RTI/Eastman Warm Syngas Clean-up Technology: Integration with Carbon Capture

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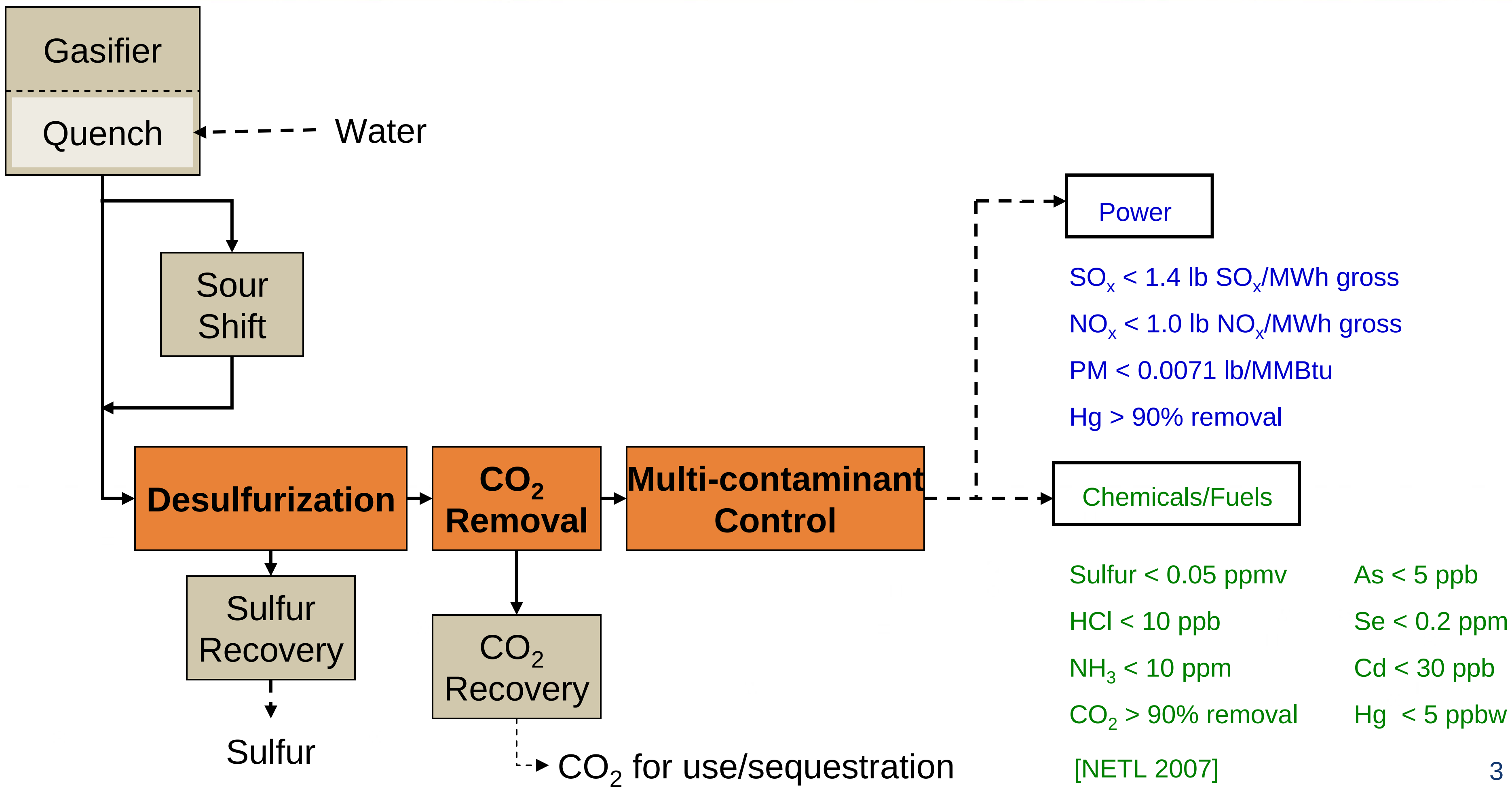
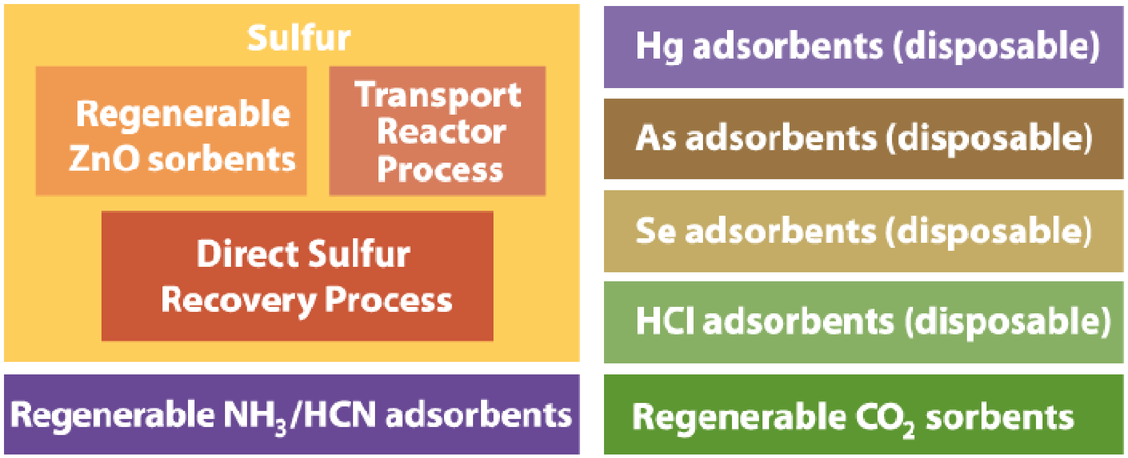
RTI International

