Comparison of a New Warm-Gas Desulfurization Process versus Traditional Scrubbers for a Commercial IGCC Power Plant

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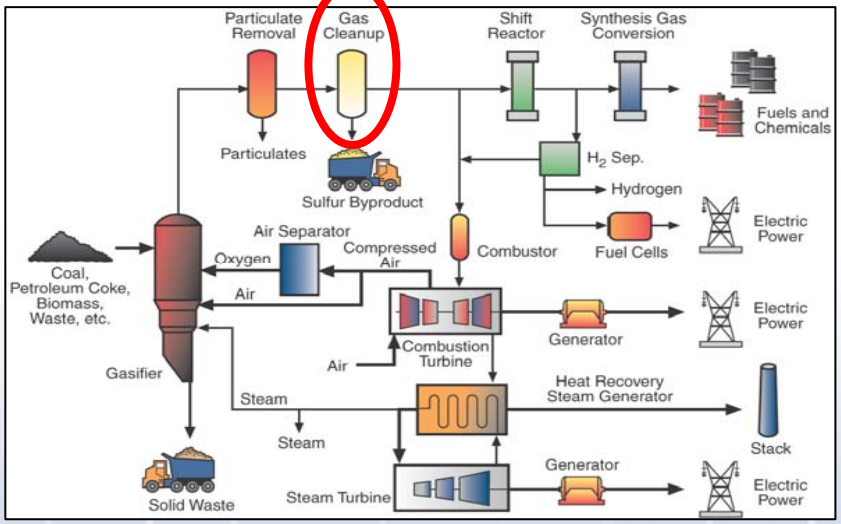
Warm Syngas Cleanup Technologies



Sulfur

- Regenerable ZnO sorbents
- Transport reactor
- Direct Sulfur Recovery Process

