ADVANCE SYNGAS CLEANUP FOR RADICALLY ENGINEERED MODULAR SYSTEMS (REMS)

DE-FE0031522

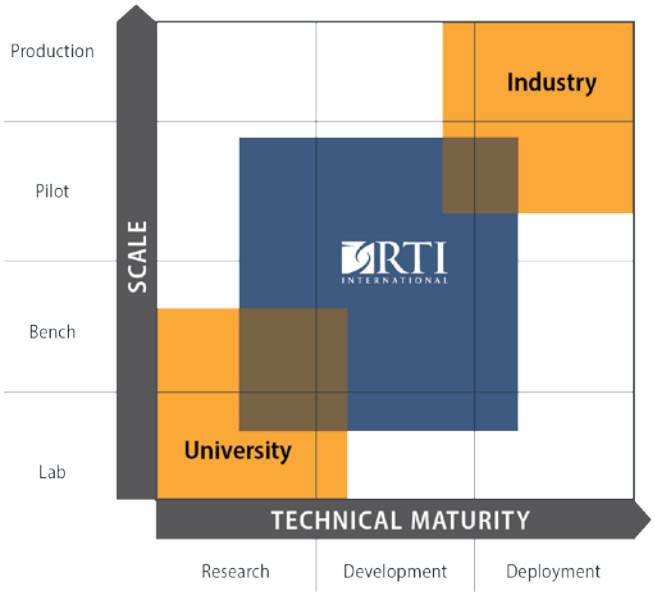
February 9th, 2018

Project Kickoff Meeting

delivering **the promise of science**
for global good

Energy Research at RTI International

RTI develops advanced process technologies in partnership with leaders in energy



Full alignment with industry objectives

From concept to demonstration

Defined commercialization pathways

Flexible intellectual property arrangements

Potential leveraging of industrial R&D funding with government provided funding


Natural Gas


Clean Coal / Syngas Processing


Advanced Materials


Carbon Capture & Utilization


Industrial Water Treatment


Biomass Conversion

NATIONAL ENERGY TECHNOLOGY LABORATORY

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
BIOENERGY TECHNOLOGIES OFFICE

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
ADVANCED MANUFACTURING OFFICE

