



# Performance and Cost Comparisons of Alternate IGCC Based CO<sub>2</sub> Capture Technologies

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## What's new?

A quantitative evaluation of multiple viable pathways for pre-combustion CO<sub>2</sub> capture

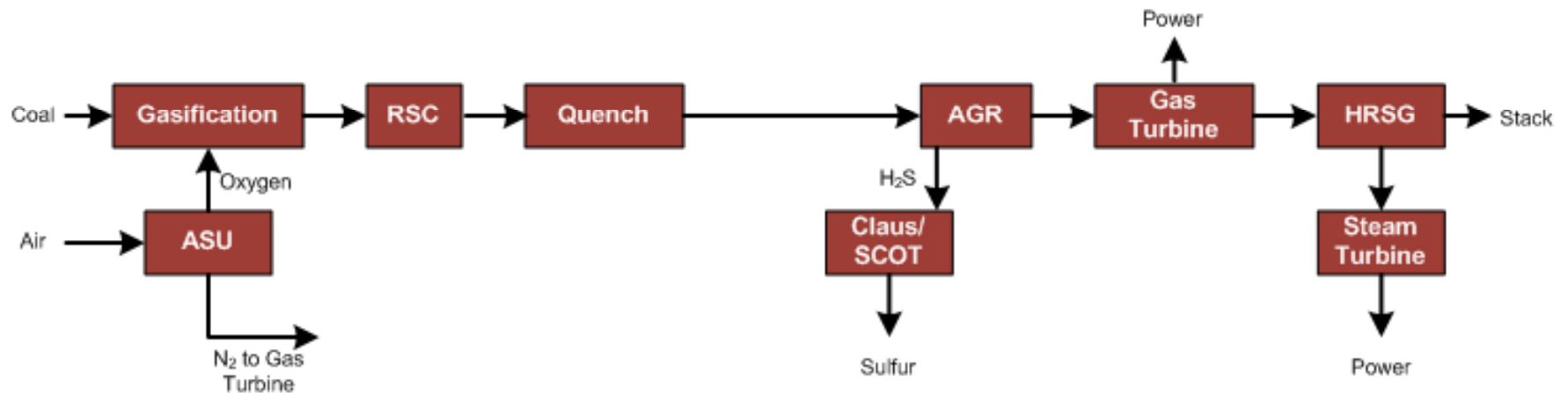
## Why is it important?

Advanced technologies can significantly reduce the impact of CO<sub>2</sub> capture for IGCC

# Methodology

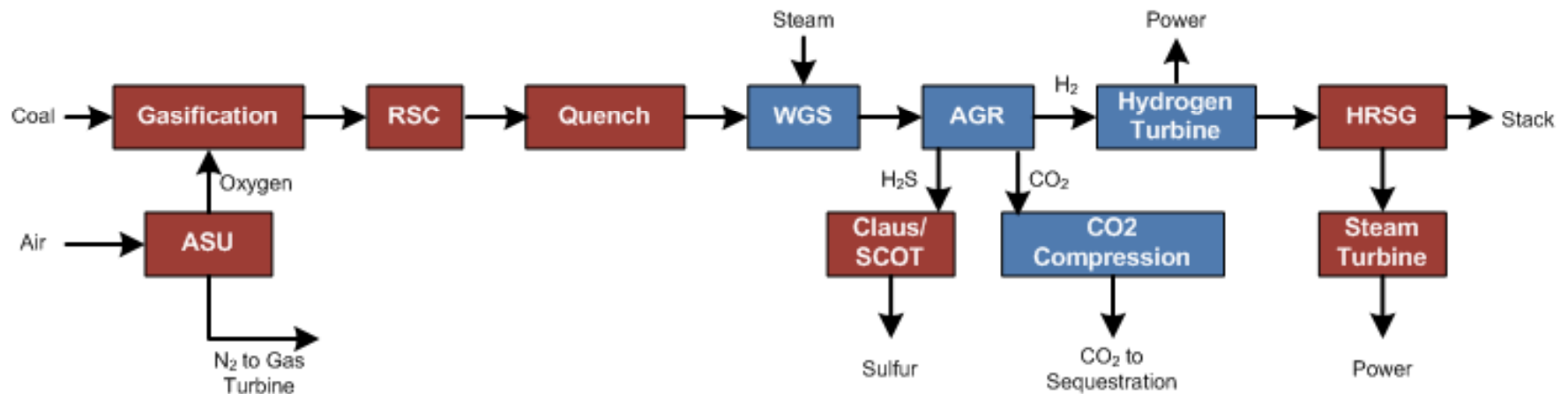
- Use the Aspen Plus simulator to model processes
- Start with a baseline that represents conventional CO<sub>2</sub> separation technology in an integrated gasification combined cycle (IGCC) plant
- Examine alternate methods of pre-combustion CO<sub>2</sub> separation
- Quantify effects of technology improvements

