Breakthrough Hybrid CTL Process Integrating Advanced Technologies for Coal Gasification, NG Partial Oxidation, Warm Syngas Cleanup and Syngas-to-Jet Fuel

DOE/NETL Cooperative Agreement DE-FE0023592

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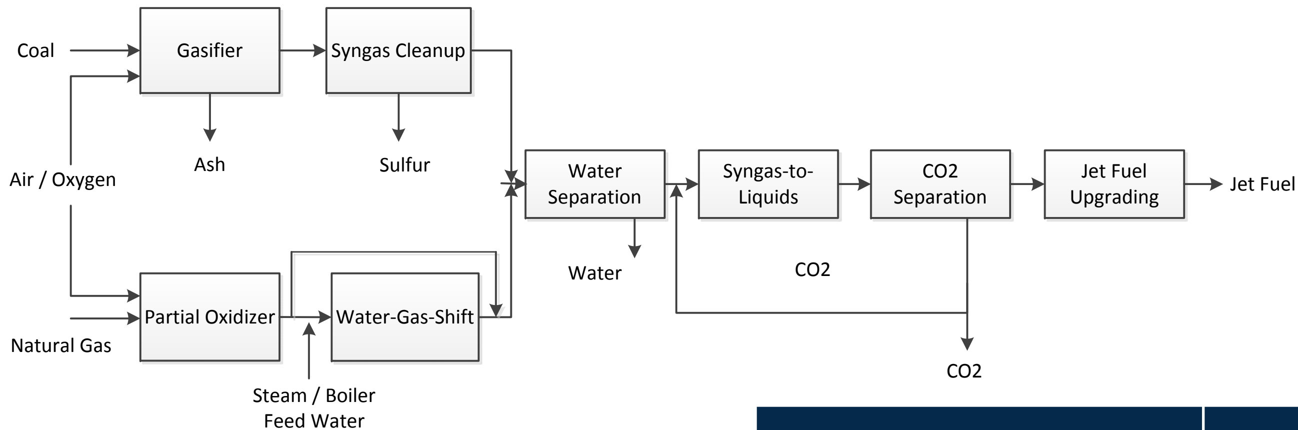
Overview

Breakthrough hybrid coal-to-liquids process integrating several emerging technologies and adapting some commercially available technologies to produce cost-competitive jet fuel.



Development Team

- RTI International
- GTI
- Aerojet Rocketdyne (AR)

- AR\GTI Compact Gasification System
- AR\GTI Partial Oxidation Unit
- RTI Warm Syngas Cleanup
- Syngas-to-Liquid System
- Axens Hydroprocessing Technology

Technology	Benefits		
	Cost of Electricity Reduction	Thermal Efficiency Improvement	Capex Reduction
Advanced gasification with dry feed (AR)	>15%	7-10% (Cold gas)	23%
Warm syngas Cleanup (RTI)	5-10 %	>3% (HHV)	10-15%
Cumulative Impact	20-25%	7-8% (HHV)	33-38%

