Indirect Liquefaction of Coal-Biomass Mixtures for Production of Jet Fuels with High Productivity and Selectivity

2015 Gasification Systems and Coal & Coal-Biomass to Liquids Workshop

DOE/NETL, Morgantown, WV

Presented by

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Southern Research

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Project Objectives

- Develop process intensification approaches to reduce the cost of CTL/CBTL for production of JP-8 jet fuel.
  - Autothermal reforming of raw syngas from gasification
  - Fischer-Tropsch synthesis
- Testing of Autothermal Reactor (ATR) and Fischer-Tropsch (FT) technologies using a coal gasifier slip stream
- Goal is to be ready for integrated pilot / demo scale efforts by the end of the project, accelerating potential commercialization of CTL and CBTL.

PROJECT PARTICIPANTS

- Southern Research (Lead)
- Precision Combustion, Inc. (Autothermal reformer)
- Chevron (Co-zeolite hybrid FT catalyst)
- IntraMicron (FT heat exchange reactor technology)
- National Carbon Capture Center (Testing host site)
- Southwest Research Institute (Product qualification support)
- Nexant (TEA/LCA support)

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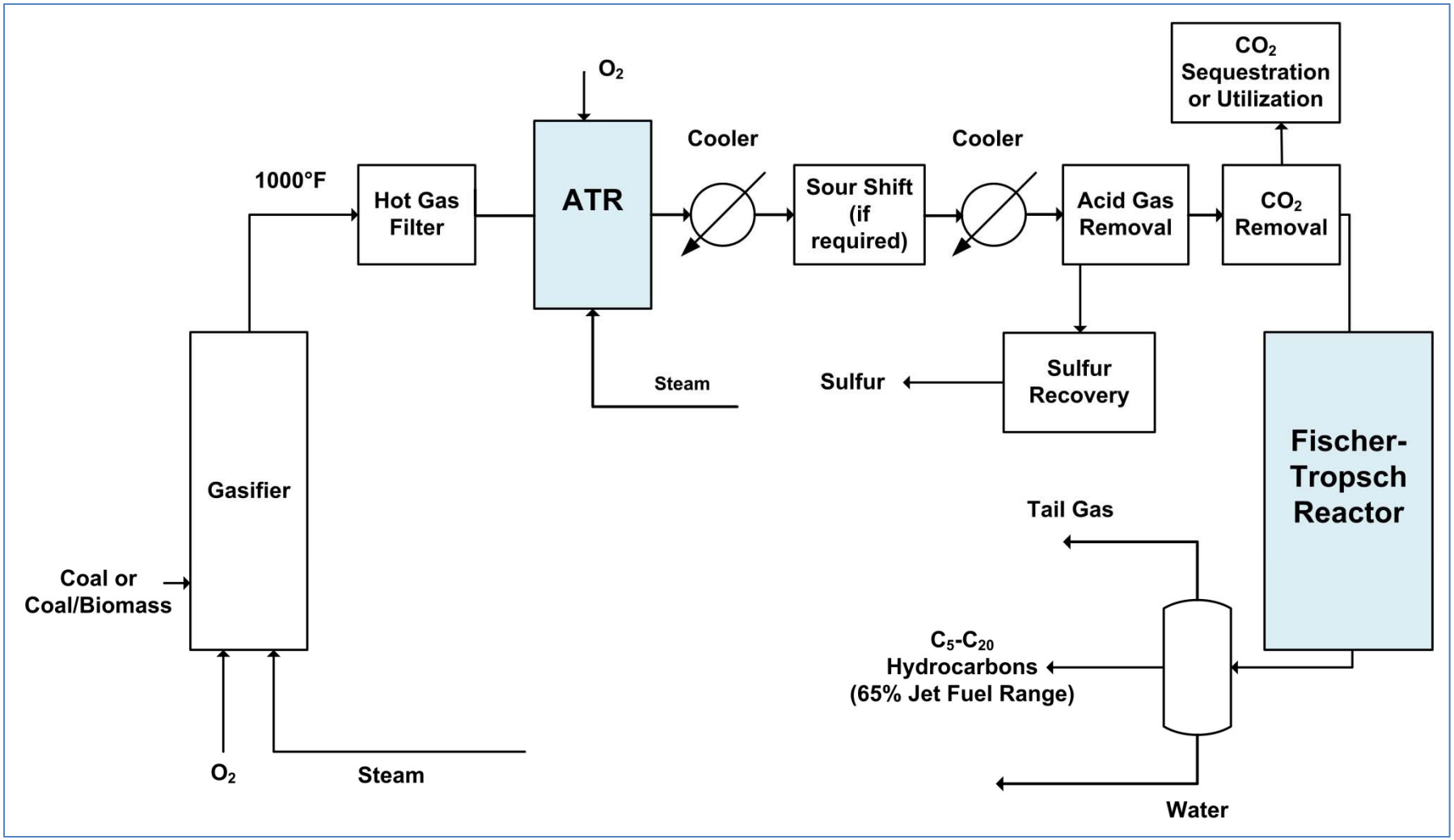
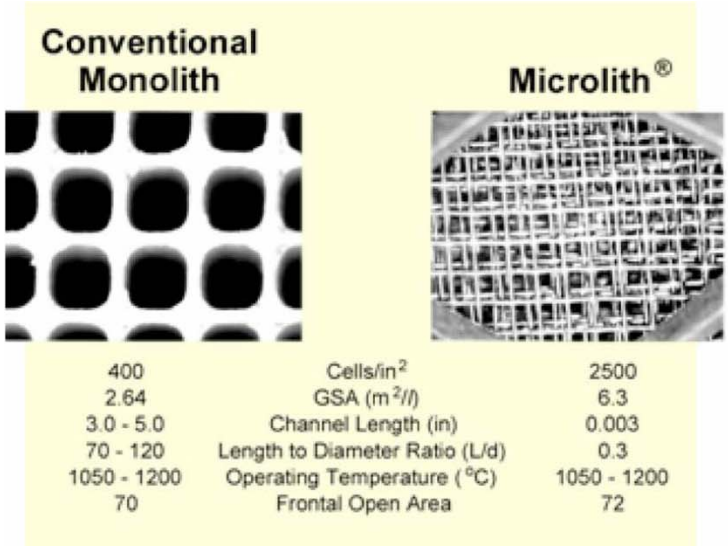
CTL Process Concept



