the Energy to Lead

ADVANCED GASIFIER AND WATER GAS SHIFT TECHNOLOGIES FOR LOW COST COAL CONVERSION TO HIGH HYDROGEN SYNGAS

DOE/NETL Cooperative Agreement DE-FE0023577

- **Don Stevenson, Executive Director**

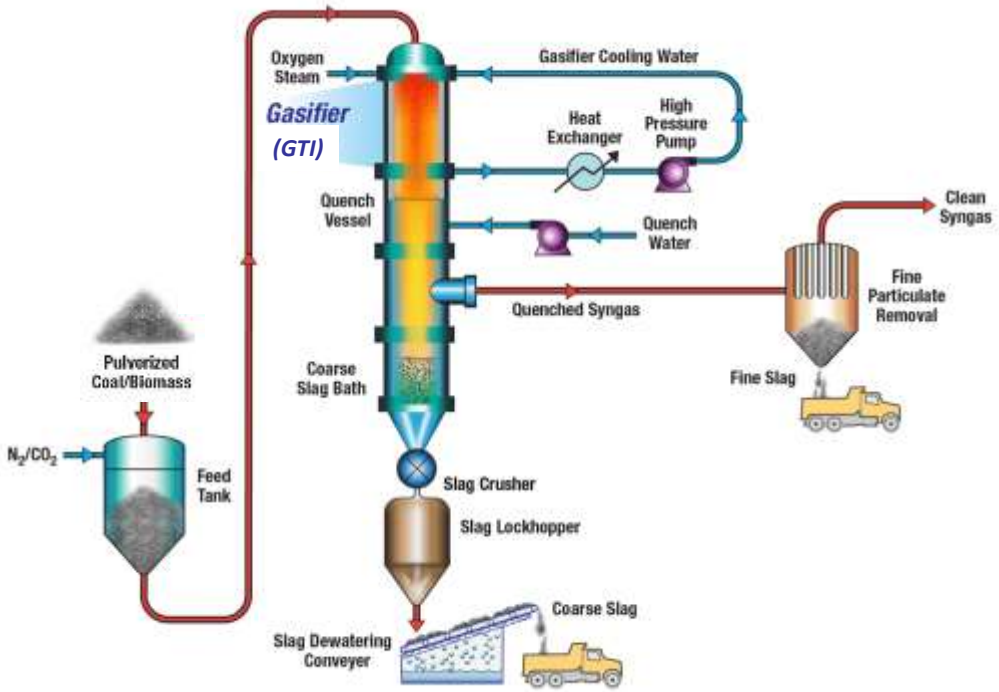
- DOE Gasification and C&CBTL Workshop
  Morgantown, WV
  August 10, 2015

gti

AGWGST Program Team

- Gas Technology Institute
  - Compact gasifier technology
- RTI International
  - Advanced Water Gas Shift reactor technology
- Coanda Research & Development
  - Cold flow simulation of gasifier quench zone
- Nexant, Inc.
  - Techno-economic analysis showing integrated benefits of GTI, RTI technologies

Compact Gasifier Overview



Compact Gasifier Attributes:

- Dry feed for high efficiency, feedstock flexibility
- Rapid mix injector + plug flow reactor for 90% smaller volume
- Advanced cooling design for robust thermal margins, long component life
- Eliminates black water system
- Long MTBF, short MTTR for high availability

Benefits:

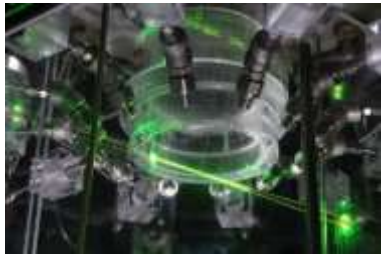
- High CGE: 2-4% > than other dry feed, 7%-9% > than slurry
- Lower capex: ~15-25% plant cost reduction vs. lowest cost entrained flow tech
- 15%-25% reduction in cost of product (power, chemicals, liquids)

Principles of Operation

- Dry feed system enables use of low rank coals
- Multi-element feed splitter
  - Uniform splitting assures good O_2/coal ratio at each element
  - Establishes “plug flow” to minimize recirculation, accelerate gasification
- Advanced cooled liner design
  - Keeps metal temperatures < 550°C for long life
  - High thermal margins enables operation on coals with high ash fusion temperature (AFT)
- Rapid spray quench
  - Flexibility to provide dry syngas from 350°C to 800°C
  - High degree of flexibility for process optimization

Gasifier Development Needs

- **Quench Zone Modeling**
  - Slag blockage, misdirected syngas flow

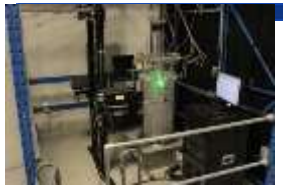


- **Highly Reactive Feedstocks**
  - Potential for aggressive thermal environments near burner

