



RTI Warm Syngas Cleanup Operational Testing at Tampa Electric Company's Polk 1 IGCC Site

DOE Cooperative Agreement DE-FE0026622
Project Kick-off Meeting
January 7, 2016

DOE/NETL Program Manager: K. David Lyons
RTI Project Manager: Raghurib Gupta

Agenda

- Background
- Project Objective
- Technical Approach
- Project Structure
- Project Management Plan (including Risk Management)
- Project Schedule
- Project Budget

Project Background

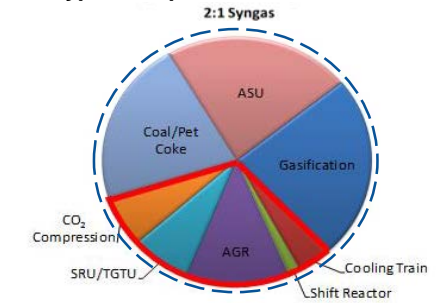
Value Drivers of RTI Warm Syngas Cleanup Technology



Syngas Cleanup is a Major Cost Driver

Efficiency Improvements Reduce All Elements of Cost

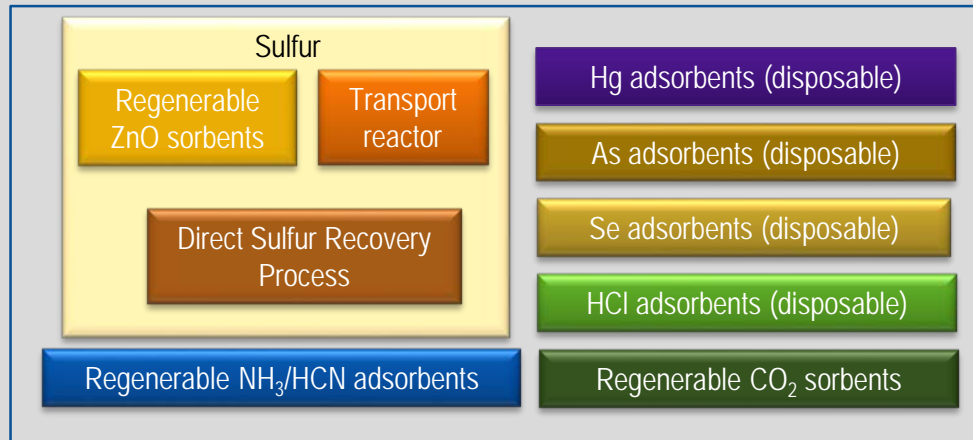
Typical Capital Cost Breakdown



RTI Technology Reduces Cost and Improves Efficiency!

RTI Warm Syngas Cleanup Technology Platform

RTI PILOT PLANT TEST UNITS AT EASTMAN COAL GASIFICATION PLANT



50-MW_{equiv} TEST PROJECT w/CC UNDERWAY AT TAMPA ELECTRIC SITE

RTI has developed a platform of warm syngas cleanup technologies:

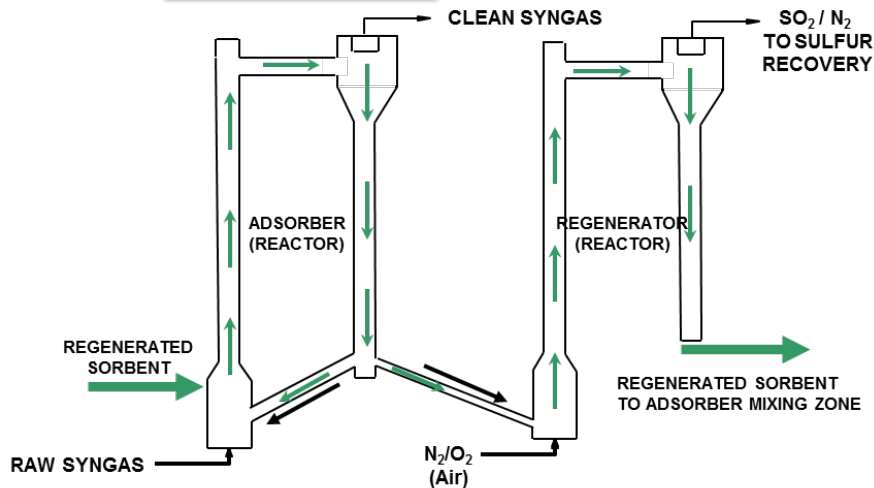
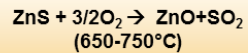
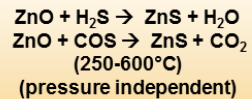
- Increase efficiency and lower costs
- Operate at 250-600°C
- Pressure independent
- Effective for all forms of sulfur
- Fully compatible with all CO₂ capture
- Flexible modular approach enables specific syngas purity needs to be met
- Systems tested on actual coal-based syngas
- Warm desulfurization process (WDP) now being tested through 50-MW_{equiv} scale