arpa·e

EMISSIONS REDUCTION ALBERTA

GASSNOVA

SINTEF

HALDOR TOPSOE

Masdar

CLARIANT

THE LINDE GROUP

BASF
We create chemistry

VEOLIA

CASALE

BERKELEY LAB

CLEMSON UNIVERSITY

NC STATE UNIVERSITY

STANFORD UNIVERSITY

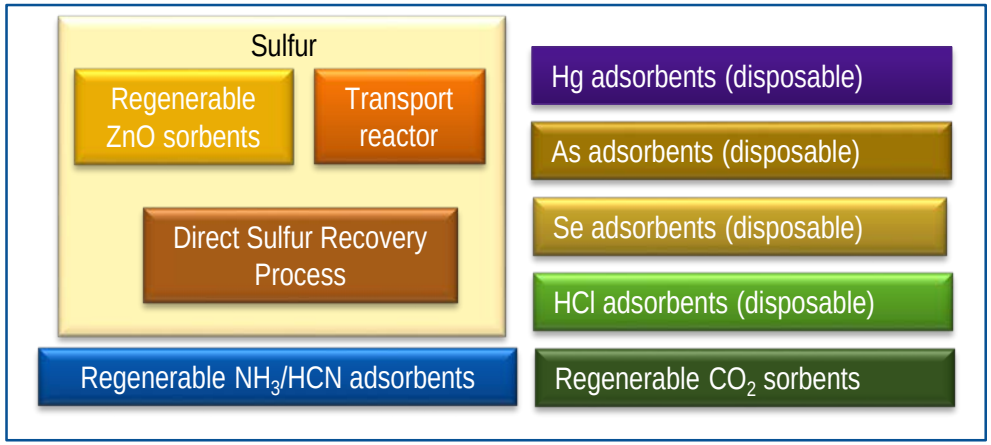
MIT

Duke UNIVERSITY

UC RIVERSIDE
UNIVERSITY OF CALIFORNIA

RTI Warm Syngas Cleanup Technology Platform

RTI PILOT PLANT TEST UNITS AT EASTMAN COAL GASIFICATION PLANT



PRE-COMMERCIAL DEMO PROJECT w/CC AT TAMPA ELECTRIC SITE

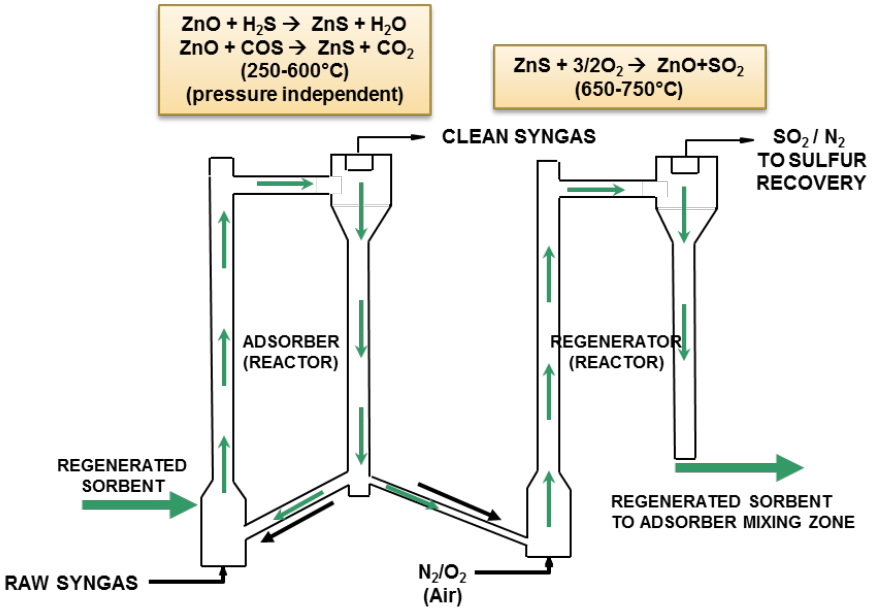
RTI has developed a platform of warm syngas cleanup technologies:

- Increase efficiency and lower costs
- Operate at 250-600ºC
- Pressure independent
- Effective for all forms of sulfur
- Fully compatible with all CO_2 capture
- Flexible modular approach enables specific syngas purity needs to be met
- Systems tested on actual coal-based syngas
- Warm desulfurization process (WDP) now tested through pre-commercial demo scale of 50 MW_e syngas flow

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.

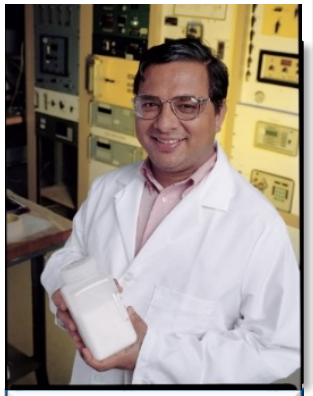


RTI Proprietary Desulfurization Sorbent

- 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 Demonstration of Warm Syngas



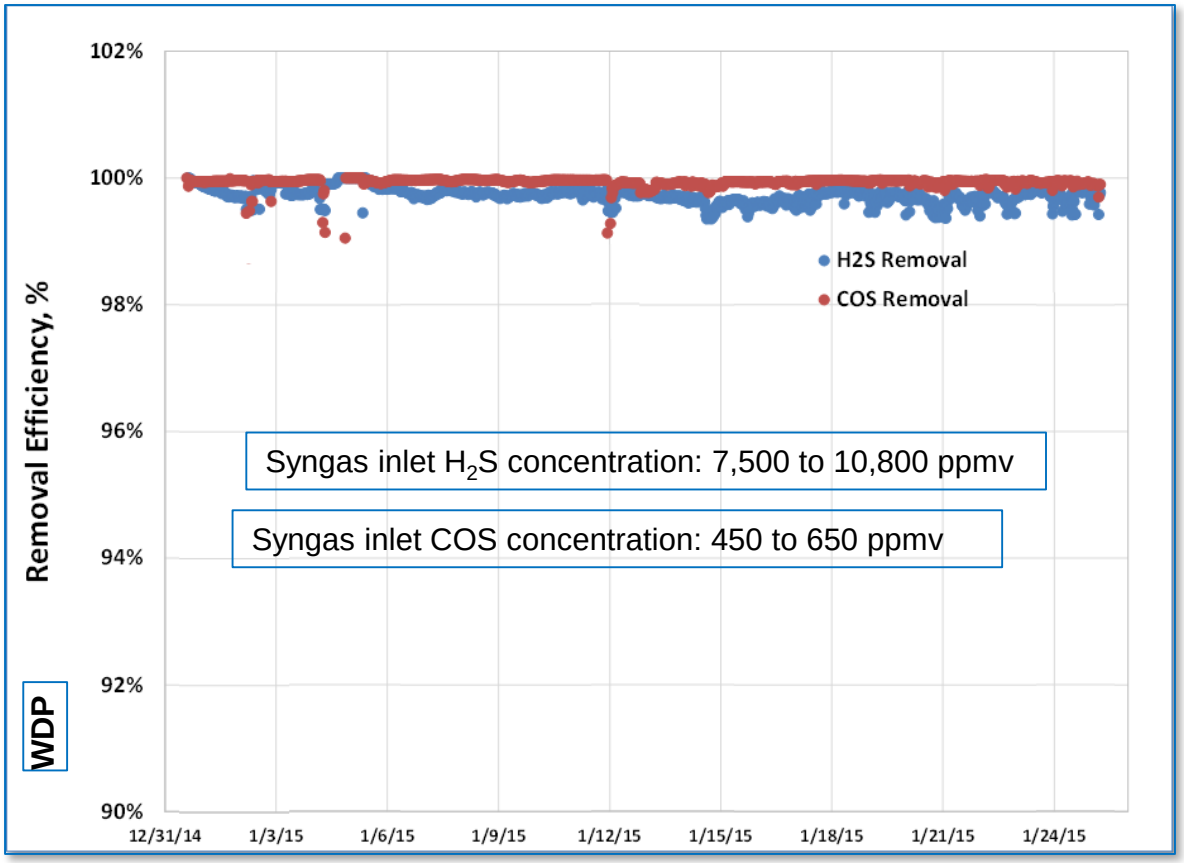
Invention (2001)
- Proprietary RTI sorbent
- High attrition resistance