- **High AFT + High Ash Coals**
  - AFT >1500˚C, >25% ash
  - Significant limitation for existing technologies

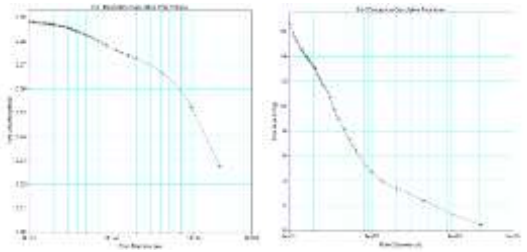
- **Carbon Conversion Kinetics**
  - Need better data to address final ~5% carbon conversion
  - Study porosimetry, surface area per unit mass as function of conversion

Test Program Matures Technology to Readiness for 500-1000 TPD Demonstration



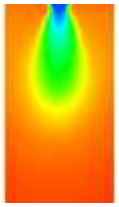
Quench Zone Flow Visualization, Localized Spray Data

Quench Zone Design Guidance



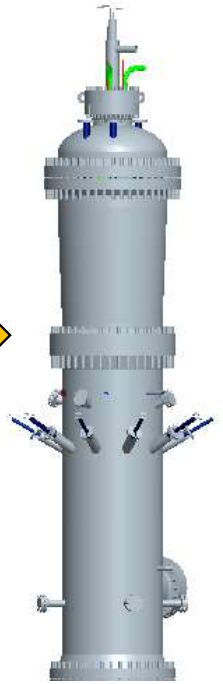
Char Porosimetry Data

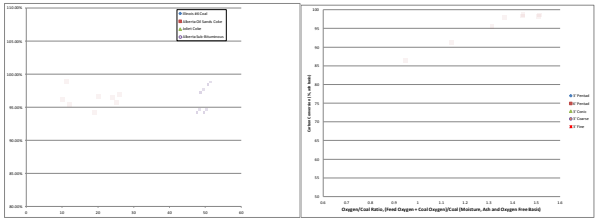
Test Results



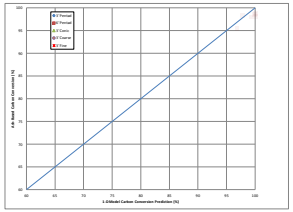
CFD Model: Scale-up, Environments, Mixing

Technical Readiness





Carbon Conversion & Heat Load Data



1-D Model: Carbon Conversion, Heat Loss

Pilot Scale Test Data

Validate Scale-up & Performance Design Tools

500-1000 TPD Gasifier

Advanced Water Gas Shift Technology

Primary reaction pathway is the Water Gas Shift (WGS) reaction

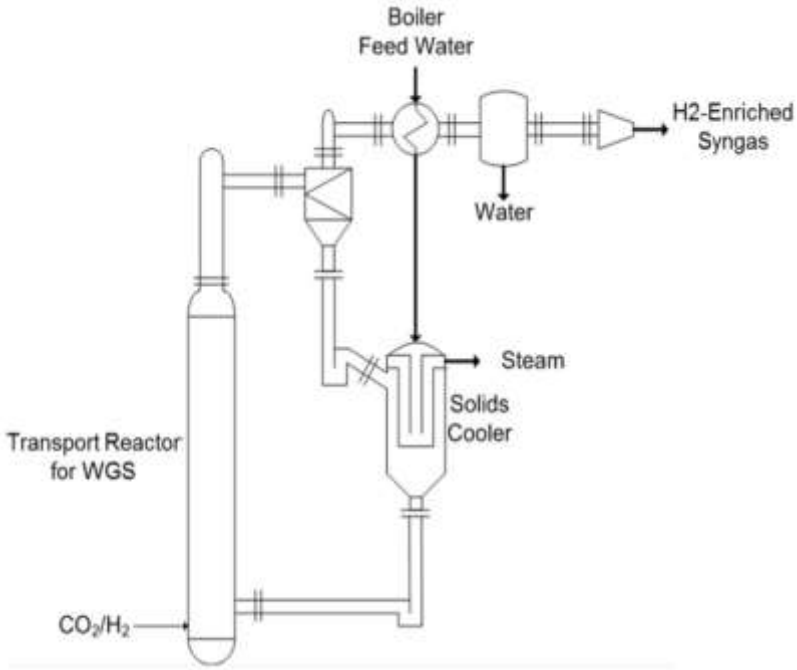
$$CO + H_2O = CO_2 + H_2 \qquad \Delta H = -41 \text{ kJ/mol}$$

Challenges

- Proactive reactor temperature control required
  - WGS reaction is exothermic
  - Coal-derived syngas has high CO concentration
- WGS reaction is equilibrium limited
  - Lower temperatures maximize H_2 production
  - High-activity lower-temperature catalysts are poisoned by syngas contaminants