RTI Warm Syngas Desulfurization Process (WDP)

A unique process technology based on transport reactor design (related to commercial FCC reactor designs)...



... and on the development of a highly active, attrition-resistant sorbent.

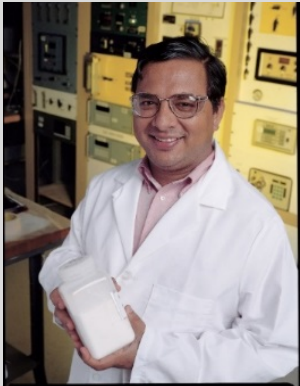


RTI Proprietary Desulfurization Sorbent

- R&D 100 Award
- Unique highly-dispersed nanostructures
- Developed in long-term cooperation with Clariant (~100 tons to date)
- Covered by extensive US & International patents, including several recent improvements

Part of comprehensive high temperature contaminant removal platform.

From Lab- to Large-Scale Testing of Warm Syngas Cleanup



Invention (2001)

- Proprietary RTI sorbent
- High attrition resistance



Lab/bench testing (2001-2003)

- RTI International, NC
- Concept proven & modeled



Pilot testing (2006-2008)

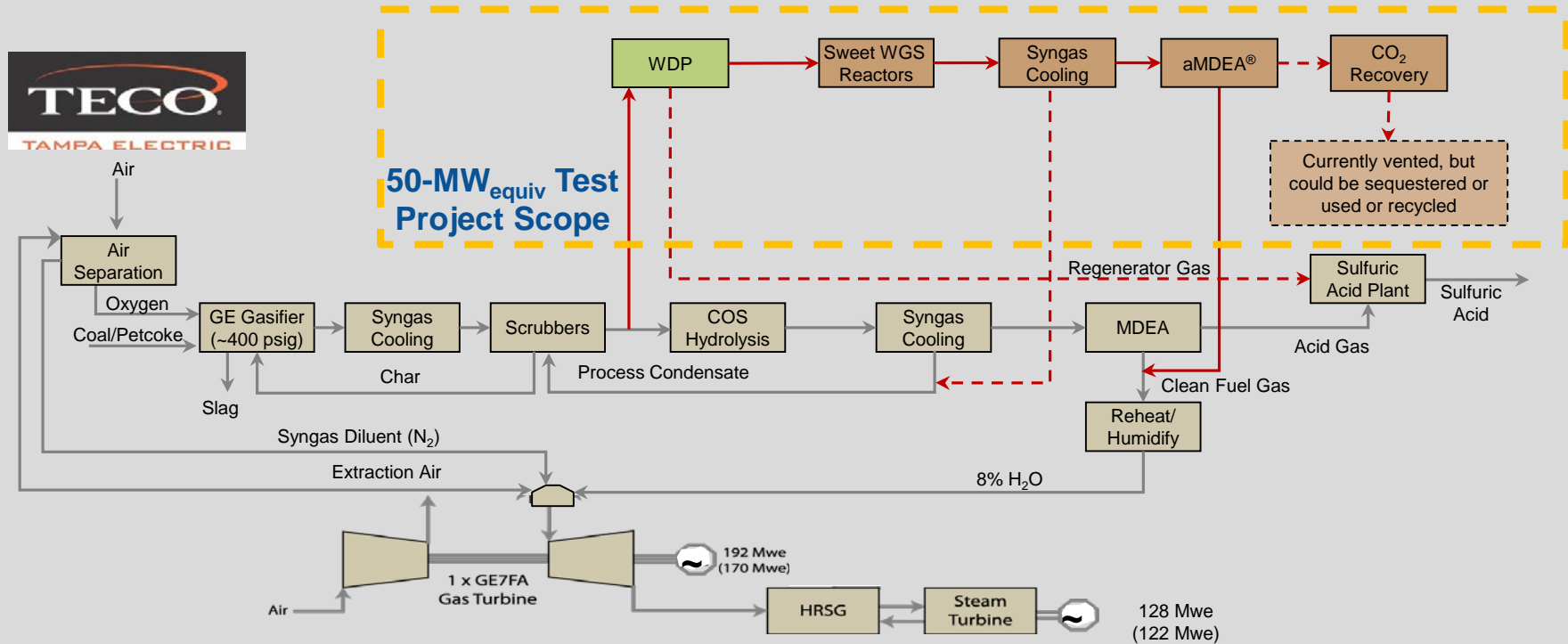
- Eastman Chemical Co., TN
- 3000 hr, coal-based syngas