# Conventional Non-Capture IGCC Process



- Illinois #6 bituminous coal
- Cryogenic air separation
- Dry feed entrained gasifier
- Cold gas desulfurization
- Combustion syngas turbine with air integration
- Steam bottoming cycle (1,800 psi / 1,050 °F / 1,050 °F)
- 85% capacity factor

# Conventional IGCC with Carbon Capture



- Water Gas Shift (WGS) converts CO to CO<sub>2</sub>
- Additional acid gas removal (AGR) stage for CO<sub>2</sub> separation
- CO<sub>2</sub> compression to 2,200 psig for pipeline transport
- Hydrogen turbine
- Steam bottoming cycle (1,800 psia / 1,000 °F / 1,000 °F)
- 90% carbon capture

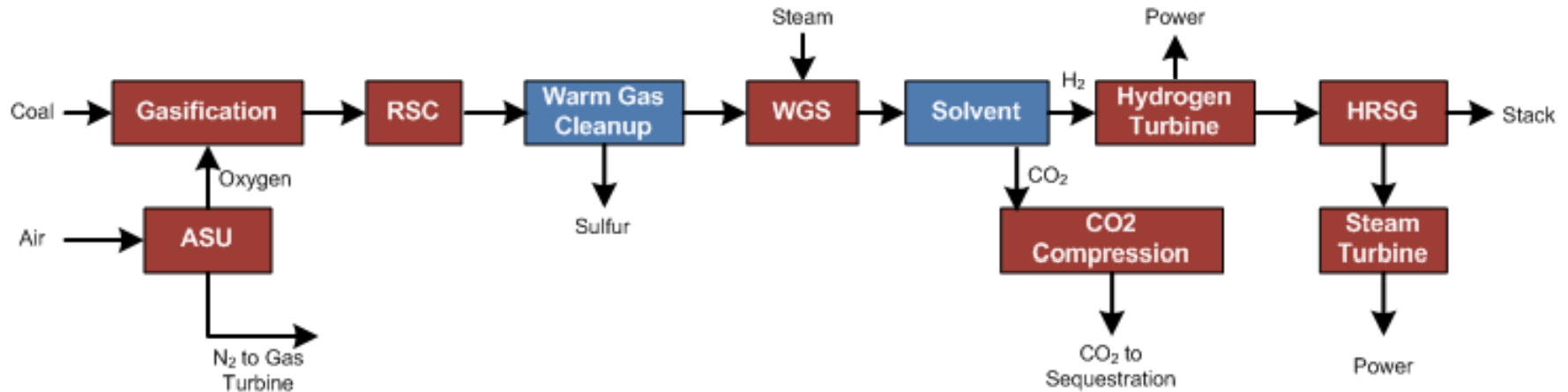
# Impacts of CO<sub>2</sub> Separation

- Adds plant equipment for water gas shift, CO<sub>2</sub> separation, and CO<sub>2</sub> compression sections
- Increases coal feed rate for turbine fuel production
- Increases parasitic load for O<sub>2</sub> production, CO<sub>2</sub> separation, CO<sub>2</sub> compression, and shift steam generation
- Increases plant capital cost due to greater flowrates and additional plant sections
- Increases plant cost on a \$/kW basis due to decreased net power generation
- Cost of electricity (COE) increases by as much as 40% over the non-capture IGCC process