Lab/bench testing (2001-2003)
- RTI International, NC
- Concept proven & modeled

Pilot testing (2006-2008)
- Eastman Chemical Co., TN
- 3000 hr, coal-based syngas

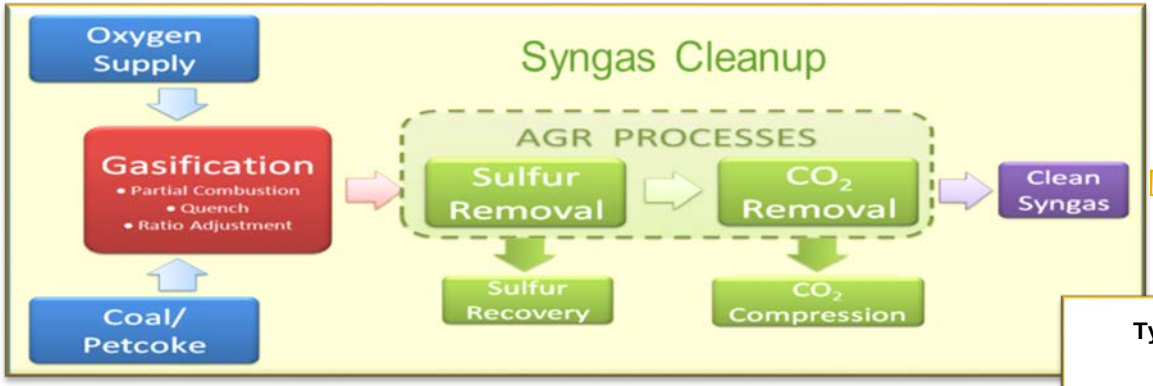
Demonstration – Syngas Cleanup & CO_2 Capture (2010-2016)
- Tampa Electric Co., Polk 1 IGCC Plant, FL
- Testing underway, 50-MW_{equiv} coal/petcoke-based syngas

High Total Sulfur Removal and Stable Operation



- Over 3000 hours of WDP testing at 50 MW-scale
- ~99.9% total sulfur removal from RTI WDP step
- >99.99% total sulfur removal achieved WDP + aMDEA®
- Sorbent attrition rate in line with design expectations
- Sorbent sulfur capacity steady - no sign of deactivation
- Successful operation both below and above design rate

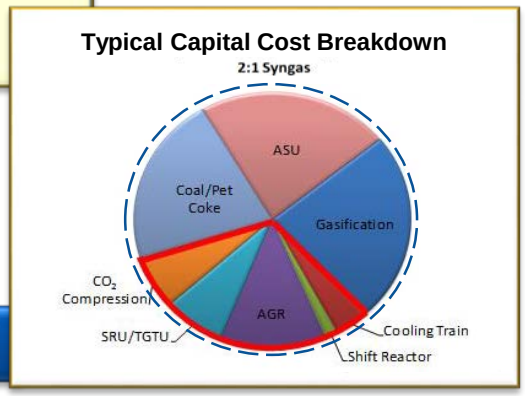
Value Drivers of RTI Warm Syngas Cleanup Technology



Graphics Source:
Eastman Chemical Co.

Conversion to clean power, DRI, or chemicals/fuels

Syngas Cleanup is a Major Cost Driver

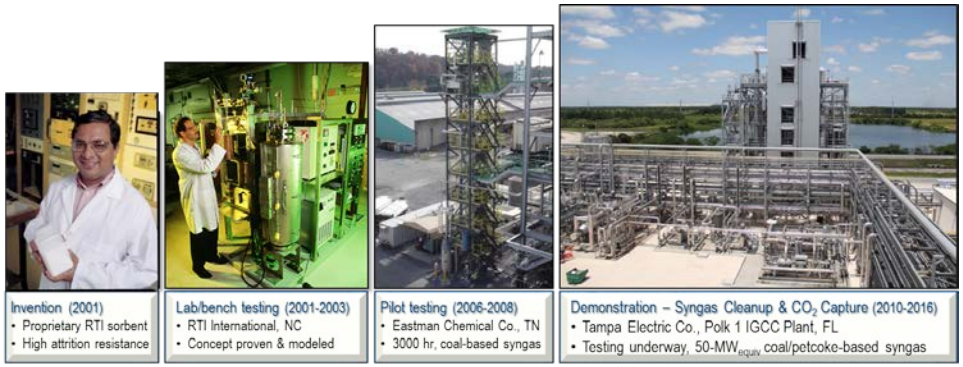


Efficiency Improvements Reduce All Elements of Cost

RTI Technology Reduces Cost and Improves Efficiency!

Will Be True Regardless of Scale

WDP Potential to Address REMS



NEAR REMS-scale

How does this technology development apply to REMS & low-sulfur coals?