50-MW_{equiv} testing with CO₂ capture (2010-2016)

- Tampa Electric Company, Polk 1 IGCC Plant, FL
- Testing underway, 50-MW_{equiv} coal/petcoke-based syngas

Integration of Warm Syngas Cleaning and Carbon Capture Systems at Tampa Site



20% slipstream test (~50 MW_{equiv}) cleans ~2MMscfh of raw syngas from the TECO gasifier.

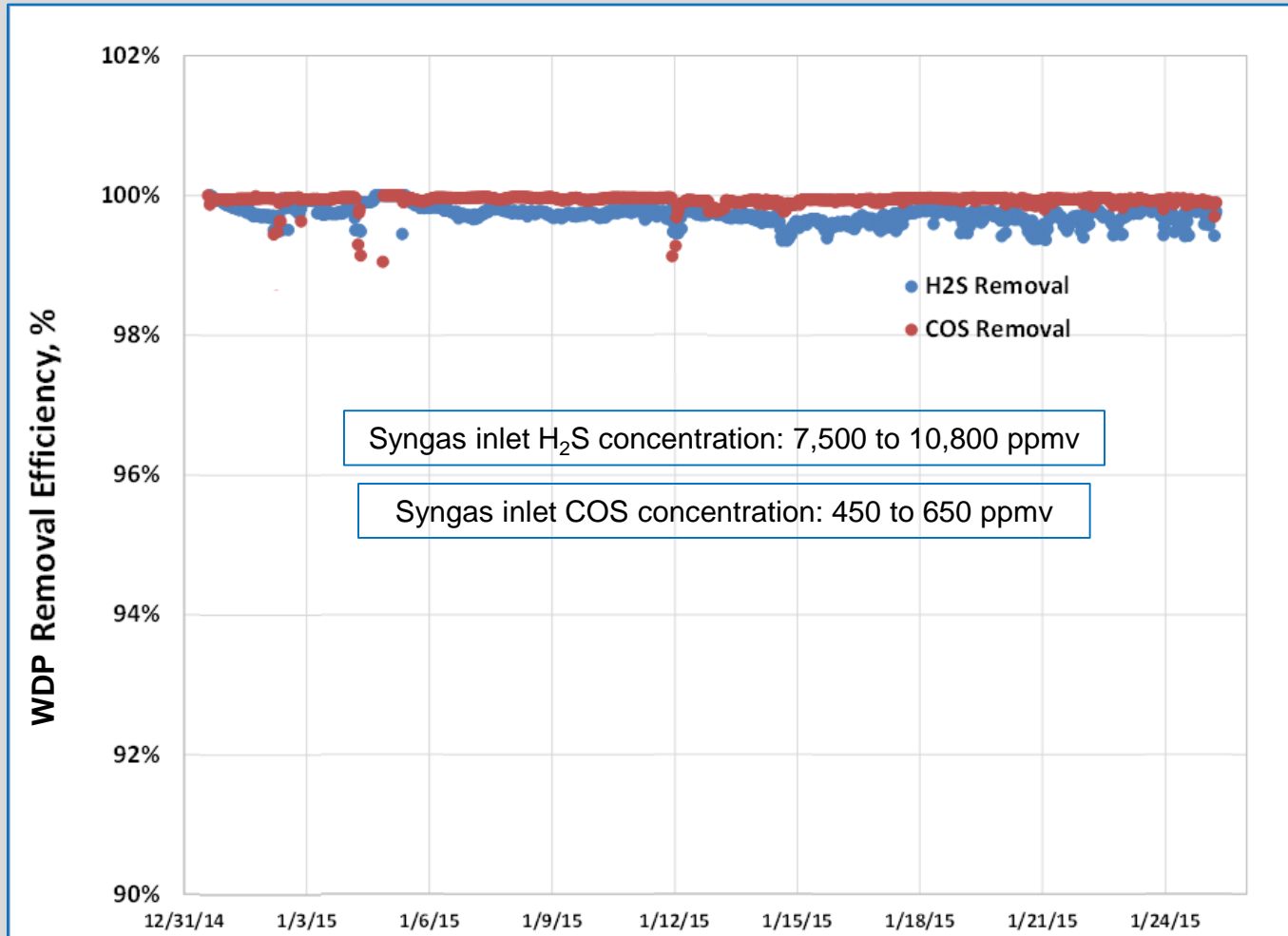
RTI WDP 50-MW_{equiv} Test Project Performance – ARRA Funding Period