# Examine Four Carbon Capture Alternatives to Reduce the Impact of CO<sub>2</sub>

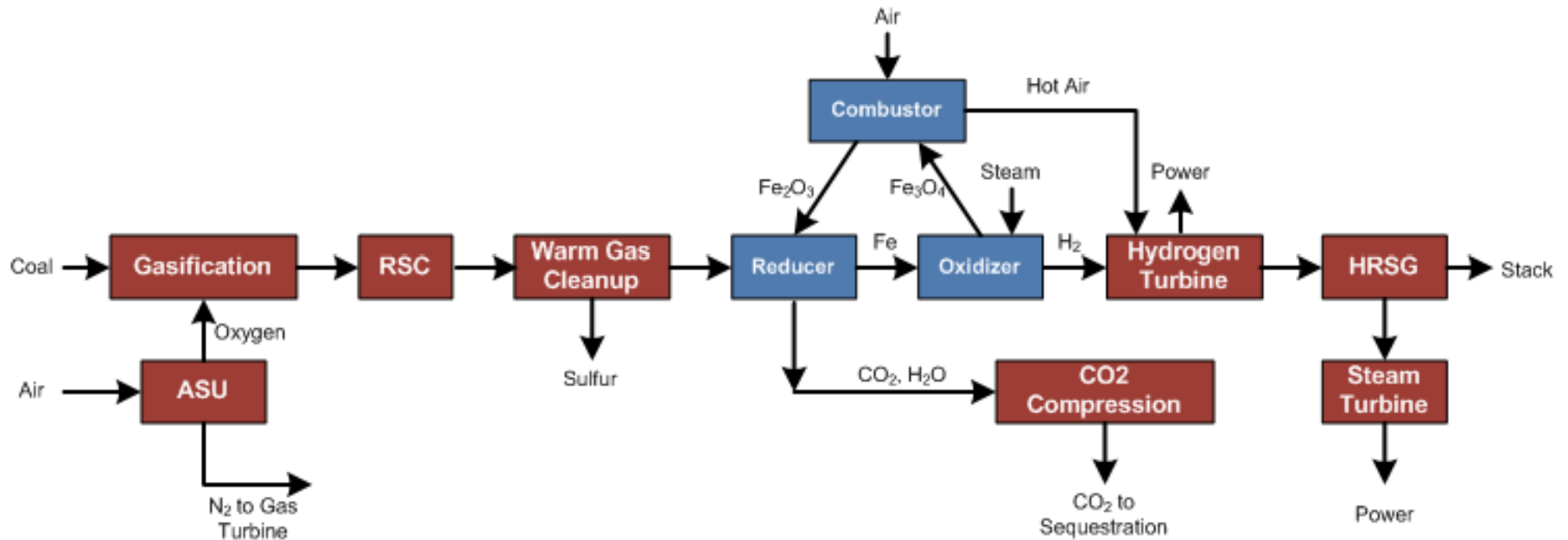
- Conventional IGCC with physical solvent acid gas removal
- Warm gas cleanup (WGCU) for desulfurization with physical solvent CO<sub>2</sub> separation
- Warm gas cleanup with syngas chemical looping (SCL) for CO<sub>2</sub> separation
- Warm gas cleanup with hydrogen membrane for CO<sub>2</sub> separation

