The Potential Impact of Developing Technologies on the Economics and Performance of Future IGCC Power Plants

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For the best of reasons

Acknowledgement

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Study Objective

Starting with present-day baseline, evaluate improved IGCC performance and cost resulting from DOE-funded R&D over the next 18 years. Examine both with and without CO_2 capture.

Study results will help to prioritize technology development based on relative impact. Results will also help to assess the impact of future potential CO_2 emissions restrictions.

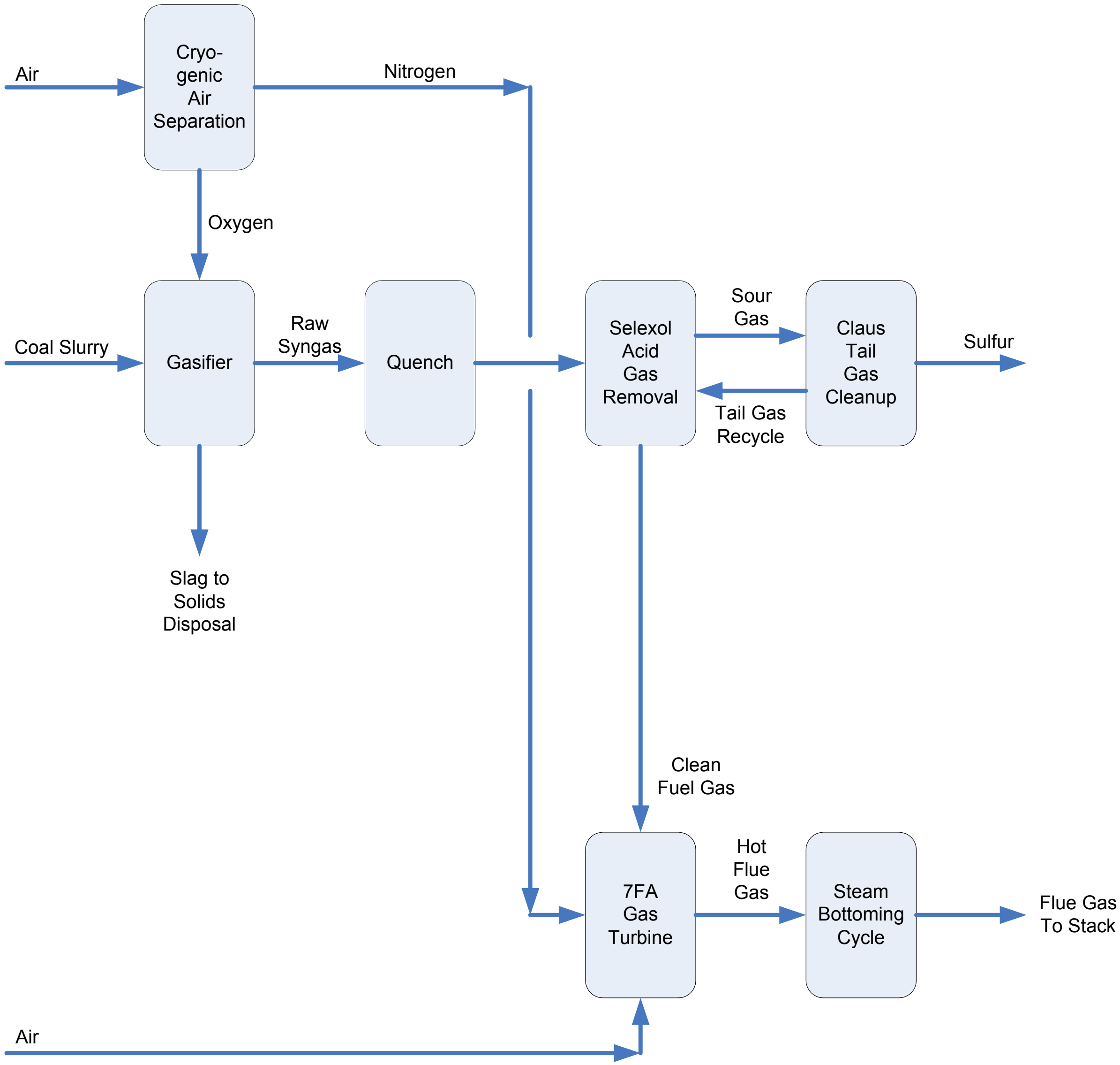
Methodology

- Use Aspen Plus simulator to provide model "transparency"
- Start with a baseline that represents currently-available technology
- Create a series of cases both with and without CO_2 separation
- Implement step-wise process changes in order to quantify effects of technology improvements
- Analyze cumulative effects to show full potential of IGCC technology

Baseline IGCC Plant

- Nominal 600 MWe net power generation
- Illinois #6 bituminous coal feedstock
- Single stage, slurry-fed, oxygen-blown, entrained gasifier with radiant syngas cooler
- Cryogenic air separation unit
- Selexol acid gas removal, with Claus tail gas treatment
- GE 7FA combustion gas turbine
- Three-pressure level steam cycle with 1800 psia / 1000 ^{o}F / 1000 ^{o}F