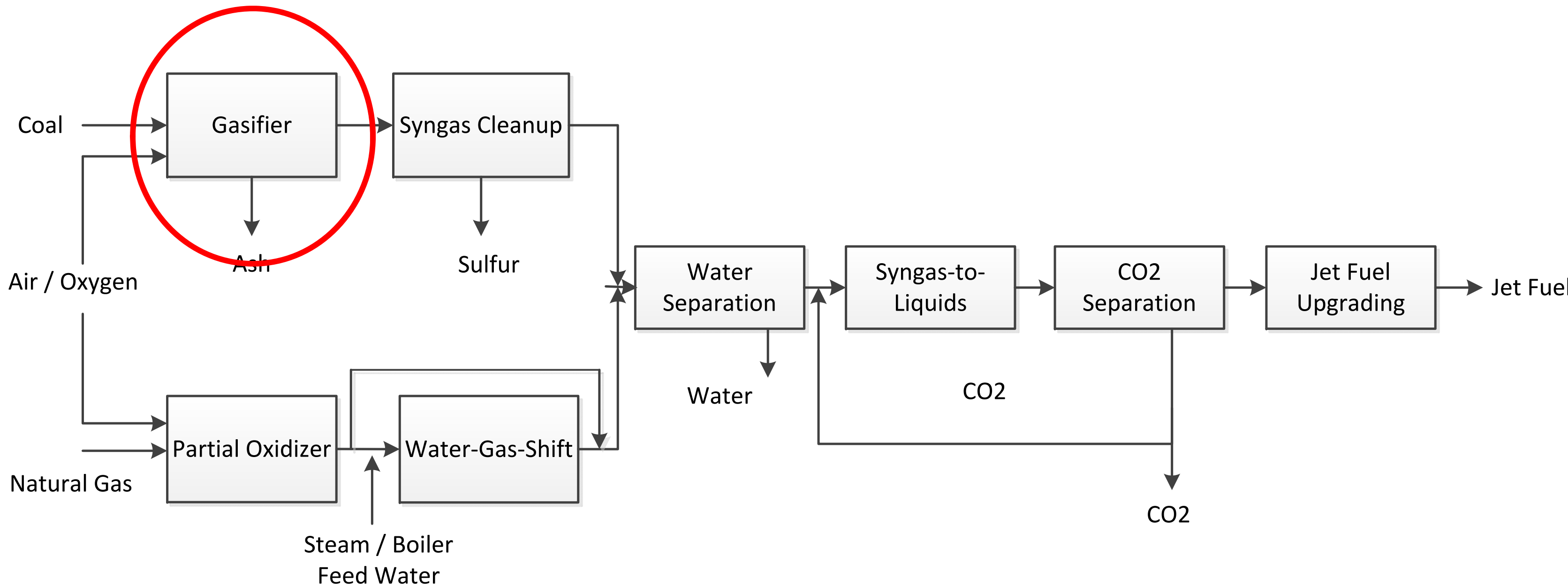
Current Effort Objectives

1. Advance the constituent technologies of the hybrid process to TRL 5-7:
   - Demonstrate integrated operation of AR\GTI's gasifier and POX units with RTI's STL process at pilot-scale (~1 bbl/day).
   - Demonstrate the jet-fuel intermediate generated during this integrated pilot-scale test is suitable for upgrading into jet-fuel using commercial refinery processes.

2. Demonstrate the feasibility of the proposed hybrid process to produce cost competitive jet fuel and lower GHG emissions.

3. Develop a commercialization plan for commercial deployment within the next 5 to 15 years.

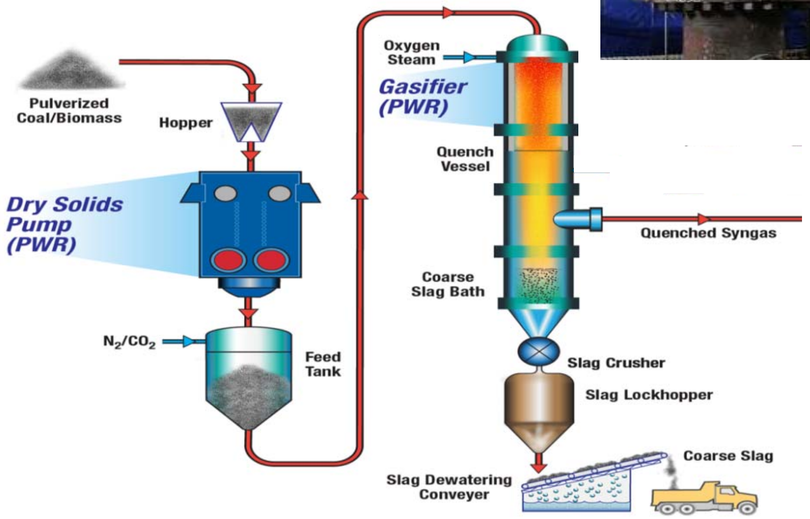
Aerojet Rocketdyne\GTI Compact Gasification System



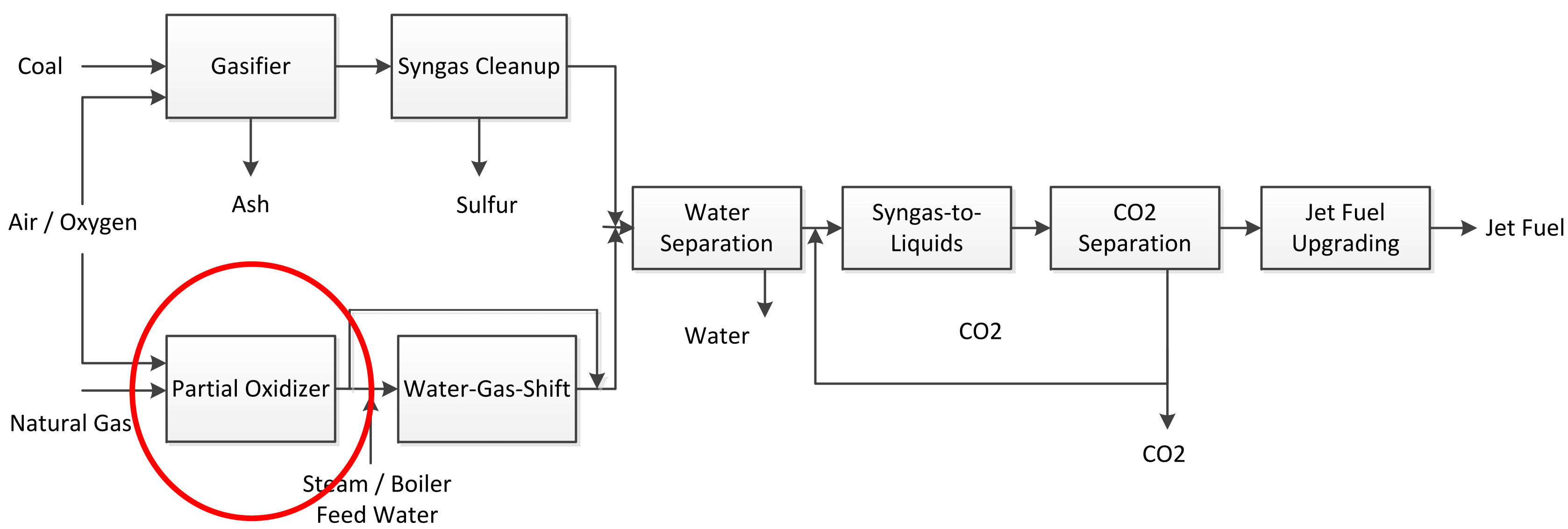
Aerojet Rocketdyne\GTI Compact Gasification System