# Warm Gas Cleanup With Physical Solvent CO<sub>2</sub> Separation



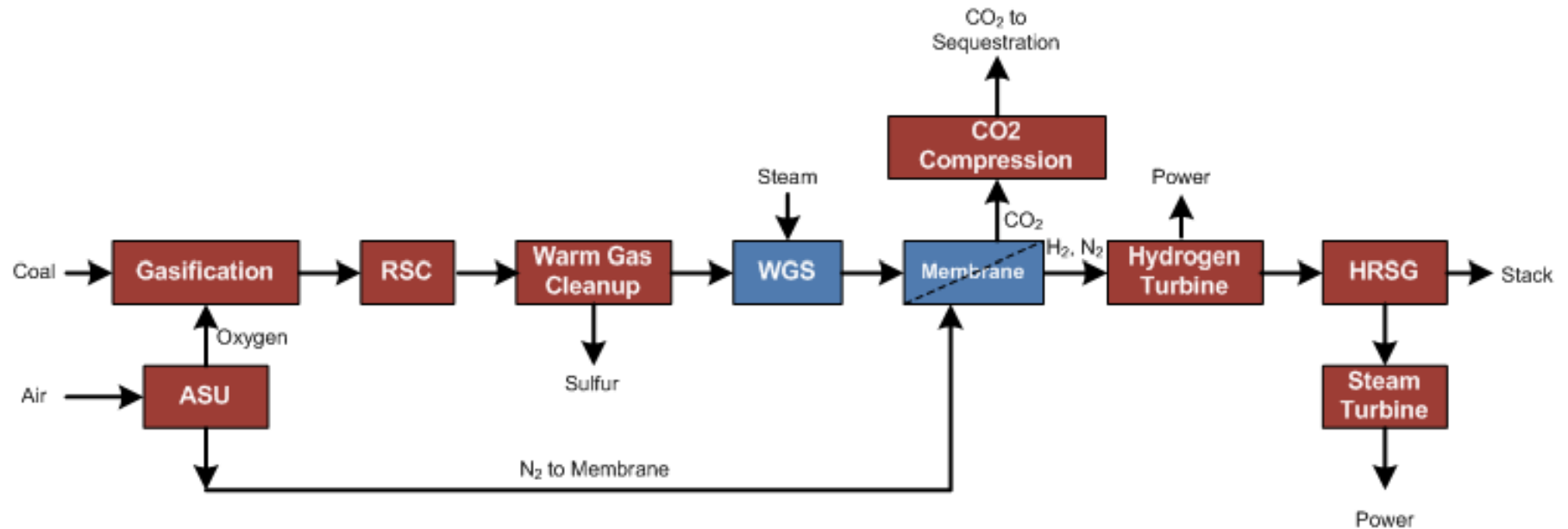
- Transport desulfurization with Direct Sulfur Reduction Process
- Warm gas chloride, NH<sub>3</sub>, and Hg removal
- Sweet water gas shift
- CO<sub>2</sub> removal by liquid solvent at low temperature (100 °F), producing CO<sub>2</sub> at intermediate pressure (<150 psia)

# Warm Gas Cleanup With Syngas Chemical Looping for CO<sub>2</sub> Separation



- CO reduction of Fe<sub>2</sub>O<sub>3</sub> separates the CO<sub>2</sub> stream at high pressure (730 psia)
- Oxidation of Fe produces H<sub>2</sub> fuel for the turbine
- Further oxidation of Fe<sub>3</sub>O<sub>4</sub> supplies hot air to the turbine

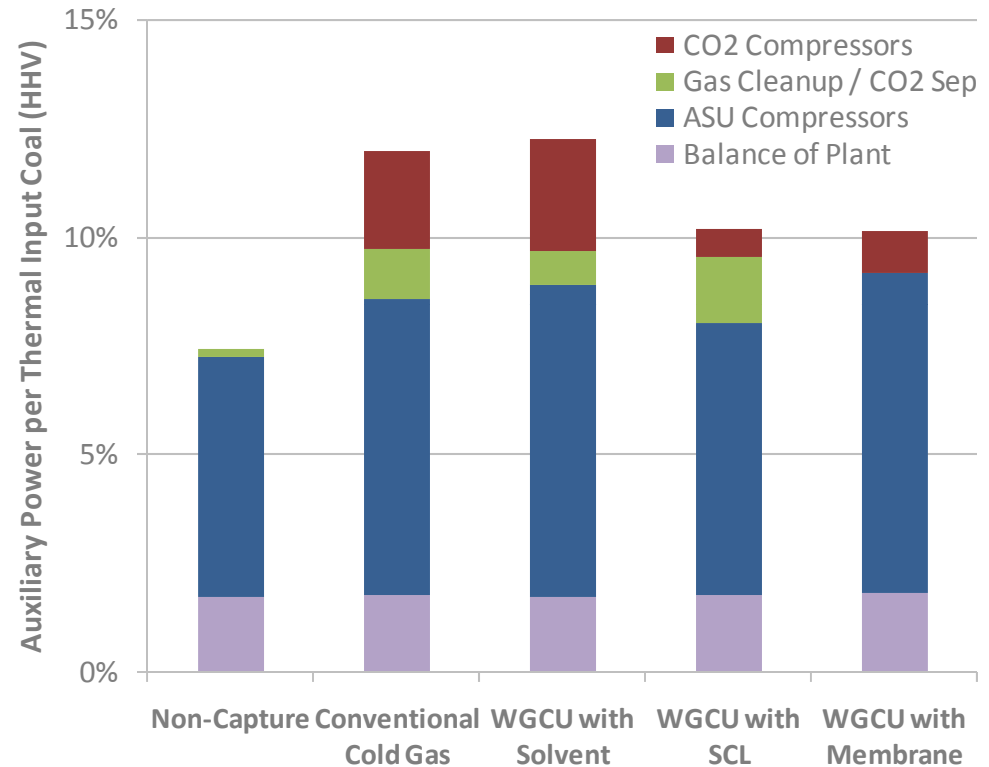
# Warm Gas Cleanup With Hydrogen Membrane for CO<sub>2</sub> Separation



