



**WESTCARB Annual Business Meeting**

**Economics of Site-Specific Retrofit CO<sub>2</sub> Capture**

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**PRELIMINARY**



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## Objective & Focus of the Study

- **Objective**
  - Evaluate Impacts of Adding a CO<sub>2</sub> 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)

- **CO<sub>2</sub> 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

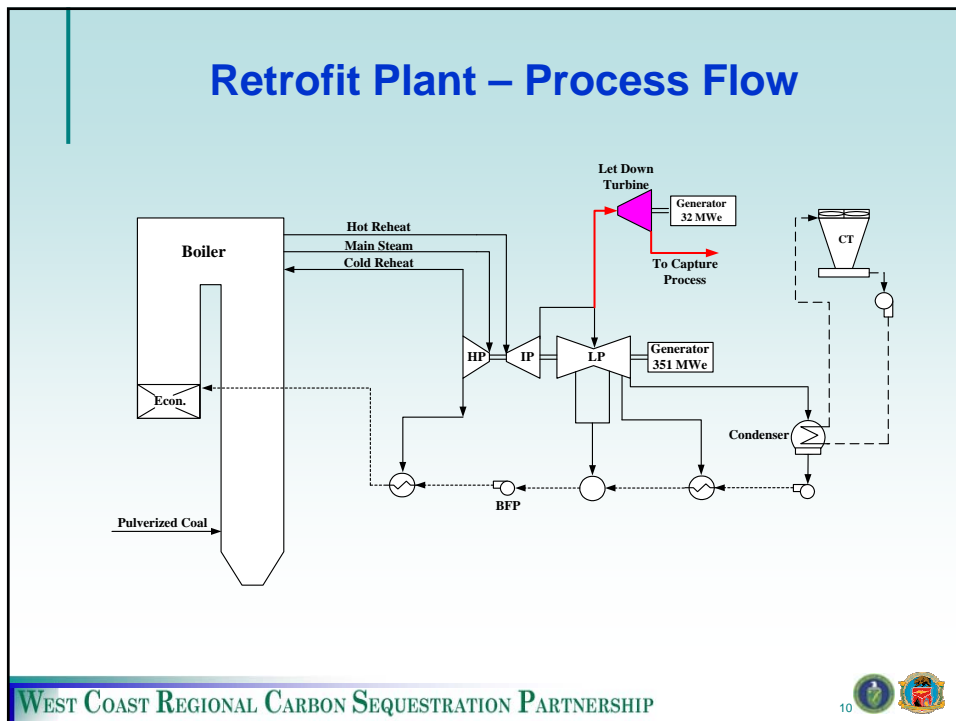
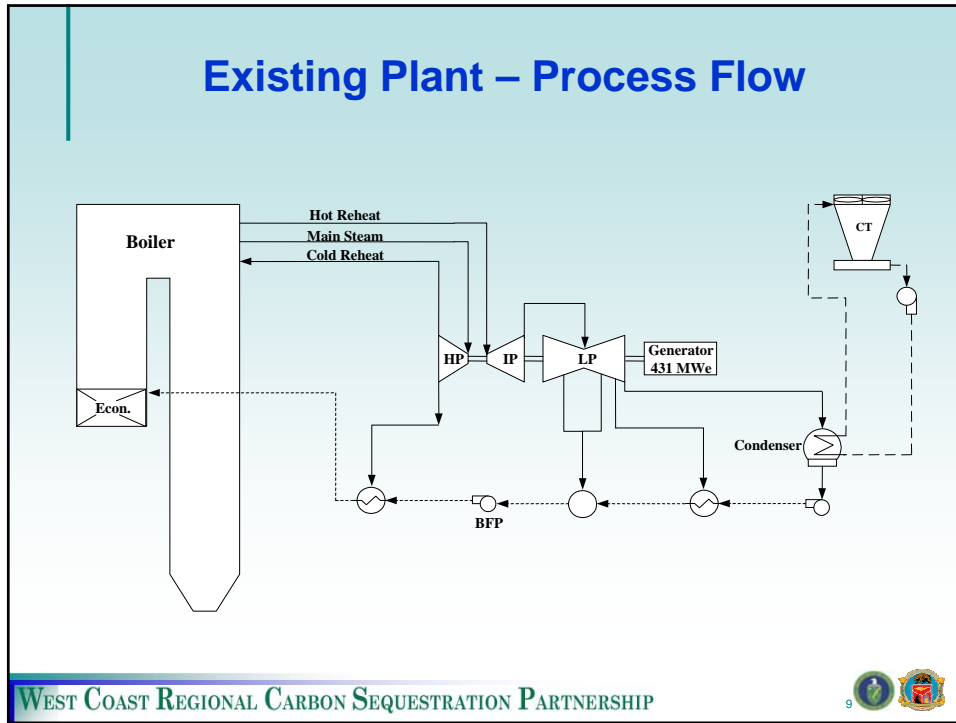
- **Located in One of the Seven WestCarb States**
- **Sub-Critical Pulverized Coal Fired**
  - **2,400 psig/1,000°F/1,000°F**
  - **Gross Generation – 431 Mwe**
  - **Net Generation – 372 Mwe**
  - **Net Plant Efficiency – 33.9%**
  - **Coal – Bituminous**
  - **Cooling System – Wet Cooling Tower**
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