Baseline IGCC Plant

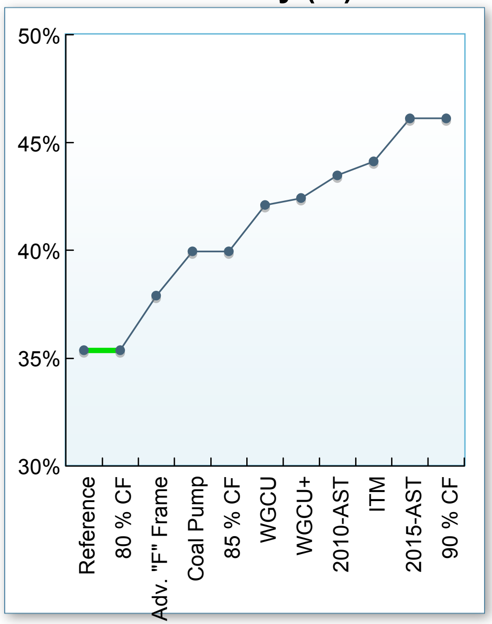


Technology Improvements Examined

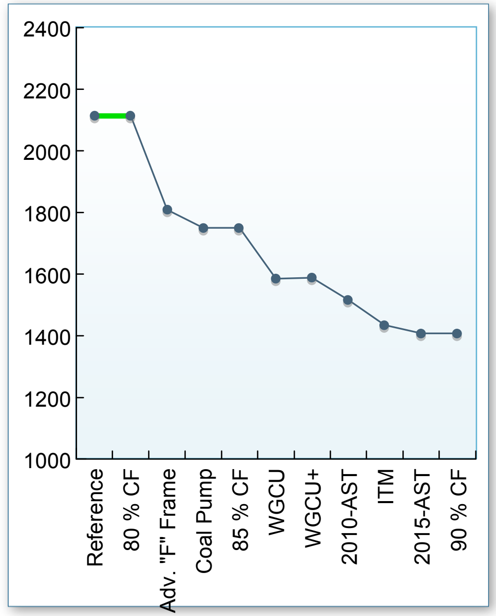
- Coal feed pump
- Warm gas cleanup
- Ion Transport Membrane
- Advanced syngas turbines
- Enhanced capacity factor

80% Capacity Factor

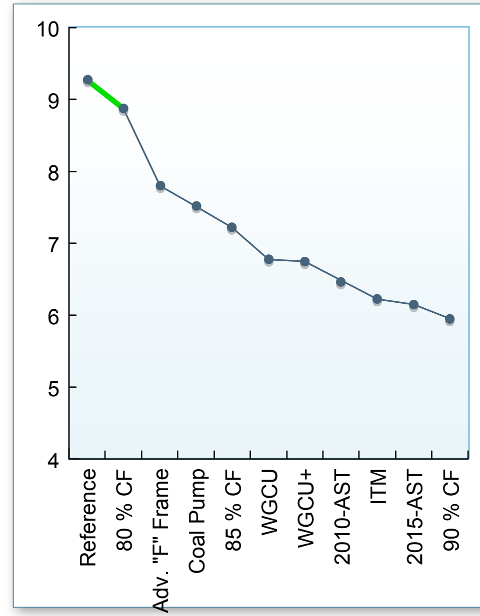
Efficiency (%)



TPC ($/kW)

