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Integrated Gasification Fuel Cell (IGFC) System Studies

Office of Systems, Analyses & Planning

Systems Analysis Team

- **Assessment of state-of-the-art and advanced technologies**
  - Guide Research
    - Compare potential of advanced technologies to current SOA
    - Identify process conditions & performance targets
  - Inform policy & regulation
    - Unbiased assessments of technology options
  - Overall technical & environmental performance
    - Efficiency, resource use (feedstocks, water), emissions (stack & life-cycle)

CO_2 Emissions – Why is this relevant?

- **Supreme Court ruled that carbon dioxide is classified as a pollutant under the 2007 Clean Air Act, therefore the U.S. Government has the authority to regulate CO_2 emissions**
- **Carbon capture and sequestration is an administration priority – NETL's role is to assist in the development of technologies that enable this goal**

Water Use – Why is it important?

- USGS reports that power generation is second only to agriculture in total U.S. freshwater consumption[1]
- Projected population shifts to western and southeastern U.S. will result in thermoelectric growth that exceeds the national average to 2030[2]
- Limited freshwater in these areas could be inadequate to meet projected power generation needs

1. “Estimate Use of Water in the United States in 1995,” http://www.usgs.gov/watuse/pdf1995/pdf/circular1200.pdf
2. “Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements,” http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/2007%20Water%20Needs%20Analysis%20-%20Final%20REVISED%205-8-08.pdf

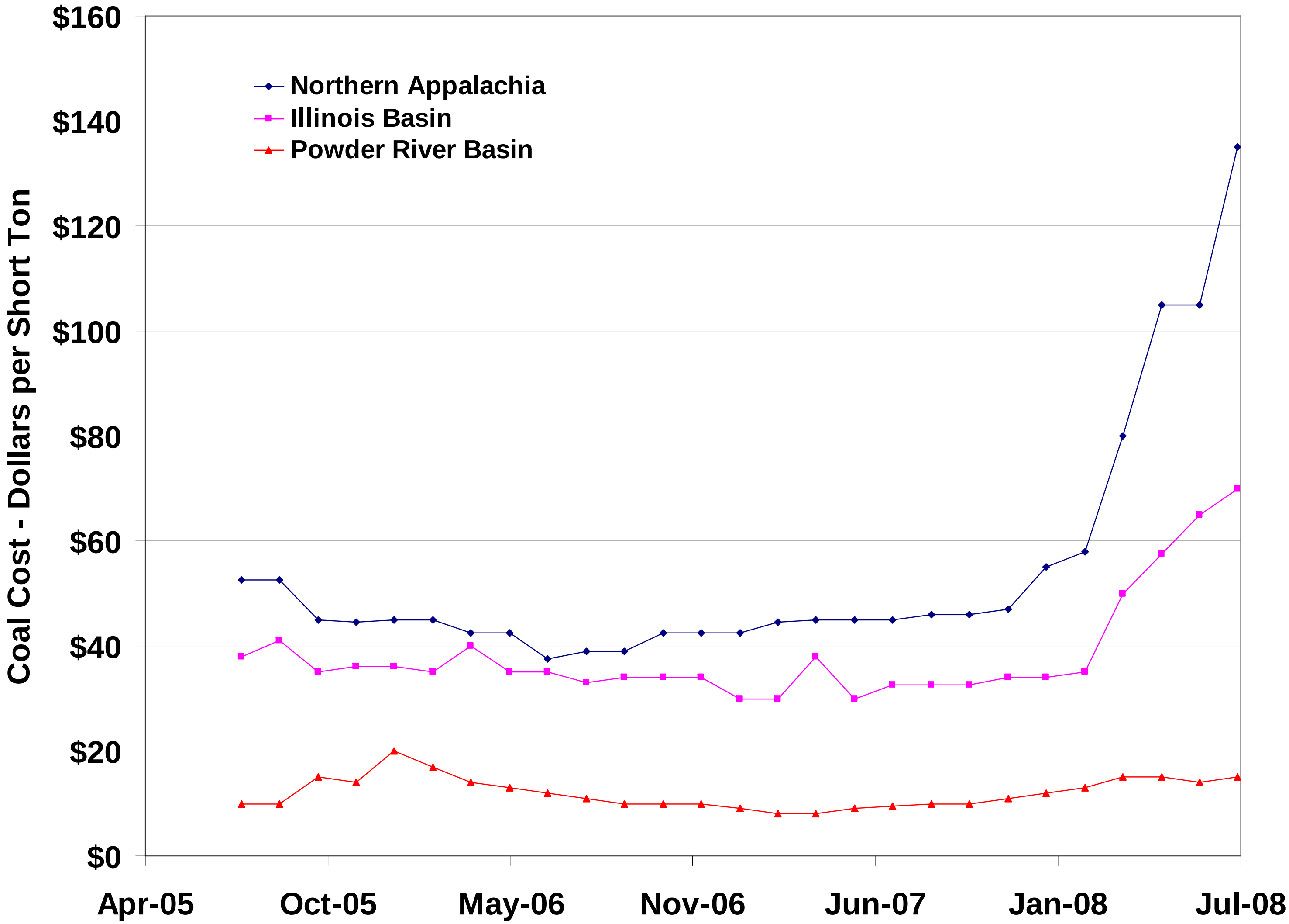
Energy Efficiency – Why is it Important?