Compact Gasification System
- 90% reduction in gasifier volume
- Cold gas efficiency improvements
  - 7% - 10% versus water slurry feeders
  - 2% - 4% versus dry feed systems
- Gasifier surface temperatures of 1000°F
  - >2 year life injectors (< 4 months GE injectors)
  - >10 year life cooling liner (1-3 year for refractory)
- Dry ash recovery eliminates black water collection system and waste water treatment requirements.
- >15% lower cost of electricity for IGGC
- >25% lower cost for hydrogen

PWR's Dry Solid Pump
- 32 GWh/y reduction in lock hopper power requirements (3000 tpd plant)
- Demonstrated performance with both coal and coal/biomass mixtures

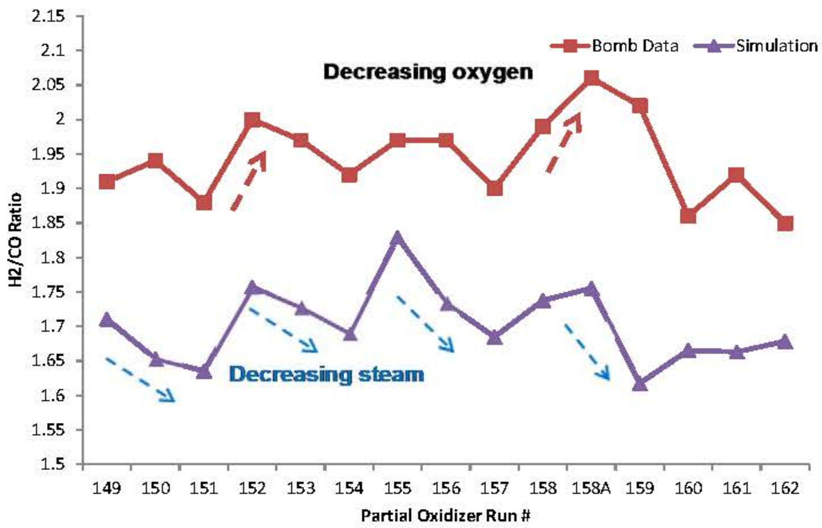


Aerojet Rocketdyne\GTI Partial Oxidation Unit

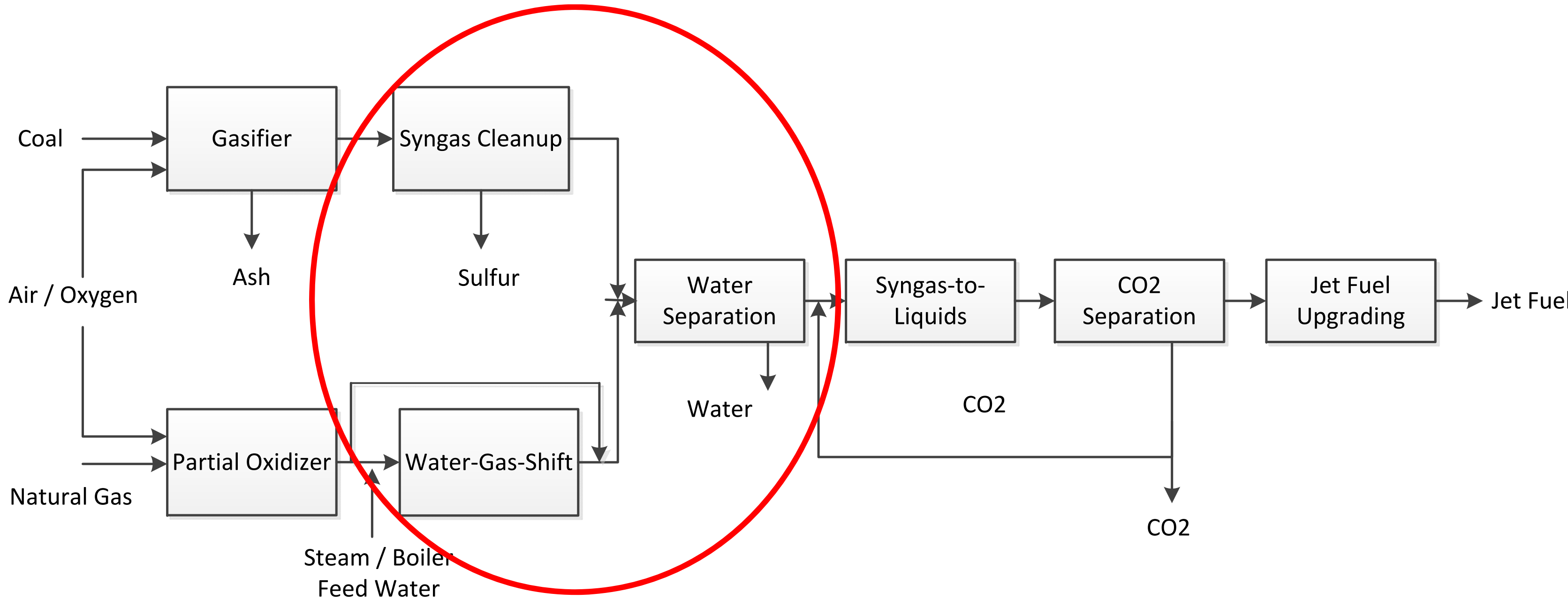


Aerojet Rocketdyne\GTI Partial Oxidation Unit

- Developed with a focus on distributed gas-to-liquid production (~1,000 BPD)
- 80 hours of pilot scale (~450 MSCF/day NG feed) POX unit testing was performed in 2013
  - Validated performance and design approach
  - Demonstrated the ability to directly yield syngas with H_2:CO molar ratios near 2.0
  - Potential to eliminate the need for downstream water-gas-shift reactors
- Designed and fabricated a prototype POX unit