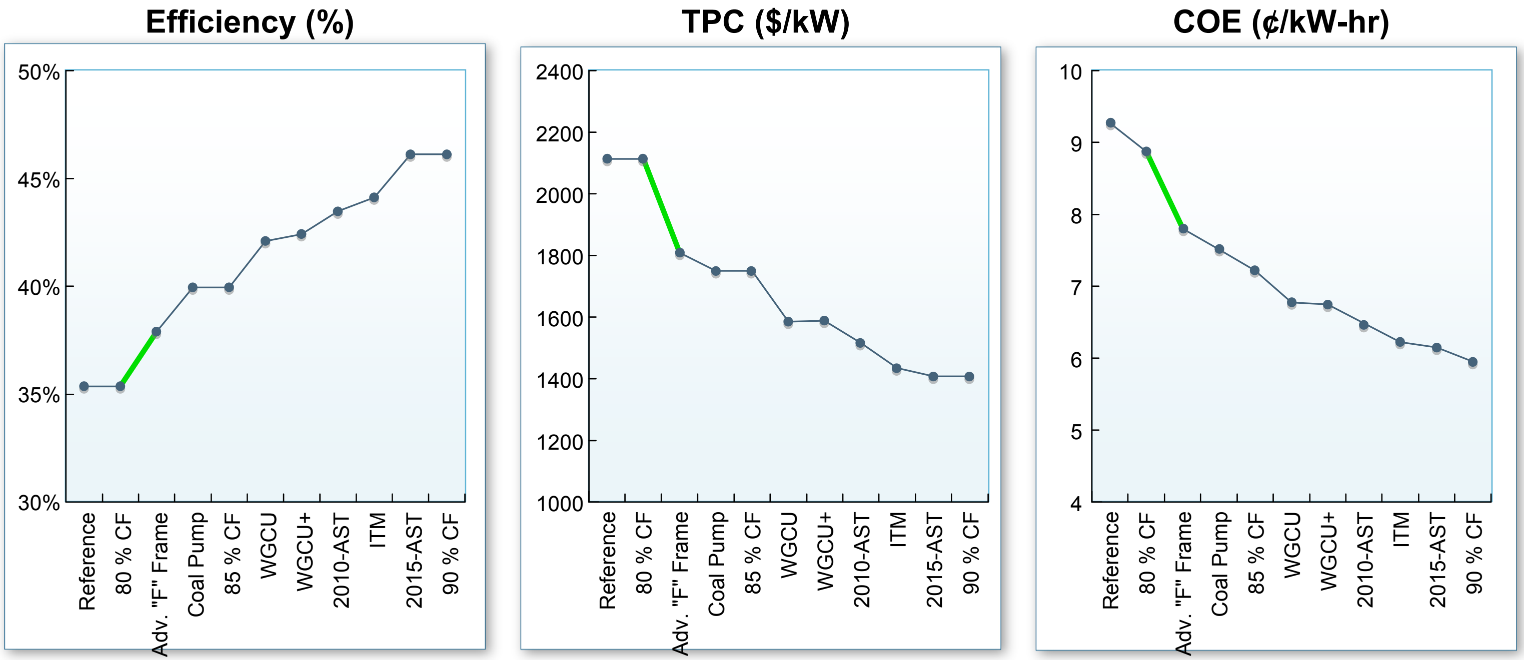


COE (¢/kW-hr)



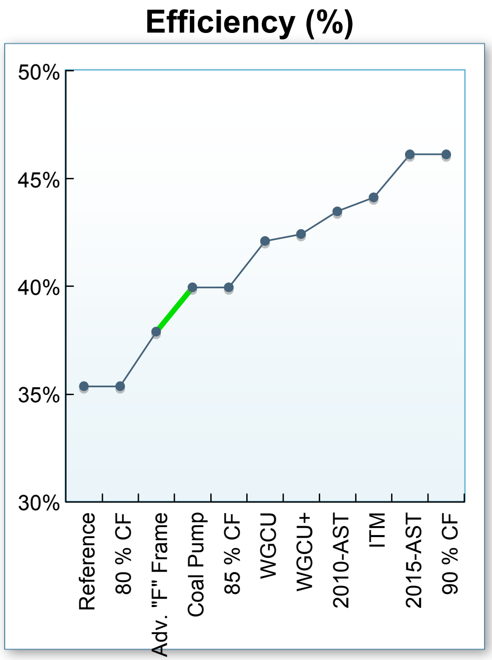
- More time on-stream resulting from operating experience in DOE demonstration programs.
- No effect on process efficiency or total plant cost.
- COE reduces by 4.0 mills/kW-hr because of increased plant revenues.

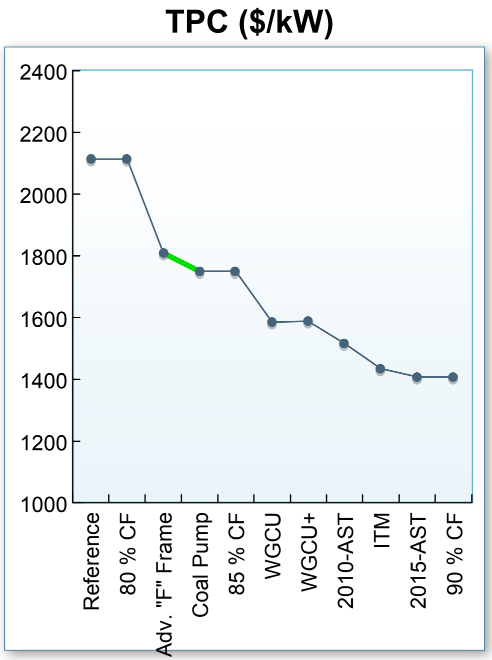
Advanced "F" Frame Syngas Turbine

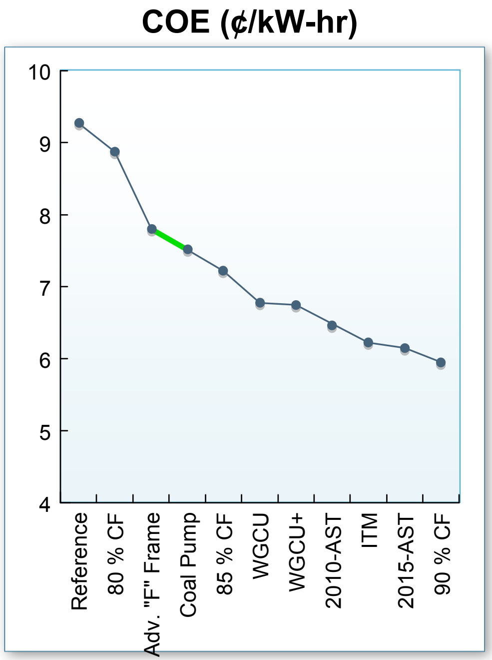


- Process efficiency increases by 2.5 percentage points due to air integration, increased pressure ratio, increased turbine exit temperature, and higher steam cycle superheat temperature.
- TPC decreases by $304/kW because of increased net power production.
- COE decreases by 10.7 mills/kW-hr because of reduced TPC and also reduced fuel cost from large efficiency increase.