- **NETL Power Systems Goal → 45-50% net efficiency (coal HHV) by 2010 and 55-60% net efficiency (coal HHV) by 2015**
- **Energy Information Administration (EIA) Annual Energy Outlook (AEO) 2008 predicts[1]:**
  - 41% increase in energy produced by coal plants from 2006 to 2030
  - Percentage of nation's power generated by coal increases from 49% to 54%
- **Coal costs have risen drastically since 2005**
  - Increased efficiency lowers capital and operating costs

1. http://www.eia.doe.gov/fuelcoal.html

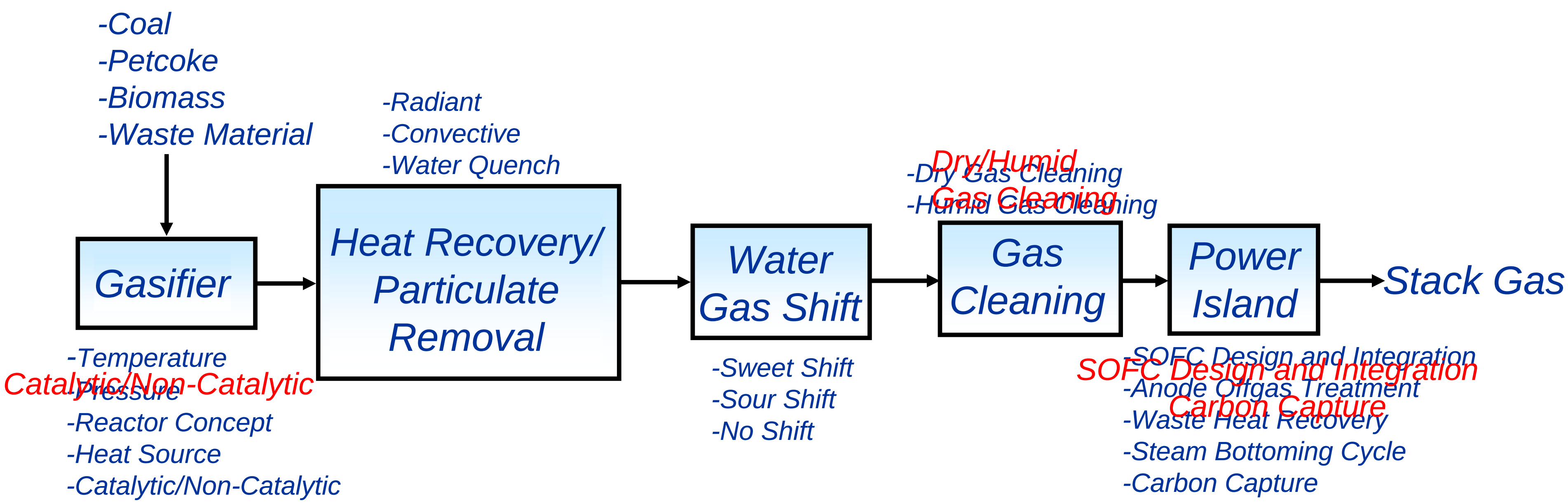
Historic Coal Prices[1]

Since 2005, coal prices have at least doubled



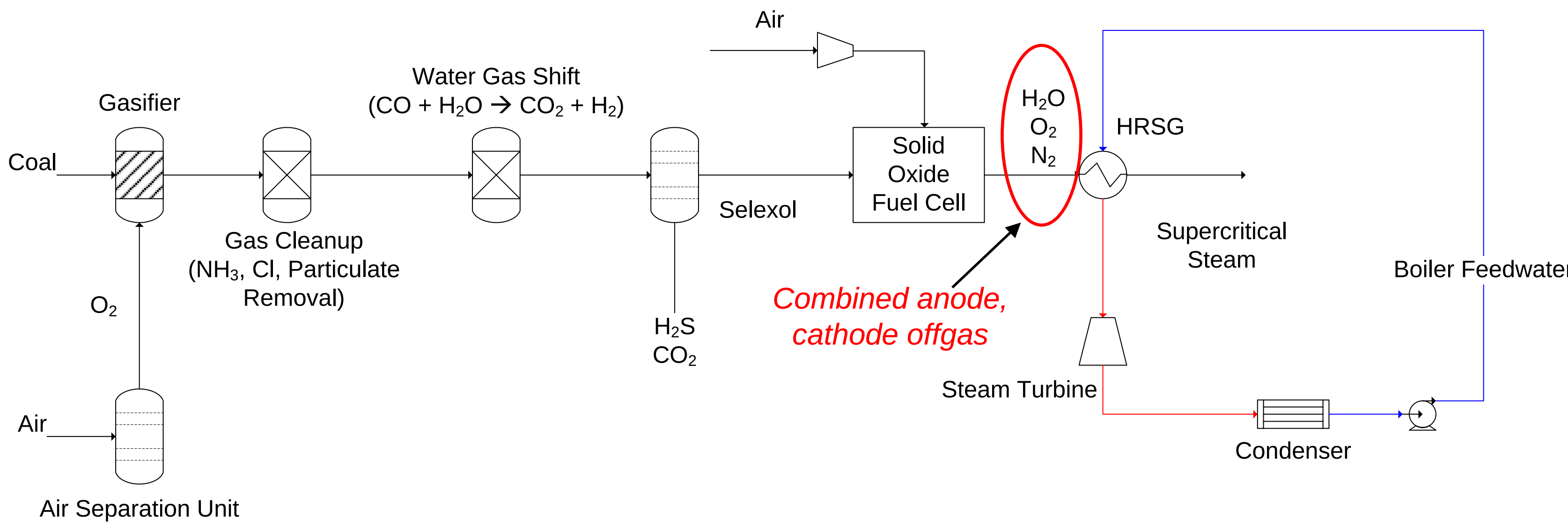
1. http://www.eia.doe.gov/cneaf/coal/page/coalnews/coalmar.html