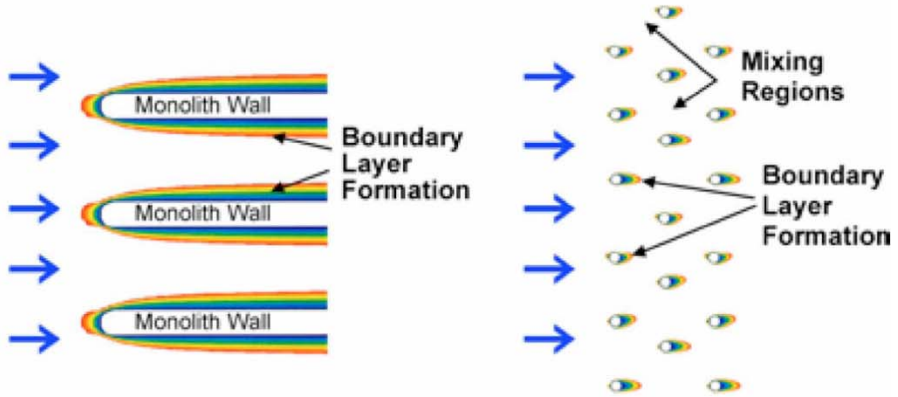
Autothermal Reactor (ATR)