Coal Feed Pump

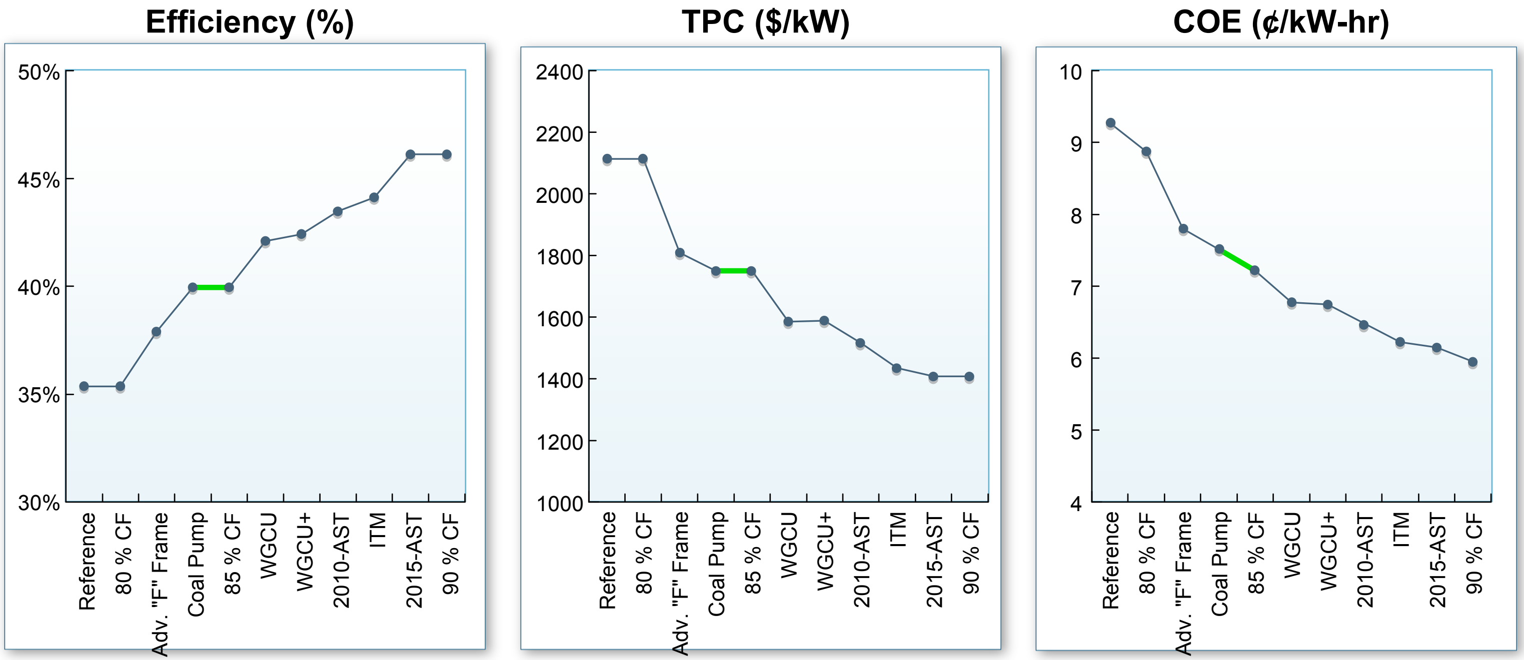






- Process efficiency increases by 2.1 percentage points because there is no slurry water to evaporate in the gasifier, and therefore reduced coal feed rate. Auxiliary power also decreases because of reduced oxygen requirement.
- Plant cost decreases by $60/kW as result of smaller equipment sizes with reduced coal throughput.
- COE decreases by 2.9 mills/kW-hr because of capital cost savings and increased fuel efficiency.