System Integration Choices



Baseline IGFC Combined Cycle

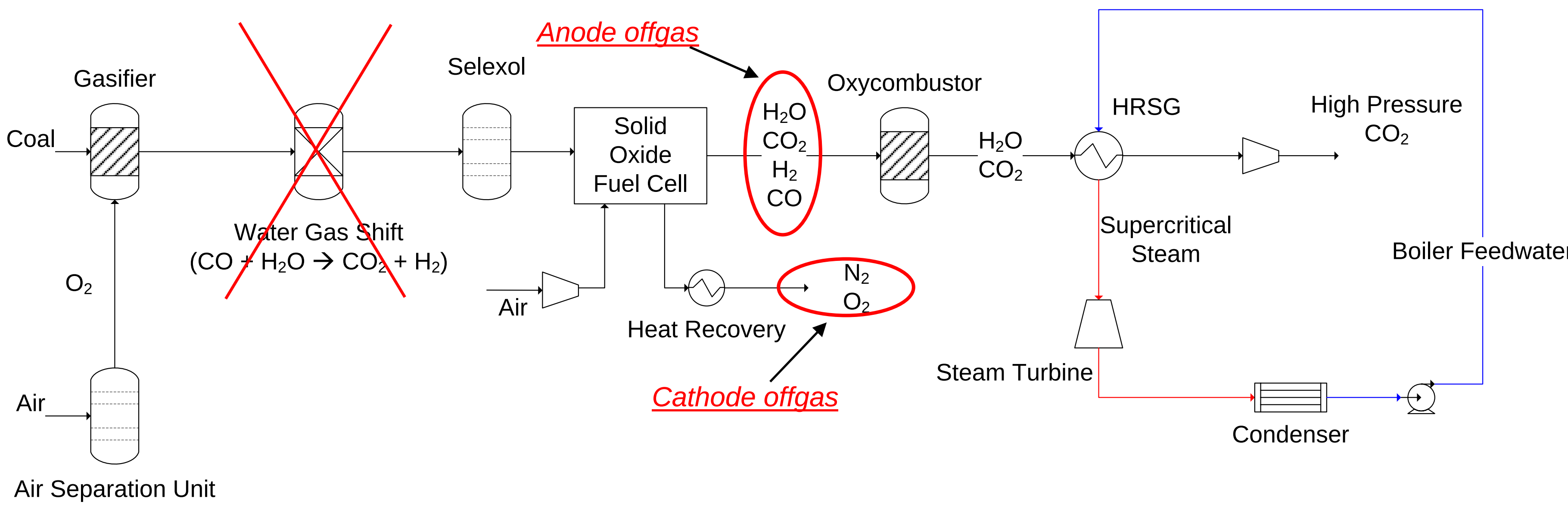
Atmospheric SOFC with combined anode and cathode offgas



- **Single pass SOFC**
- **Precombustion CO_2 capture (Selexol process)**
- **Waste heat recovery in subcritical steam cycle (1600psia/1100 ºF)**
- ***43.3% system efficiency (coal HHV basis)***