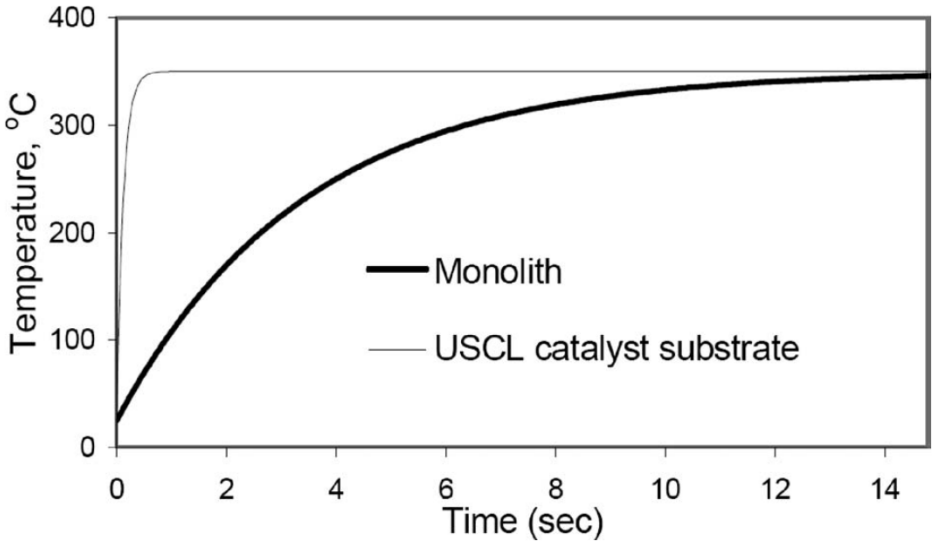
- Based on PCI's Microlith Technology
  - Reform light hydrocarbons
  - Reform heavy hydrocarbons and tar
  - Decompose ammonia
  - Adjust H_2/CO ratio
- Candidate sulfur tolerant reforming catalysts developed by Southern Research and PCI
- Ability to operate in a wide range of steam to carbon (S/C) ratios in the presence of sulfur.

Microlith Advantages and Comparison with Monolith



400	Cells/in^2	2500
2.64	GSA (m^2/l)	6.3
3.0 - 5.0	Channel Length (in)	0.003
70 - 120	Length to Diameter Ratio (L/d)	0.3
1050 - 1200	Operating Temperature (^{o}C)	1050 - 1200
70	Frontal Open Area	72





- Very low catalyst amount coated on metal mesh
- Very short channel length/diameter and low thermal mass
- High mass/heat transfer rates
- High surface area compared to monolith
- Low pressure drop

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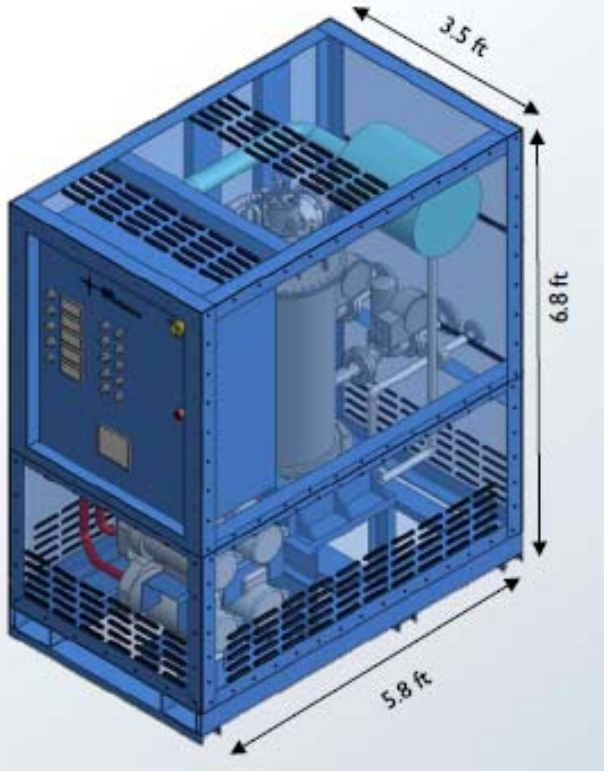
PCI's Modular 1 MW (thermal) Fuel Processor



