RTI INTERNATIONAL | turning knowledge into practice

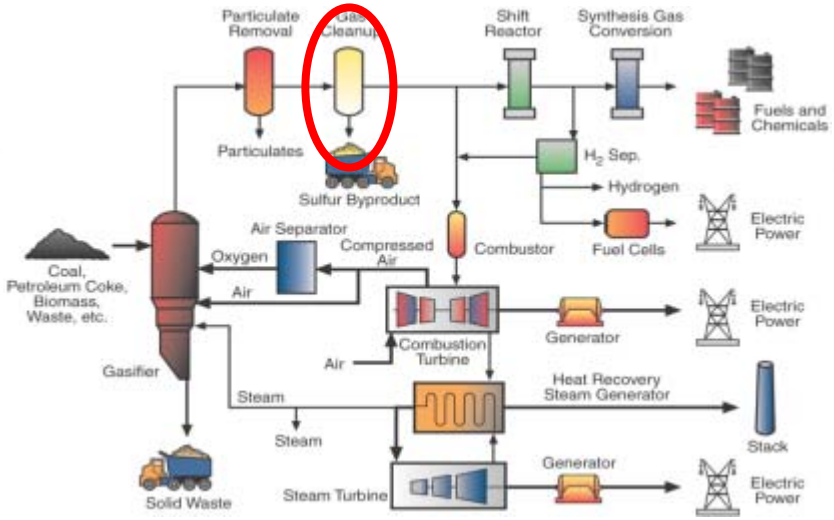
Status of RTI/Eastman Warm Gas Clean-up Technology and Commercialization Plans

Raghubir Gupta, Brian Turk, and Markus Lesemann
RTI International

Jerry Schlather and David Denton
Eastman Chemical Company

Gasification Technologies Conference
October 8, 2008

Syngas Cleaning Technology Platform



Sulfur

Regenerable ZnO sorbents

Transport reactor

Direct Sulfur Recovery Process

Hg adsorbents (disposable)

As adsorbents (disposable)

Se adsorbents (disposable)

HCl adsorbents (disposable)

Regenerable NH_3/HCN adsorbents

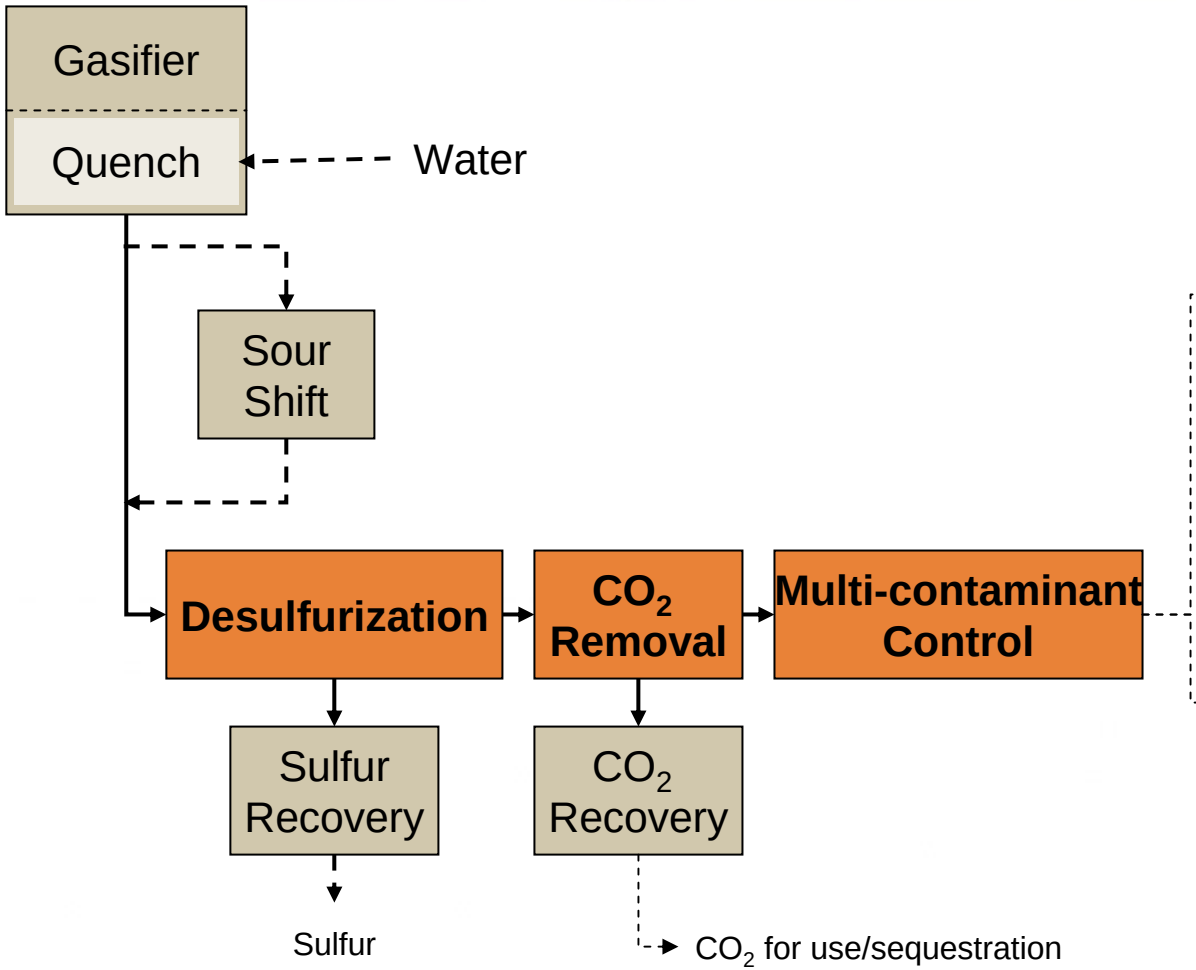
Regenerable CO_2 sorbents

Operating Temperatures > 250 °C (482ºF)