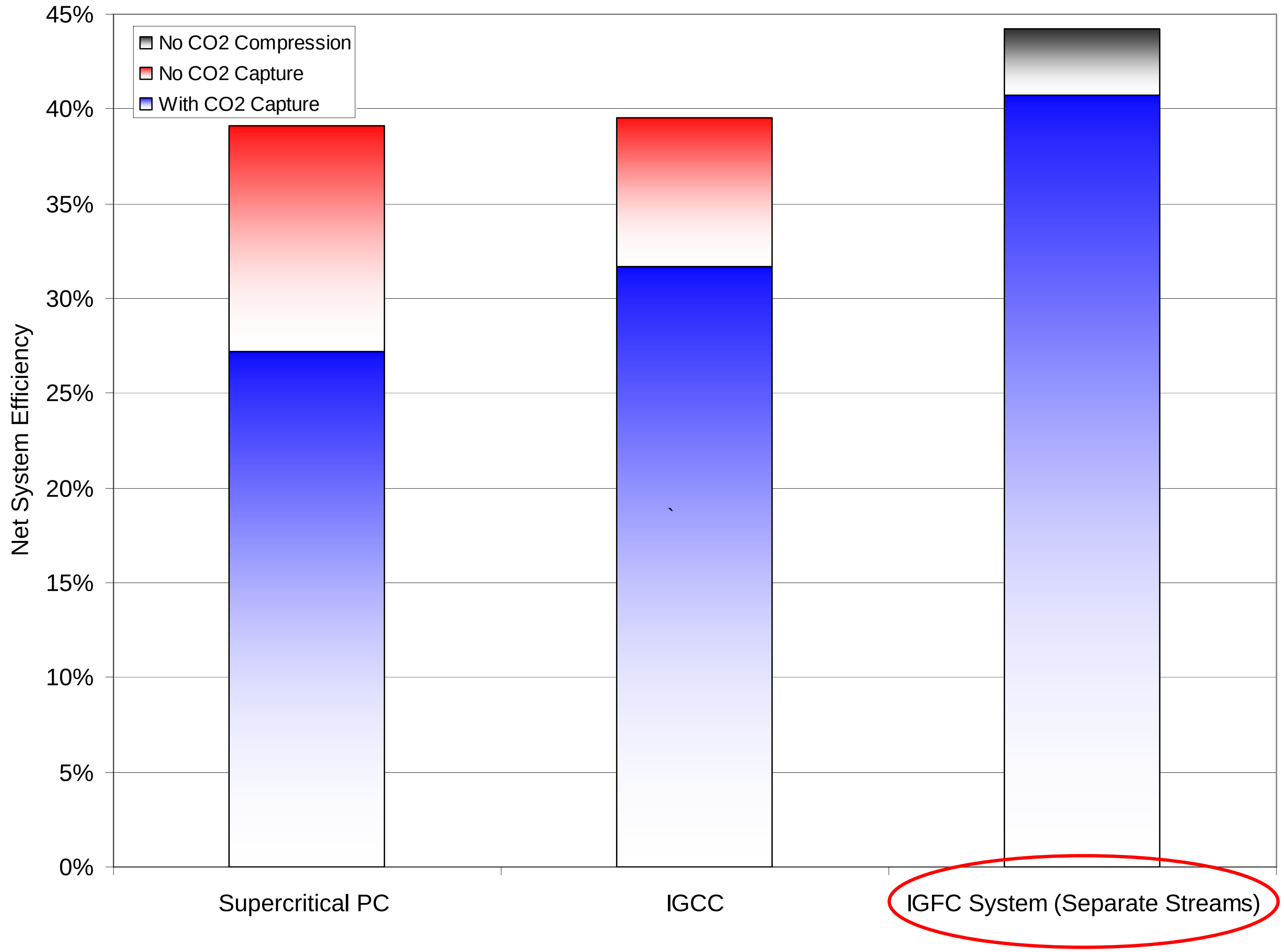
System Advancement

Separated Anode and Cathode Offgas Streams

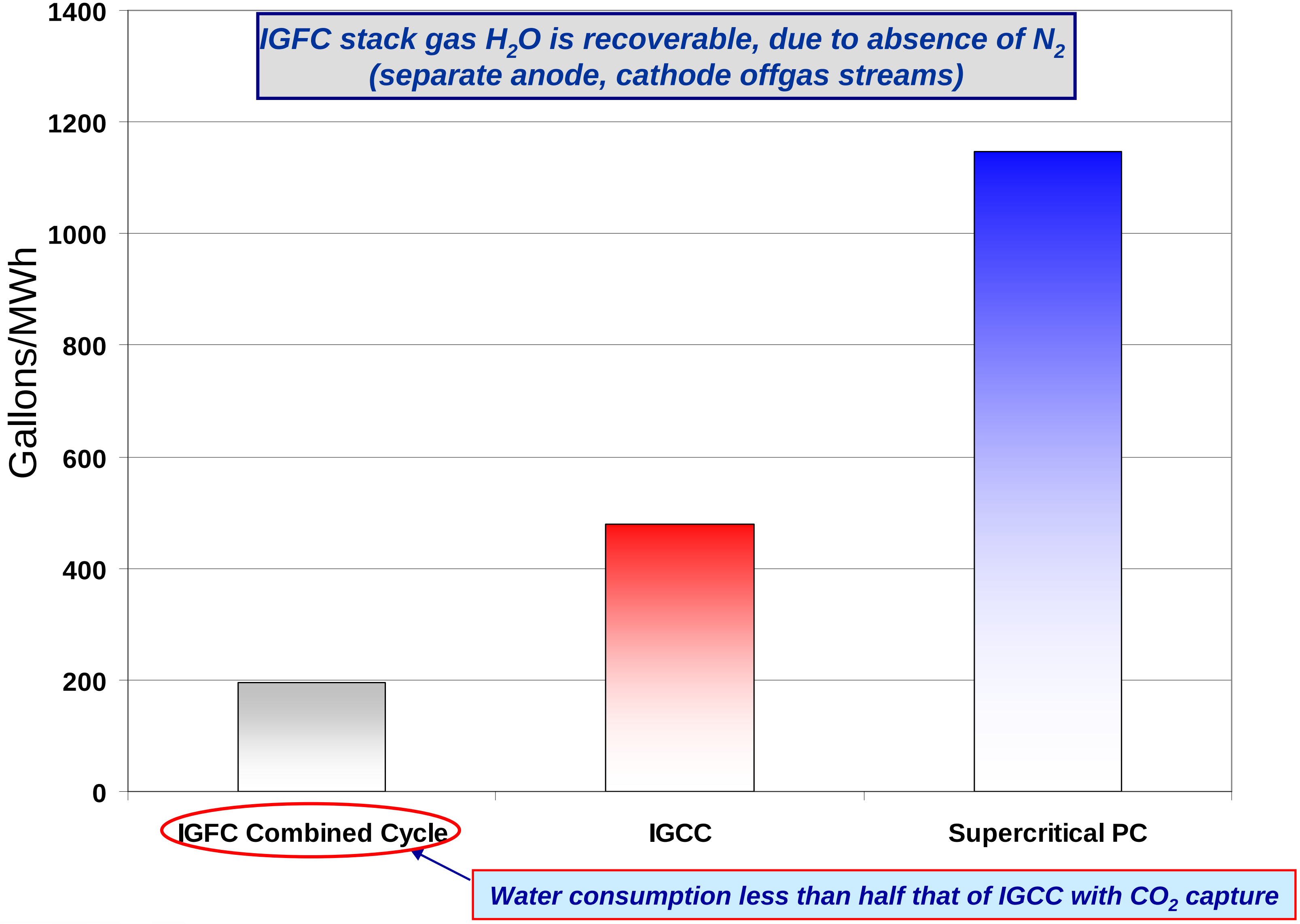


- **Separate anode, cathode offgas streams**
- **Recover residual anode fuel heating value in oxycombustor**
  - No dilution of products with N_2
- **Reaction products are CO_2 and H_2O, which can be condensed**
- ***Eliminate requirement for precombustion CO_2 capture***
- ***44.2% system efficiency (coal HHV basis)***
  - *1% improvement by separating anode, cathode offgas*