DOE/RTI/TECO/Clariant Team

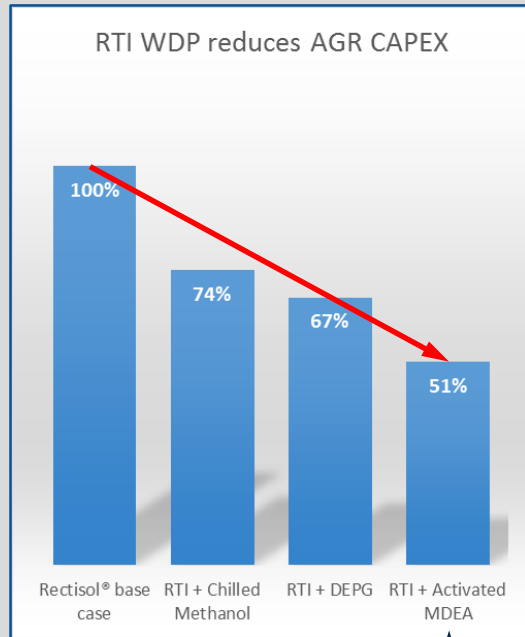
- Construction achieved on schedule & under budget
- > 500,000 total labor hours with no significant injury (other than minor first aid)
- Unit performed as expected with almost 1,500 syngas operation hours by end of ARRA funding (9/30/15)
- ~99.9% total sulfur removal from RTI WDP step
- >99.99% total sulfur removal achieved WDP + aMDEA[®] (sub-ppmv levels of total sulfur in cleaned syngas)
- Sorbent attrition rate in line with design expectations
- Sorbent sulfur capacity steady - no sign of deactivation
- Successful operation both below and above design rate
- Gasification unit was down for an extended period in mid-2015 (with no syngas to thus feed the RTI unit), resulting in need for an extension of the operational testing time period.