EASTMAN

RTI INTERNATIONAL

Process Integration – Modular Approach



Power

- SO_x < 1.4 lb SO_x/MWh gross
- NO_x < 1.0 lb NO_x/MWh gross
- PM < 0.0071 lb/MMBtu
- Hg > 90% removal

Chemicals/Fuels

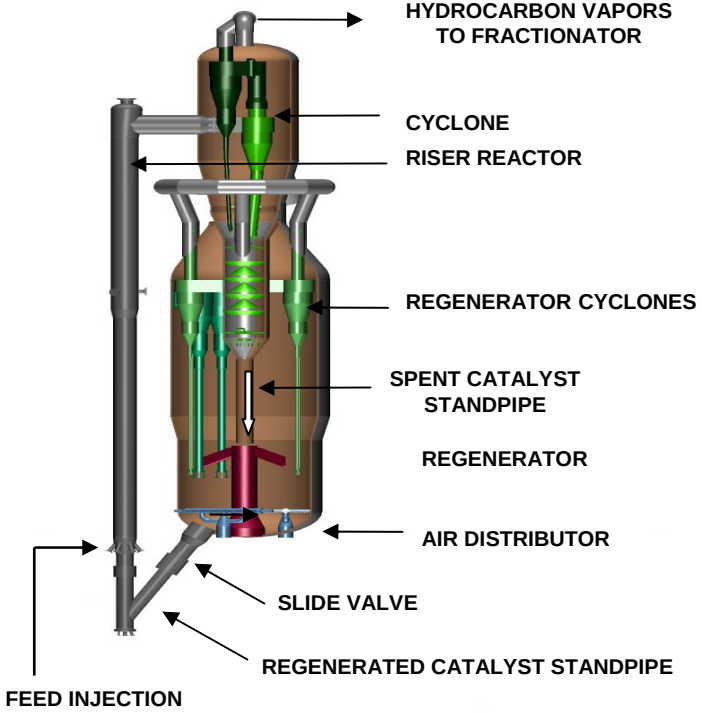
Sulfur < 50 ppb	As < 5 ppb
HCl < 10 ppb	Se < 0.2 ppm
NH_3 < 10 ppm	Cd < 30 ppb
CO_2 > 90% removal	Hg < 5 ppbw

[NETL 2007]

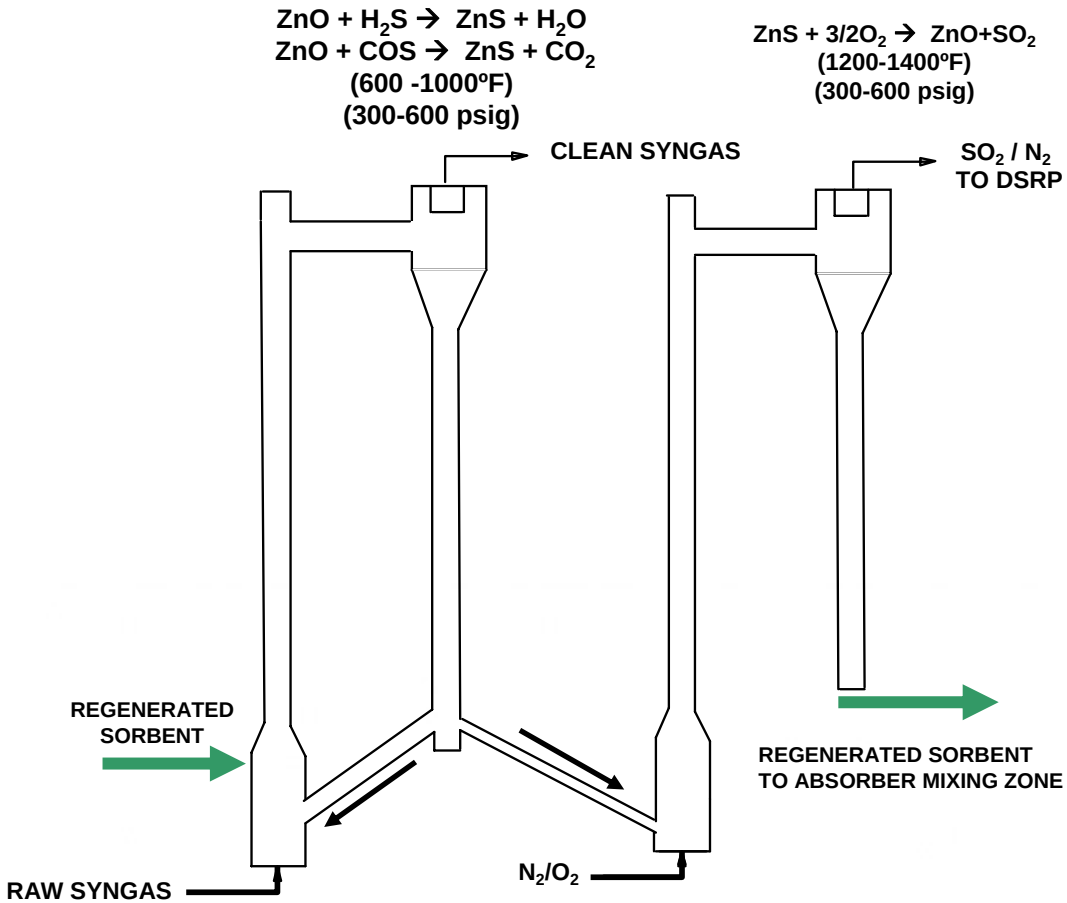
EASTMAN

RTI INTERNATIONAL

Transport Desulfurization Reactor System



Commercial FCC Reactor
Source: KBR



EASTMAN

RTI INTERNATIONAL

Desulfurization Sorbent Characteristics

- ZnO supported on zinc aluminate
  - High attrition resistance (mechanical stability)
  - Inert support (chemical stability)
- Unique highly dispersed ZnO nanostructures with grain size <50 nm
  - High reactivity (short residence time in the reactor)
- Produced on commercial scale by major catalyst manufacturer
- Covered by US/International patents
- Won 2004 R&D 100 Award