- Hg adsorbents (disposable)
- As adsorbents (disposable)
- Se adsorbents (disposable)
- Regenerable NH_3/HCN adsorbents
- HCl adsorbents (disposable)
- Regenerable CO_2 sorbents

Operating Temperatures > 250 °C

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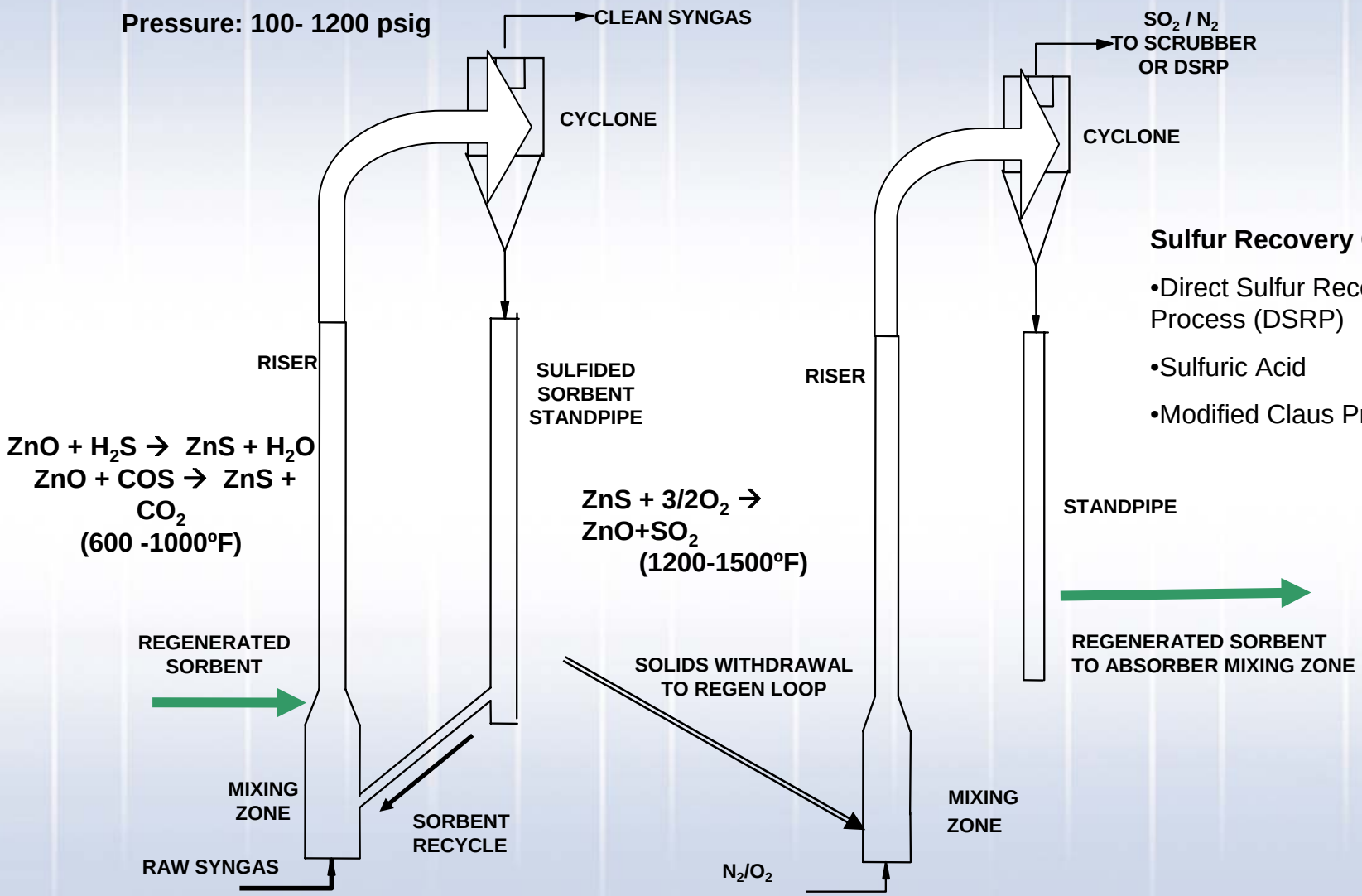
Transport Desulfurization Reactor System