- Established 1958 as collaboration between state government, area universities and business leaders
- Mission: to improve the human condition by turning knowledge into practice
- One of the world's leading research institutes
- FY2008 Revenue: $710 million
- Staff : 4000+
- Notable Achievements:
  - Taxol® and Camptothecin™
  - Cochlear ear implants
  - Wind shear avoidance system

Warm Syngas Clean-up Technology – Modular Approach



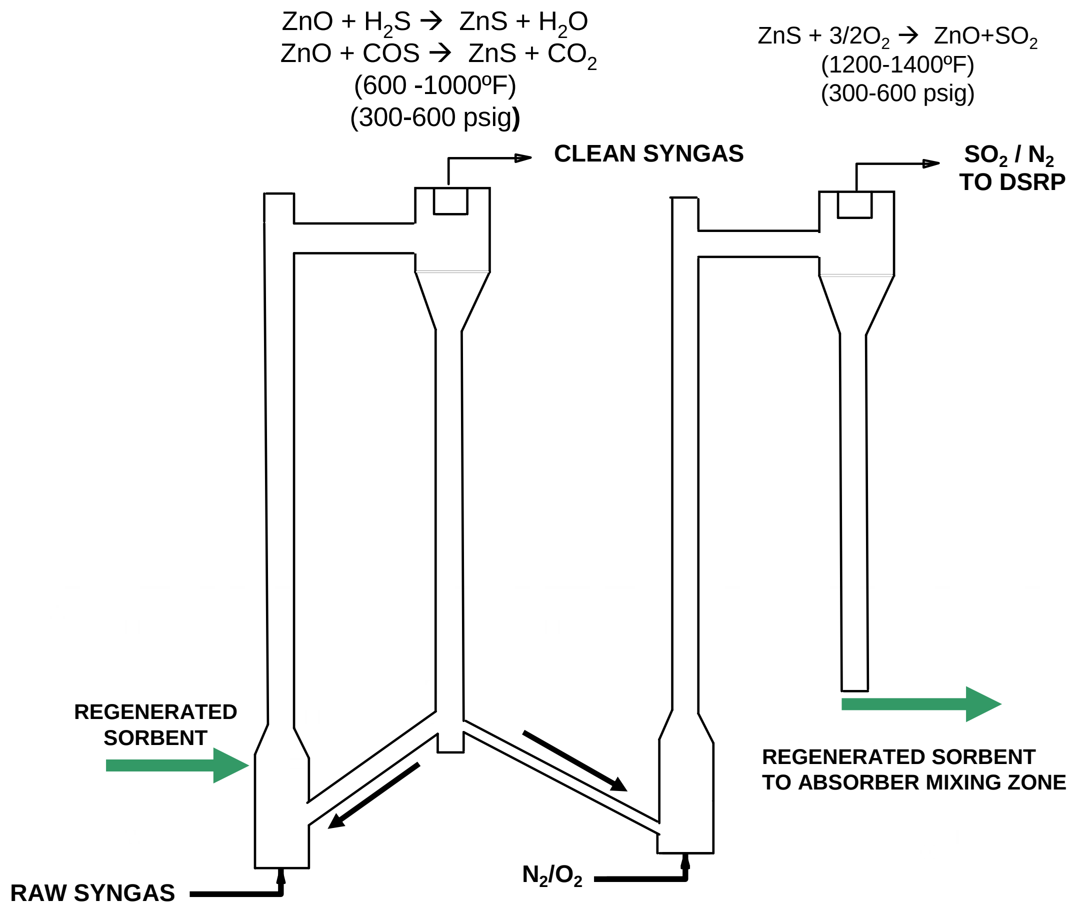
Warm Syngas Clean-up Technology Platform