Installed Pilot Plant Systems

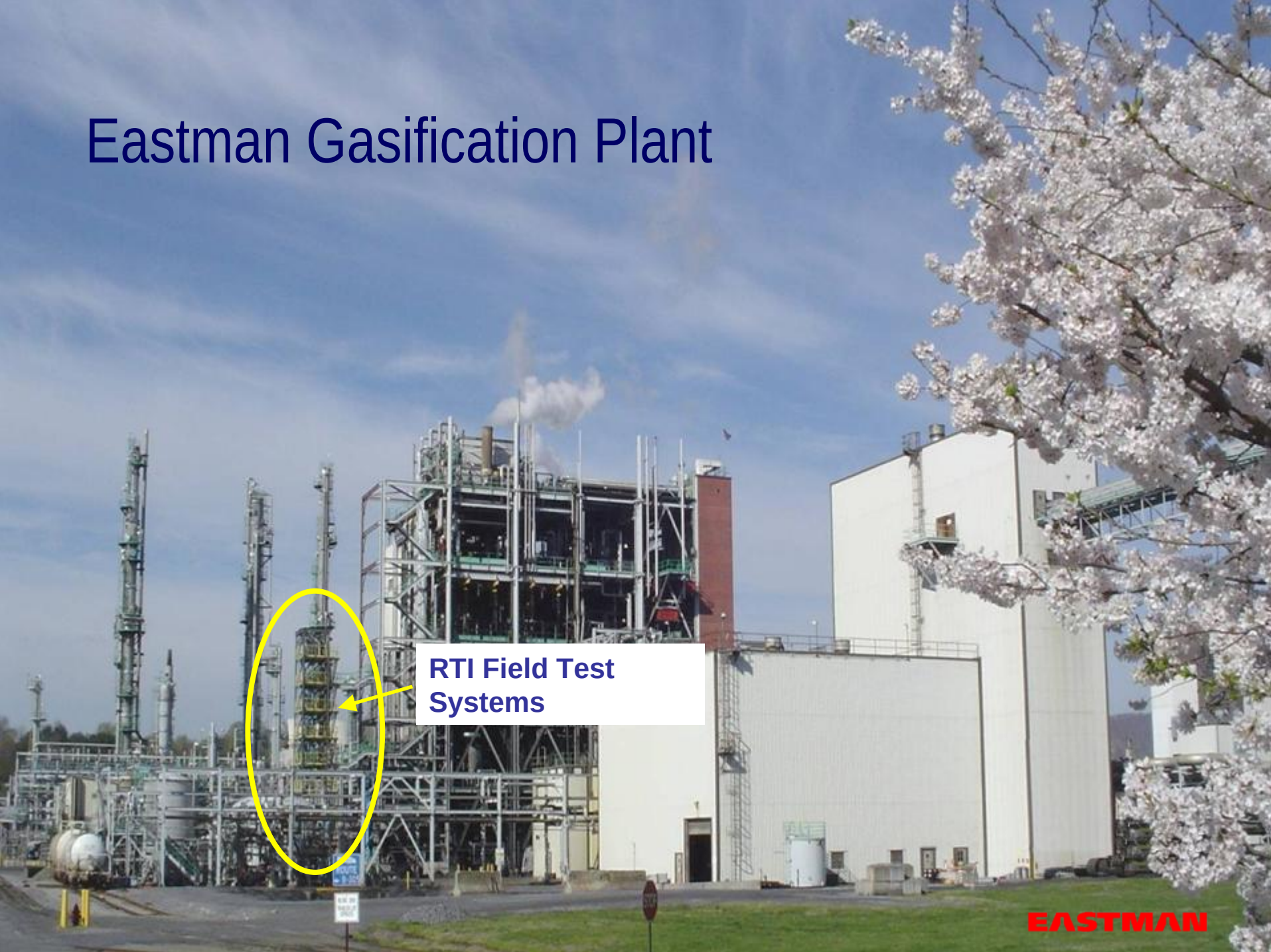
Eastman's Kingsport, TN, Coal Gasification Facility

Direct Sulfur Recovery Process (DSRP)