  - Incorporating burner element and cooled liner designs
  - Support testing of the POX unit with natural gas using either oxygen or air.
  - Designed to enable recycle of byproduct and/or wastewater streams to the unit
- POX technology offers the potential to reduce GTL plant capital cost by 10-15%.



RTI Warm Syngas Cleanup Technology Platform



RTI Warm Syngas Cleanup Technology Platform

RTI PILOT PLANT TEST UNITS AT EASTMAN COAL GASIFICATION PLANT

Sulfur

Regenerable ZnO sorbents

Transport reactor

Direct Sulfur Recovery Process

Hg adsorbents (disposable)

As adsorbents (disposable)

Se adsorbents

HCl adsorbents

Regenerable NH_3/HCN

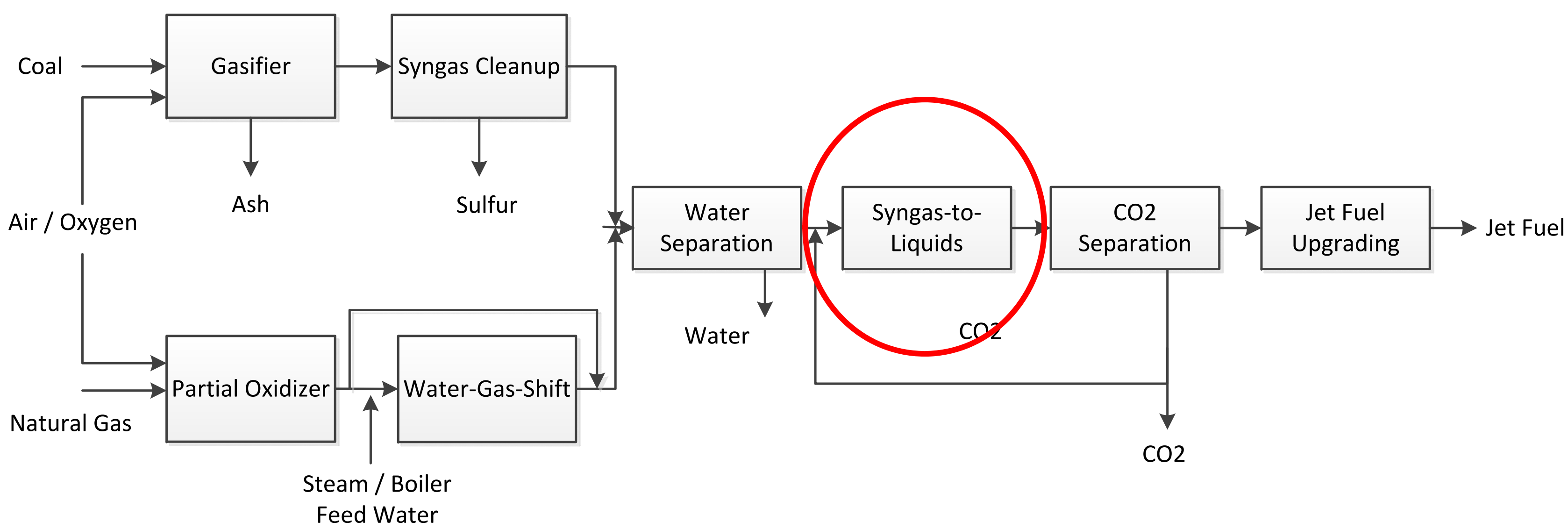
Regenerable CO_2 sorbents

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

- Enhance overall process efficiency and lower costs by operating at temperatures of 250ºC to 600ºC with small footprints!
- Pressure independent
- Effective for all forms of sulfur
- Fully compatible with conventional and warm CO_2 capture

- Flexible modular approach meets:
  - New EPA electric power generation specifications
  - Industrial production specifications
- Systems tested on actual coal-based syngas
- 50-MWe demo project with carbon capture at Tampa Electric's Polk 1 IGCC site