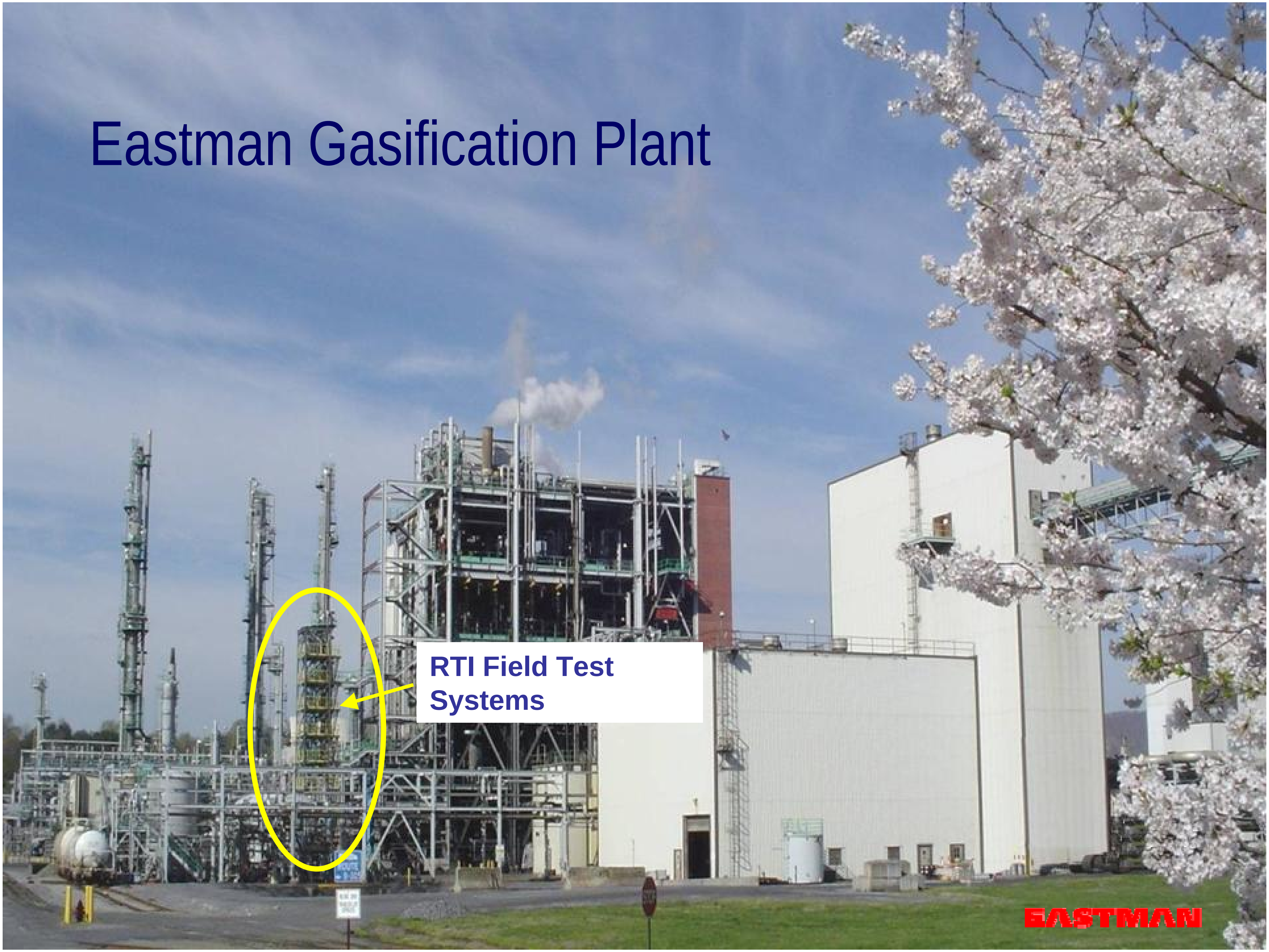
Unique Features

- Operating temperatures > 450ºF
- Pressure independent
- Effective for both H_2S and COS
- Fully compatible with conventional and warm CO_2 capture
- Flexible modular approach meets
  - Power specifications
  - Chemical production (methanol, SNG, FT,…) specifications

Installed Pilot Plant Systems
Eastman's Kingsport, TN, Coal Gasification Facility



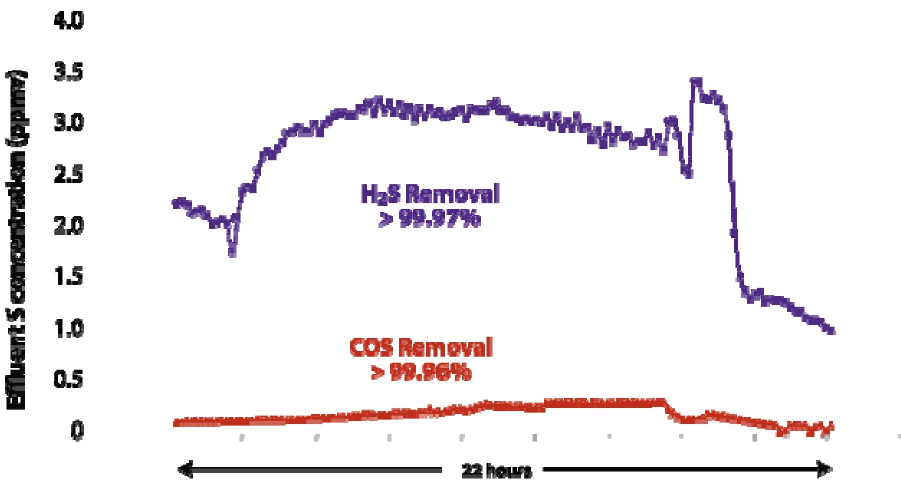
Eastman Gasification Plant



Technology Development

Extensive pilot plant tests completed at Eastman Chemical Company with coal-derived syngas.