- Low temperature (450 °F) shift prior to the membrane favors CO conversion to CO<sub>2</sub>
- N<sub>2</sub> sweep gas on the permeate side of the membrane reduces H<sub>2</sub> partial pressure, enabling 90% H<sub>2</sub> recovery
- CO<sub>2</sub> non-permeate exits at high (750 psia) pressure

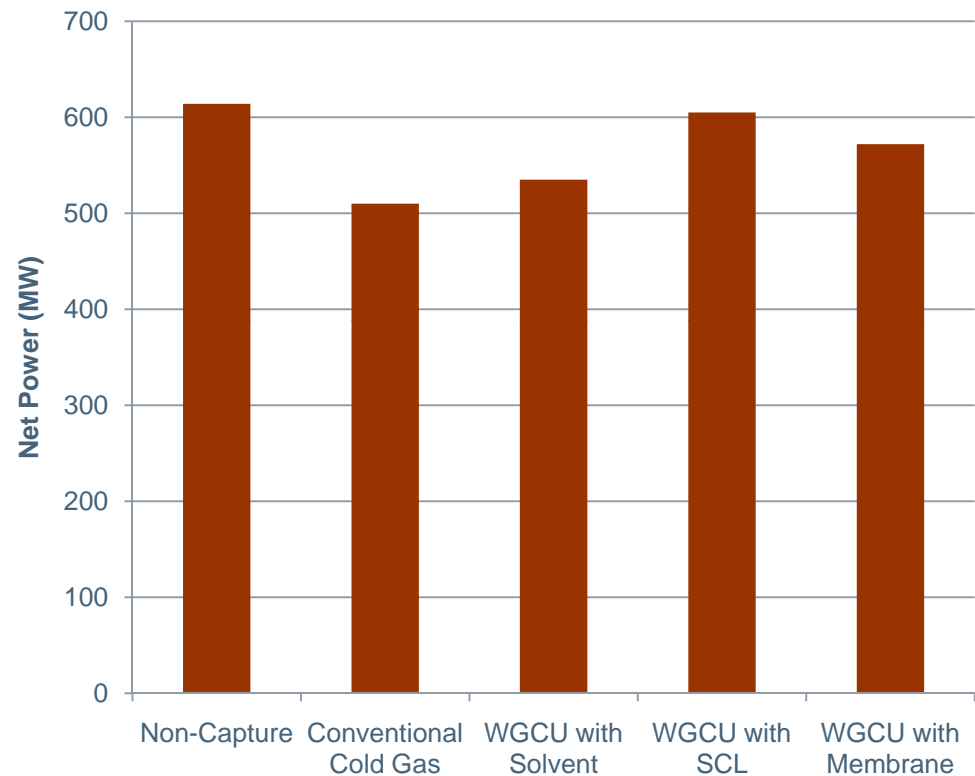
# Auxiliary Power

- CO<sub>2</sub> separation and compression (to 2,200 psig) increases auxiliary power for all capture cases
- Solvent CO<sub>2</sub> separation processes desorb CO<sub>2</sub> at much lower pressure (<150 psia) than SCL or membrane (>700 psia), with correspondingly greater parasitic loss for CO<sub>2</sub> compression