50-MW_{equiv} Test Plant Results: High Total S Removal and Stable Operation

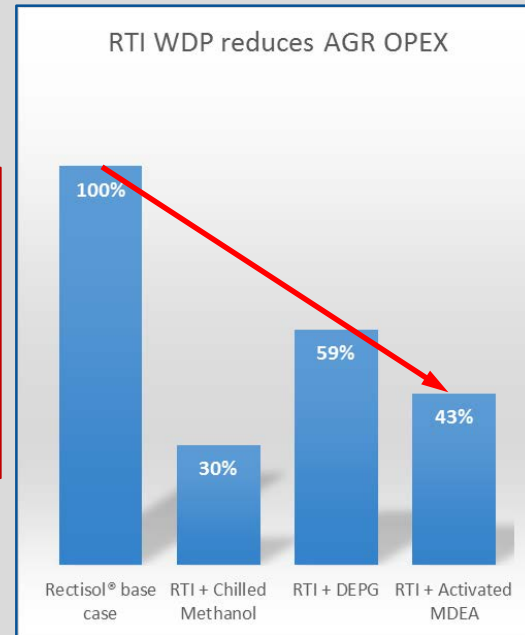


Techno-Economics: Coal to Methanol Case

(2 x 300-MW_e Shell-type solids-fed gasifiers with PRB or Shenhua Mix coal)



RTI WDP improves economics for all carbon capture options!



Non-labor, non-feedstock operating costs

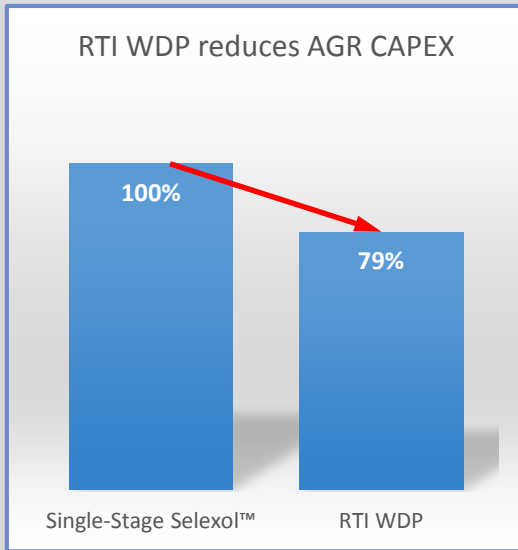
Technology used in RTI Test Plant

NOTES:

- Cost savings indicated are across the entire block from raw warm syngas exiting the gasifier block through cleaned syngas feed to the methanol conversion step, including the sulfur recovery unit.
- These analyses do not include additional benefits to the entire plant that might occur from overall efficiency savings.

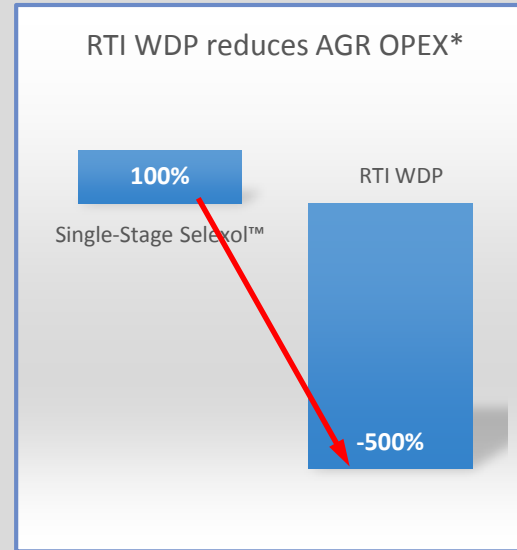
IGCC Cases

(2 x 300 MW_e Shell-type gasifiers w/PRB or Shenhua Mix coal)