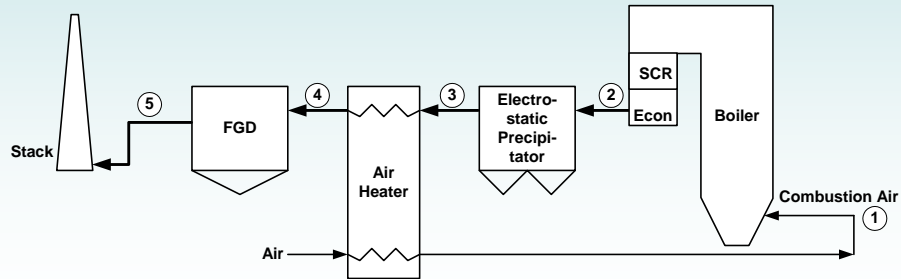
## Capture Plant Design Criteria

- **Maximum SO<sub>2</sub> in Flue Gas - <10 ppmv**
- **CO<sub>2</sub> Removal from Flue Gas – 90%**
- **CO<sub>2</sub> Concentration at Plant Discharge – Min. 99%**
- **CO<sub>2</sub> Pressure at Plant Discharge – 2,200 psig.**





## Existing Plant – Flue Gas Process Flow



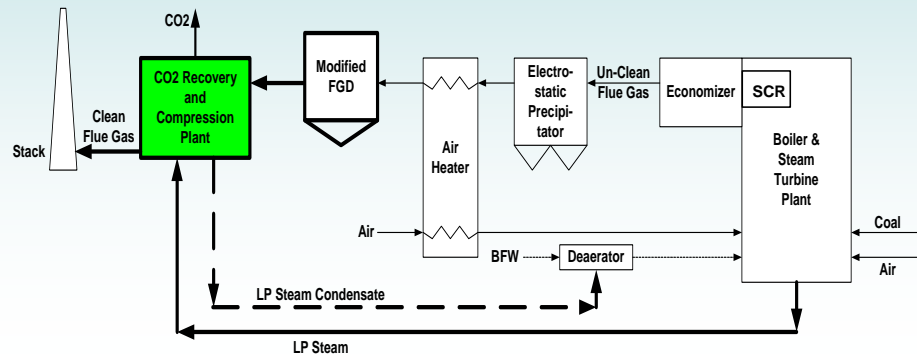
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## Integrated Plant Process Flow

- Major Interfaces:

