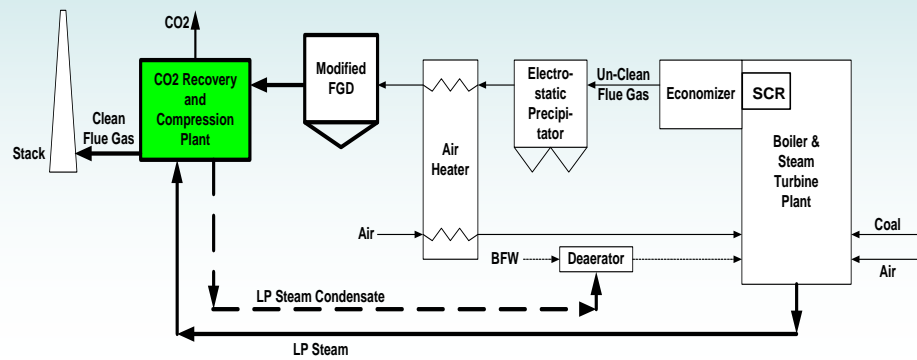
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Integrated Plant Process Flow

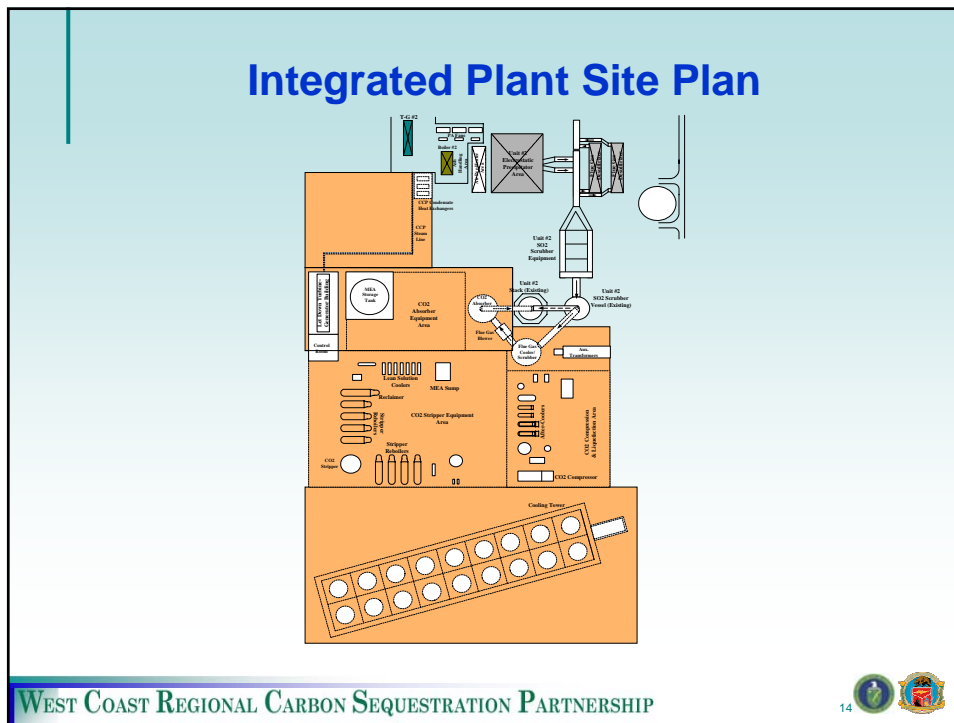
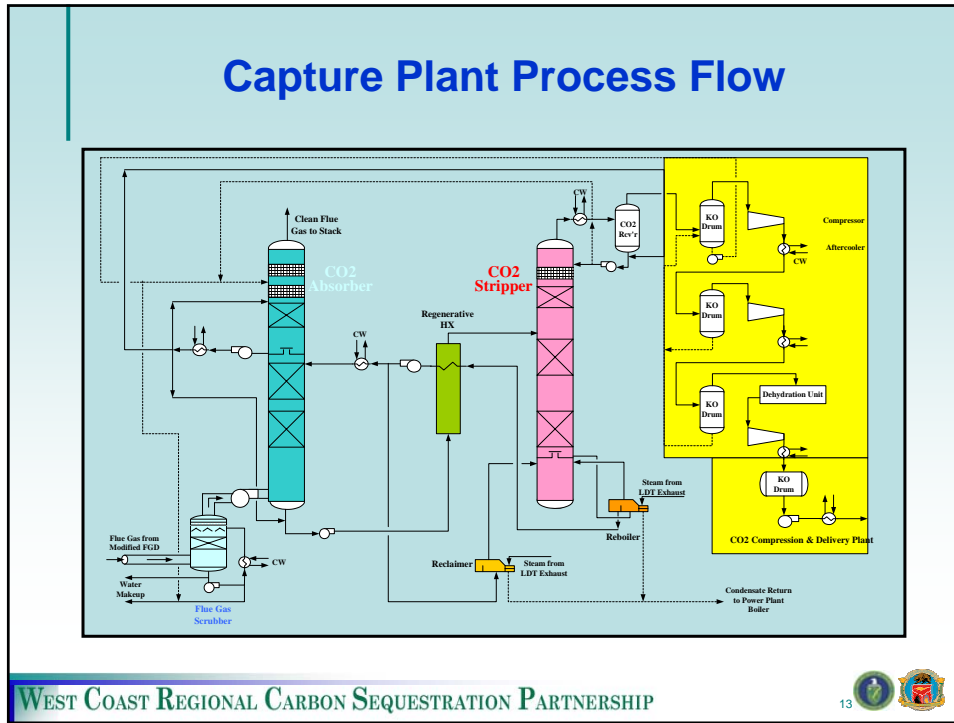
- Major Interfaces:

