Innovative Gasification to Produce Fischer-Tropsch Jet and Diesel Fuel

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Acronyms and definitions

- BP – budget period (i.e., project phase)
- BPD – barrel per day
- BTL – biomass-to-liquids
- F-76 – military spec diesel fuel
- FT – Fischer-Tropsch process
- IE – independent engineer engaged by the DOE to monitor and review project details
- JP-5 and JP-8 – military spec jet fuel
- Syngas – process gases comprised of primarily hydrogen and carbon monoxide used to synthesize fuels, chemicals, or their intermediates
Goal Statement

• Frontline will demonstrate the performance of an integrated biomass-to-liquids (BTL) pilot plant utilizing innovative gasification and gas conditioning technologies coupled with an FT process.

• This project meets the goals of the innovative pilot integrated biorefinery by
  – using renewable lignocellulosic feedstocks such as wood and other waste feedstocks
  – producing advanced biofuels in the form of military fuels F-76 diesel and JP-5 and JP-8 jet

• This project supports the US Government and particularly Department of Defense’s objectives of using ‘alternative’ forms of energy such as FT-based biofuels
Quad Chart Overview

Timeline

• Start Date: 10/1/2013
• End Date: 6/30/15 (BP-1B), 12/2016 Project
• Percent Complete: BP-1B~60%, Project~7%

Barriers

• Barriers addressed
  – It-B. Risk of First-of-a-Kind Technology

Budget

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<tr>
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<th>Total Costs FY 10–FY 12</th>
<th>FY 13 Costs</th>
<th>FY 14 Costs</th>
<th>Total Planned Funding (FY 15-Project End Date)</th>
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Partners

• Partners
  o FY14: Frontline (100%)
  o FY15: Frontline (48%); SGC (51%); Delphi(1%)
• Other interactions/collaborations
  • Stanley Consultants – engineering partner
1 - Project Overview - Partners

- Frontline BioEnergy, LLC, based in Ames Iowa, provides thermal gasification technology for the conversion of biomass and waste derived feedstocks.
- SGC Energia, based in Houston Texas, develops alternative energy projects based on their XTLH® (carbon-based feedstocks to liquid hydrocarbons) platform that utilizes FT catalysis.
- Stanley Consultants, based in Muscatine, Iowa and a 100 year engineering firm, currently ranked 75th on the ENR top 500, provides engineering and bid package services as requested by Frontline.
- Delphi Engineering and Construction LLC, based in The Woodland, Texas, provides project and construction management services for federal projects.
1 - Project Overview - History

• Thermal gasification is a centuries old process used for personal, municipal, industrial, and utility purposes
  – Fuel for automobiles in times of petroleum scarcity
  – Gas works for providing fuel to gas lights and homes in the late 19th and early 20th centuries
  – Fuel gas production for firing boilers, internal combustion engines, combustion turbines, or natural gas displacement
  – Syngas production for fuel/chemical synthesis
  – Frontline has extensive experience in biomass gasification including the startup of a commercial gasifier in Benson, Minnesota

• The Fischer-Tropsch (FT) process was developed in Germany in 1925 to produce lubricants and fuels from non-petroleum feedstocks such as coal, natural gas, and biomass
  – Catalytic process that converts synthesis gas, carbon monoxide and hydrogen, into a broad range of hydrocarbon (HC) liquids
  – The HC liquids can be further refined into synthetic lubricants and fuels
  – SGC Energia is successfully operating a nominal 1-BPD FT pilot plant and are constructing an 1100 BPD commercial FT plant, both on the Gulf Coast
1 - Project Overview - History

- **2005.** Frontline founded
- **2006.** Frontline begins pilot work on CLEANGAS® technology, the frontrunner of TarFreeGas®.
- **2008.** First commercial plant demonstrating its PMFreeGas® started up at CVEC in Benson, MN
- **2011.** SGC Energia becomes equity partner
- **January 2013.** Frontline successfully demonstrates TarFreeGas®
- **March 2013.** Frontline’s TarFreeGas® technology selected by DenYon Energy for its poultry litter gasification project
- **April 2013.** Frontline awarded IBR project by the US DOE to produce drop-in military fuels
Gasification is a Thermochemical Process