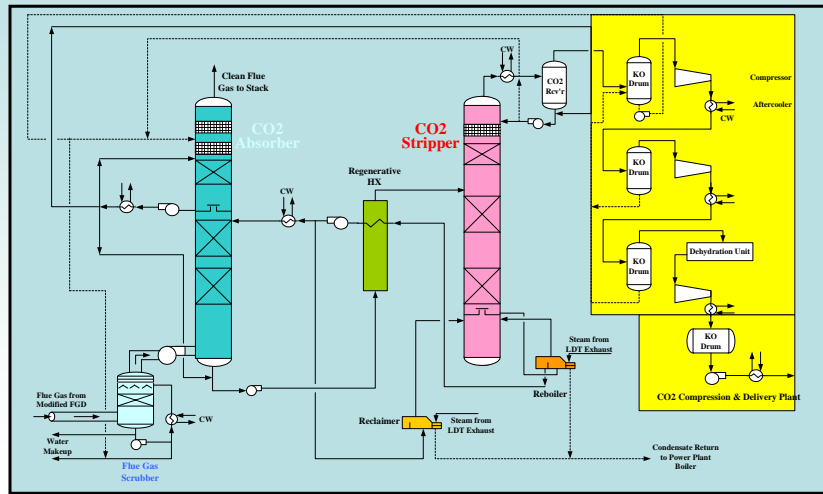
- Large Ducting @ Inlet & Outlet of Capture Plant
- Low Pressure Steam Supply – Additional Steam Turbine
- Condensate Return



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## Capture Plant Process Flow

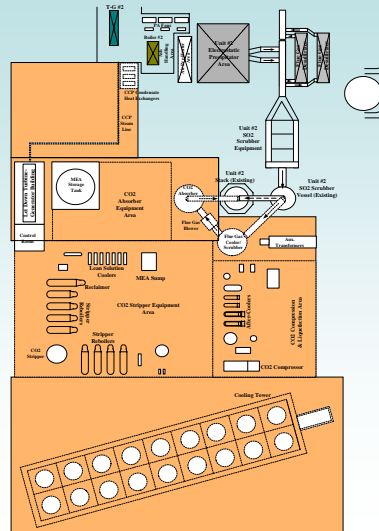


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## Integrated Plant Site Plan



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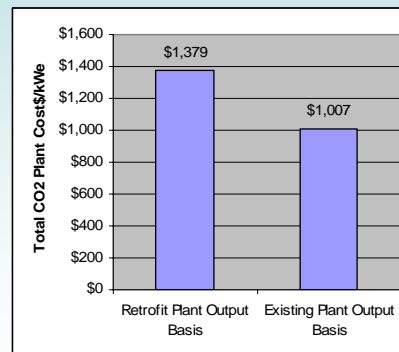
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## Integrated Plant Performance

Plant Performance	Existing Plant No CO <sub>2</sub> Capture	Retrofit Plant W/CO <sub>2</sub> 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 <sub>2</sub> production, tons/yr	3,357,637	3,357,637
CO <sub>2</sub> removal, tons/yr	0	3,023,083
CO <sub>2</sub> emission, tons/yr	3,357,637	334,554

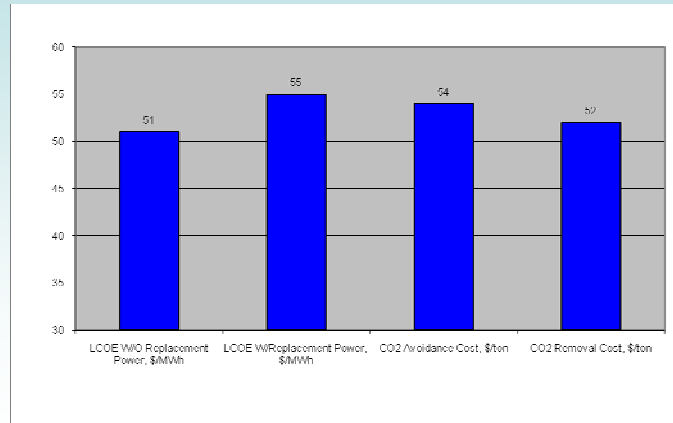
## Capture Plant Capital Cost

Net Plant Output, kWe-retrofit	271,631
Net Plant Output, kWe-existing	371,785
<b>Summary Plant Cost</b>	
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