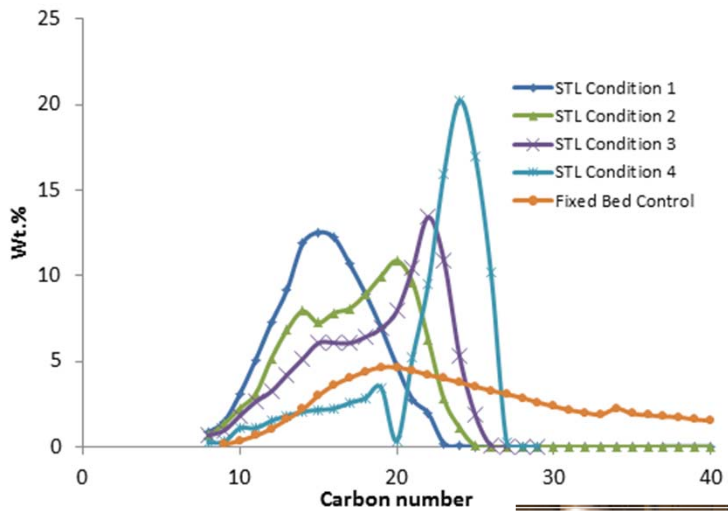
Syngas-to-Liquids System



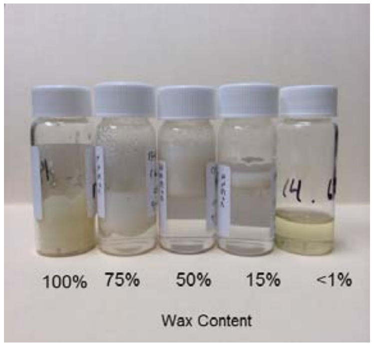
Syngas-to-Liquids System

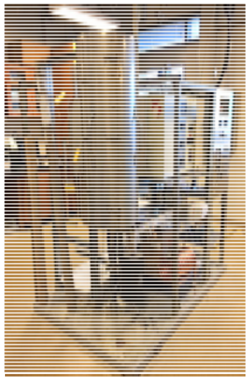
RTI is developing an STL process with the following features:

- Produces a targeted narrow carbon range distribution of fuel products
- Achieves heat management through reduced reactant partial pressure
- Utilizes commercial and emerging F-T catalyst compositions

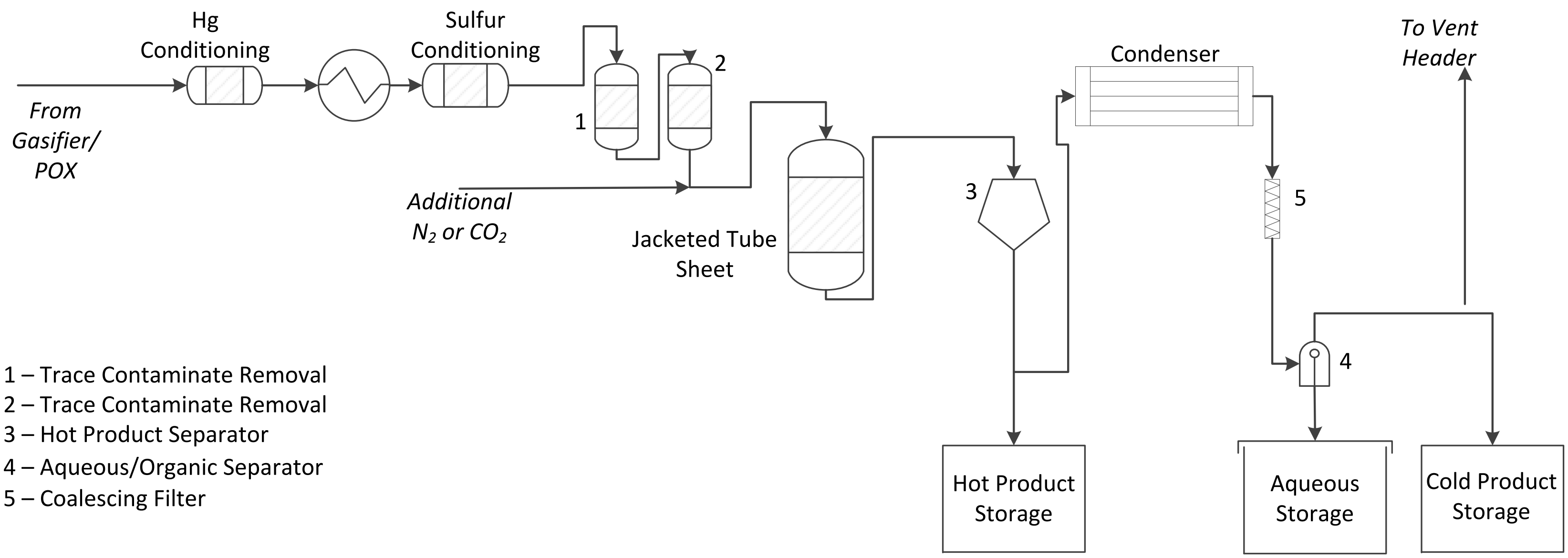


Single pass CO conversion efficiencies of over 60% with selectivity to C_8-C_{18} liquid products of 65% have been achieved.