IGFC Efficiency Comparison to PC, IGCC



IGFC Water Consumption Comparison to PC, IGCC



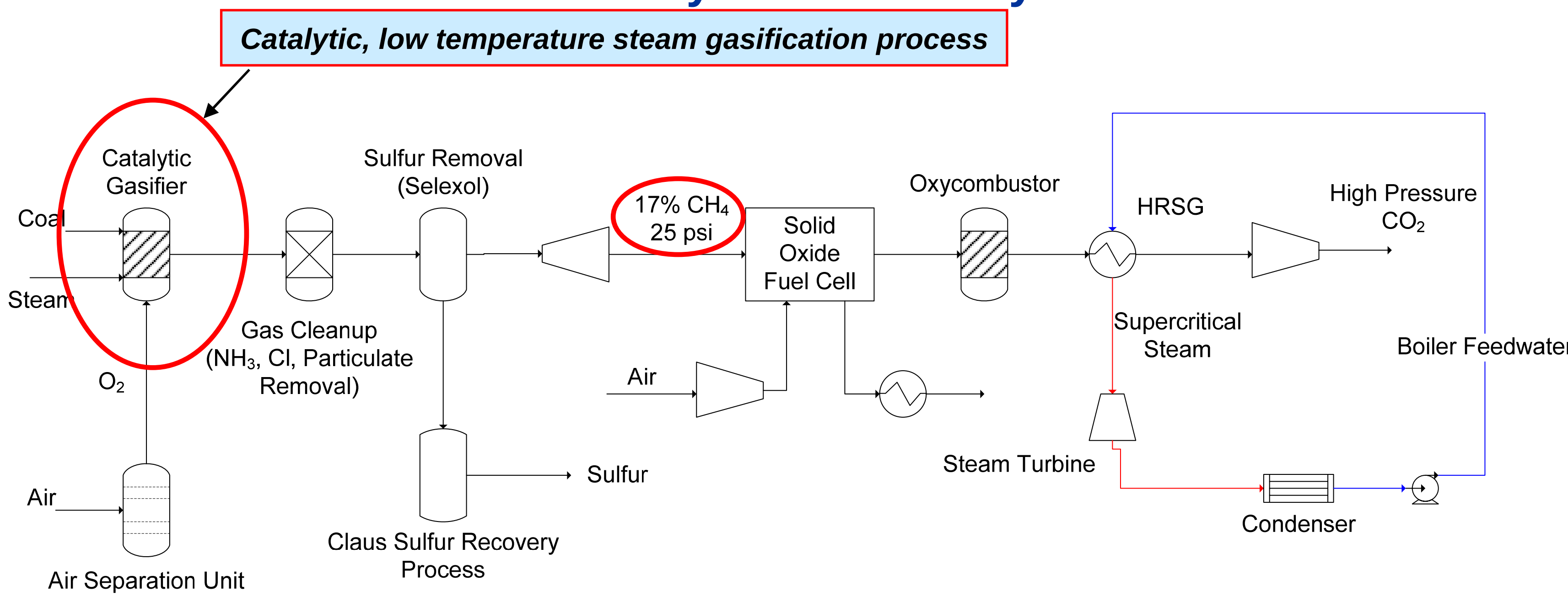
Effect of High Methane Syngas

- **For SOFC, syngas composition should be high in CH_4**
  - Endothermic CH_4 reforming can serve as a heat sink to exothermic H_2 oxidation, reducing stack thermal management load (cooling air blowers)
  - $H_2 + ½ O_2 \rightarrow H_2O$ **EXOTHERMIC**
  - $CH_4 + H_2O \rightarrow CO + 3H_2$ **ENDOTHERMIC**
- **Select a gasifier that produces syngas with high CH_4 concentration**

Gasifier Selection

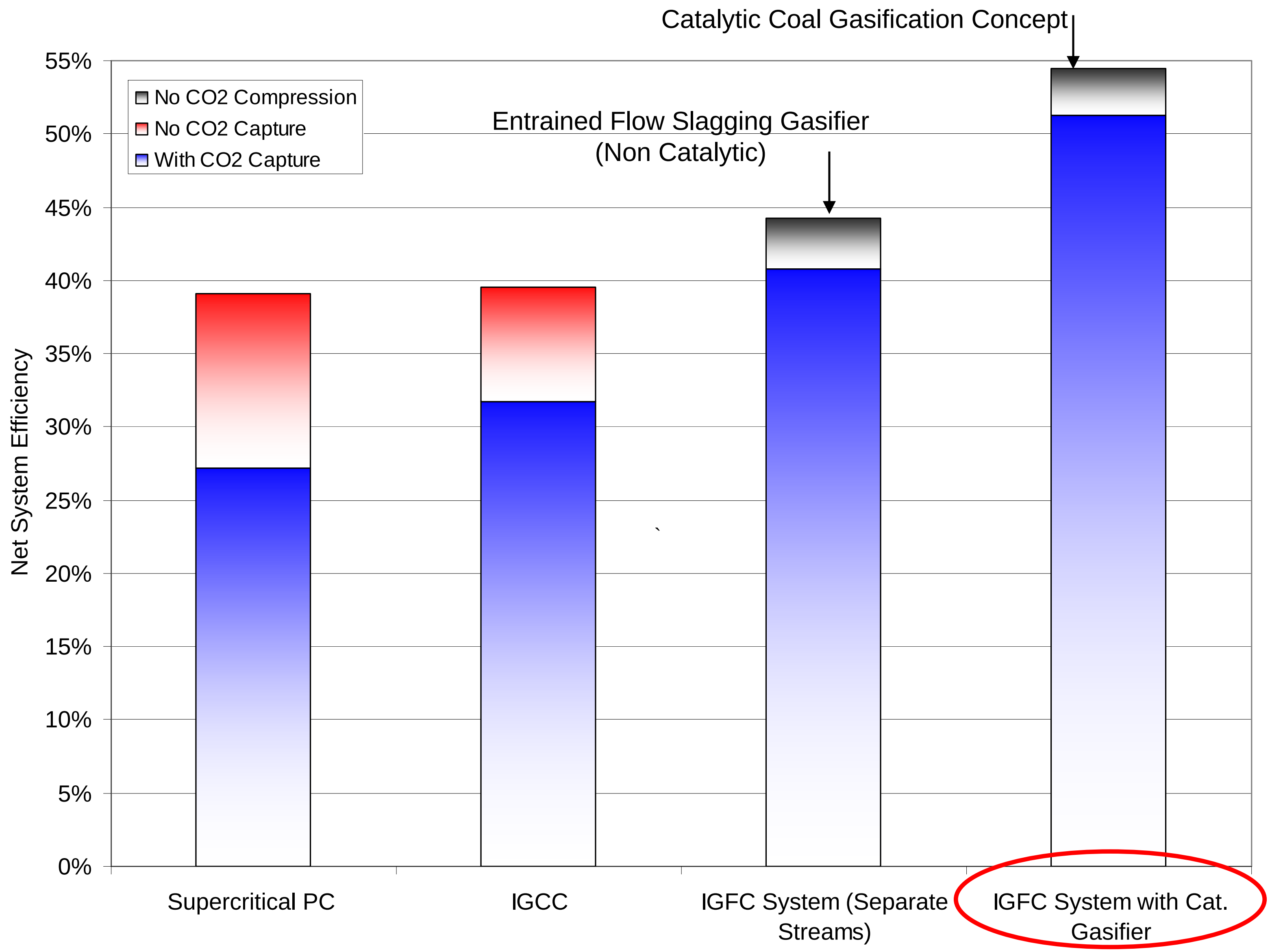
- **Catalytic coal gasification concept produces high methane yields at low gasification temperature**
- **Concept of catalytic coal gasification to produce SNG is not new**
  - Great Point Energy's bluegas™ process
  - Catalytic gasification concept to produce pipeline-quality SNG from coal and other feedstocks
- **Assumed for this analysis that SOFC can handle up to 25% CH_4**