Conventional solutions

- Large additions of steam
- Multiple reactor stage with inter-stage cooling



Proposed solution

- **Leveraging commercial FCC technologies (transport reactor with solids cooler)**
- **RTI's expertise in developing attrition-resistant fluid-bed materials**

AWGS Technology Road Map

Critical technical challenges

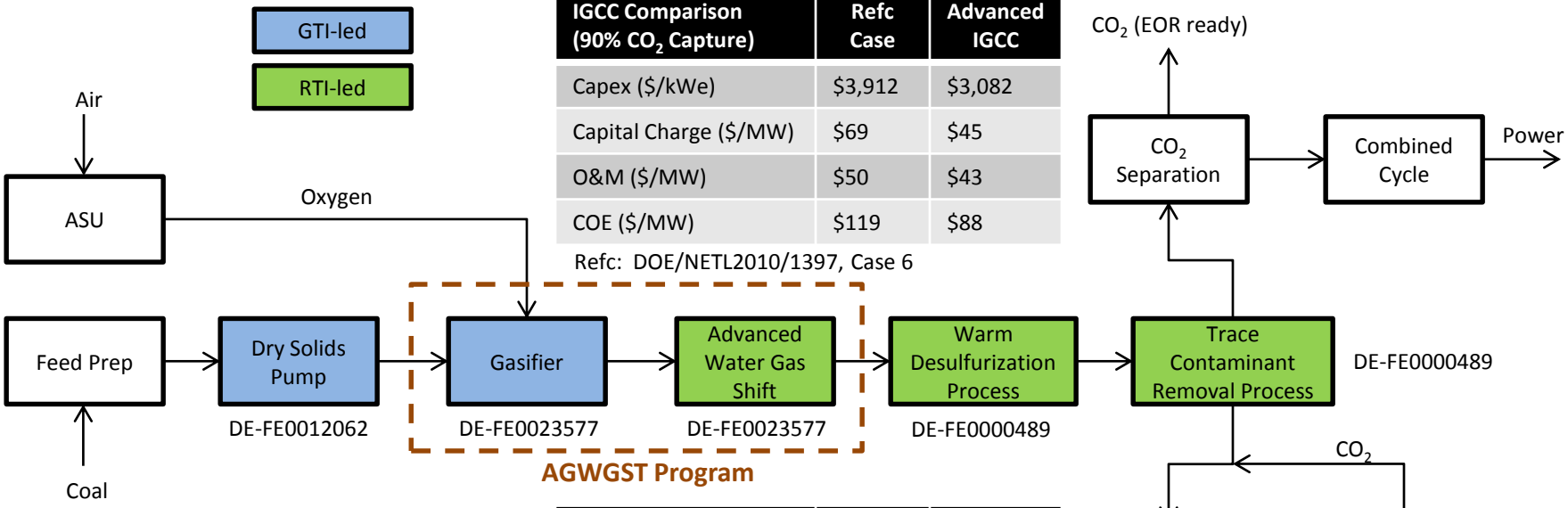
- Development of attrition-resistant WGS catalyst formulation
- Successfully leveraging existing commercial technologies

Stage	Research Objectives	Status
Technical feasibility	• Demonstrate fluidizable WGS catalysts that possess attrition resistance and WGS activity. • Perform preliminary techno-economic analysis to assess cost and efficiency benefits	Completed by 12/31/2014 (DE-FE0012066)
Catalyst Development	• Optimize fluidizable WGS catalyst for attrition resistance and WGS activity • Complete lab-scale testing of catalyst performance using simulated syngas mixtures at typical operating conditions to determine catalytic performance (activity, stability and selectivity • Update preliminary TEA to assess cost and efficiency benefits	In Progress (DE-FE0023577)
Pilot-plant Testing	• Demonstrate performance of fluidized-bed catalyst in a pilot-scale transport reactor with a solids cooler using real coal-derived syngas.	Optional Task (DE-FE0023577)
Demonstration	• Demonstrate expected commercial performance in demonstration-scale equipment with real commercial syngas and a commercially produced catalyst.	Future project

Integration with Balance of Plant

- Standard coal pulverization equipment
- Ultra-dense phase feed system, fed by conventional lock hoppers or Dry Solids Pump
- Standard oxygen, steam supply to gasifier
- Reactant supply skid for high pressure torch igniter (GTI supplied equipment)
- High pressure BFW in closed loop gasifier cooling system
- Recycled process condensate for quench
- Standard slag bath process
- Cyclone/candle filters for fines removal (dry recovery)