Sulfur Recovery Options

- Direct Sulfur Recovery Process (DSRP)
- Sulfuric Acid
- Modified Claus Process

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Installed Pilot Plant Systems

Eastman's Kingsport, TN Coal Gasification Facility

Direct Sulfur Recovery Process (DSRP)

Warm Gas Desulfurization System (WGDS)

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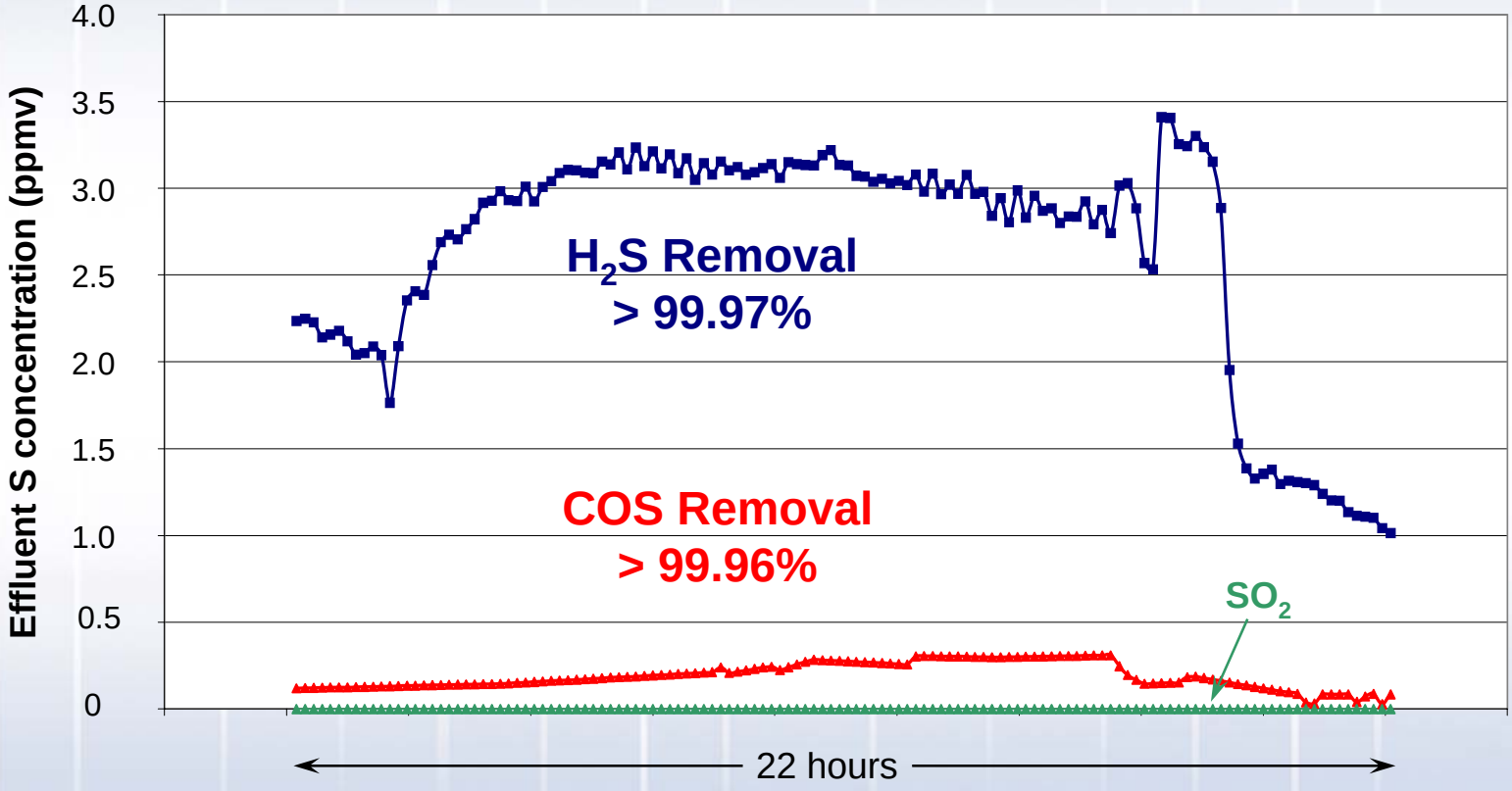
Typical Sulfur Concentrations in Effluent Syngas