IGFC Combined Cycle with Catalytic Gasifier

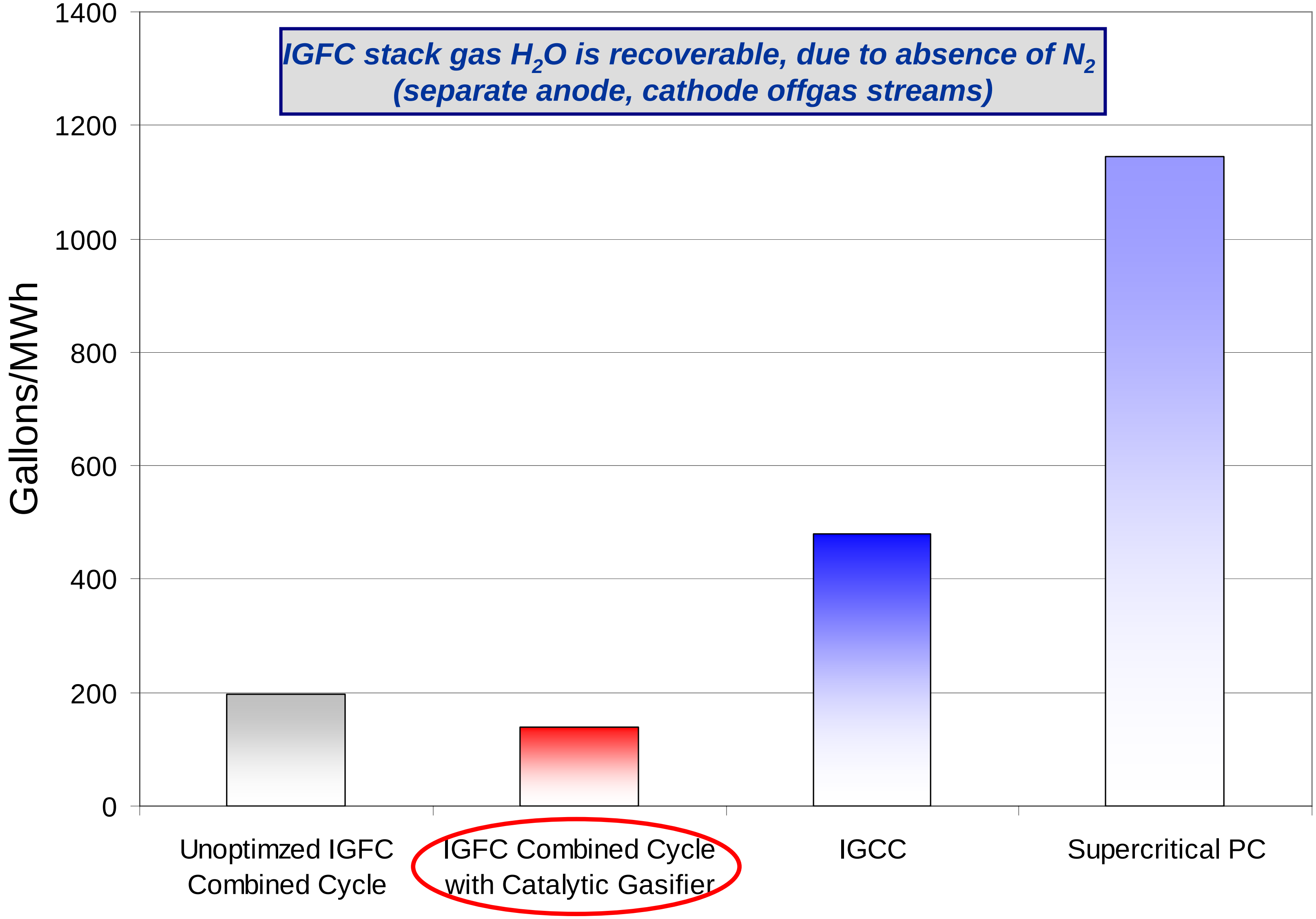


- **Low temperature, catalytic gasifier (high cold gas efficiency)**
- **High methane syngas (reduced stack cooling load)**
- **Separate anode and cathode offgas (no precombustion CO_2 capture)**
- **Waste heat recovered in supercritical steam cycle**
- ***54.5% efficiency (coal HHV)***
  - *~10% efficiency improvement by using different gasifier*