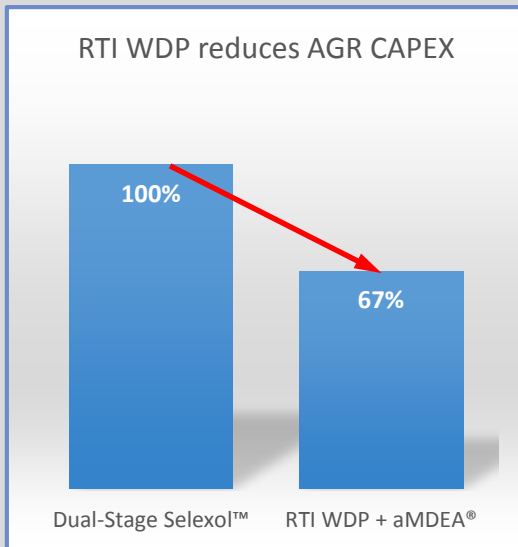


CAPEX and OPEX are for AGR + WGS + LTGC + SRU blocks

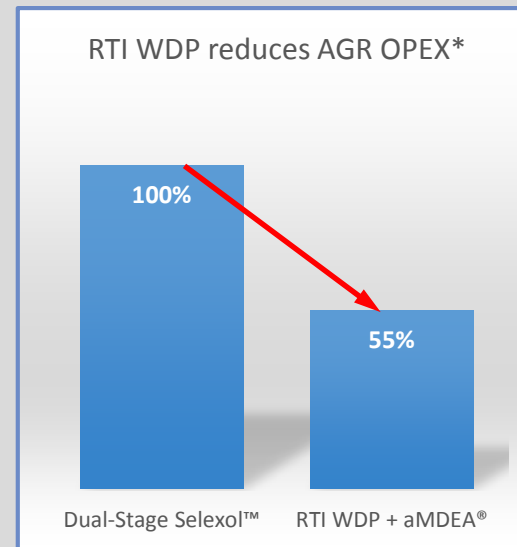
IGCC w/o Carbon Capture



* Non-labor, non-feedstock OPEX



IGCC with Carbon Capture



Project Objective

Overall Objective for Operational Testing

The overall objective of this project is to mitigate the technical risks associated with the scale up and integration of the warm syngas cleaning and carbon dioxide (CO₂) capture technologies, enabling subsequent commercial demonstration.

Technical Approach

Technical Approach for Operational Testing

50-MW_{equiv} testing to date of RTI's WDP technology has shown that the technology has great potential to provide clean syngas from coal and petcoke-based gasification at increased efficiency and at lower capital and operating costs than conventional syngas cleanup technologies. However, before the technology can be deemed ready for scale-up to a full commercial-scale demonstration, additional R&D testing is needed at the site to address the following critical technical risks:

- WDP sorbent stability and performance
- Impact of WDP on downstream cleanup and conversion steps
- Metallurgy and refractory
- Syngas cleanup performance and controllability
- Carbon capture performance and additional syngas cleanup

Technical Approach – Key Actions

- Operation to achieve an additional 3,000 hours of syngas operation within the performance period, with a target of achieving 1,000 hours of those hours via continuous operation of the entire integrated system,
- Rapid turnaround of repairs and/or modifications required as necessary to return any specific unit to operating status with documentation and lessons learned to support technology maturation, and
- Proactive performance of maintenance activities during any unplanned outages and if possible while operating.

Key Technical Data to Obtain

- Desulfurization performance based on the sulfur concentrations of inlet and effluent syngas
- Sorbent regenerability
- Temperature profiles in adsorber and regenerator
- Sorbent circulation between adsorber and regenerator loops
- Sorbent attrition
- Activity of the water gas shift catalyst
- CO₂ removal performance of the amine system
- Final sulfur content of the syngas from the amine unit
- Purity of the CO₂ stream produced from the regeneration of the amine
- Analysis and testing of gas, liquid, and solid samples obtained during operation of the process units
- Performance and reliability data generated during operation and relevant to assessment of the economic, environmental, and efficiency benefits of the warm syngas cleanup technologies
- Identification of possible design modifications and lessons learned from operation that may reduce technology risk

Current Project Update Summary

- The syngas interchanger was rebuilt (with improved metallurgy) to address some observed sulfur-induced corrosion of the tubes and re-installed in late November, 2015. The new design seems to be working well (will monitor regularly).
- Since restart of the WDP test plant in early December, 2015, the WDP unit has operated well, except for some very short outages related to peripheral equipment.
- The WDP unit has consistently been able to reduce inlet sulfur content from as much as 14,000 ppmv to around 10 ppmv (99.9%).
- Downstream clean syngas exiting the activated amine carbon capture block has consistently been below 500 ppbv, and has been as low as 180 ppbv to date (>99.99% total sulfur removal).
- We have now achieved over 2,000 total syngas operation hours (as of 12/31) and hope to achieve as many as 4,000 total syngas operation hours by the time that the unit shuts down for the IGCC plant's annual spring outage, expected to occur in late April, 2016.