Dirty syngas composition: 7,771 ppmv H_2S
440 ppmv COS

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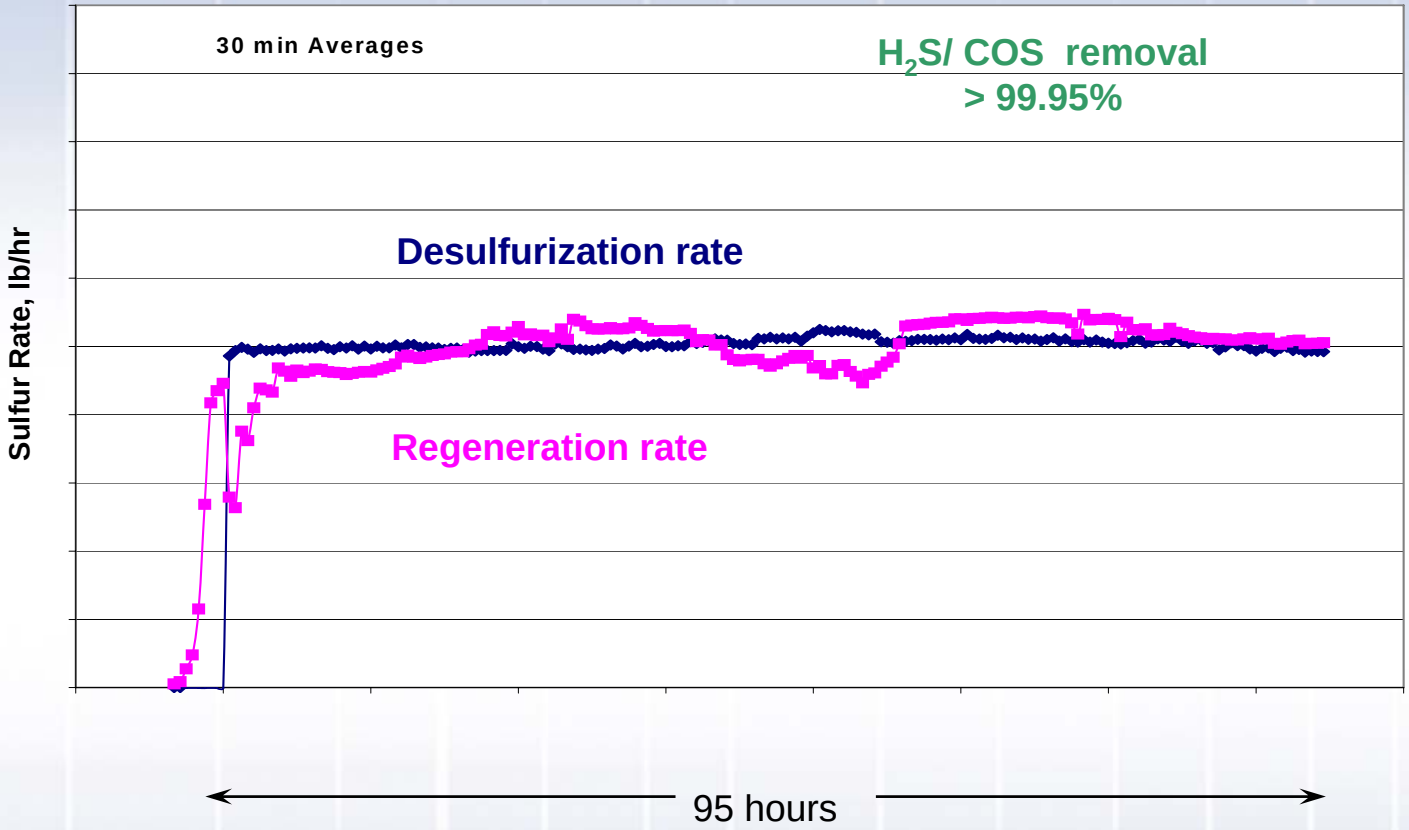
Desulfurization Process Reliability



On-Stream Factor

61% (Several auxiliary equipment failures) [Feb '07 to May '07]

81% (Main faulty auxiliary equipment removed) [May '07 to Present]

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Desulfurization Pilot Plant
Summary of Parametric Testing

Total of 3,017 hr of syngas operation

Pressure, psig	300	450	600
Inlet Concentration, S ppmv	8,661	7,023	8,436
Effluent Conc. S ppmv Range	5.9 0.4 – 9.3	10.7 2.4-20.6	5.7 3.3-18.1
S Absorbed, lb/hr	4.1	4.4	5.0
S Removal, %	99.93	99.82	99.90

All data are averages over multiple hours of operation

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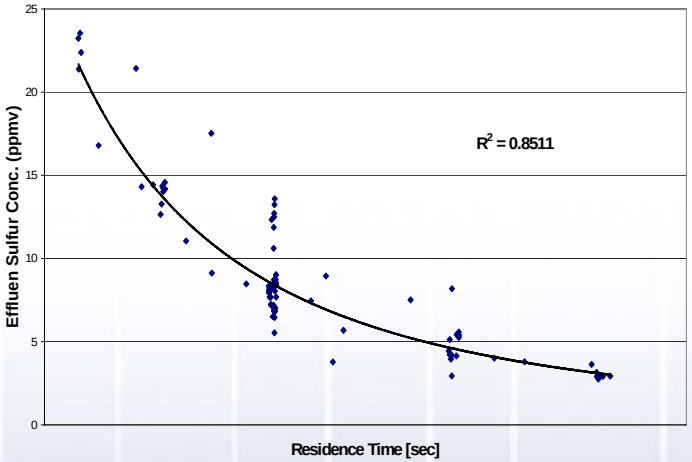
Progress in 2006-2007: Parametric Testing Program

- Operating conditions
  - Effluent sulfur concentrations over target operating conditions
  - Regeneration exotherm
- Sorbent
  - Active life
  - Attrition
    - ~5-50 lbs/MM lbs circulated