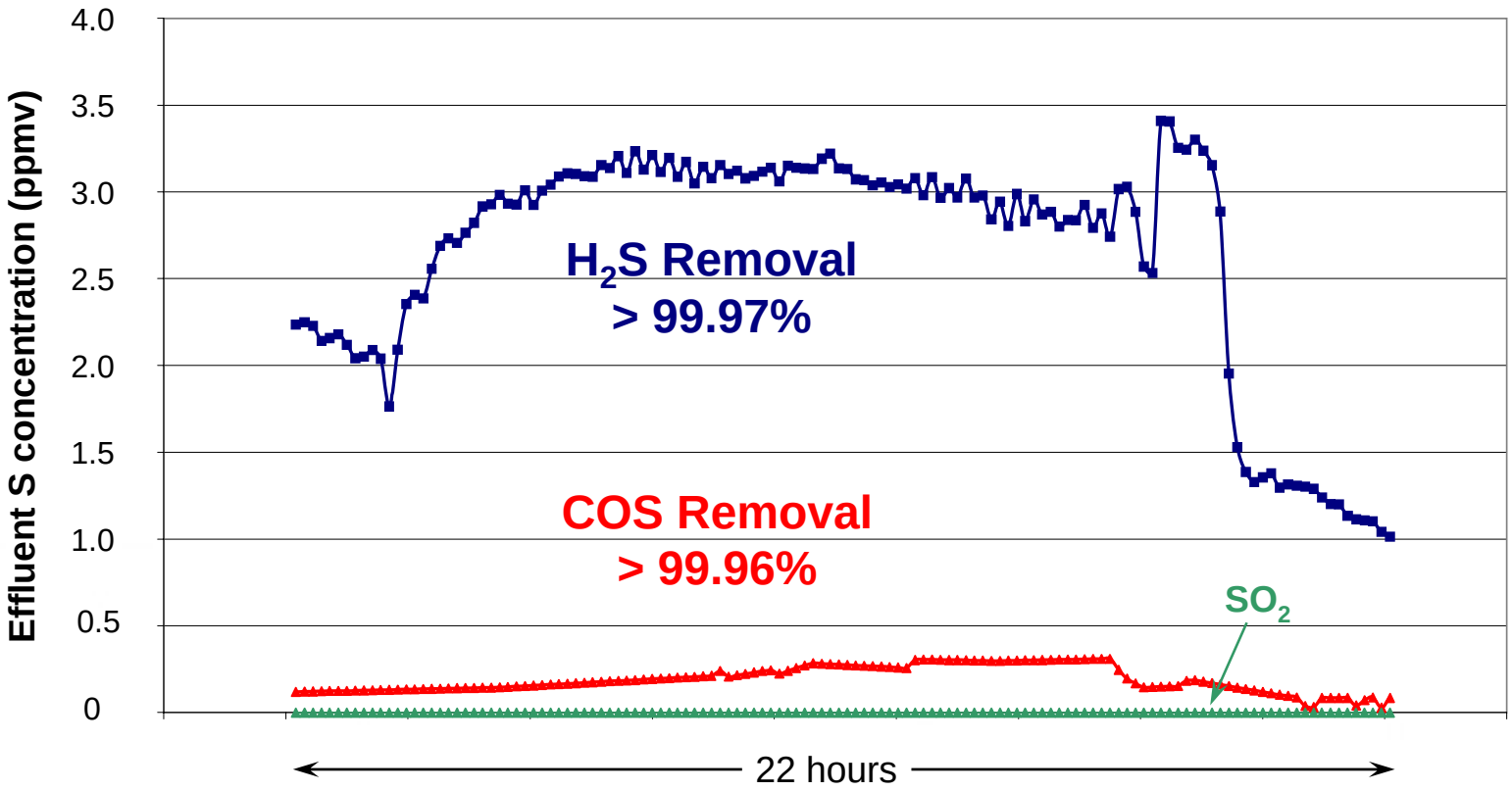
High Temperature Desulfurization Process (HTDP)

Multi-contaminant Control Test System (MCC)

Eastman Gasification Plant



Typical Sulfur Concentrations in Effluent Syngas



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

EASTMAN

RTI INTERNATIONAL

Desulfurization Pilot Plant
Summary of Parametric Testing

More than 3,000 hours of syngas operation

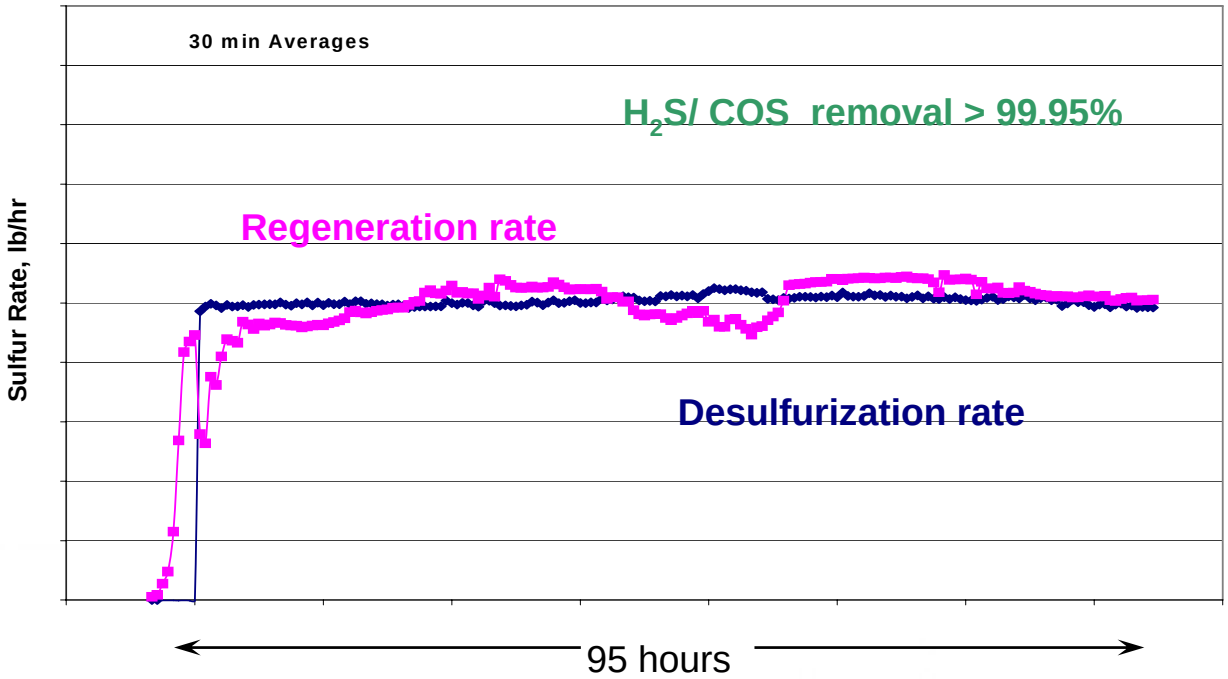
Pressure, psig	300	450	600
Inlet Concentration, S ppmv	8,661	7,023	8,436
Effluent Conc. S ppmv **Range**	5.9 0.4 – 9.3	10.7 2.4-20.6	5.7 3.3-18.1
S Absorbed, lbs/hr	4.1	4.4	5.0
S Removal, %	99.93	99.82	99.90