- **Combustion**
  Fuel + Excess Air $\rightarrow$ Heat + Hot Exhaust Gas + Ash

- **Direct Gasification**
  Fuel + Limited Air $\rightarrow$ “Producer Gas” + Heat + Char-ash + CH*

  Fuel + Limited Oxygen $\rightarrow$ “Syngas” + Heat + Char-ash + CH*

- **Indirect Gasification and Pyrolysis**
  Fuel + Heat $\rightarrow$ “Syngas” or “Pyrolysis Gas” + Char-ash + CH*

CH* $\equiv$ condensable hydrocarbons, a.k.a. pyrolysis oils or “Tar”

“Tars are the Achilles heel of biomass gasification.”
- Dr. Tom Reed
1 - Project Overview - Objectives

- Scale-up and demonstrate performance of Frontline’s innovative TarFreeGas® gasification technology; low ‘tar’ syngas greatly simplifies downstream gas processing – reducing costs
- Demonstrate novel syngas conditioning process technologies to produce additional value streams such as fertilizer co-products
- Successfully integrate TarFreeGas®, the gas conditioning processes, and an existing FT reactor to produce FT intermediate products, achieving a 1000 hours of integrated operation
- Convert FT intermediates to diesel and jet fuel samples conforming to military specifications
- Demonstrate a range of fuel flexibility by successful fuel production from wood and refuse derived fuel (from municipal solid waste) feedstocks
- Obtain performance data to inform commercial plant design
2 - Approach (Technical)

- **Syngas production**
  - Leverage unit operation data and critical operating parameter testing from Frontline’s lab-scale TarFreeGas® system
  - Unit operations include pressurized gasification, filtration, quench, shift, compression, acid gas removal, polishing

- **FT catalysis**
  - Syngas to SGC Energia’s nominal 1 barrel-per-day FT pilot plant
  - Production of ‘light’ and ‘heavy’ FT intermediates

- **Intermediate upgrading**
  - Employ conventional hydroprocessing unit operations, hydrotreating and/or hydrocracking, and distillation and blending with petroleum-based fuels; an outside lab (i.e., Wright Patterson AFB) will produce gallon quantities of spec fuels
2 - Approach (Management)

• Frontline is the lead organization; Jerod Smeenk is the PI
• Critical success factors include
  – Technical performance – integrated operation of the gasifier, gas conditioning, and FT unit operations to produce FT intermediates suitable for upgrading to military spec diesel and jet fuel
  – Feedstock flexibility – demonstrate the ability to use low-cost, non-food feedstocks
  – Product optionality – produce military spec diesel and jet fuel
• Challenges to achieving successful project results include
  – Technical risk: on-spec operation of each unit operation and the integration of the many unit operations
  – Budget risk: the procurement, installation, and operation costs are greater than the available budget; nothing in work-to-date suggests we are over budget
  – Schedule risk: Frontline has a small team which governs the progress rate
3 – Technical Accomplishments/Progress/Results

• Project is parsed into three phases/budget periods (BP)
  – BP 1A (complete) – due diligence review by the DOE and independent engineers
  – BP 1B (in progress) – detailed design of the integrated system including all equipment specification; includes all equipment and contractor costing
  – BP 2 (future) – procurement, construction, and operation

• Schedule status
  – BP 1A completed July 2014; issuance of IE report and ‘Go’ decision by the DOE for BP 1B
  – BP 1B started in August 2014 and scheduled for completion in June 2015; presently two months behind but working hard to complete on schedule; primary reason for schedule slip is Frontline’s desire to obtain additional lab-scale data to inform design of the pilot gasifier
  – BP 2 scheduled for 18 months
3 – Technical Accomplishments/Progress/Results

• **Building on success**
  – Frontline commercial gasifier and pilot plant
  – SGC FT pilot plant and forthcoming commercial project