  [FCC ~50-100 lbs/MM circulated]



- Operating/control procedures
  - Stable solids circulation
  - Thermally neutral process operation
- Commercial startup/shutdown procedures

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Direct Sulfur Recovery Process (DSRP) Summary

Chemistry

$$SO_2 + H_2 \rightarrow 1/n\ S_n + H_2O$$

Operation

- ~115 hr on-stream to date
- Up to 98 % sulfur recovery demonstrated
  - Highly effective and stable catalyst
- On-stream time limited
  - Frequent plugging of small diameter sulfur lines

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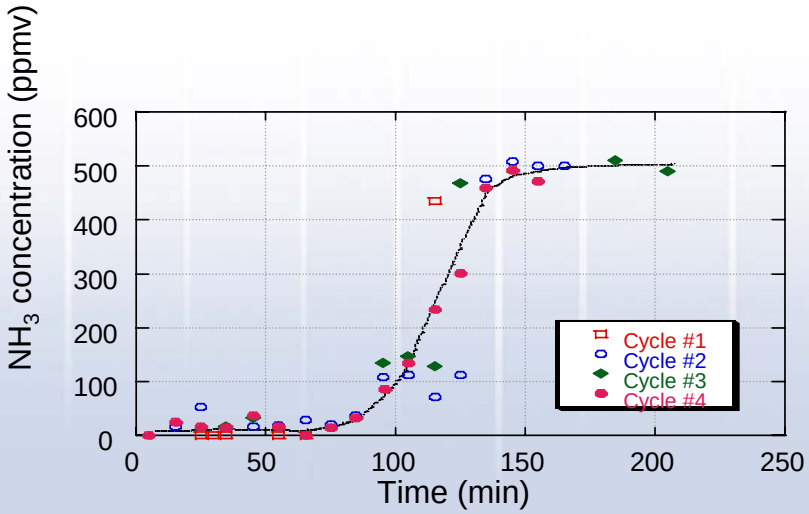
Treating Syngas Contaminants beyond Sulfur

- Modular fixed bed technologies for syngas cleaning beyond sulfur at temperatures > 200 ºC
  - Regenerable fixed-bed ammonia process
  - Inexpensive disposable HCl sorbents
  - Disposable fixed-bed sorbents for trace contaminants
    - Hg
    - As
    - Se
    - Multifunctional sorbents



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Technology Readiness for Commercial Deployment

- **Performance in real syngas**
  - Field testing has provided actual performance resulting from exposure to real coal-derived syngas
- **Process reliability**
  - Sorbent performance
    - Extended testing to evaluate long-term chemical deactivation and mechanical attrition
  - Process control and stability
    - Demonstrated and refined ability to control process at stable operating conditions
- **Sorbent production scale-up**
  - Commercially manufactured 8,000 lbs of sorbent for pilot-plant testing
- **Process scale-up**
  - Successfully scaled process up to 0.3 MW
  - Actively working on a 50-MW demonstration unit
- **Modular fixed bed cleanup technologies for additional syngas contaminants**
  - Fixed bed adsorbents for HCl, NH_3, As, Hg, and Se