Key Strengths of WDP still apply

- Rapid reaction rates of desulfurization and regeneration
- Proven material chemistry and scale-up
- Fundamentally applicable to any sulfur concentration and pressure
- Modular design expected to reduce capital costs over other technologies
- Anticipate similar energy savings and GHG reductions as large-scale

Knowledge gaps for application

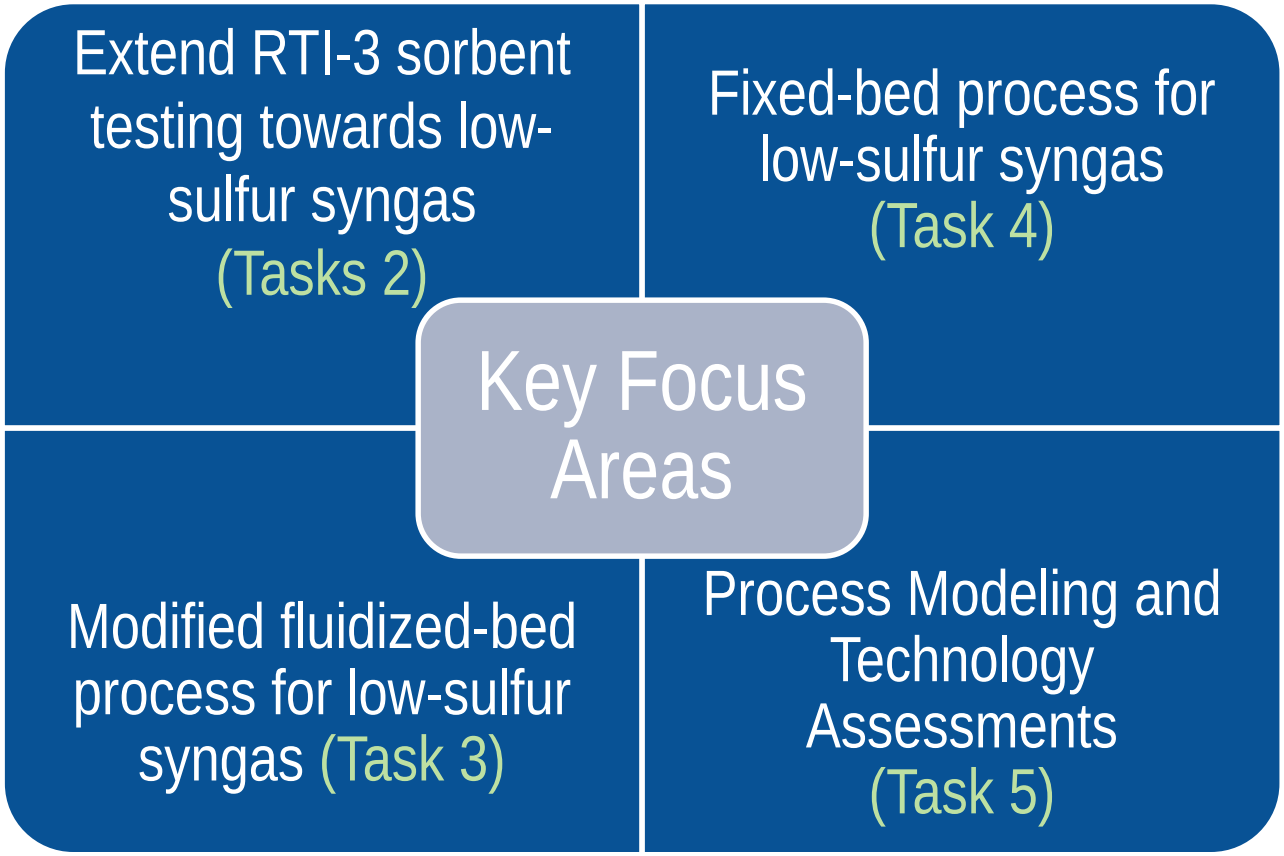
- Expanded experimental data for low-sulfur syngas
- Identify modifications to the current process configurations to enable deployment of modular, cost-competitive cleanup systems
- Hydrodynamic data for fluid bed regenerator
- Processing steps to yield fixed-bed extrudate
- Performance of fixed-bed system extrudate

Project Objectives

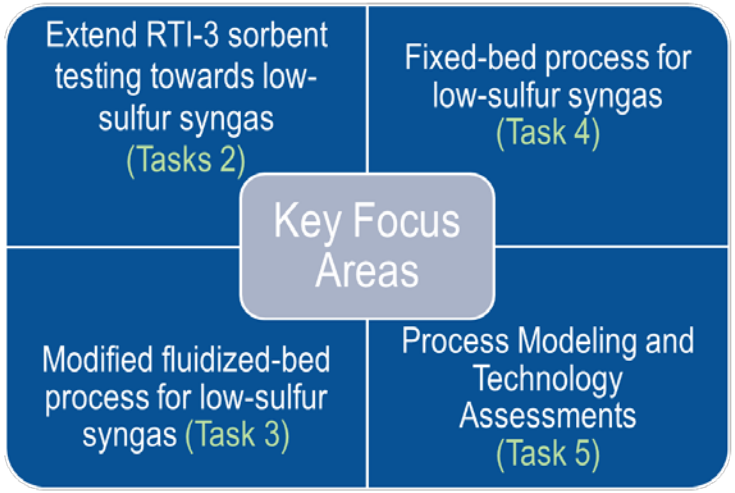
Objective: Develop modular sorbent-based warm syngas cleanup designs that will enable 1- to 5-MW REMS-based plants utilizing all of our abundant domestic coal reserves to be cost-competitive with large state-of-the-art commercial plants.