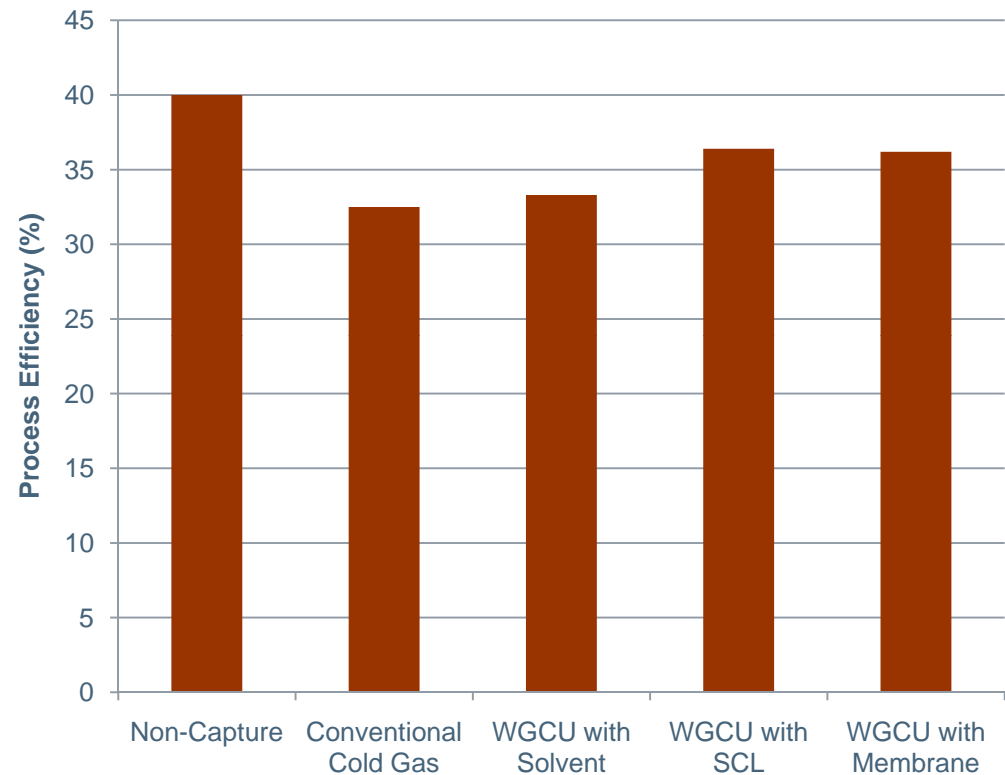
# Net Plant Power

- Despite increased coal feed rate, increased parasitic losses result in less net power than the non-capture case.
- Decreased net plant power, when divided into total plant cost (TPC), will increase TPC on a \$/kW basis