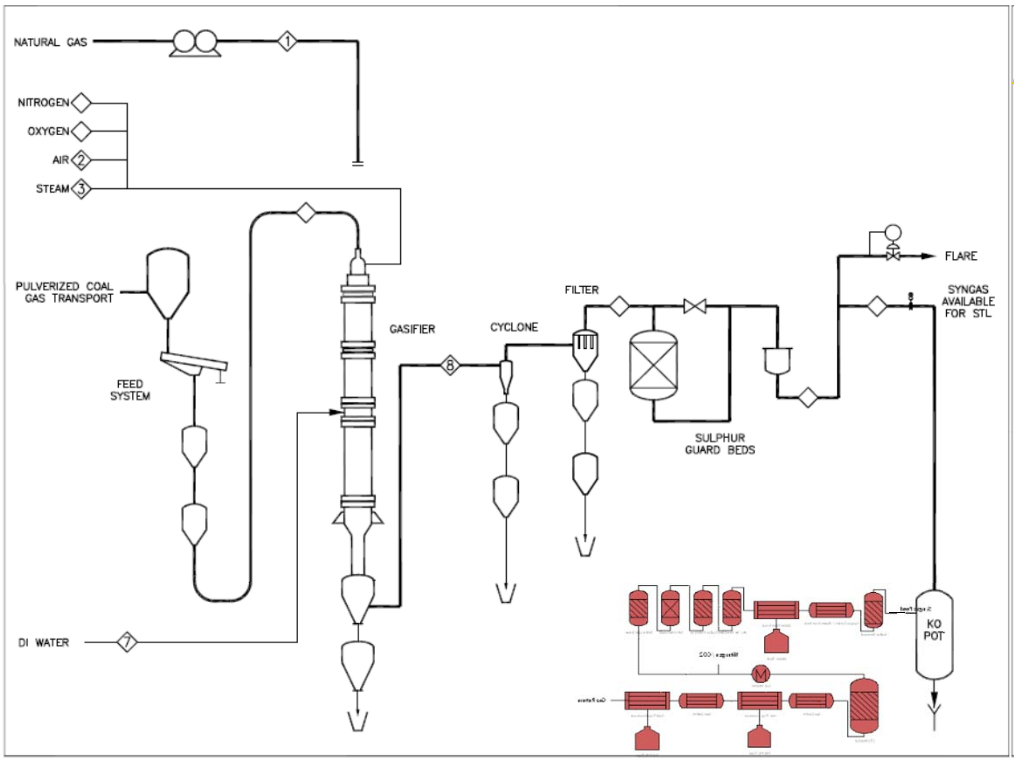
1BPD Pilot-Scale STL System

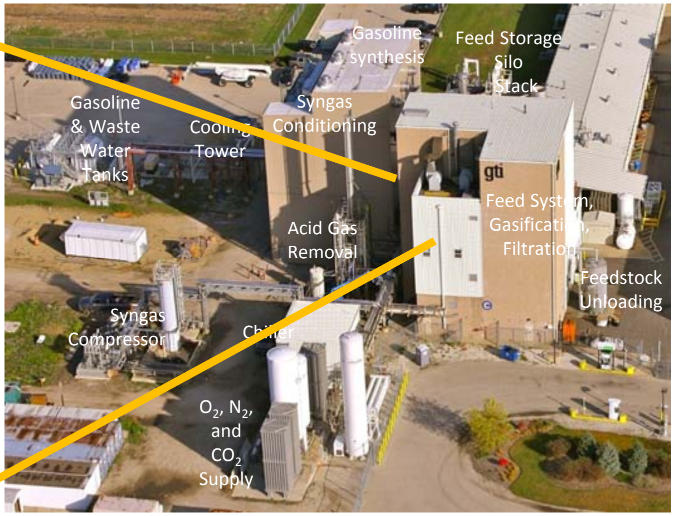


1 – Trace Contaminate Removal
2 – Trace Contaminate Removal
3 – Hot Product Separator
4 – Aqueous/Organic Separator
5 – Coalescing Filter

System to demonstrate STL technology with relevant syngas from gasifer and POX systems.