- Sorbent desulfurization testing for low-sulfur syngas
  - Collect desulfurization performance experimental data for low-sulfur syngas
- Modification to the Fluid-Bed Process
  - Collect fluid-bed hydrodynamic data at cold-flow and typical regenerator operating conditions
- Developing a Fixed-Bed Process
  - Optimize the processing steps that yield an extruded formulation of WDP sorbent
  - Experimental data on the desulfurization performance of the fixed-bed sorbent
  - Develop rapid cycle fixed-bed process
- Collect Bench-Scale Data
  - Experimental data for the fluid- and fixed-bed systems with simulated gas to reduce risk associated with design and operation of prototype system
- Process Design, Optimization, and Feasibility
  - Conceptual fluid- and fixed-bed process designs
  - Cost estimation and optimization of conceptual design
  - Cost estimation for the overall REMS for combined heat and power or polygen

Framework for Project

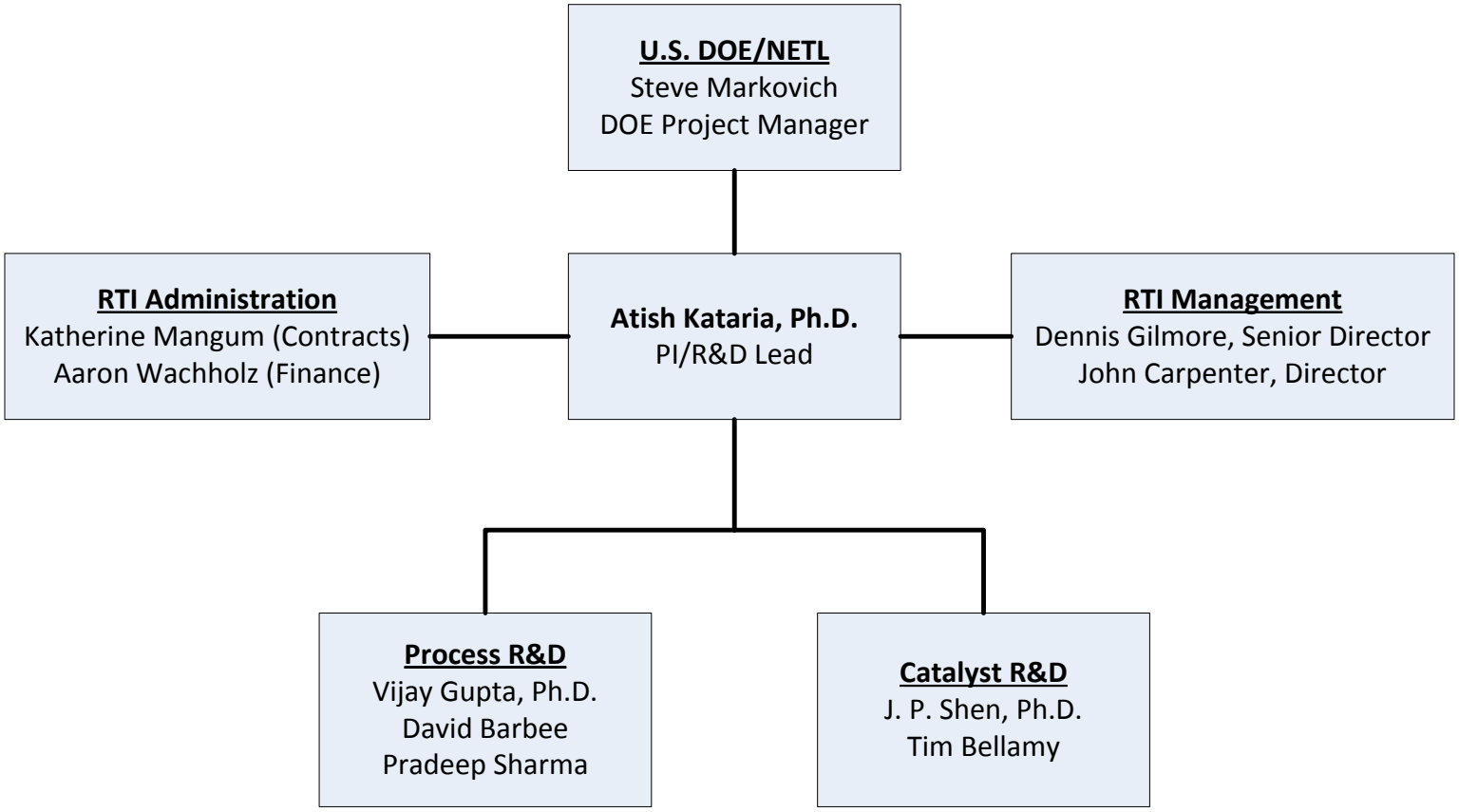


Task List



Task	Description
1	Project Management and Planning
2	Low-Sulfur Syngas Testing
3	Fluid-Bed Regenerator Development
4	Fixed-Bed Sorbent Development
5	Techno-Economic Analysis