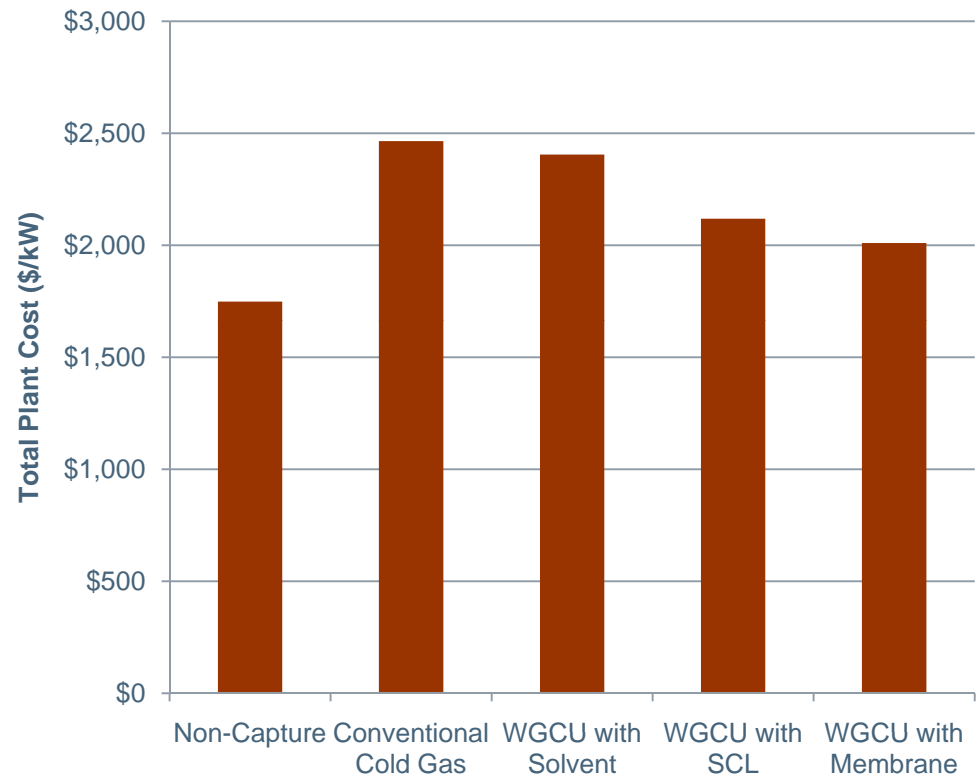
# Net Process Efficiency

- Increased coal feed rate combined with decreased net plant power results in decreased efficiency
- Elimination of sour water stripper and solvent regeneration increases steam turbine power
- Production of CO<sub>2</sub> at elevated pressure reduces parasitic compressor load



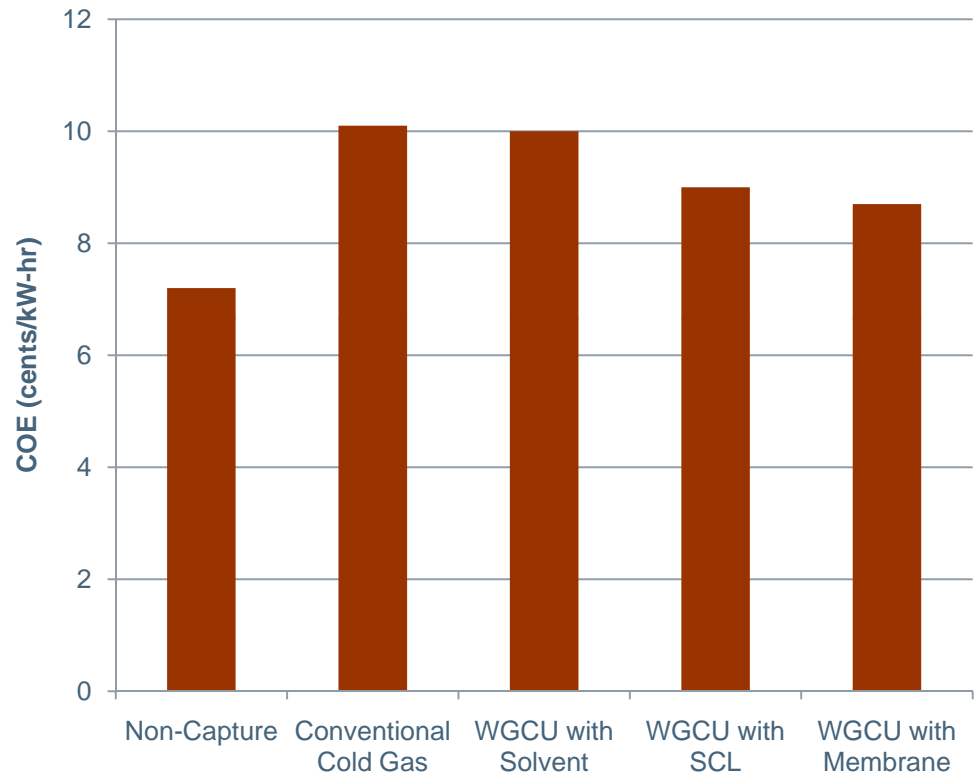
# Total Plant Cost

- Change in net plant power has the single greatest impact on TPC on a \$/kW basis
- Added equipment for water gas shift, CO<sub>2</sub> separation, and CO<sub>2</sub> compression increases capital cost
- Increased coal flow rate increases equipment sizes and therefore plant cost
- TPC of SCL and membrane processes is lower than solvent processes because of less decrease in net power generation



# Cost of Electricity

- Similar shape to TPC chart shows dominance of capital costs on COE
- Conventional gas cleanup and CO<sub>2</sub> separation process increases COE by ~40%
- Advanced gas cleanup and CO<sub>2</sub> separation processes have potential to reduce this impact to ~20%



# Summary

- Requirements for CO<sub>2</sub> separation will increase the COE of IGCC power generation over non-capture processes due to additional equipment and reduced net power generation
- Advanced technologies such as syngas chemical looping and hydrogen membranes paired with warm gas cleanup have the potential to significantly reduce the performance and cost impact of CO<sub>2</sub> separation
- Success factors include producing CO<sub>2</sub> at elevated pressure, minimizing process steam use, and minimizing gas cleanup auxiliary power use