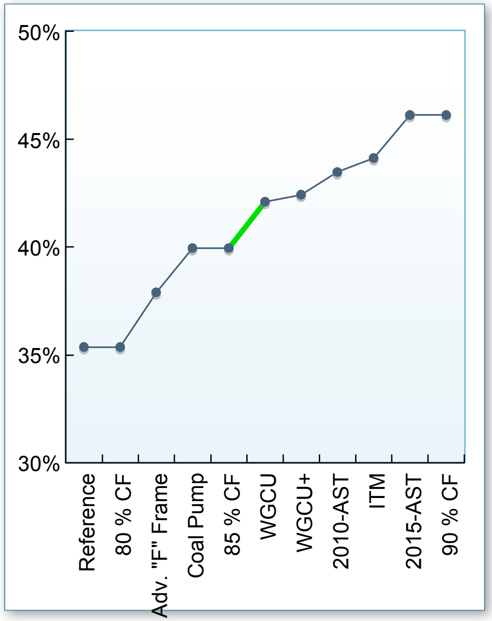
85% Capacity Factor



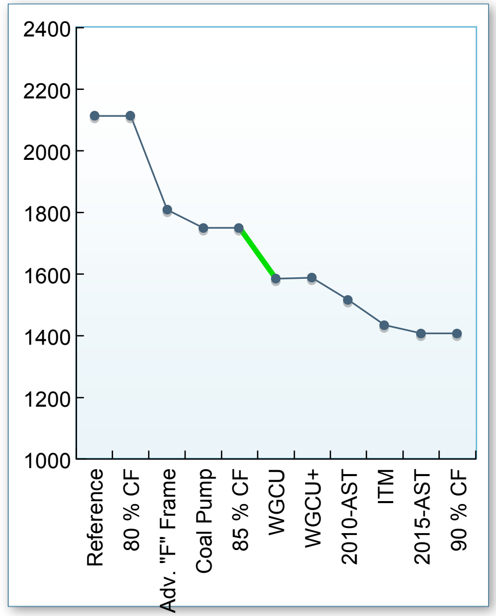
- Increased plant availability reflects improvements in RAM resulting from DOE-sponsored R&D on vessel refractories and instrumentation.
- No effect on process efficiency or plant cost.
- COE decreases by 2.9 mills/kW-hr as result of increased plant revenues.

Partial Warm Gas Cleanup

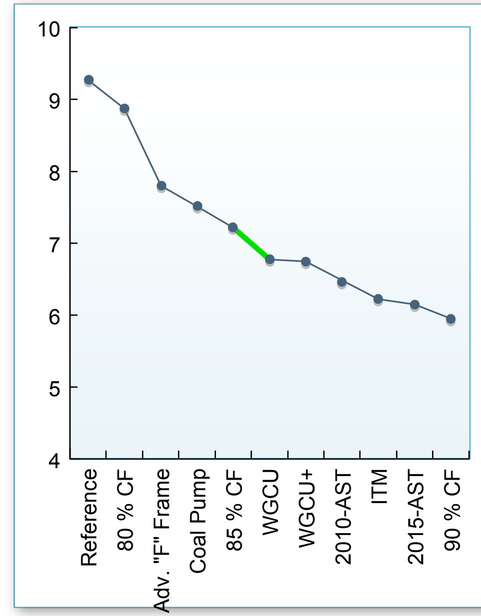
Efficiency (%)



TPC ($/kW)



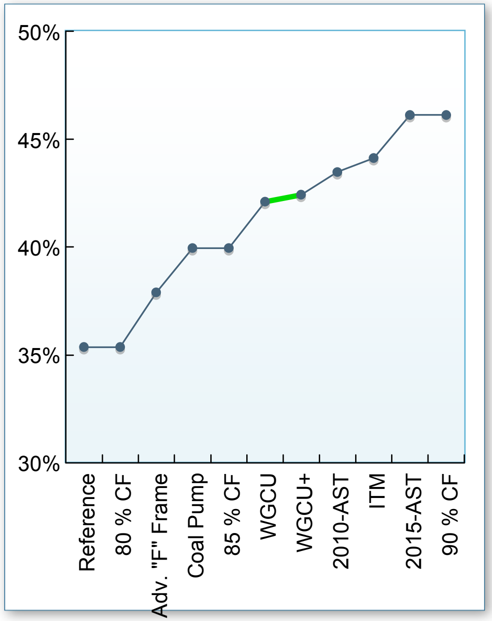
COE (¢/kW-hr)



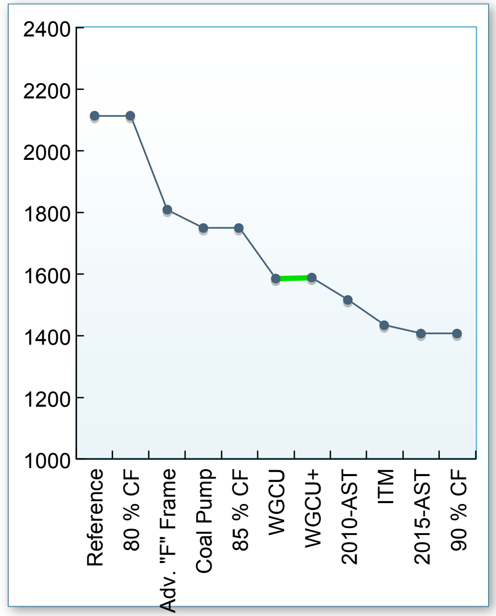
- Process efficiency increases by 2.2 percentage points from significant increase in steam turbine power by eliminating Selexol and Sour Water Stripper reboilers and less syngas reheat duty.
- Gas cleanup cost decreases by $81/kW, and increased net power production contributes $83/kW reduction in all other plant sections for a total of $164/kW reduction in TPC.
- COE decreases by 4.5 mills/kW-hr because of decreased TPC and increased fuel efficiency.