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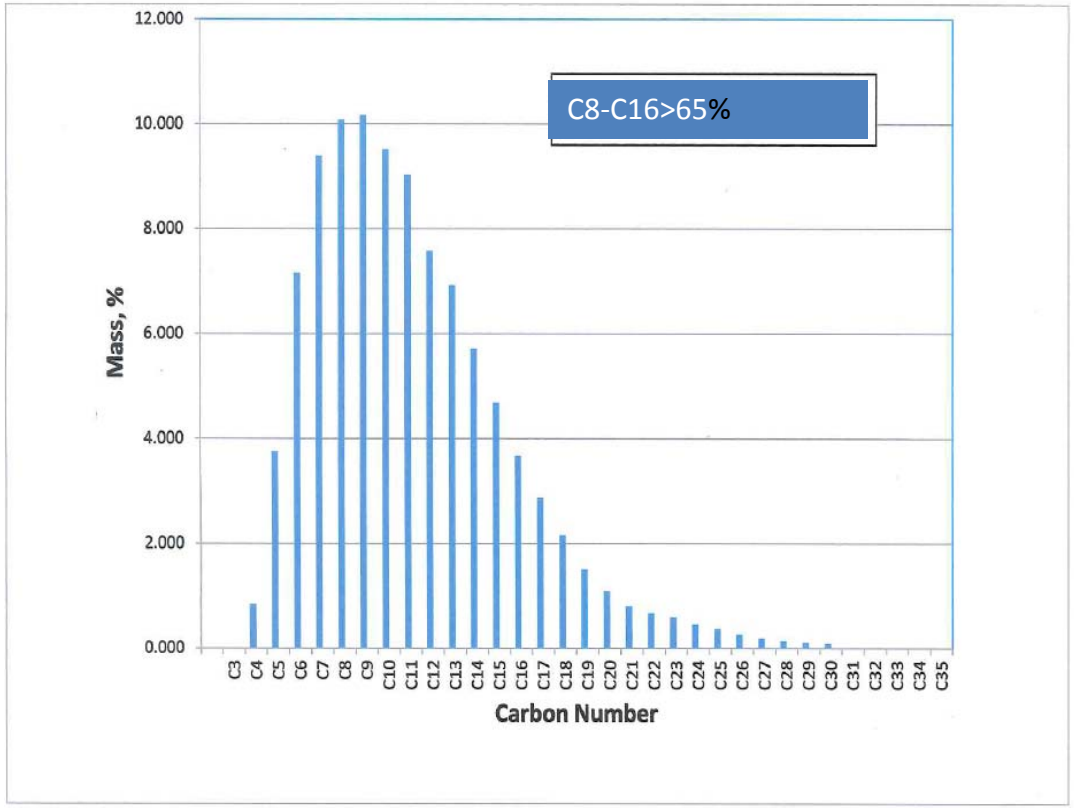
Chevron Cobalt-Zeolite Hybrid Catalyst

Time on stream (h)	254	326	419	440
Pressure (atm)	10	10	15	20
CO conversion (%)	35.1	34.5	38.4	41.7
CH_4 selectivity (%)	12.6	12.6	12.3	11.9
C_2 selectivity (%)	1.7	1.7	1.7	1.4
C_3-C_4 selectivity (%)	10.8	11.1	8.9	7.9
C_5-C_{20} selectivty (%)	74.9	74.6	77.4	79.0
C_{21} + selectivity (%)	2	0	0	0

Reference: Kibby C. L., Jothimurugesan K., Das T., Saxton; R. J., Burton, Jr. A. W., US Patent Application 20110144219 (2011)