- High Temperature Desulfurization Process (HTDP)
  - >99.9% total sulfur removal (H_2S and COS) for >3,000 hours
  - Low attrition rates ~31 lb/million lb circulated

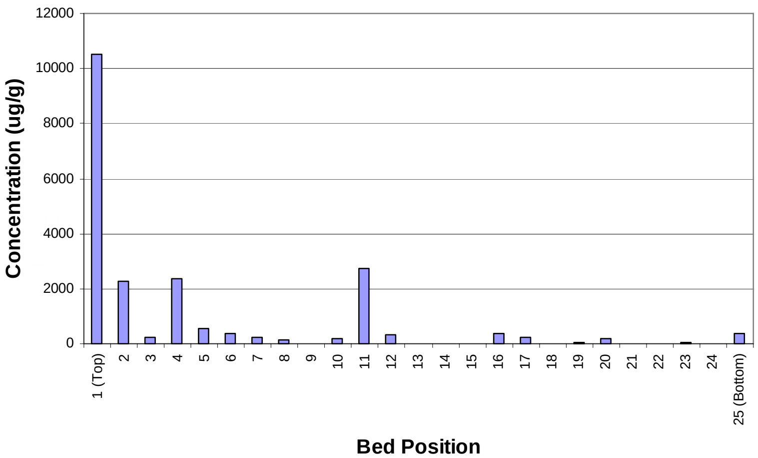


Pressure, psig	300	450	600
Inlet Concentration, S ppmv	8,661	7,023	8,436
Effluent Conc. S ppmv Range	5.9 0.4–9.3	10.7 2.4–20.6	5.7 3.3–18.1
S Removal, %	99.93	99.82	99.90

More than 3,000 hours of syngas operation

Technology Development (Cont.)

- Direct Sulfur Recovery Process (DSRP)
  - Fixed bed catalytic process for conversion of SO_2 into S
  - >98% SO_2 conversion demonstrated in integrated mode
- Ammonia/HCN removal (~400°F)
  - Fixed-bed regenerable adsorbents
  - >90% ammonia and HCN removal demonstrated
- Hg, As, and Se removal (~400°F)
  - Disposable fixed-bed sorbents
  - >90% Hg, As, and Se removal demonstrated
- HCl removal using disposable sorbents
  - Effluent HCl concentrations <50 ppbv