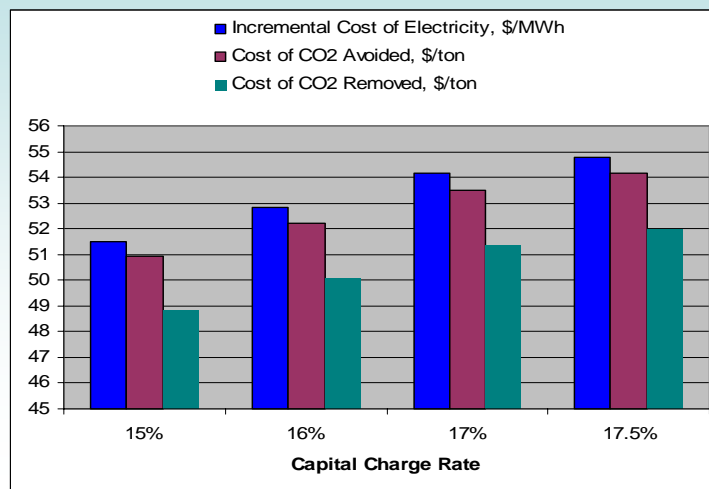


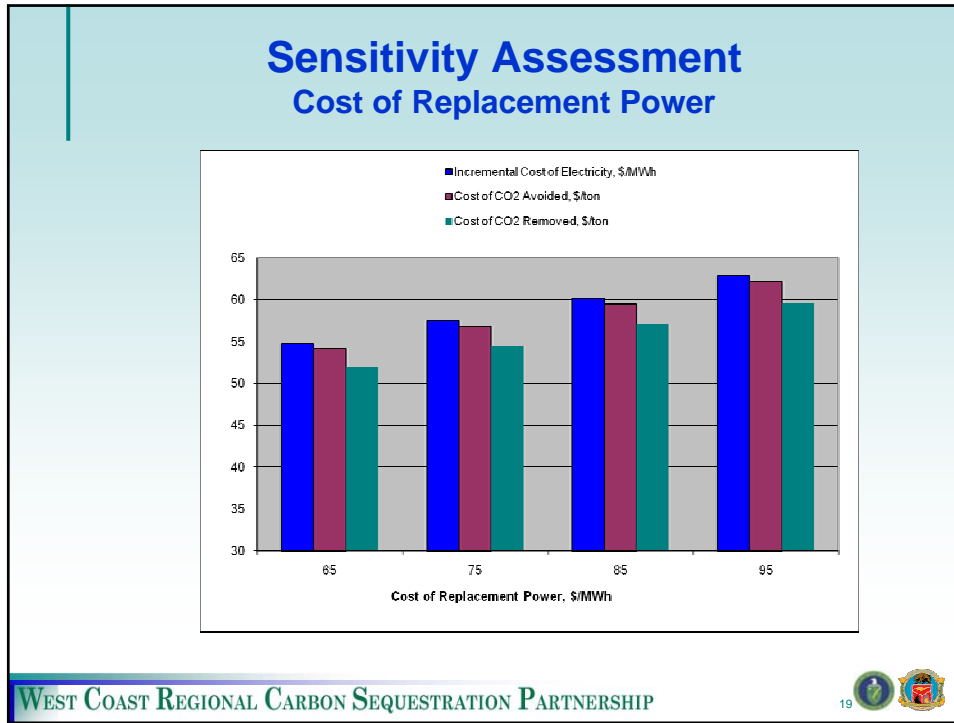


## Incremental Costs Electricity; CO<sub>2</sub> Removal; CO<sub>2</sub> Avoidance



## Sensitivity Assessment – Financing Cost





### 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 <sub>2</sub> 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 <sub>2</sub> Avoided	\$/ton	54	57
Cost of CO <sub>2</sub> 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 Ft<sup>2</sup>

### ■ Conclusion

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