Production of clear wax free liquids

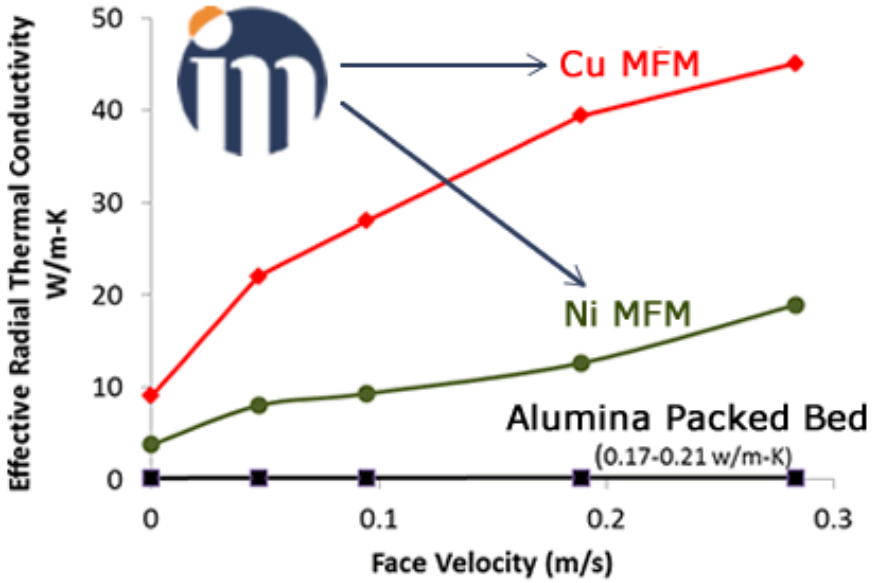
Chevron Hybrid Catalyst Liquid Product Distribution and Features



- Highly selective: >70% hydrocarbon liquids
- 5x greater yield than traditional catalysts
- Eliminate production of undesirable wax
- CAPEX and OPEX reductions

IntraMicron's Microfibrous Entrapped Catalysts (MFEC)

Cu-entrapped FT Catalyst Particles

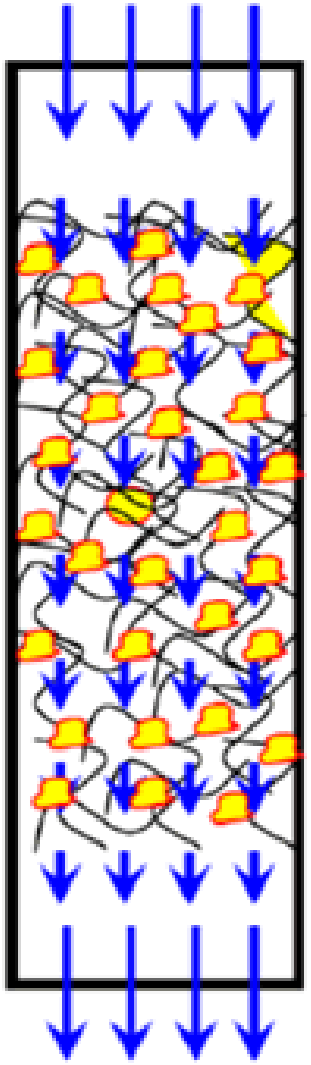


MFEC Allows

- **Use of simpler fixed beds**
- **Large diameters up to 2-6 inches**
- **Very high activity catalyst particles**
- **Isothermal operation**

Resulting in

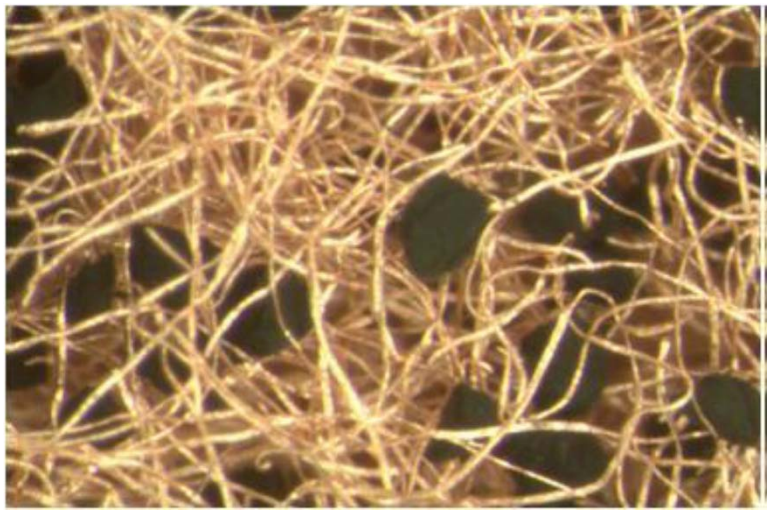
- **High productivity and selectivity**
- **Shorter and fewer tubes**
- **Reduced cost**



Images from http://www.intramicron.com

IntraMicron-Southern Research Heat Exchange Reactor

Thermo-siphon heat removal system to achieve nearly isothermal operation in a large bench-scale reactor incorporating IntraMicron's MFEC technology.