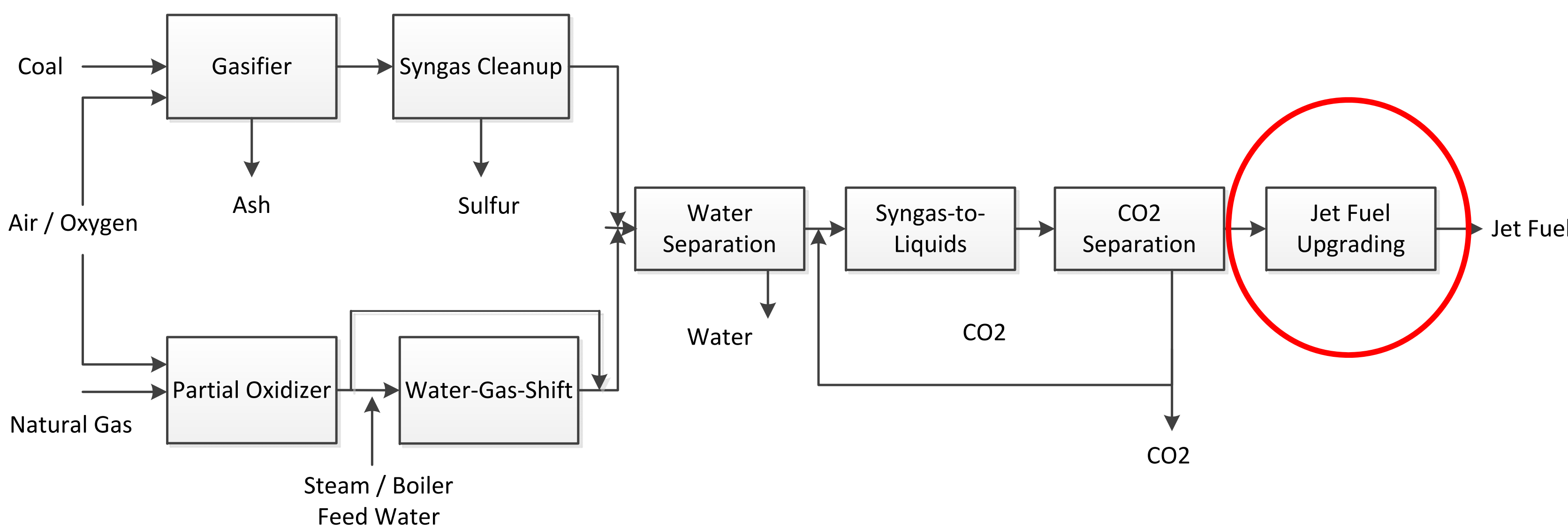
1 BPD Pilot Plant Testing with Syngas at GTI





GTI's Gasification Pilot Plant

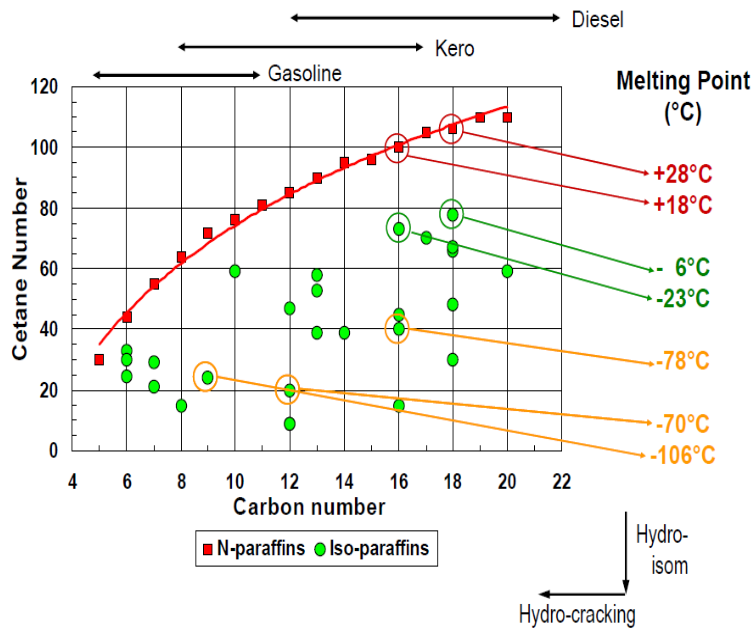
Axens Hydroprocessing Technology



Axens Hydroprocessing Technology

Axens' technologies have been developed to ensure:

- Minimum production costs by careful balancing of the hydrotreatment reaction pathway (hydro-isomerization vs hydro-cracking).
- Minimum impact of CO/CO_2 inhibition
- Fine tuning of product cold flow properties
- Superior fuel stability in operation



Property	Typical Vegan Jet Product
Density, kg/m3	766
D86 T10, ºC	169
D86 FBP ºC	272
Freezing point ºC	-57
Flash point ºC	68

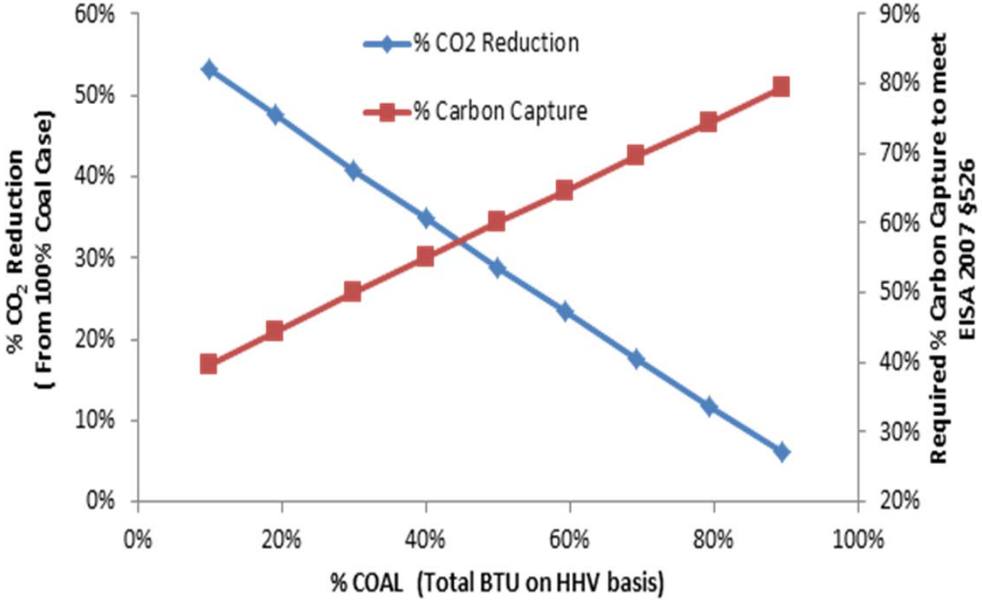
Cost-Competitive Production of Coal-Derived Jet Fuel