- Large Ducting @ Inlet & Outlet of Capture Plant
- Low Pressure Steam Supply – Additional Steam Turbine
- Condensate Return



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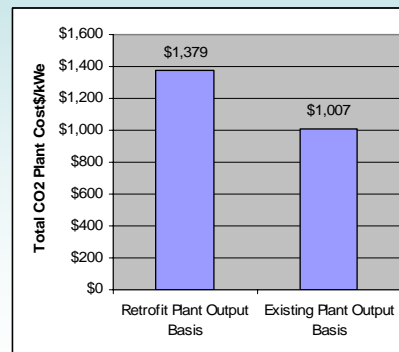


Integrated Plant Performance

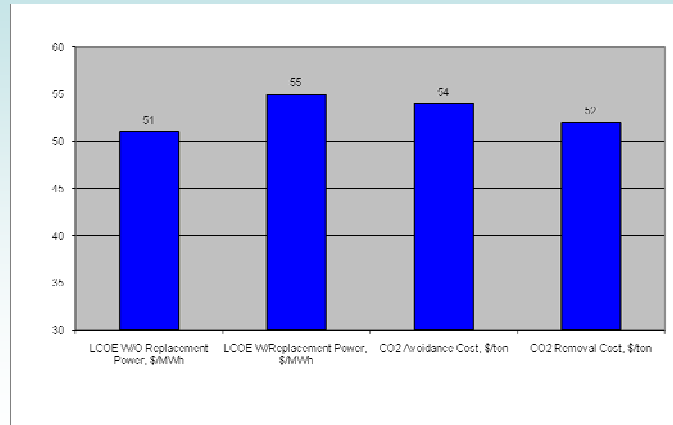
Plant Performance	Existing Plant No CO ₂ Capture	Retrofit Plant W/CO ₂ Capture
Gross plant output, kWe	430,685	382,816
Plant auxiliary power, kWe	58,900	111,185
Net plant output, kWe	371,785	271,631
Net plant efficiency	33.9%	24.8%
CO ₂ production, tons/yr	3,357,637	3,357,637
CO ₂ removal, tons/yr	0	3,023,083
CO ₂ emission, tons/yr	3,357,637	334,554

Capture Plant Capital Cost

Net Plant Output, kWe-retrofit	271,631
Net Plant Output, kWe-existing	371,785
Summary Plant Cost	
Capture & Recovery Equipment, \$K	44,866
Compression Plant Equipment, \$K	16,706
Total Commodities, \$K	72,866
Balance-of-Plant Adjustment, \$K	55,427
Indirect Costs, \$K	87,550
Project Contingency, \$K	56,485
Process Contingency, \$K	40,669
Total Plant Cost (TPC), \$K	374,569
\$/kWe-retrofit	\$1,379
\$/kWe-existing	\$1,007