Integration With Other DOE Projects – 25% Reduction in Cost of Products



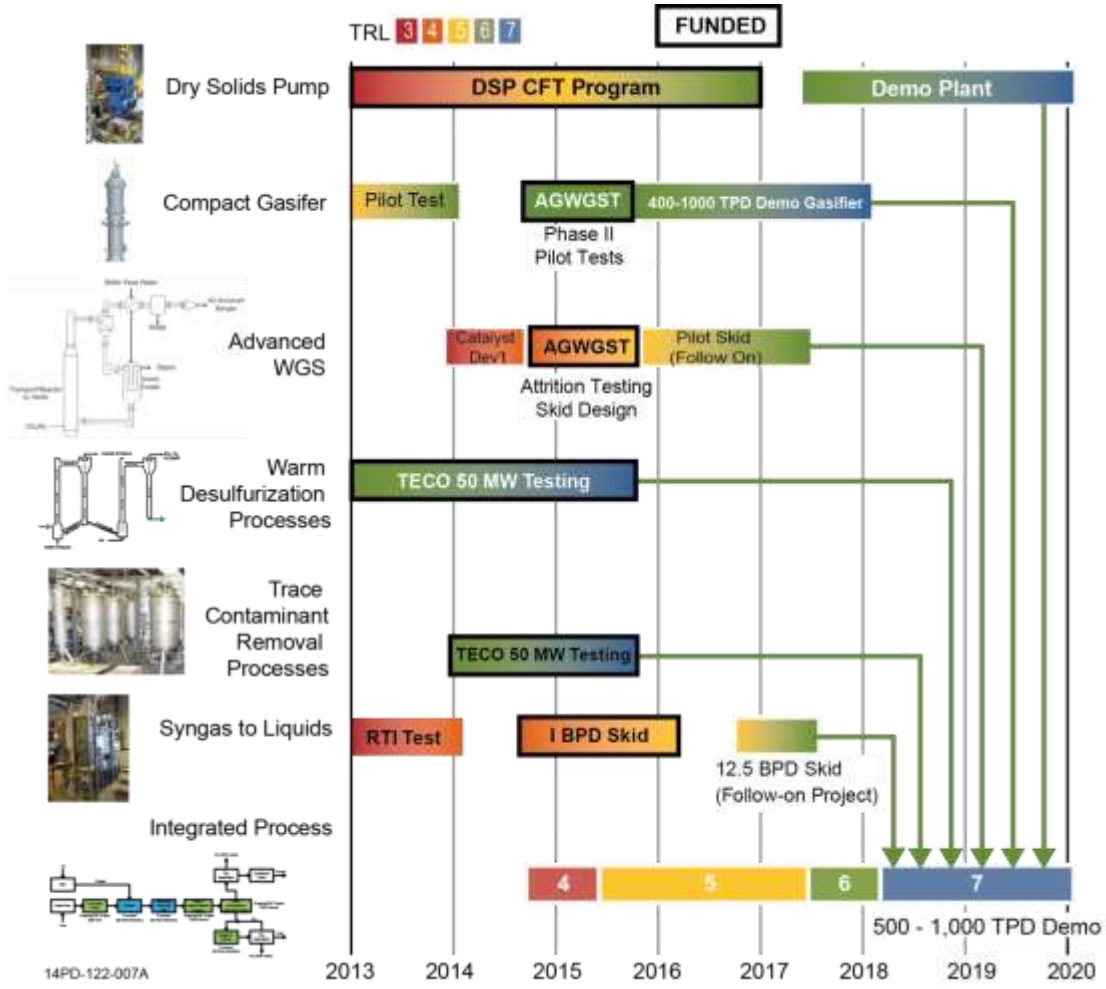
IGCC Comparison (90% CO_2 Capture)	Refc Case	Advanced IGCC
Capex ($/kWe)	$3,912	$3,082
Capital Charge ($/MW)	$69	$45
O&M ($/MW)	$50	$43
COE ($/MW)	$119	$88

Refc: DOE/NETL2010/1397, Case 6

CTL Comparison (GHG equivalent to oil)	Refc Case	Advanced CTL
Capex ($/bpd)	$136K	$97K
Capital Charge ($/bbl)	$70	$50
O&M ($/bbl)	$45	$36
Fuel Cost ($/bbl)	$115	$86
Oil Equiv ($/bbl)	$95	$68

Refc: DOE/NETL-2012/1542, Case BRW00

Technologies on Path for 2020 FOAK Commercially Relevant Demo



Conclusion

- GTI and RTI technologies offer potential for >25% reduction in cost of power, fuels
- GTI compact gasifier is ready for demonstration plant scale up after program
- RTI AWGS technology ready for pilot plant test after program
- Techno-economic analysis will assess integrated benefits of these technologies
- Technologies on track for 2020 demonstration

Turning Raw Technology into Practical Solutions

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