Full Warm Gas Cleanup

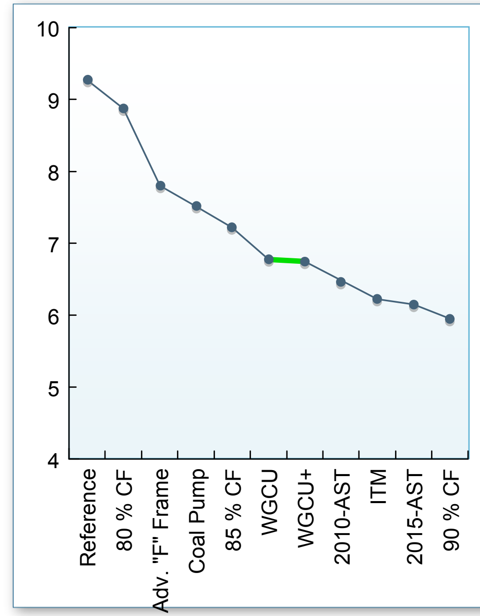
Efficiency (%)



TPC ($/kW)

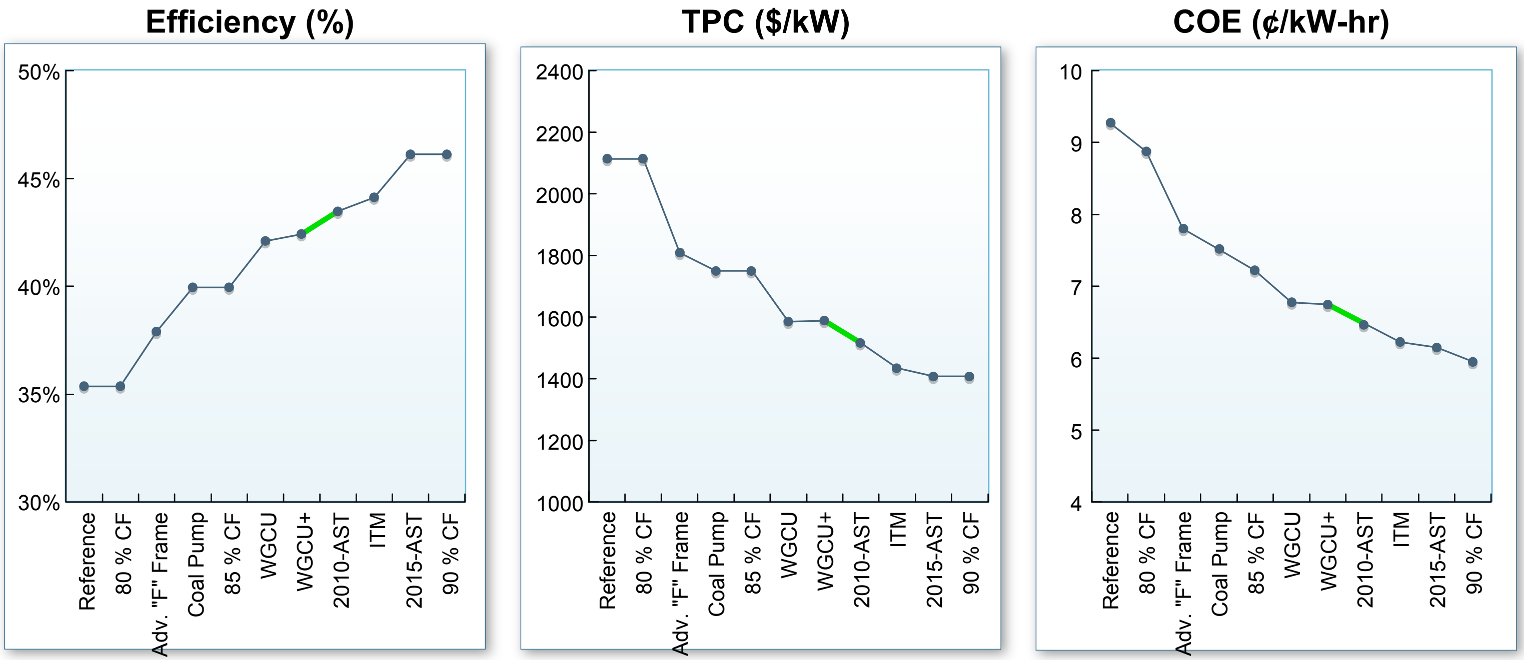


COE (¢/kW-hr)