Task 1-Project Management - Team



Project Timeline & Budget

Task Name	Period of Performance							
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Task 1: Project Management								
Task 2: Low-Sulfur Syngas Testing								
Task 3: Fluid-Bed Reactor Testing								
Subtask 3.1: Cold-flow testing								
Subtask 3.2: Pressurized and hot testing								
Subtask 3.3: Sulfur testing								
Task 4: Fixed-Bed Sorbent Development								
Subtask 4.1: Sorbent production								
Subtask 4.2: Sorbent development								
Subtask 4.3: Sorbent testing								
Subtask 4.4: Extended multicycle testing								
Task 5: Process Development								
Milestones								

	Total Project	
	Government Share	Cost Share
Applicant	$1,598,982	$399,746
Total	$1,598,982	$399,746
% of Total	80.0%	20.0%

Project Milestone Log

ID	Budget Period	Title	Completion Date
1	1	Submission of revised PMP to DOE	2/1/2018
2	1	Pilot-scale sorbent batch at RTI	3/31/2018
3	1	Testing to generate a database for fluidized-bed sorbent desulfurization performance for low-sulfur syngas completed.	9/30/2018
4	1	Hydrodynamic cold-flow testing supporting design of fluid-bed regenerator completed.	8/31/2018
5	2	Demonstration testing of fluid-bed regenerator design at simulated operating conditions validating design for techno-economic analysis completed.	6/30/2019
6	2	Demonstration testing of fixed-bed sorbent and process at simulated operating conditions validating design for techno-economic analysis completed.	11/30/2019
7	2	Completion of techno-economic analyses for a full REMS plant incorporating fluid- and fixed-bed modular desulfurization systems, with goal of achieving a cost target of < $90/MWh[1].	12/31/2019

[1] This value is based on values provided in DOE/NETLs' "Cost and Performance Baseline for Fossil Energy Plant Volume 3a: Low Rank Coal to Electricity IGCC Cases (DOE/NETL2010/13990) which have been updated for 2016 costs.

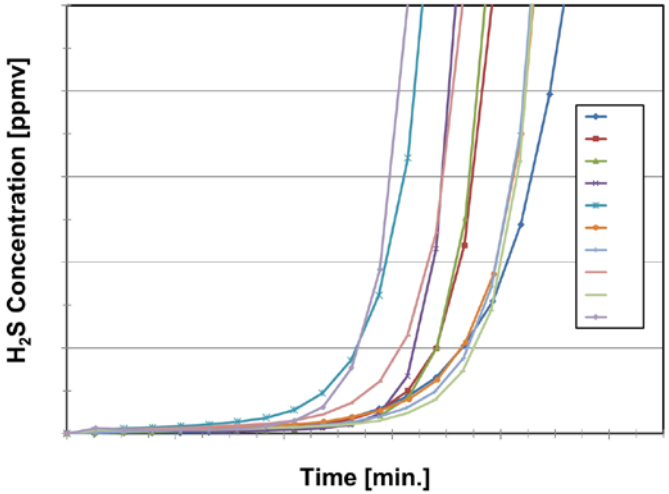
Risk Management

Category	Risk Description	Resolution Strategies
Technical	Fluidized testing at actual operating conditions requires operation at adequate scale.	Cold-flow testing in a pilot-scale unit will allow effective testing at ambient conditions to establish the fundamental hydrodynamic phenomenon. Subsequent testing in a hot and/or pressurized system will extend the databased on the similarity of the gas and particle properties like density, viscosity, and drag.
Technical	Development of an effective fixed-bed desulfurization sorbent.	The chemical composition of the proposed fixed-bed sorbent has been proven at pre-commercial demonstration scale, limiting the issue to developing an effective process for packaging this chemical composition in a form that can be used for fixed-bed processes.
Resources	Specialized testing systems are necessary for low-sulfur syngas test, fluidized-bed testing, and sorbent development.	RTI plans to use existing systems that have been designed and operated for the specific testing planned. No new testing systems will be necessary for this project.