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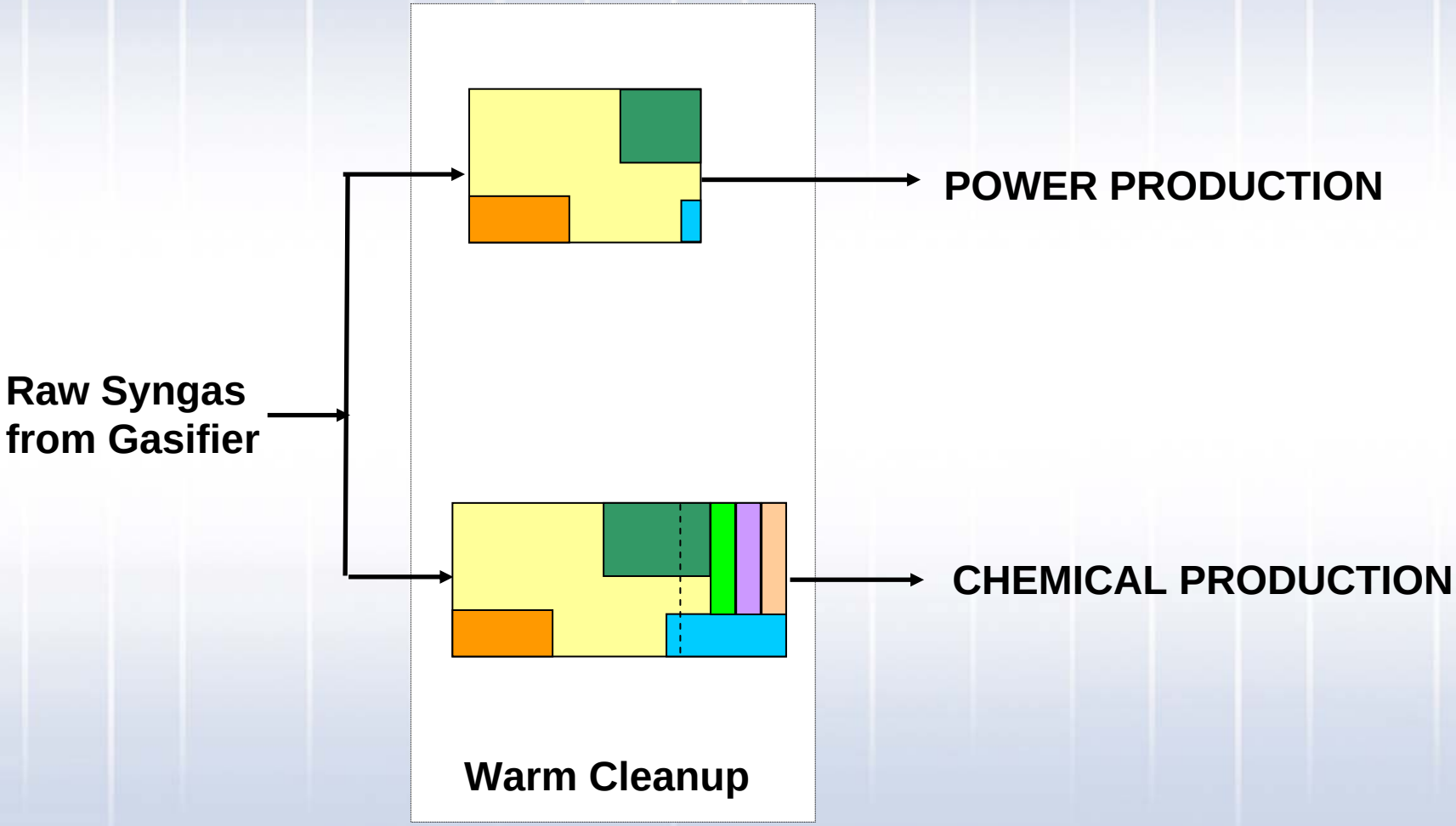
Application of RTI/Eastman Warm Syngas Cleaning Platform



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Commercial Design & Economics

Design Basis for Comparison of Warm Gas Clean-Up (WGCU) Technologies vs. Traditional Scrubbers

Illinois No. 6 Coal (2006 DOE, preliminary)

U.S. Midwest site

Nominal 600 MW capacity

GE Gasification – Radiant Cooling

Conventional cryogenic ASU without integration to GT

GE 7FB based power train

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Design Basis – Different Elements

Base Case

- Gas Quench & Scrubbing
- Low Temp. Gas Cooling
- Selexol™ AGR
- Claus sulfur recovery with SCOT tail gas treating
- Ambient Temperature Mercury removal

Warm Gas Clean-Up

- Convective Cooler
- Warm Gas Desulfurization Process (WGDS)
- Direct Sulfur Recovery Process (DSRP)
- High Temperature Mercury Removal Process
- SCR (no LT cooling to remove NH_3)

Independent Technical analysis performed by Nexant using WGCU design provided by RTI & Eastman