- Average attrition rate: 31 lbs/MM lbs of sorbent circulated

Typical attrition rate for FCC catalysts is 50-100 lbs/MM lbs of catalyst circulated.

All data are averages over multiple hours of operation

Desulfurization Process Reliability



On-Stream Factor

Pre-improvements	~60%
Post-improvements	>80%

EASTMAN

RTI INTERNATIONAL

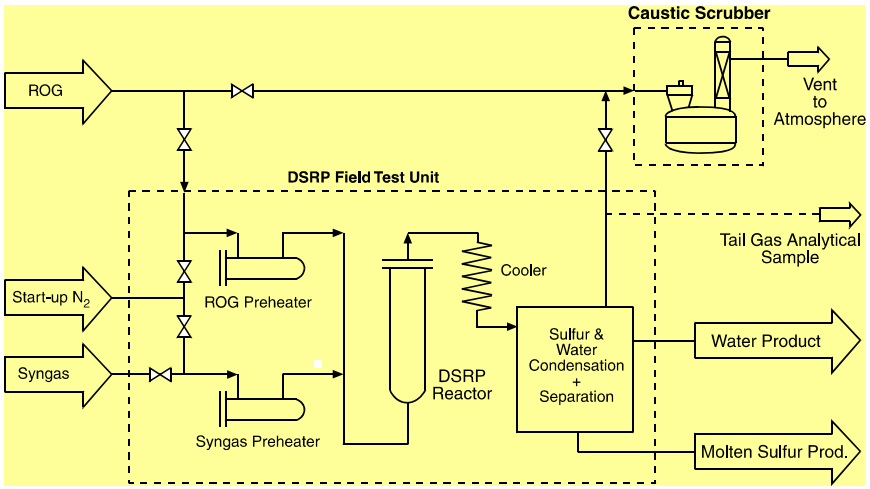
Direct Sulfur Recovery Process

Reaction chemistry:

$SO_2 + 2H_2 \rightarrow 1/n\ S_n + 2H_2O$

$SO_2 + 2CO \rightarrow 1/n\ S_n + 2CO_2$

Temperature: 500-600ºC
Pressure: 300-600 psig
Reactor design: Fixed bed

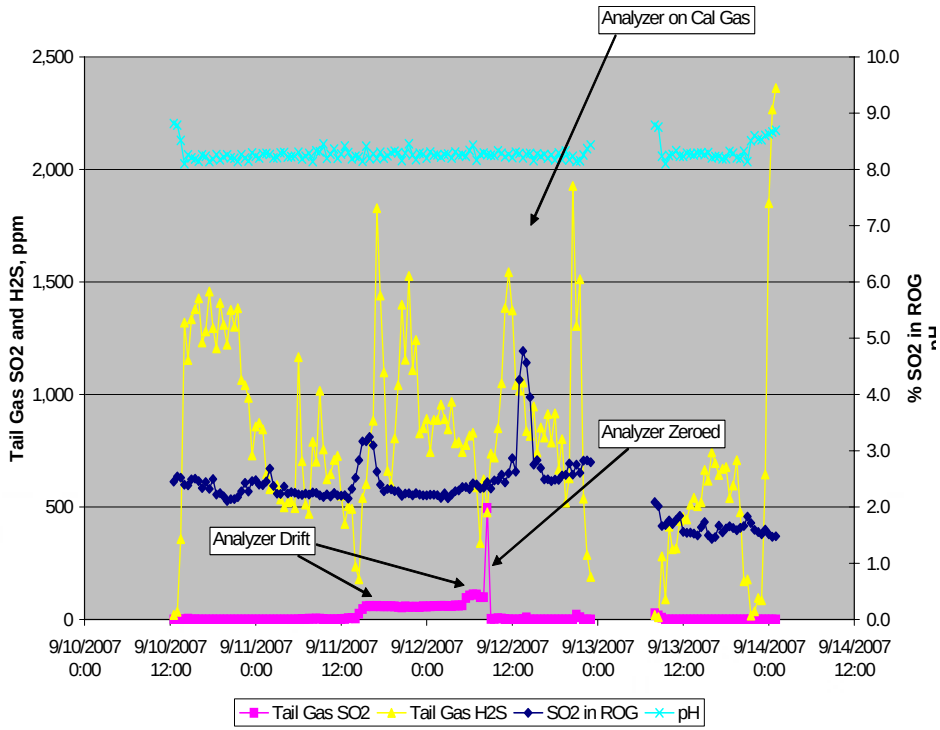


EASTMAN

RTI INTERNATIONAL

DSRP Operations

- Integrated operation
  - Effluent from regenerator of transport desulfurization system
  - Real coal-derived syngas
- 99.8% SO_2 conversion
- Produced liquid sulfur product