Task 2.0: Low-Sulfur Testing

- The primary objective is to study the desulfurization performance of WDP sorbent for low-sulfur syngas streams
- Parametric testing will cover the typical operating conditions of temperature, pressure, syngas composition (with an emphasis on steam concentration), and residence time
- Testing will primarily use the fluid-bed WDP sorbent available for testing without any formulation modification and available as a commercial product
- A small portion of the effort will support testing of the fixed-bed sorbent formulation with emphasis on parameters and ranges where it's performance differs compared to fluid-bed sorbent
- Testing will be performed in our existing Bench-Scale Sorbent Testing System

Bench-Scale Sorbent Testing System

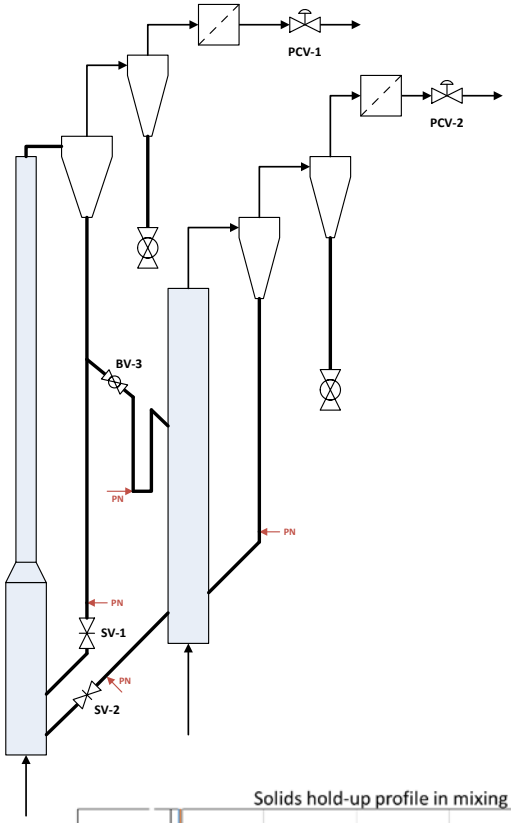


- Sorbent testing in simulated syngas and oxidation gases
- Suspended quartz reactor inside stainless steel pressure vessel
- Operating conditions up to 40 barg and 700°C
- Automated, multi-cycle testing capability
- Utilizes 100-300 g material
- Extensively used for WDP sorbent development and qualification of toll manufactured material

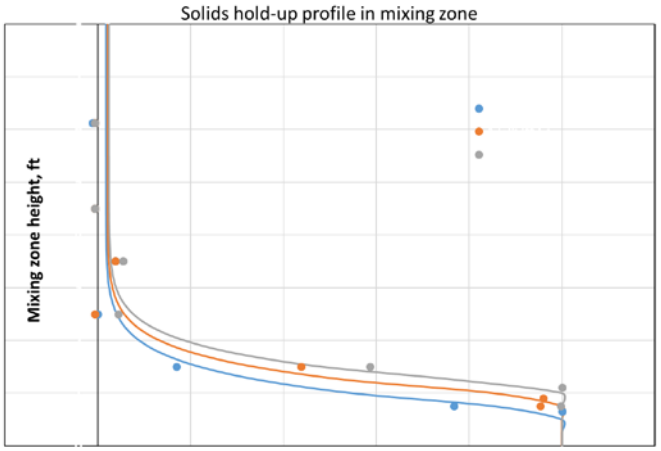
Task 3.0: Fluid-Bed Regenerator Development

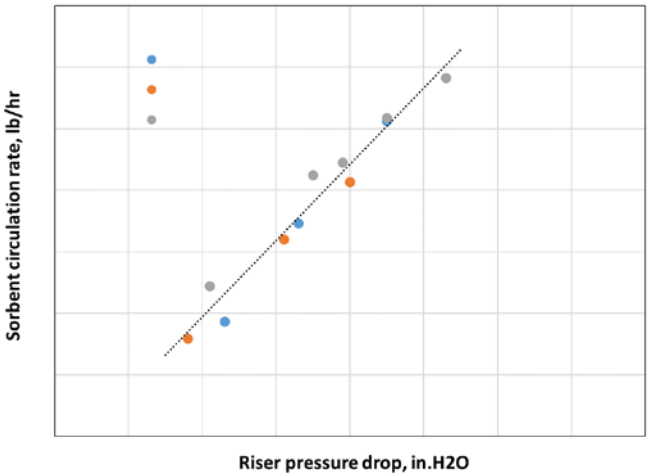
- Proposing the development of a fluid-bed regenerator for low-sulfur syngas applications
- Efforts will begin with cold-flow testing to acquire hydrodynamic data for the sorbent at key regions within the fluid-bed reactor system
- Additional hydrodynamic data will be collected in the hot-flow testing system at a combination of pressure and/or temperature to enable extending the application of the data to commercially relevant operating conditions
- Perform cycling sorbent sulfur testing in the hot-flow unit under simulated operating conditions