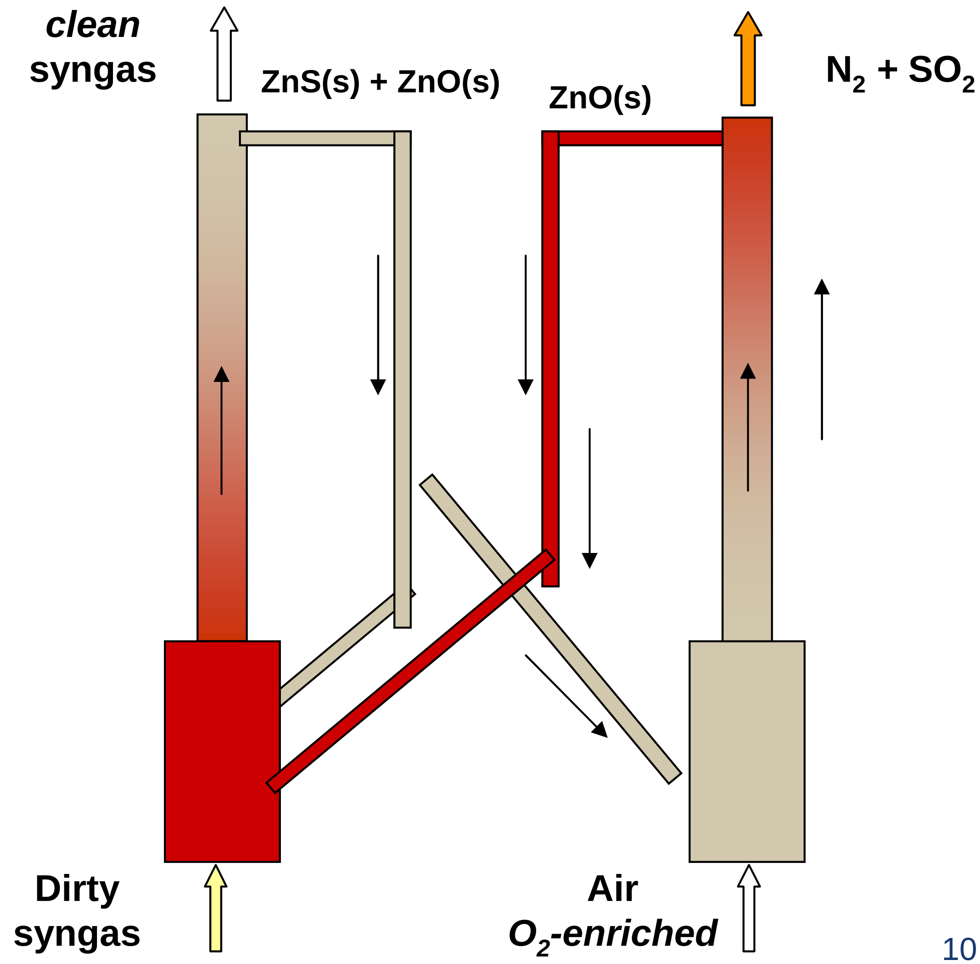


Summary of Techno-Economic Evaluation for Power Applications

- Comparison of RTI/Eastman Warm Gas Clean-Up technologies with conventional syngas clean-up technologies performed by Nexant
  - 600 MW case study—GE Reference plant as a base case
  - Increase efficiency by 3.6 points HHV
  - Dispatch 56 MWe more power
  - Reduce CAPEX by $264/KW
  - Reduce COE by 0.69 ¢/kwh
  - Reduce makeup water consumption by 25%
  - Reduce wastewater by 60%
- Independent analysis performed by Noblis confirmed these results (http://www.netl.doe.gov/technologies/coalpower/gasification/pubs/market.html)

CFD Modeling for Transport Desulfurizer

- Collaborative model development with DOE/NETL
- Model includes
  - Absorption transport reactor
    - Recycle loop
    - Regeneration loop
  - Regeneration transport reactor
- Model validation with RTI bench-scale and Eastman pilot plant results
- Validated model will be used for design scale-up of 50 MW demonstration unit

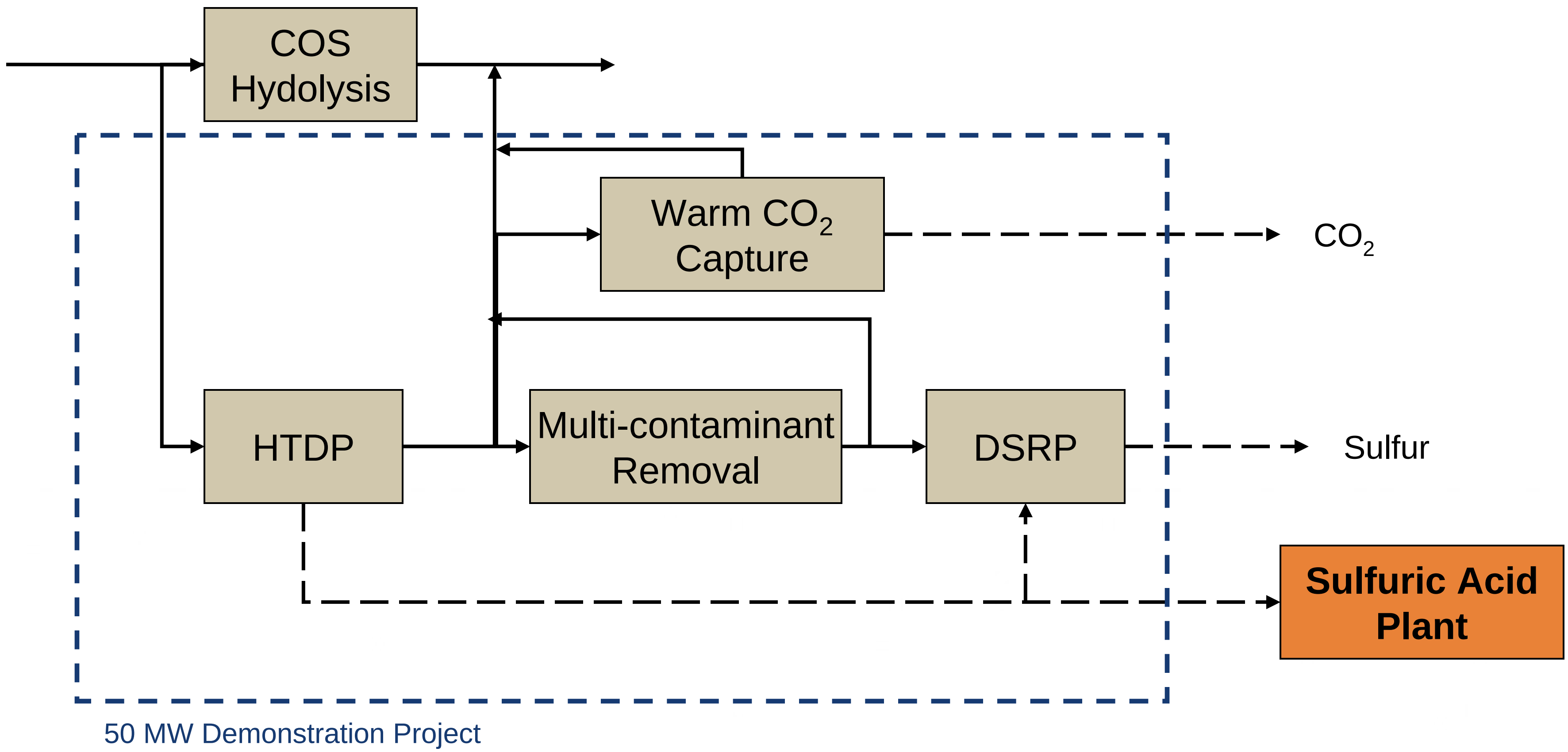


50 MW WGC Demonstration at Tampa Electric Company's Polk Power Station

Objectives

- Design, construct, commission, and operate a warm syngas cleaning demonstration system with real syngas
- Establish relevant commercial operating experience
- Establish RAM (reliability, availability and maintenance) targets
- Mitigate design and scale up risk for commercial plant