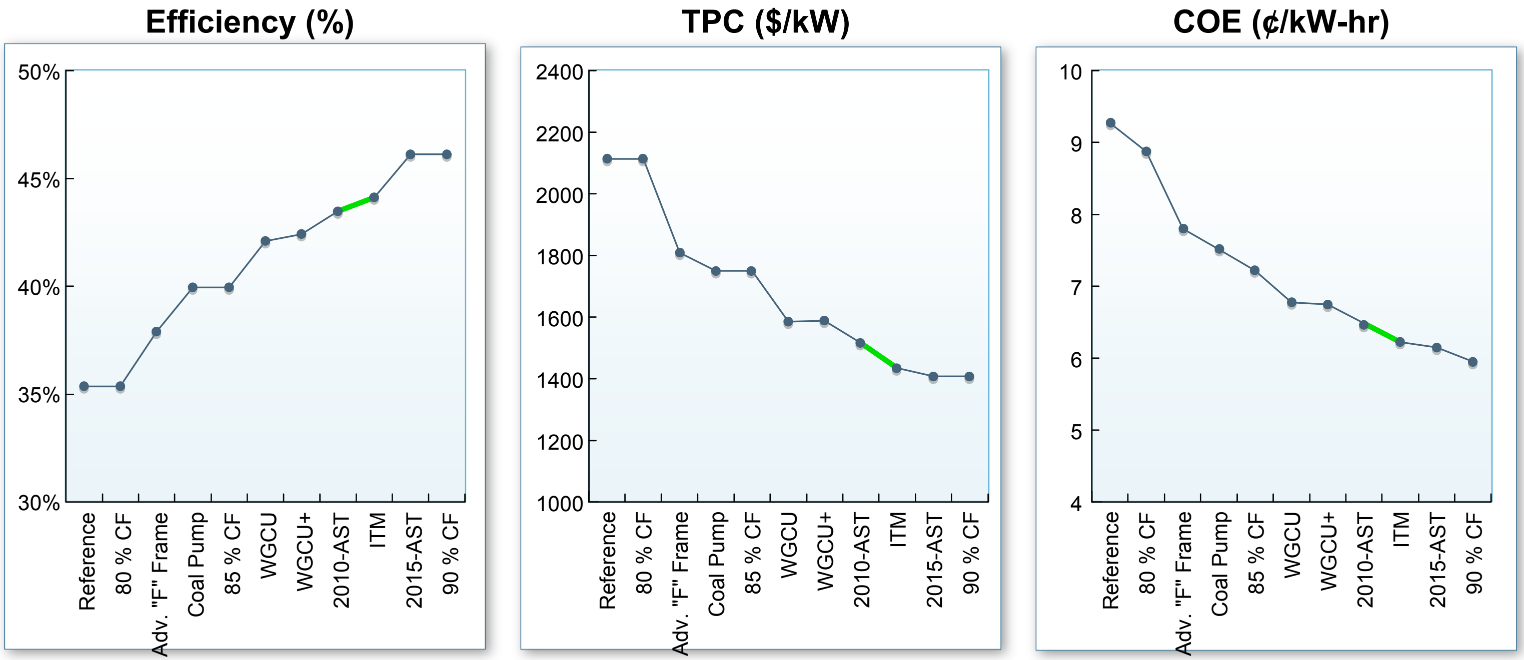
- Process efficiency increases by 0.3 percentage points with dry feed gasifier. There is no appreciable moisture in syngas, so it doesn't make as much difference within cold/warm gas NH_3 and Hg removal as it does with a slurry feed gasifier.
- NH_3 and Hg removal have small impact on both plant cost and net power, so there is a small increase of $3/kW TPC.
- Negligible decrease of 0.2 mills/kW-hr in COE.

2010–AST Syngas Turbine



- DOE is sponsoring advanced turbine development. 2010 targets for increased power rating and pressure ratio result in 1.0 percentage point increase in efficiency.
- The increased net power production results in $72/kW decrease in TPC.
- Decreased TPC and increased fuel efficiency contribute to a further 2.7 mills/kW-hr reduction in COE.

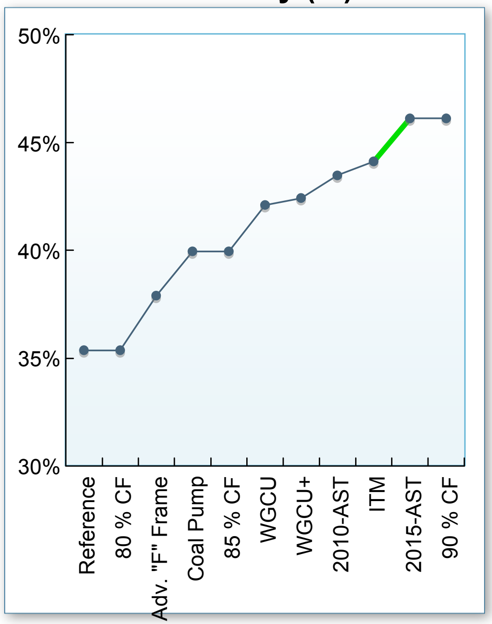
Ion Transport Membrane



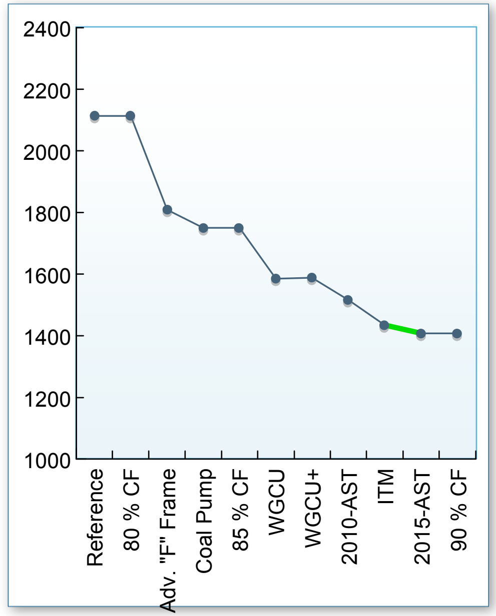
- ITM replaces the cryogenic ASU, eliminating the N_2 compressor. Steam turbine power increases because ASU steam requirement is eliminated and humidifying steam is no longer needed.
- Net process efficiency increases by 0.7 percentage points.
- Decrease in cost of ASU by one-third and increased plant power contribute to $82/kW decrease in TPC.
- Decreased TPC is largely responsible for the 2.6 mills/kW-hr reduction in COE.