IGFC Efficiency Comparison to PC, IGCC



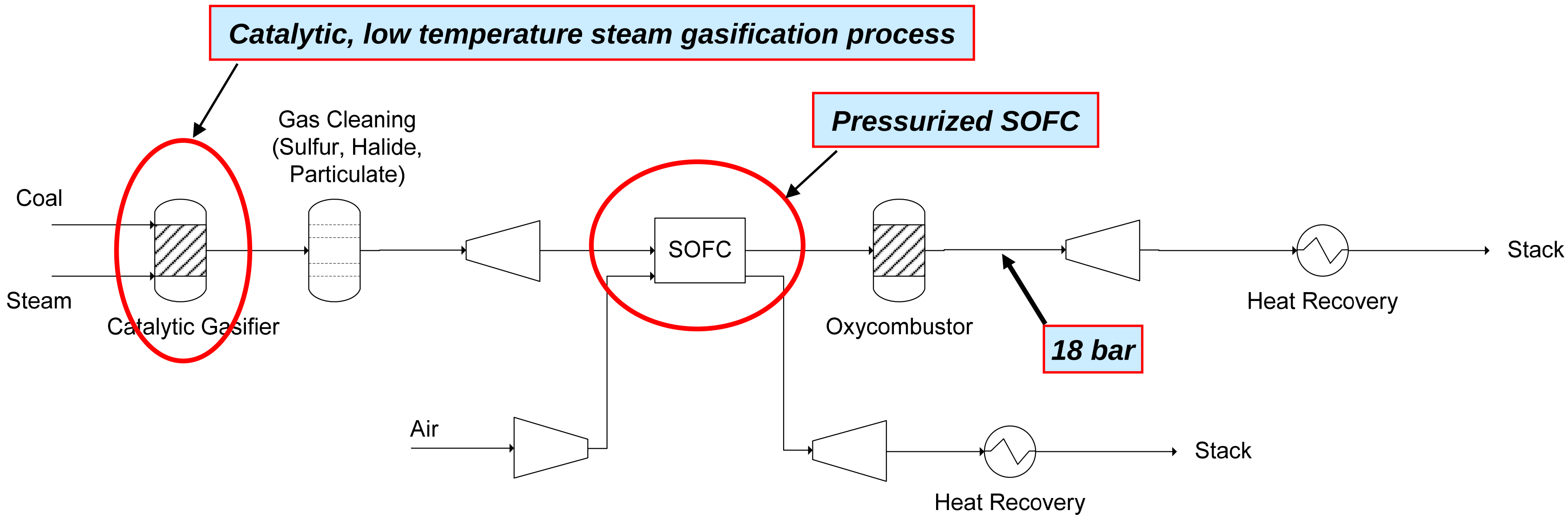
IGFC Water Use Comparison to PC, IGCC



Improved IGFC System

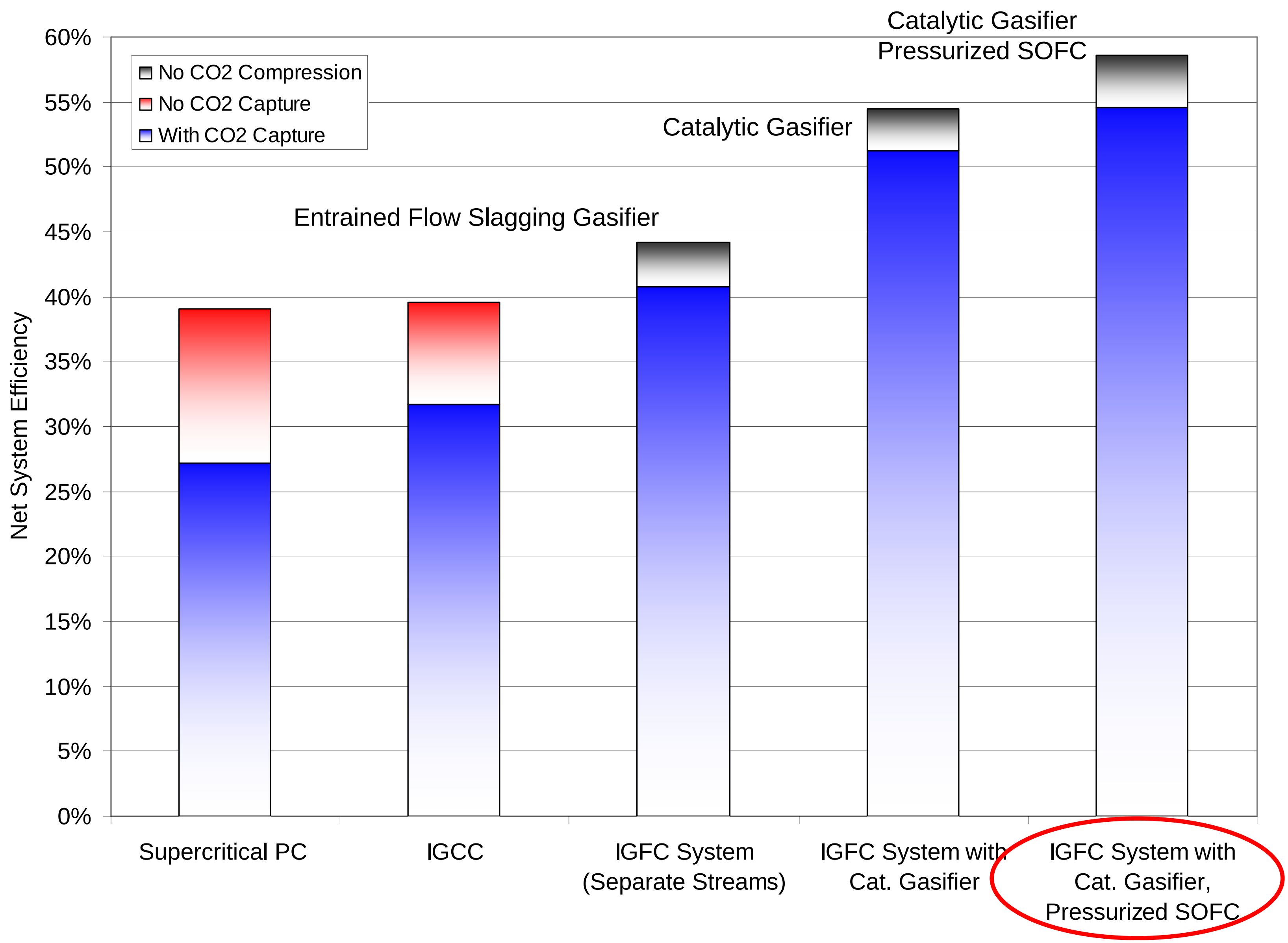
- **SOFC with minimal overpotential loss (high efficiency)**
- **Humid gas cleaning system (maintains H_2O in vapor phase)**
- **High methane gasifier (catalytic coal gasification)**
- **Pressurized SOFC operation**
  - Voltage improved by pressurized operation
  - High pressure anode offgas for expansion through turbine
    - *Elimination of steam cycle, reduced water footprint*