• **Project site is secured and being prepared for construction**
  – Located in Pasadena, Texas at SGC Energia’s XTLH® Technical Center US
  – Home to the FT pilot plant; currently operating on bottled syngas from tube trailers
  – Utility upgrades are in progress to accommodate the gasifier system
  – SGC’s Technical Center supports this effort as well as their commercial project
3 – Technical Accomplishments/Progress/Results
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3 – Technical Accomplishments/Progress/Results

• Detailed design status
  – Frontline process engineering deliverables completed: design description/basis, process flow diagrams, heat and material balances, piping and instrumentation diagrams
  – Other Frontline detailed design including datasheets, reactor and vessel design, equipment layout, site layout is ongoing
  – Civil, structural, and electrical design is underway and being performed by Stanley Consultants
  – Construction bid documents being developed:
    • Module fabrication
    • Site excavation and foundations
    • Field erection
    • Site electrical upgrades and distribution to modules
  – Site interviews of potential subcontractors and vendors
3 – Technical Accomplishments/Progress/Results

• **Costing** - Frontline will request quotes from multiple fabricators or service providers for:
  - Fabrication of the multiple modules that make up the gasifier and gas conditioning process
  - Control system integration including control system architecture design, procurement, and programming
  - Site development and concrete foundations
  - Field mechanical erection, pipe rack installation and piping interconnects, and final assembly
  - Field electrical installation including site upgrades and distribution to modules
4 - Relevance

• This project readily fits the BETO MYPP goals by
  – Producing drop-in, advanced biofuels using sustainable feedstocks
  – Reducing U.S. dependence on foreign oil by producing military spec diesel and jet fuel
  – Motivating growth of the bioenergy industry through use of non-food biomass such as wood, ag residues, and sorted waste
  – Integrating the processes of biomass gasification and FT synthesis to produce useable liquid fuel products
4 – Relevance - Continued

• This project demonstrates advanced thermal gasification technology that substantially reduces “tars” in the syngas out of the gasifier reactor (i.e., reformation of tars in the gasifier reactor)
  – Reduction of tars greatly simplifies downstream gas cleanup and conditioning
  – Reduction of tars essentially eliminates production of a hazardous waste and reduces the hazards associated with handling/management of that waste
  – Reformation of tars increases syngas yield and conversion efficiency
5 – Future Work

- **BP 1B – detailed design**
  - Identify firm costs for the fabrication, procurement, and construction of the pilot plant
  - Obtain a ‘Go’ decision from the DOE

- **BP 2 - construction**
  - Procurement – most procurement to be executed by Frontline
  - Fabrication and erection – module fabrication and craft field work
  - Control system – integrator for procurement and programming
  - Commissioning – loop checks, unit operation validation, emergency shutdown validation
5 – Future Work – Continued

• **BP 2 – operation**
  – Feed system, gasifier, and gas conditioning startup – confirm syngas quality
  – 1000 hrs of integrated operation for production of FT intermediates
  – Upgrade of FT intermediates to military spec F-76, JP-5, and JP-8

• **Explore future market opportunities**
  – Government
    • Federal
    • DOD
    • State and local agencies
  – Commercial
    • Private waste companies
    • Add partners for total solutions (waste-to-fuels)
Summary

• Project aligned with BETO MYPP goals and objectives
  – Use of renewable, non-food feedstocks
  – Production of military spec diesel and jet fuel

• Demonstration of innovative thermal gasification technology for the production of low-tar syngas

• Integration with FT process for synthesis of hydrocarbon intermediates with subsequent upgrading to military spec fuel

• Working on detailed design – completion target this summer

• Begin BP-2, procurement/fabrication/construction/operation upon ‘Go’ decision’ from the DOE
Thank you!

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Types of Conversion Systems

Biomass & Waste Conversion

Biological

Thermochemical

Combustion

Gasification

Pyrolysis
Types of Gasification Systems

Gasification Systems

Indirectly Heated
- External Fuel (Many approaches)
- Media Heating (allothermal)
- Plasma (electric-based)

Directly Heated
- Air-Blown
- Oxygen-Blown
Direct Gasification Reactors

- Directly Heated
  - Fluidized Media Bed
    - Bubbling Fluidized Bed (PMFreeGas®)
  - Transport Reactor
  - Fixed Bed
    - Updraft
    - Downdraft