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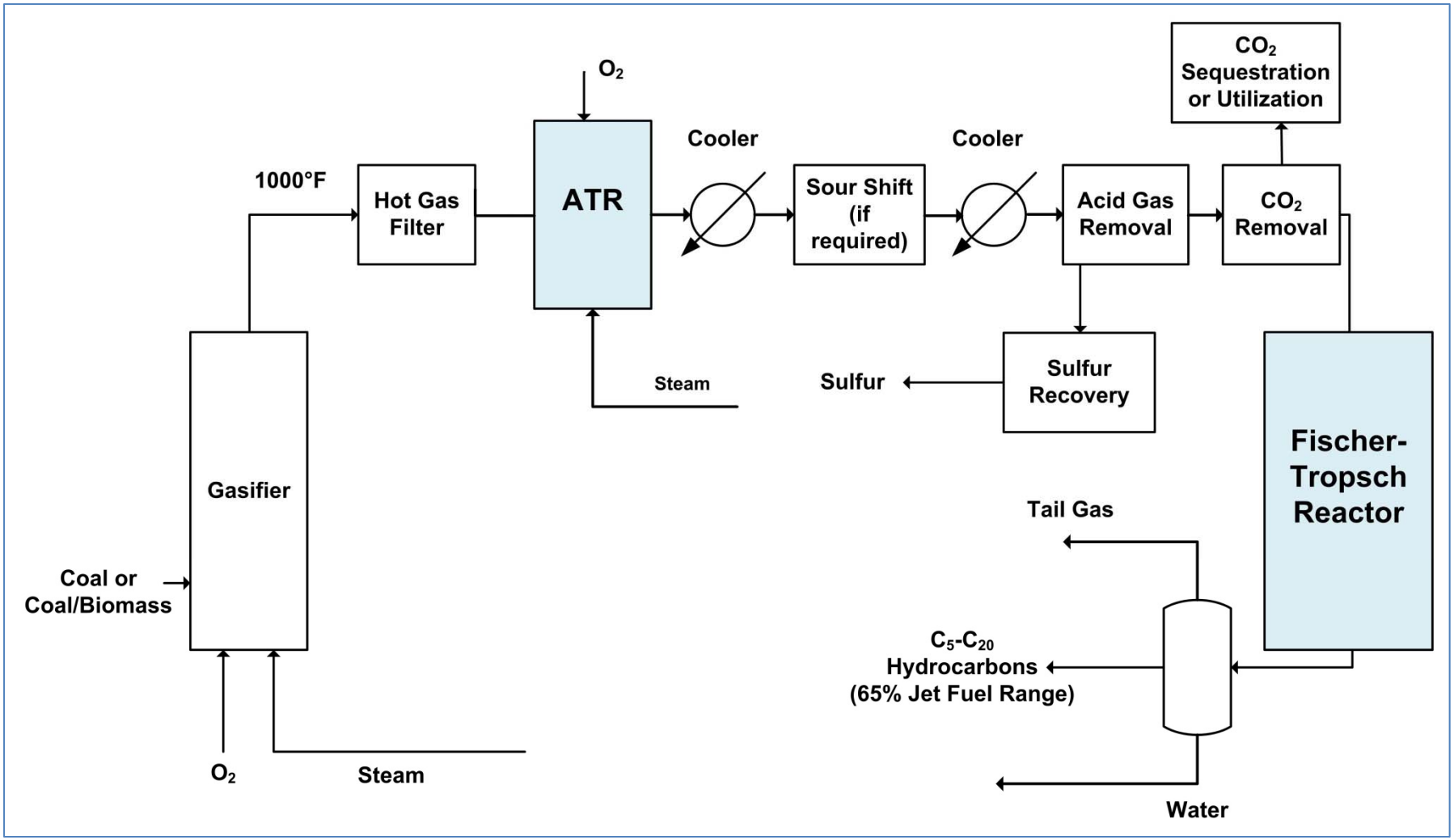
CTL Process Integration