EASTMAN

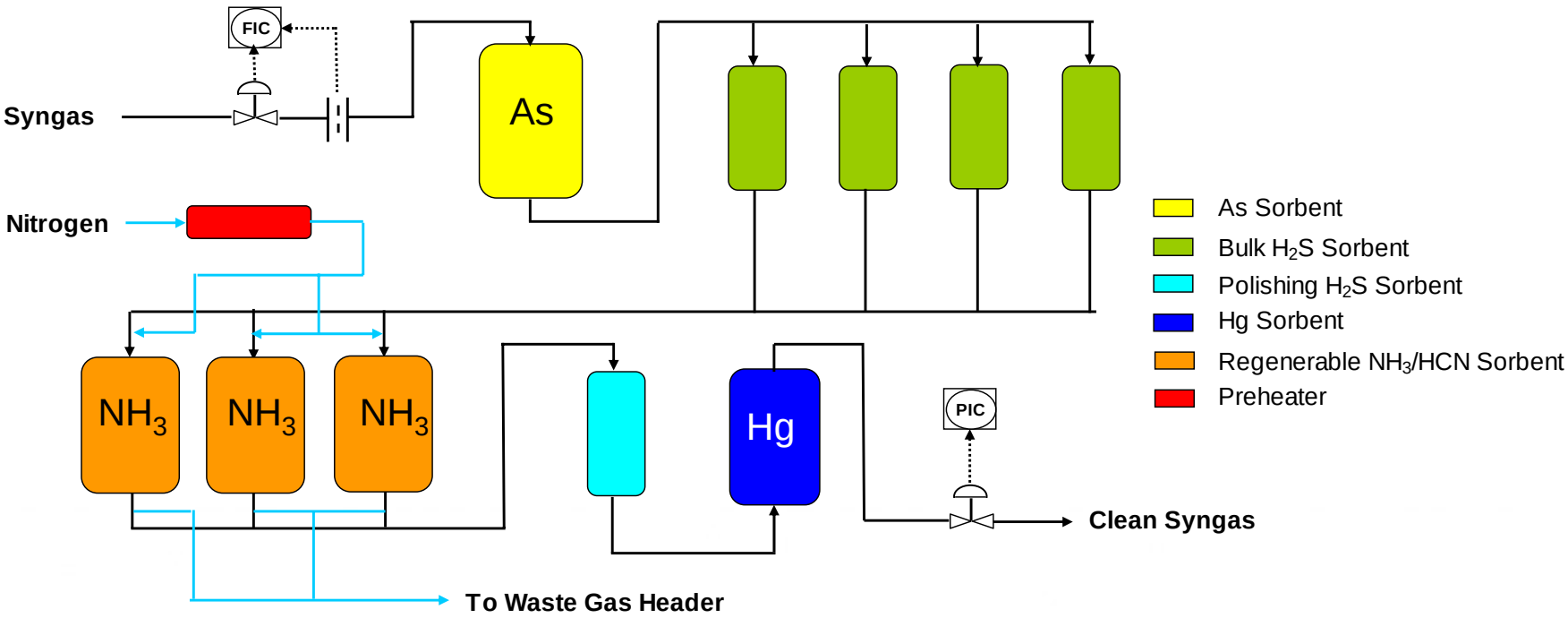
RTI INTERNATIONAL

Multicontaminant Control Removal

- Removal of contaminants other than sulfur from syngas under high-pressure, high-temperature conditions
- Target contaminants: Hg, As, Cd, Se, HCl, Ammonia, HCN
- Test program
  - Extensive sorbent screening at RTI
  - Capacity tests on selected sorbents
  - Evaluation of potential process integration issues
    - Effect of S on sorbent effectiveness for other contaminants
    - Multicontaminant effects
  - Field demonstration of most promising sorbents with coal-derived syngas at Eastman

Ammonia and trace metal skid for testing at Eastman

Multi-contaminant Control Test System (MCC)



Test Conditions with Coal-derived Syngas

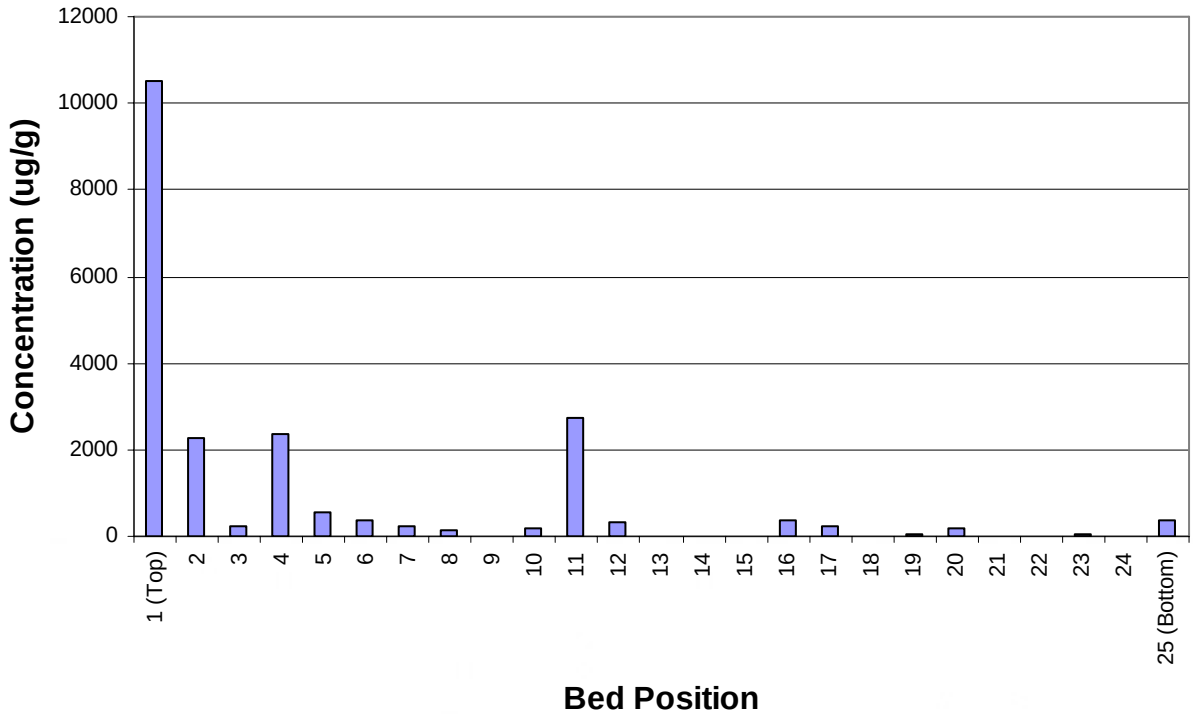
Temperature:	200ºC
Pressure:	850 psig
Flow:	500 scfh
Time:	525 hours