	BRW00	Case A: Advanced CTL (no POX)	Case B: Integrated CTL – Co-Fired Coal and Natural Gas	Case C: Integrated CTL with Natural Gas POX (oxygen)	Case D: Integrated CTL with Natural Gas POX (air)
Total Owners Cost $/bpd	$135,640	$97,432	$90,602	$88,939	$89,230
Capital Charge[1] $/bbl	$70.00	$50.28	$46.76	$45.90	$46.05
O&M $/bbl	$44.50	$35.86	$38.66	$38.29	$38.36
Plant Gate Fuel Cost $/bbl	$114.50	$86.14	$85.42	$84.19	$84.41
Cost of Oil Equivalent $/bbl	$95.40	$69.46	$68.88	$67.90	$68.07

The hybrid CTL process provides potential savings for both capital and operational costs that can remain cost-competitive with petroleum-based jet fuel and when crude oil prices are at or above $70/bbl.

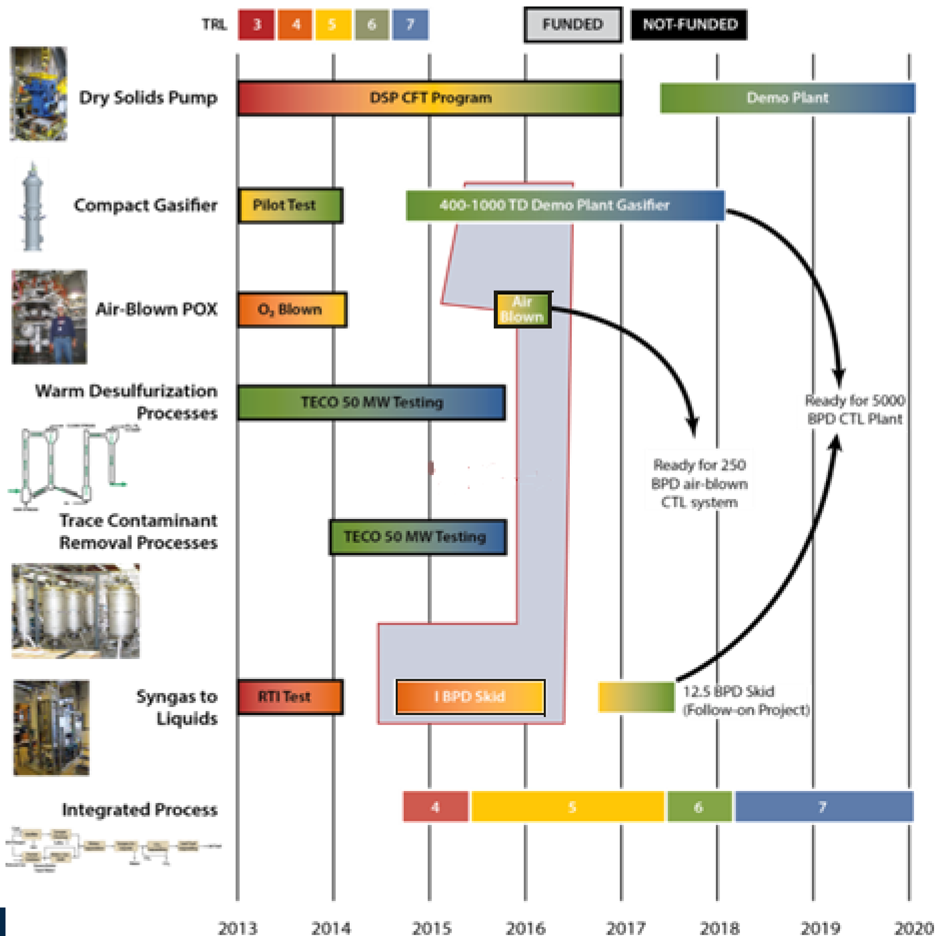
Commercial Production of Coal-Derived Jet Fuel with Low GHG Emissions

Reduction in total generated CO_2 as a function of coal in the total feedstock calculated using AR's coal gasifier and partial oxidation technologies



At a 51% coal, 49% natural gas split, only 60.5% (vs. 84% for conventional CTL) of the non-fuel-bound carbon is required to be captured in order to meet EISA 2007 §526 requirements for our hybrid CTL process.

Key Technology Status



- Leverages ongoing parallel activities in other DOE and commercialization projects on many of the technology components
- Furthers the TRLs of the less mature STL and partial oxidation technologies

All of the key technologies should be ready for integrated hybrid CTL demonstration testing, and within 3-5 years of full commercial readiness, by project end.

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