Block Flow Diagram for 50 MW WGC Demonstration Project

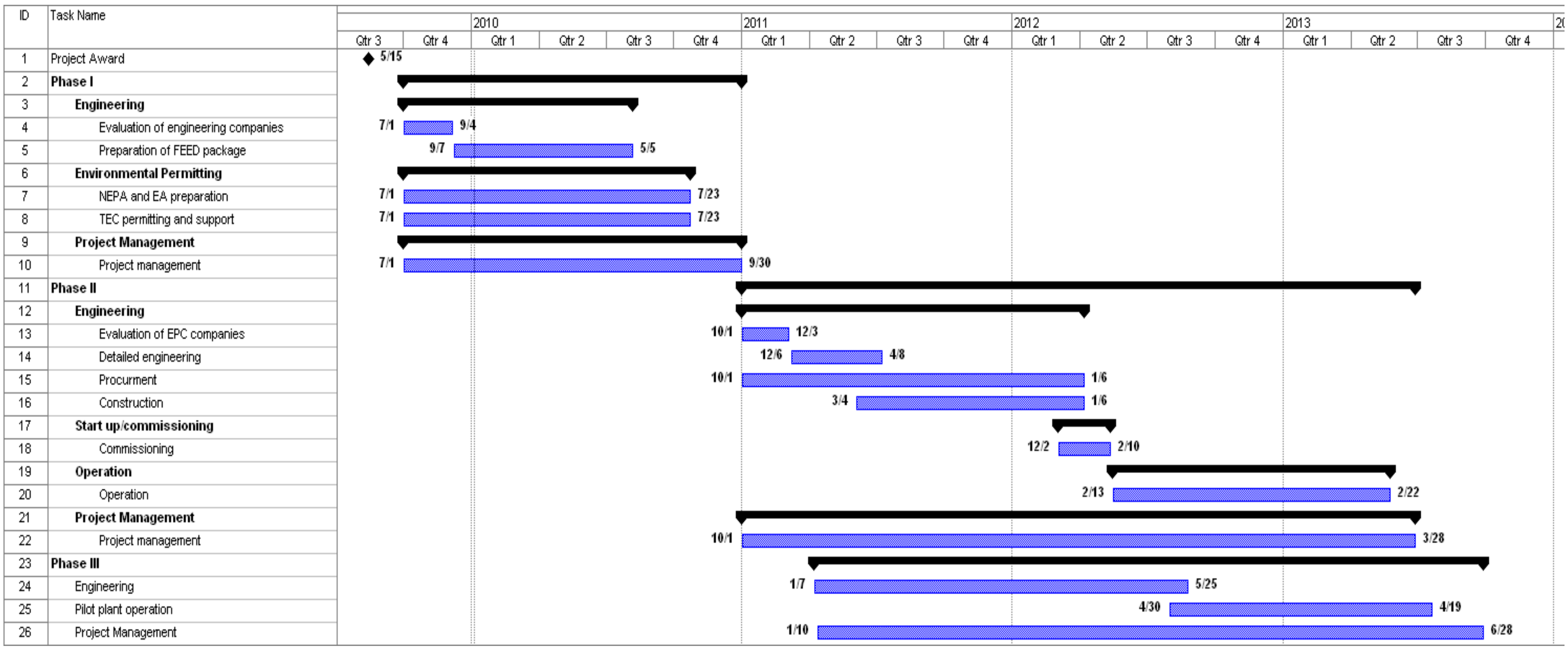


Specific WGC Demonstration Goals

Technology	Size	Operation	Performance
HTDP	50 MWe[1]	5,000 h	Total sulfur < 5 ppmv
DSRP	5 tpd sulfur (25% of HTDP off-gas)	5,000 h	>95% SO_2 Conversion
Trace Contaminants (Hg, As and Se)	5 MWe	5,000 h	>90% Removal
CO_2 Removal	0.5 MWe	5,000 h	>90% Removal