EASTMAN

RTI INTERNATIONAL

Arsenic Removal during Field Test

- As loading at bed inlet was 1 wt%
  - 3 wt% capacity demonstrated with simulated syngas
- No As breakthrough observed



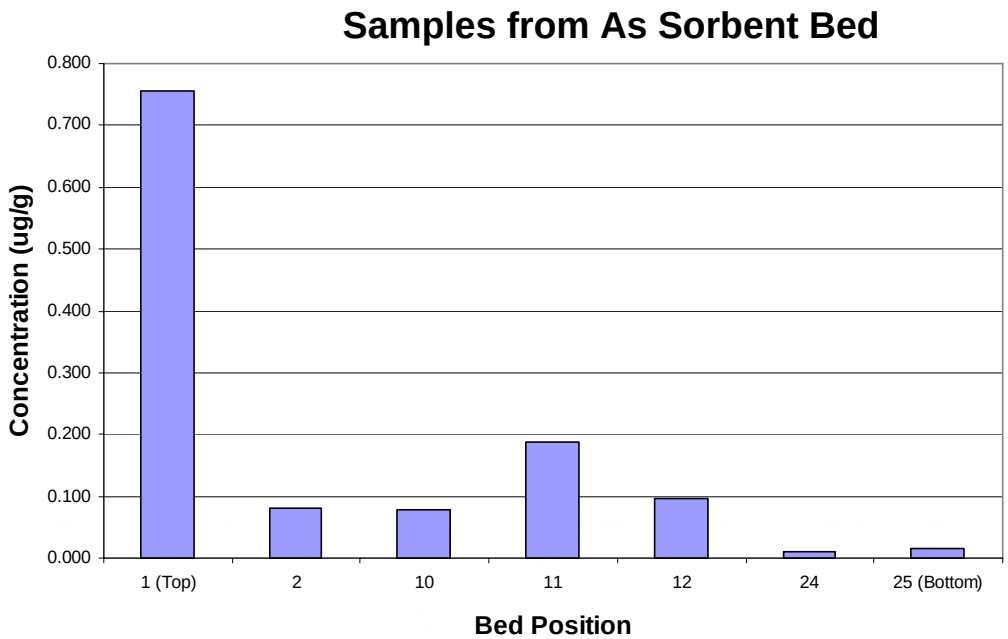
Demonstrated effective As removal from coal-derived syngas at high temperatures and pressures

EASTMAN

RTI INTERNATIONAL

Mercury Removal during Field Test

- High Hg concentrations detected at syngas inlet to As sorbent bed
- No Hg breakthrough observed
- Hg concentrations in Hg sorbent bed were below detection limits



Demonstrated effective multi-contaminant removal of Hg and As from coal-derived syngas at high temperatures and pressures

EASTMAN

RTI INTERNATIONAL

Ammonia/HCN Removal

- Acidic Adsorbent
  - Regenerated by temperature swing
- Multiple fixed-beds for continuous NH_3/HCN removal
- Results with coal-derived syngas
  - NH_3
    - Inlet NH_3: 440 -500 ppmv
    - Outlet NH_3: 6-20 ppmv
  - HCN
    - Inlet HCN: ~50 ppmv
    - Outlet HCN: ~1 ppmv

Demonstrated effective NH_3 and HCN removal from coal-derived syngas at high temperatures and pressures.