IGFC Combined Cycle with Catalytic Gasifier and Pressurized SOFC

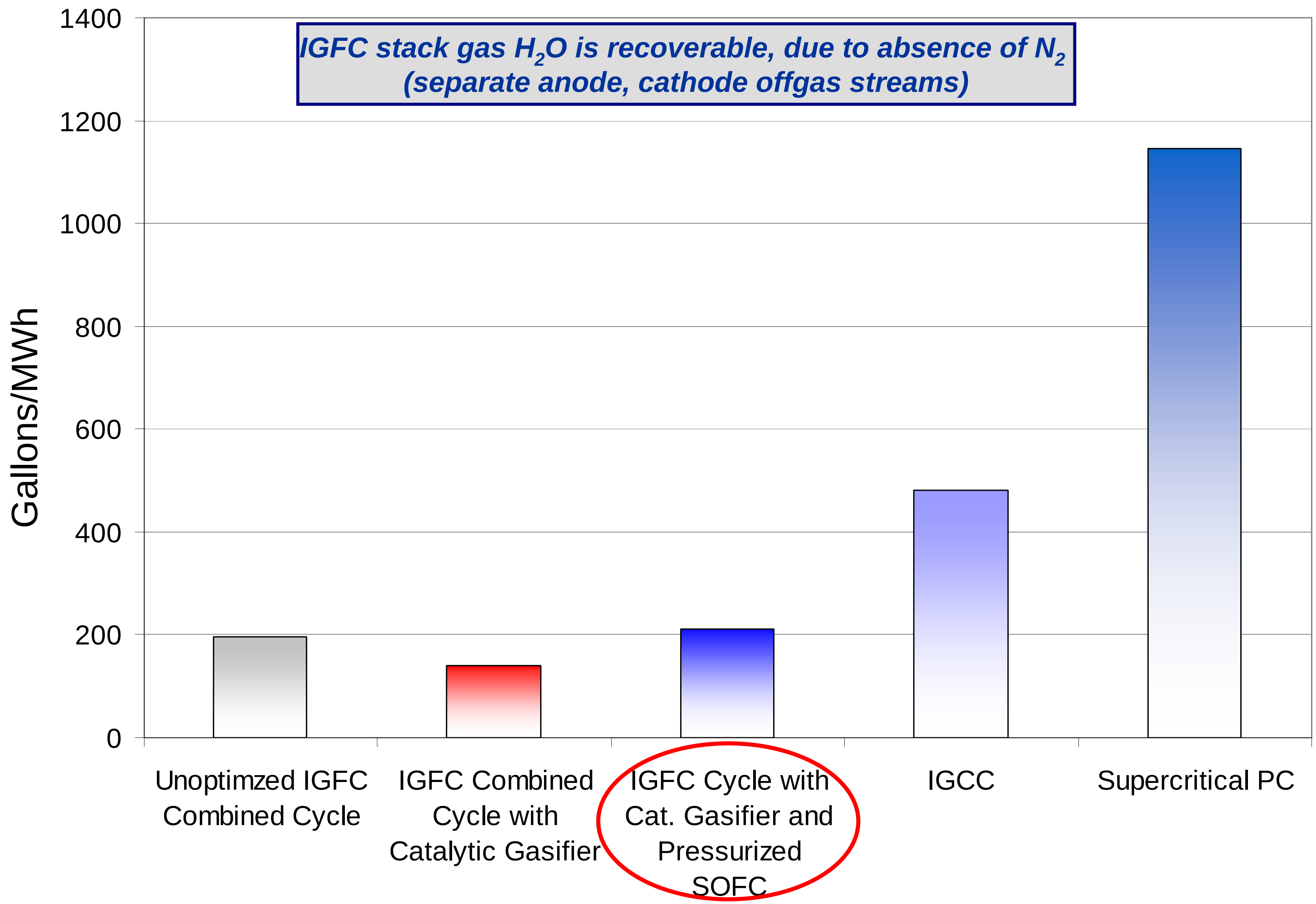


- **Low temperature, catalytic gasifier (high cold gas efficiency)**
- **High methane syngas (reduced stack cooling load)**
- **Separate anode and cathode offgas (no precombustion CO_2 capture)**
- **Pressurized SOFC**
- **Turbine expander after oxycombustion (18:1 PR)**
- ***58.6% efficiency (coal HHV)***

IGFC Efficiency Comparison to PC, IGCC



IGFC Water Use Comparison to PC, IGCC



Conclusions

- **Fuel cell power system is attractive with respect to carbon capture, water use, and efficiency**
- **System advances needed to achieve high efficiency cycles:**
  - High methane syngas (catalytic gasifier)
  - Humid gas cleaning
  - Achieve targeted SOFC performance
- **Continued interaction between systems analysis group and research program**