[1]50 MWe is equivalent to 2,000,000 scfh of syngas on dry basis

50 MW WGC Demonstration Project Schedule

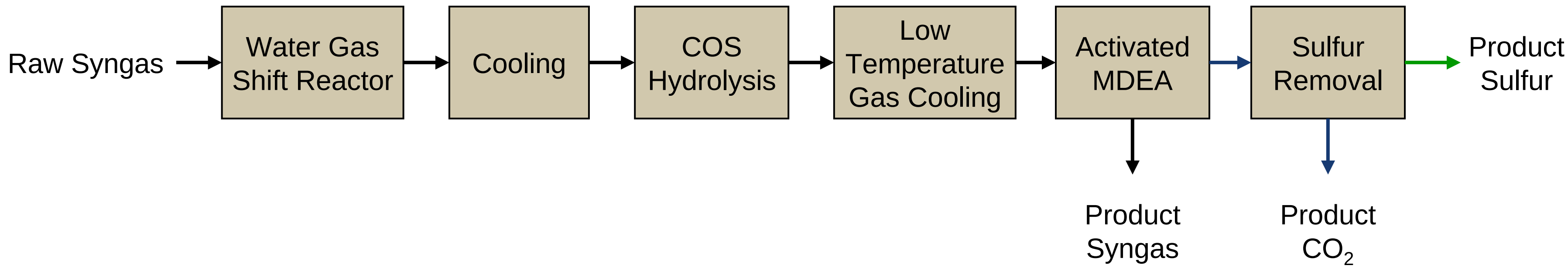


Integration of Carbon Capture Technology

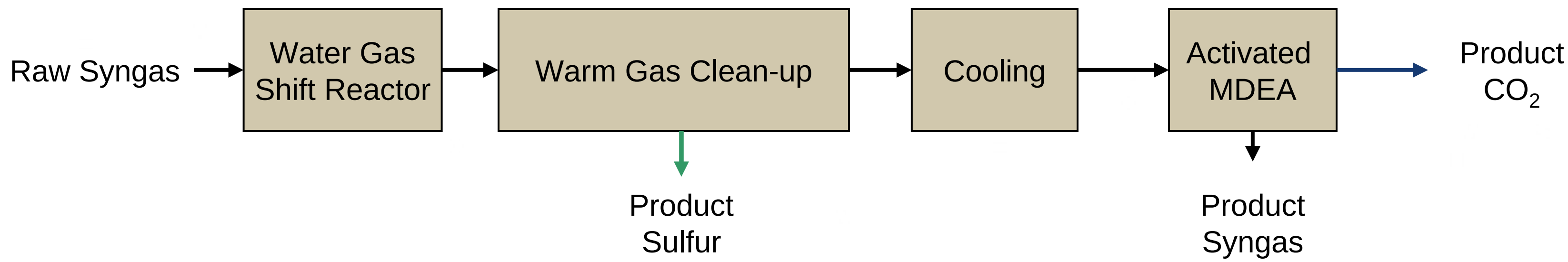
- WGC can be readily integrated with existing CO_2 capture technology
  - Cost and performance advantages from dedicated separation
- Several warm CO_2 capture options are in development pipeline
  - Regenerable CO_2 sorbents
  - WGC and hydrogen/CO_2 membrane separation
  - CO_2 separation with chemical looping

Integration of Carbon Capture Technology

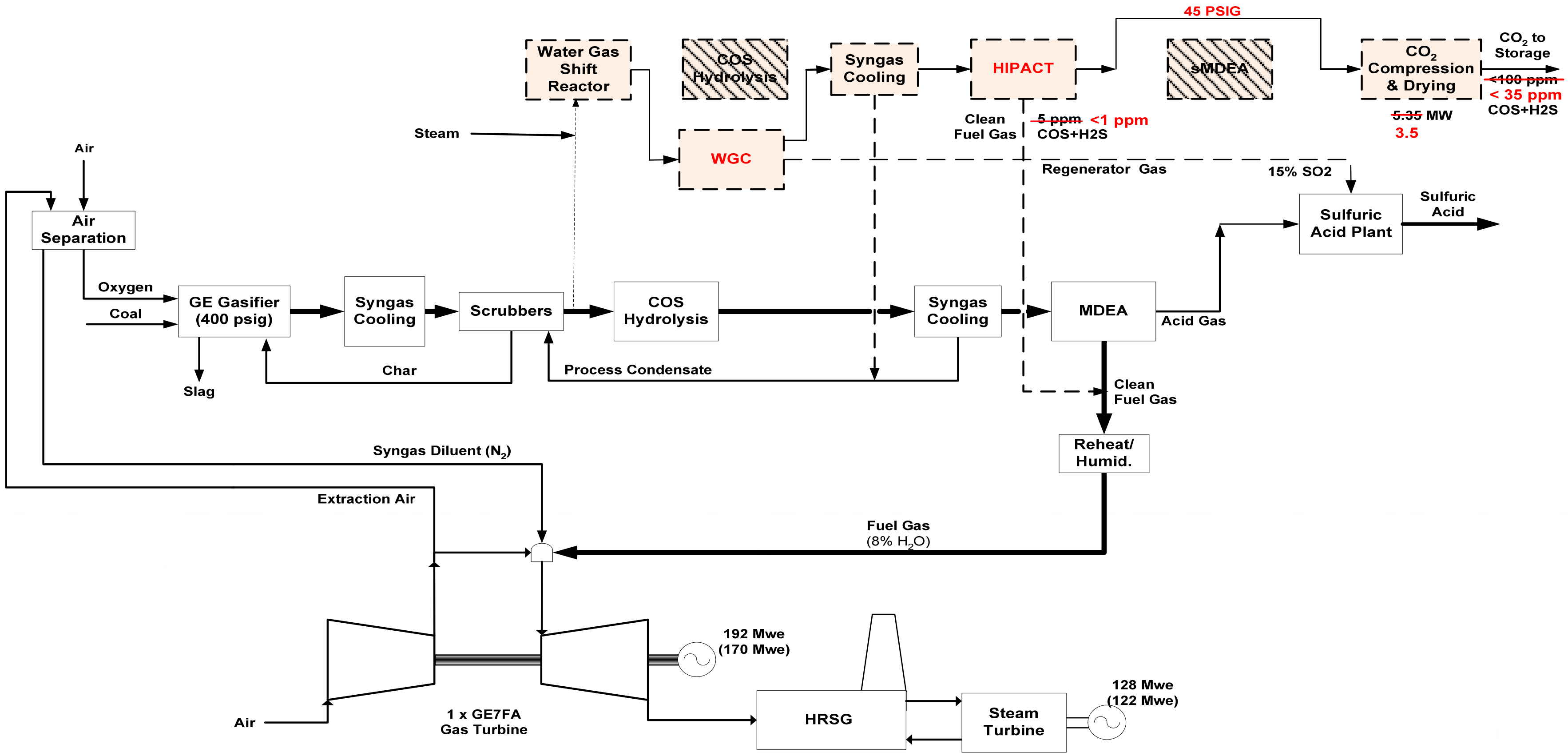
Conventional low temperature CO_2 and sulfur removal