Project Structure

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Project Team



Overall project management responsibility, engineering, day-to-day operations oversight, and laboratory support



Provision of the site, syngas slipstream feedstock, test unit product/by-product off-takes, process operators, and operations and maintenance support



Operations and maintenance support, on-site process engineers, safety and an experienced site manager



Assistance with the compilation and analysis of process data, on-site process engineer



Sorbent and catalyst supply



The Chemical Company

Activated amine supply

RTI Team



Raghbir Gupta,
Project Manager



Brian Turk



David Denton



Atish Kataria



Gary Howe



John Albritton



David Barbee



Vijay Gupta



JP Shen



Himanshu Paliwal

Project Management Plan

Project Plan - Project Tasks

- **Task 1: Project Management**
 - Develop and maintain an updated project management plan (PMP) to meet all technical, schedule, and budget objectives
 - Conduct project activities according to the approved PMP
 - Effectively identify, assess, monitor, and mitigate technical, schedule, budgetary, safety, and environmental risks
 - Submit required technical, and financial and other reports per Federal Assistance Reporting Checklist
 - Provide detailed kick-off meeting and semi-annual project progress presentations

- **Task 2: Operation of Pre-Commercial Test System**
 - Operate the warm gas desulfurization process, water gas shift, low-temperature gas cooling, and activated amine carbon capture units at Polk 1 IGCC site to achieve an additional ~3,000 hrs of syngas operation with a target of 1,000 hrs of continuous operation of the full integrated system

Milestones

ID	Task	Description	Completion Date
<i>MS1</i>	2	Complete 3,000 hours of operation with at least 1,000 hours of continuous integrated operation	6/30/2015

Project Schedule

Project Schedule for Operational Testing

- Overall goal is to complete 3,000 hours of syngas operation with at least 1,000 hours of continuous integrated operation under this project.
- Syngas heat interchanger rebuild was completed and installed in late November, 2015, and the 50-MW_{equiv} test plant was restarted on December 2, 2015.
- WDP unit (plus the carbon capture unit for a substantial portion of time) will have been operated for ~700 hours (under the extended operational testing period starting October 1, 2015) before shutting down for a short-term gasifier outage around January 11, 2016.
- Following the short-term gasifier outage, the plan is to bring up the full integrated syngas cleanup system and run to achieve the targeted 1000 hours of continuous integrated operation and the accumulated 3000 hours of total syngas operation under this project.
- The extended operational testing period is scheduled to end at the start of the IGCC annual spring outage, now scheduled to commence in late April, 2016.

Project Budget

Project Budget

Object/Class Categories	DOE Share	RTI Cost Share	Total Estimated Project Costs
Personnel	\$ 405,119	\$ -	\$ 405,119
Fringe Benefits	\$ 153,945	\$ -	\$ 153,945
Travel	\$ 99,762	\$ -	\$ 99,762
Equipment	\$ -	\$ -	\$ -
Supplies	\$ 31,068	\$ -	\$ 31,068
Contractual	\$ 6,289,782	\$ 750,000	\$ 7,039,782
Construction	\$ -	\$ -	\$ -
Other	\$ -	\$ -	\$ -
Total Direct Costs	\$ 6,979,675	\$ 750,000	\$ 7,729,675
Indirect Charges	\$ 20,325	\$ 1,000,000	\$ 1,020,325
Total Estimated Costs	\$ 7,000,000	\$ 1,750,000	\$ 8,750,000

QUESTIONS?

Contact:
Raghubir Gupta
gupta@rti.org
919-541-8023