2015–AST Advanced Syngas Turbine

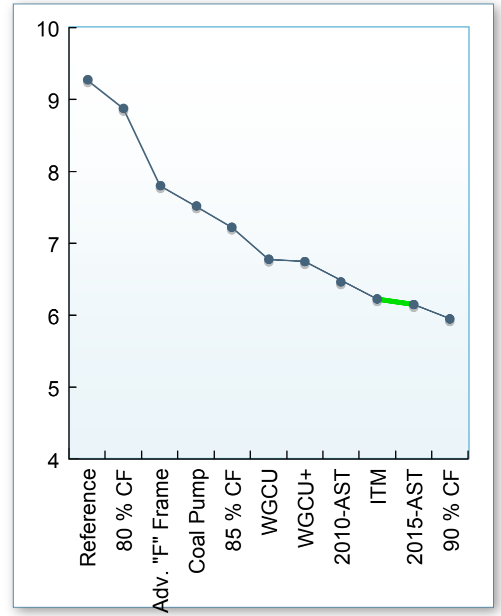
Efficiency (%)



TPC ($/kW)



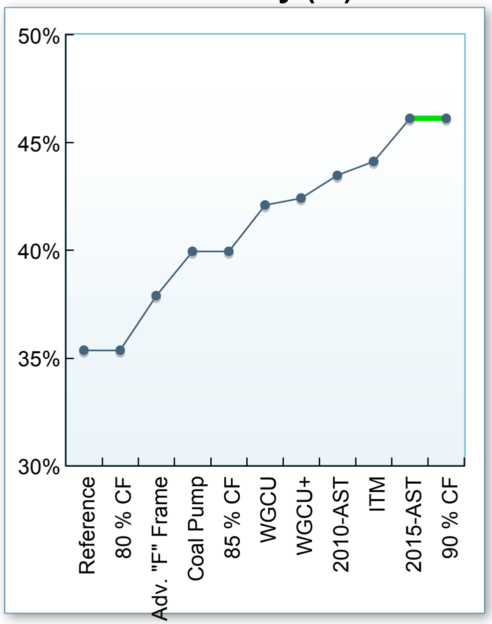
COE (¢/kW-hr)



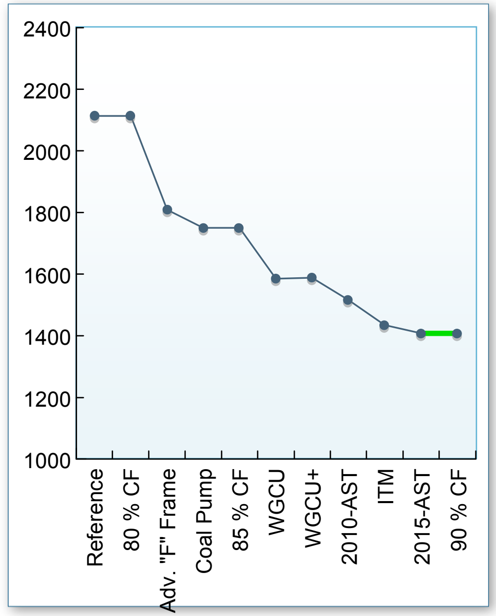
- Continued syngas turbine development provides larger engine with higher pressure ratio resulting in further efficiency improvement by 2.0 percentage points.
- Nominal plant size is 600 MW, so with introduction of 2015-AST only one train will be needed. This makes for more affordable plant, but some economy of scale is lost and TPC decreases by $27/kW.
- With plant TPC dominating the COE, there is a decrease of 0.7 mills/kW-hr despite large increase in efficiency.

90% Capacity Factor

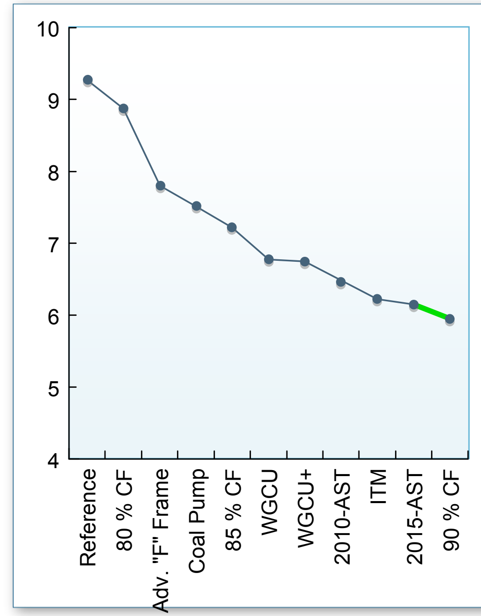
Efficiency (%)



TPC ($/kW)



COE (¢/kW-hr)



- With continued DOE-sponsored R&D to improve RAM, 90% capacity factor is achievable.
- No impact on process efficiency or TPC
- COE decreases by 2.0 mills/kW-hr resulting from increased plant revenues.

Summary

- Advanced technologies are capable of improving IGCC process efficiency by a total of 11 percentage points
- $700/kW decrease in TPC – a 33% reduction
- COE decreases by 3.3 cents/kWh – a reduction of nearly 36%
- These advanced technologies will enable cost-effective pre-combustion CO_2 capture and ultra-high efficient IGFC processes

Future Work

- Complete analysis on carbon capture process scenarios
- Extend study to low-rank coals