Warm Syngas Clean-up with conventional low temperature CO_2 removal



Integration of WGC and Carbon Capture and Storage at Polk Power Station



Source: Tampa Electric Company

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Advantages of Integration of WGC and CO_2 Conventional Capture Technology

- Ultra-Low Emission Profile

	Conventional Technology	WGC and conventional CO_2 capture
Sulfur in syngas	< 5 ppmv	< 1 ppmv
Sulfur in sequestered CO_2	< 100 ppmv	< 35 ppmv
CO_2 recovery	~75%	> 80%

- Improvements in Cost, Thermal Efficiency, Operability, and Reliability
  - Fewer Processing Steps
    - Conventional : 6 (Shift , COS hydrolysis, S / CO_2 removal, CO_2 cleanup, 2 stages of cooling)
    - WGC +CCS : 4 (Shift, WGC, CO_2 removal, 1 stage cooling)
  - Fewer heat exchangers (Shift reactor exit temperature is good match for WGC)
  - Operating pressure optimized for performance (Pressure not dictated by AGR)

Source: Tampa Electric Company

DOE Gasification Roadmap—Impact of Advanced Technology (Noblis Analysis)

Technology	Impact	Efficiency Increase* (% points)	TPC Reduction* ($/kW)	COE Reduction* (¢/kWh)
IGCC/CCS	*Efficiency down >5 pts, TPC up >$500/kW, COE up 2.5¢/kWh*			
Dry coal feed pump	Increases cold gas efficiency	1.0	-19.0	-0.08
Gasifier materials & instrumentation	Increases on-line time	0.0	0.0	-0.39
Warm gas cleanup	Eliminates cold gas cleanup thermal penalties and reduces capital cost	2.0	-319.0	-0.96
Advanced syngas turbine (AST)	Increases power output and allows air integration	0.9	-73.0	-0.25
ITM plus AST (2010)	Eliminates ASU thermal penalty and auxiliary load and reduces capital cost	0.0	-118.0	-0.33
ITM plus AST (2015)	Combination of increased power output and efficient, cheaper ASU	2.1	-89.0	-0.29
Advanced sensors and controls	Increases on-line time	0.0	0.0	-0.26
IGCC/CCS Pathway Impact		*5.9*	*-618.0*	*-2.6*
IGFC/CCS Pathway Impact	Efficient conversion of chemical energy to power and reduces capital and operating costs	*23.7*	*-716.0*	*-3.1*

*as compared to IGCC with conventional CCS technology

Source: Klara, ICEPAG 2009

Summary

- Warm Gas Clean-up Technology:
  - Offers significant capital cost and efficiency advantages over
    - Selexol – for power applications
    - Rectisol – for chemical applications
  - Represents potential enabling technology for carbon capture and storage including
    - Conventional technologies
    - High temperature membranes and sorbents
- 50 MW WGC Demonstration Project:
  - Is being hosted at Tampa Electric Company's Polk Power Station
  - Has an aggressive schedule

• Feed package	Completed: June 2010
• Environmental permitting	Completed: Oct. 2010
• Construction, commissioning and shakedown	Completed: Early 2012
• Demonstration testing	Completed: Late 2013

  - Will support commercial offering of WGC technology in 2014

Acknowledgements

- DOE/NETL for financial assistance
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  - Jenny Tennant
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- Eastman Chemical Company
- Tampa Electric Company
- Nexant
- Noblis