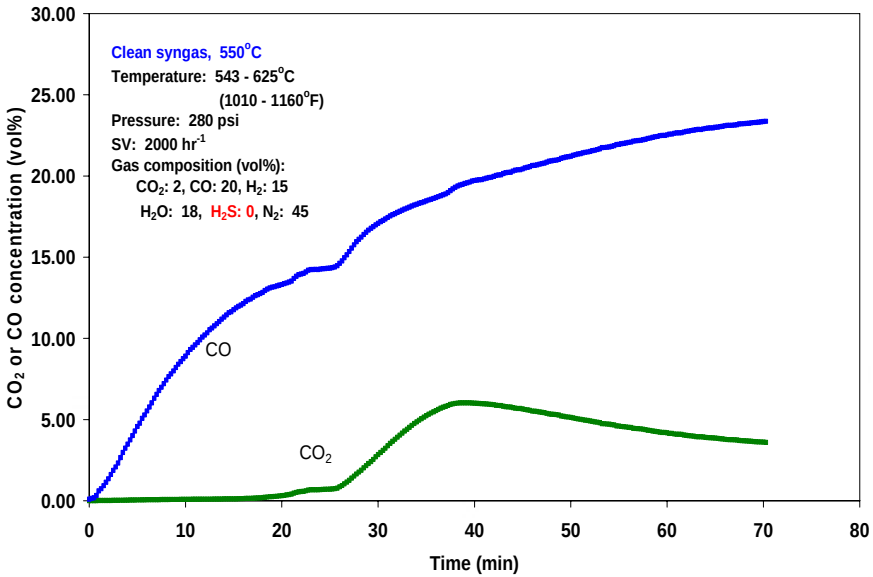
Field Testing Summary

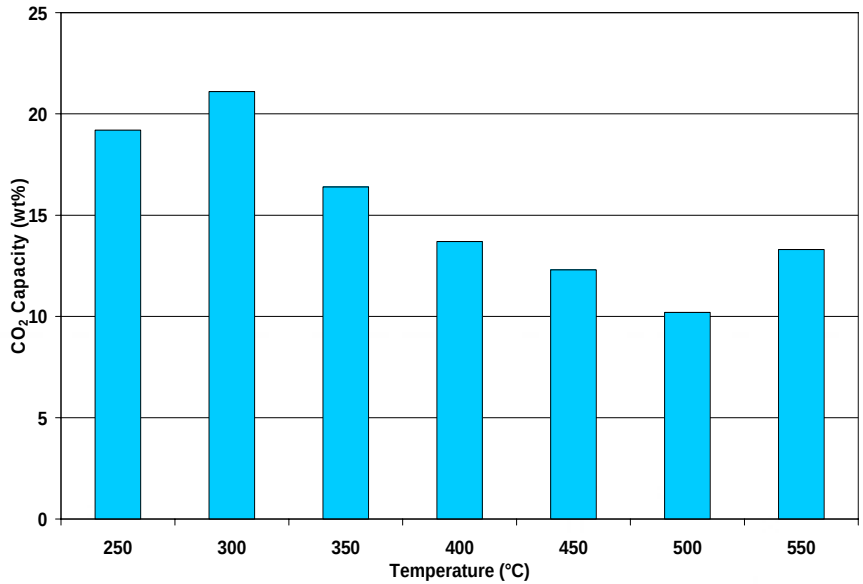
Field test demonstrated clean-up performance with real coal-derived syngas at high temperatures and pressures

- Phase I: Desulfurization technologies demonstrated
  - Transport desulfurization system
    - Desulfurization performance, process control, stability and reliability
  - Desulfurization sorbent
    - Mechanical strength, chemical activity, long-term stability
  - Direct Sulfur Recovery Process
    - Fully integrated operation of HTDP and DSRP
- Phase II: Modular fixed-bed cleanup for As, Hg, NH_3/HCN
  - Regenerable NH_3/HCN adsorbent
  - As and Hg sorbents

High-Temperature CO_2 Removal

- $Li_4SiO_4 + CO_2 \rightarrow Li_2CO_3 + Li_2SiO_3$
- $CO + H_2O \rightarrow CO_2 + H_2$
- Temperature: 250 to 500°C, Pressure: 300-600 psig





CO_2 removal from syngas at high temperatures and pressures with lithium silicate sorbent in pre-pilot phase

EASTMAN

RTI INTERNATIONAL

Techno-economic Evaluation – Comparison Basis

Project technical analysis performed by Nexant

Common Elements

- 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

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)
- High Temperature Mercury Removal Process
- SCR (no LT cooling to remove NH_3)

Results from Nexant's analysis have been confirmed by independent study by Noblis

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

EASTMAN

RTI INTERNATIONAL

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 and LT Cooling	37.2	0.0
ARG and Sulfur Recovery	185.1	168.4
Plant Air & N_2 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	585.0	641.0
Cost per Unit Output $/KWe	1,904.0	1,640.0

$264/KW CAPEX IMPROVEMENT

Summary of Techno-Economic Evaluation for Power Applications

- Comparison of Eastman/RTI Warm Gas Clean-Up technologies with conventional syngas clean-up technologies performed by Nexant
  - 600 MW case study
  - Increase efficiency by 3.6 points HHV
  - Dispatch 56 MWe more power
  - Reduce CAPEX by $264/KW
  - Reduce COE by 0.69 ¢/kwh
- Independent analysis performed by Noblis under NETL funding produced similar results

Conclusions

- Eastman/RTI Pilot Plant Testing:
  - Demonstrated technology readiness
  - Achieved desulfurization performance targets with real syngas
  - Additional fixed bed syngas cleaning options slipstream tested with real coal-derived syngas (HCl, NH_3, As, Hg, and Se)
- Technology package ready for power applications
- R&D efforts underway for chemicals/fuels application
- High-temperature CO_2 removal is being integrated

Commercialization

- Scale-up to 20-50 MW demonstration plant envisioned
- Discussions underway with potential test sites
- Engineering design package assembled
- Comprehensive technology package ready for power applications

Acknowledgments

- Financial Support from DOE/NETL
  - Contract No. DE-AC26-99FT40675
  - Cooperative Agreement No. DE-AC26-05NT42459
- Technical Guidance
  - Gary Stiegel (DOE/NETL)
  - Daniel Cicero (DOE/NETL)
  - Suresh Jain (DOE/NETL)
  - Jenny Tennant (DOE/NETL)
  - Gopala Krishnan (SRI International)
  - Gunnar Henningsen
  - Ted Knowlton (PSRI)