Subtask 3.1: Cold-Flow Testing

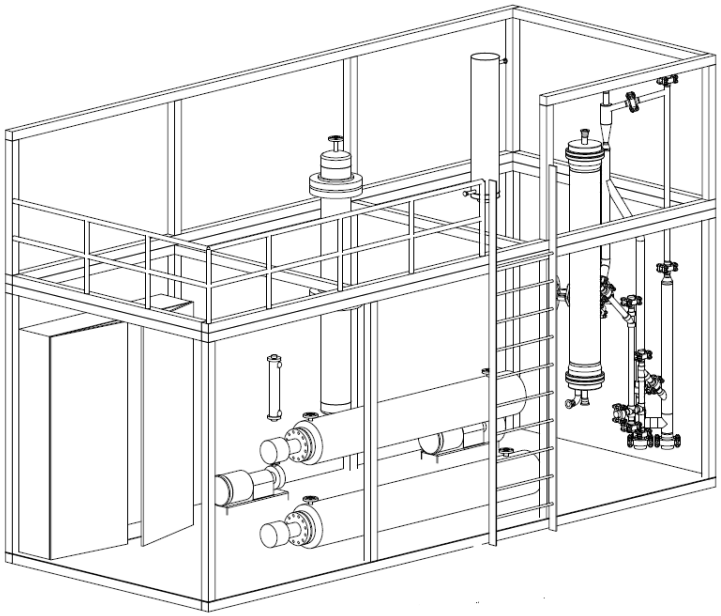


- Transport reactor absorber
  - Mixing zone-Riser Design
    - 8” mixing zone and 4” riser
- 6” fluidized bed regenerator
- 2” transfer lines
- Line size slide valves
  - Recirculation and transfer
- Two cyclones in series
- Extensively instrumented with dP transmitters





Subtask 3.2: Hot-Flow Testing



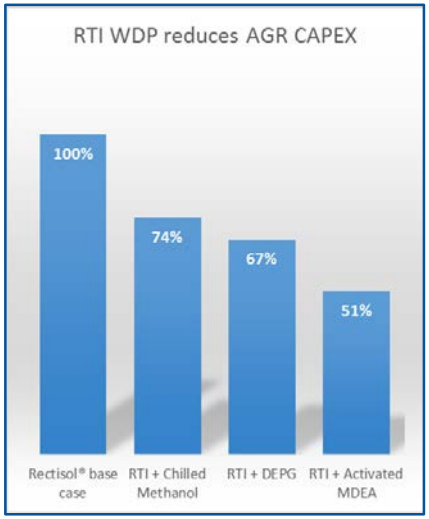
- Design similar to the cold-flow unit
- Design limits of 150 psig and 650°C
- Transport reactor absorber
  - Mixing zone-Riser Design
    - 4” mixing zone and 2” riser
- 12” fluidized bed regenerator
- Transfer lines
  - 3” standpipes and diplegs
- Easy switch orifice plates
- Extensively instrumented with dP transmitters
- Off-gas scrubber
- Will add H_2S feeding system

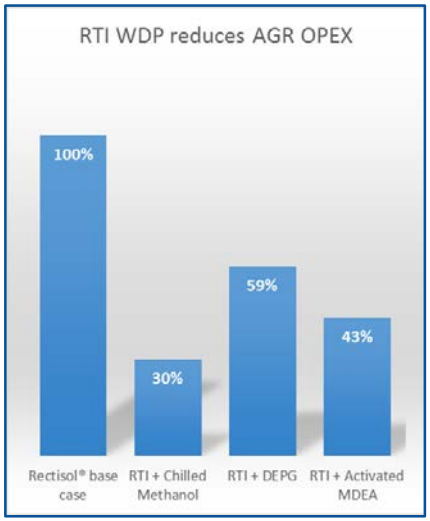
Task 4.0: Fixed-Bed Sorbent Development

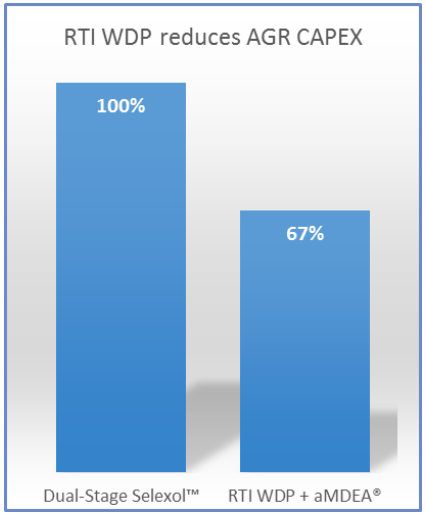
- Fixed-bed process is inherently suitable for small-scale modular systems, especially for low-sulfur syngas
- Requires formulation of a fixed-bed sorbent using proven chemistry of the fluidizable form
- Wet cake from the fluidizable RTI-3 production will be used to study the production of extrudates
- Fixed-bed sorbent formulation will be optimized using physical and chemical screening test results
- Physical properties of fresh and used sorbents will be tested for surface area, compositional analysis, XRD, and crush strength
- Bench-scale sorbent testing system will be used to study multicycle stability
- Parametric testing will be used to generate fixed bed process parameters (time sequences, regeneration conditions, purge, etc.)
- Optimized fixed-bed sorbent will be tested for extended stability for >50 cycles

Task 5.0 Techno-Economic Analysis

- Data generated from Tasks 2, 3, and 4 will be used to develop and optimize fluidized-bed and fixed-bed processes
- Potential to reduce system cost through standardization, modular production and other advanced manufacturing techniques will be investigated
- The TEAs developed in this task will be developed for the overall plant from upstream gasification to syngas conversion
- Sensitivity analyses will be utilized to help optimize the overall system integration and to assess relative benefits of RTI's WDP
- Results from this task will be captured in a TEA report as a deliverable







Questions?

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