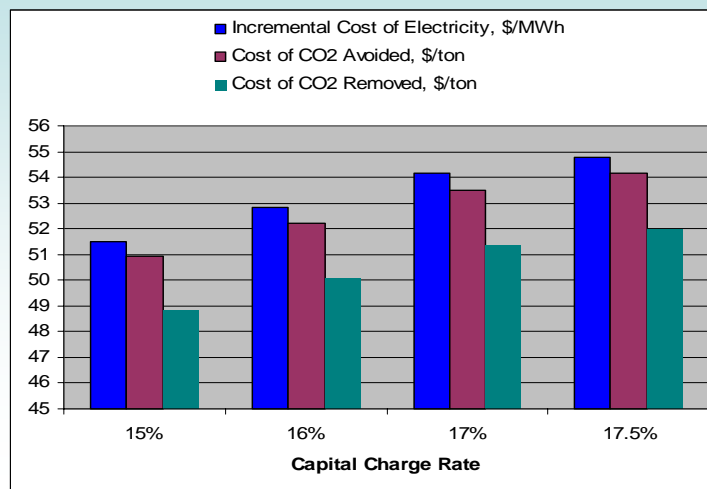
Incremental Costs Electricity; CO₂ Removal; CO₂ Avoidance



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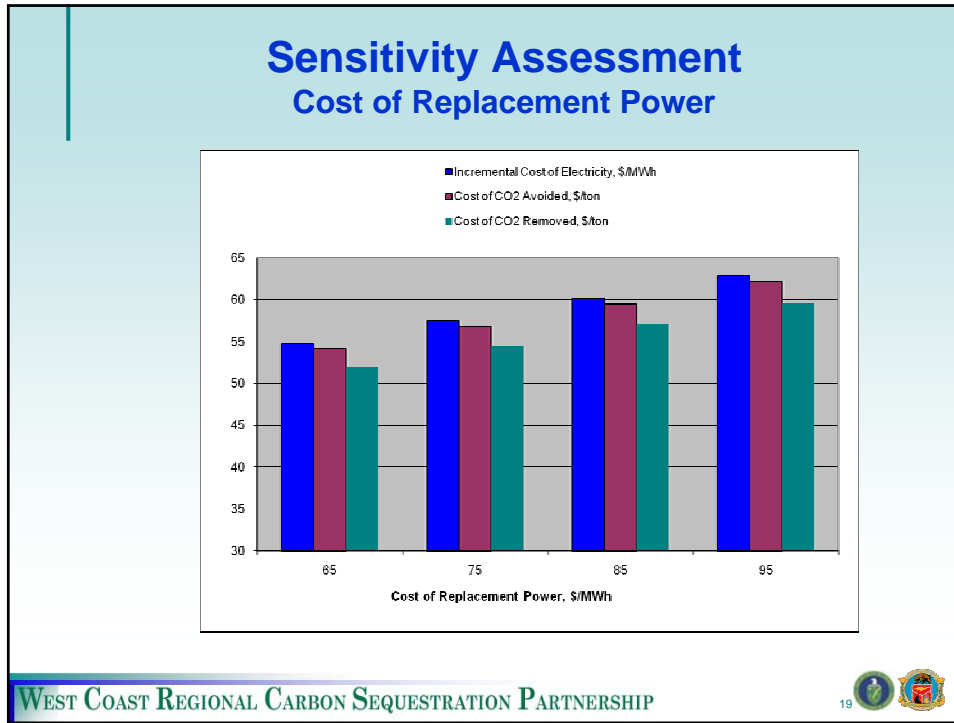


Sensitivity Assessment – Financing Cost



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Comparison with Other Study

Parameter	Unit	Present Plant	AEP Connesville Unit #5*
Net Plant Output (Base Plant)	MWe	371	434
Net Plant Output (Retrofit Plant)	MWe	271	303
Net Plant Efficiency-HHV (Base Plant)	%	34.0%	35.0%
Net Plant Efficiency-HHV (Retrofit Plant)	%	24.9%	24.5%
CO ₂ Capture, Percent of Total Production	%	90%	90%
Incremental Capital Cost	\$/kWe	1,379	1,464
Incremental Levelized Cost of Electricity	\$/MWh	55	54
Cost of CO ₂ Avoided	\$/ton	54	57
Cost of CO ₂ Removed	\$/ton	52	54
Power Penalty	%	27%	30%
Efficiency Penalty	%	27%	30%
Energy Penalty	%	112%	241%

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*Connesville plant incremental capital cost and LCOE are escalated to 4Q 2008 level

Summary and Conclusion

■ Summary

- Efficiency and Power Penalty – Approx. 27%
- Replacement Power @ \$51/MWh - Adds 0% to COE
- Replacement Power @ \$95/MWh - Adds 23.5% to COE
- Additional Water Consumption - Approx. 1,915 GPM (65% Increase)
- Additional Land Requirement – Approx. 330,000 Ft²

■ Conclusion

- Difficult for Water-Constrained Sites
- Land – Difficult for Urban-Sited Plants
- Availability of Large Replacement Power May Be a Site Limitation