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Performance Comparisons

	IGCC Base Case	IGCC with WGCU	Improvement
Imports or Feeds			
Coal Feed, STPD (AR)	5,467	5,467	
95% Oxygen, STPD	4,665	4,895	-4.9%
99% N2, STPD	7,024	3,959	43.6%
Make Up Water, GPM	5,646	4,288	24.1%
Exports or Products			
Electric Power, MW	585	641	9.6%
Sulfur, STPD	137	137	
Slag & Ash, STPD (dry)	562	562	
Waste Water, GPM	2,798	1,085	61.2%
Thermal Efficiency			
HHV %	37.6	41.2	9.6%
LHV %	39.3	43.1	9.7%

Efficiency Improved 3.6 points HHV

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Power Balance

Power Balance, MW	IGCC Base Case	IGCC with WGCU	Improvement
Gas Turbine	455.7	449.3	-1.4%
Steam Turbine	263.2	316.7	20.3%
Total Generation	719.0	766.0	6.5%
Coal Handling & Slurry Prep.	5.1	5.1	0.0%
Gasification & Scrubbing	2.8	2.8	0.0%
Air Seperation Unit	39.2	41.1	-4.8%
Oxygen Compression	23.1	24.2	-4.8%
LT Gas Cooling	0.7	0	100%
AGR / SWS / Sulfur Recovery / TGTU	2.5	6.1	-144%
Plt.Air / Inst. Air / N2 Systems	31.7	17.3	45.4%
HRSG/Boiler Plt./ BFW/DM/Cond. Sys.	8.1	7.9	2.5%
CW Pumps & CT Fans	8.2	8.1	1.2%
BOP	12.5	12.4	0.8%
Total Consumption	134.0	125.1	6.6%
Net Power for Export	585.0	640.9	9.6%

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Capital Cost Summary

CAPITAL COST, $MM	IGCC Base Case	IGCC with WGCU
Coal Handling	17.8	17.8
Gasification Block	227.3	227.3
Air Separation	80.5	83.2
COS Hydrolysis & LT Cooling	37.2	0.0
AGR & Sulfur Recovery	185.1	168.4
Plant Air & N2 Compression	23.8	15.0
Gas Turbine Generators	146.4	145.0
HRSG & BFW Systems	49.0	55.6
Steam Turbine Generator	49.2	56.1
Balance of Plant	196.4	187.2
Home Office Cost	101.3	95.5
Total	*1,114.0*	*1,051.1*
Net Power Export, MWe	585	641
Cost per Unit Output, $/KWe	*1,904*	*1,640*

$264/KW CAPEX IMPROVEMENT

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Cost of Electricity Comparison

Incomes & Expenses, $MM/yr	IGCC Base Case	IGCC with WGCU
Coal (as received)	79.2	79.2
Catalyst & Chemicals	6.0	15.0
Maintenance	33.4	31.4
Admin & Labor	14.4	14.4
Overheads & Benefits	5.0	5.0
Insurance & Taxes	22.2	21.0
Loan Repayment	98.0	92.6
Investment Recovery	53.9	51.0
Water Import	0.9	0.7
Ash/Slag Disposal	1.7	1.7
Sulfur Sale	-3.0	-3.0
Total	*311.7*	*309.0*
Annual Power Export, GW-hr	4,356	4,773
Cost of Electricity, ¢/kW-hr	*7.16*	*6.47*

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Conclusions

- Eastman/RTI Warm Gas Clean-Up technologies:
  - **Increase efficiency by 3.6 points HHV**
  - **Dispatch 56 MWe more power**
  - **Reduce CAPEX by $264 / KW**
  - **Reduce COE by 0.69 ¢/KW-hr**

  For 600 MW IGCC
- Eastman/RTI Pilot Plant testing:
  - **Demonstrated technology readiness**
    - **Achieved performance targets with real syngas**
      - **Desulfurization**
      - **Process reliability**
      - **Long term durability of desulfurization sorbent**
    - **Successfully scaled up process to 0.3 MW_t**
    - **Successfully scaled up sorbent production (8,000 lbs)**
  - **Additional fixed bed syngas cleaning options ready for pilot testing (HCl, NH_3, As, Hg, and Se)**

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Questions?