Project Goals and Vision

- Design and test a compact, pressurized, high temperature, 50 KW_{th} autothermal reformer (ATR) to:
  - Reform tar and light hydrocarbons
  - Decompose ammonia in the presence H_2S and other coal syngas contaminants, and:
  - Deliver the required hydrogen (H_2) to carbon monoxide (CO) ratio for Fischer-Tropsch (FT) synthesis.
- Demonstrate jet selective FT catalyst with >75 % liquid selectivity, no solid wax, and >0.7 g C5+/gcat/h
- Demonstrate the ATR and FT technologies at large bench-scale (300 g catalyst) using a slip stream of coal gasifier gas from NCCC
- Demonstrate significant cost savings for a large oxygen-blown CTL/CBTL plant for jet fuel production
- Demonstrate potential for commercialization of smaller modular air blown CBTL plants for jet fuel production

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Technology Maturity

- Sulfur tolerant ATR catalyst candidates developed at lab scale at Southern Research and PCI; Microlith lab-scale testing ongoing; bench-scale ATR system being designed
- FT MFEC catalyst tested for 300 hours (120 hours using coal gasifer slip stream, 5 lb/h) using Southern Research's bench-scale skid mounted system (3 feet tall, 2 inch diameter reactor) at NCCC
- Jet-selective FT MFEC testing ongoing at lab-scale; demonstrated required performance; Testing to begin at NCCC next month
- Goal is to be ready for integrated pilot / demo scale efforts by the end of the project (March 2017), accelerating potential commercialization of CTL and CBTL.

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Southern Research Fischer-Tropsch Skid Installed and Commissioned at NCCC

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SUMMARY

- Southern Research is leading a consortium to demonstrate key technologies to produce low cost jet fuel using CTL/CBTL
- Advanced process intensification approaches are being used to reduce cost
  - Compact ATR with contaminant tolerant metal-mesh catalyst to reform hydrocarbons and tar, and decompose ammonia in the presence of sulfur
  - Cobalt-zeolite wax-free jet selective catalyst with high productivity and selectivity
  - Heat exchange reactor technology to allow large diameter reactor to be used for exothermic FT reaction; to enable reduction in reactor tube height.
- The ultimate goal is to enable smaller plants to become cost effective.

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- Southern Research E&E Department Senior Staff, Engineers, and Chemists

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Introduction to Southern Research

- Established in 1941 as an independent, not-for-profit (501-c-3) center for scientific research and development
- Headquartered in Birmingham, Alabama; 8 locations in Southeastern US; 500 employees
- Serves both Government and private industry clients
- Revenue ~$80 million from contract research/services and licensing of IP derived from internal technology development
- Research divisions:
  - Engineering
  - Energy and Environment
  - Drug Discovery
  - Drug Development

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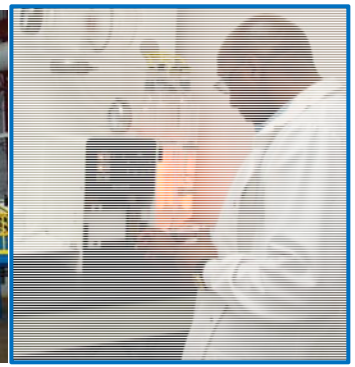
Energy and Environment
Durham, North Carolina

- Established in 2007 for alternative energy-related process research (biomass, coal, solar, waste heat) with a $30+ million investment
- Conducts lab, bench and pilot scale R&D/technology development
- Also provides contract services to private technology developers
- Capabilities include a 30,000 ft^2 high bay pilot plant, complete lab facility for process development, full interconnects, 30+ experienced PhD/MS/BS engineers and operators, 24/7 operations, Autocad and Aspen Modeling
- Pilot plant experience >30,000 hrs



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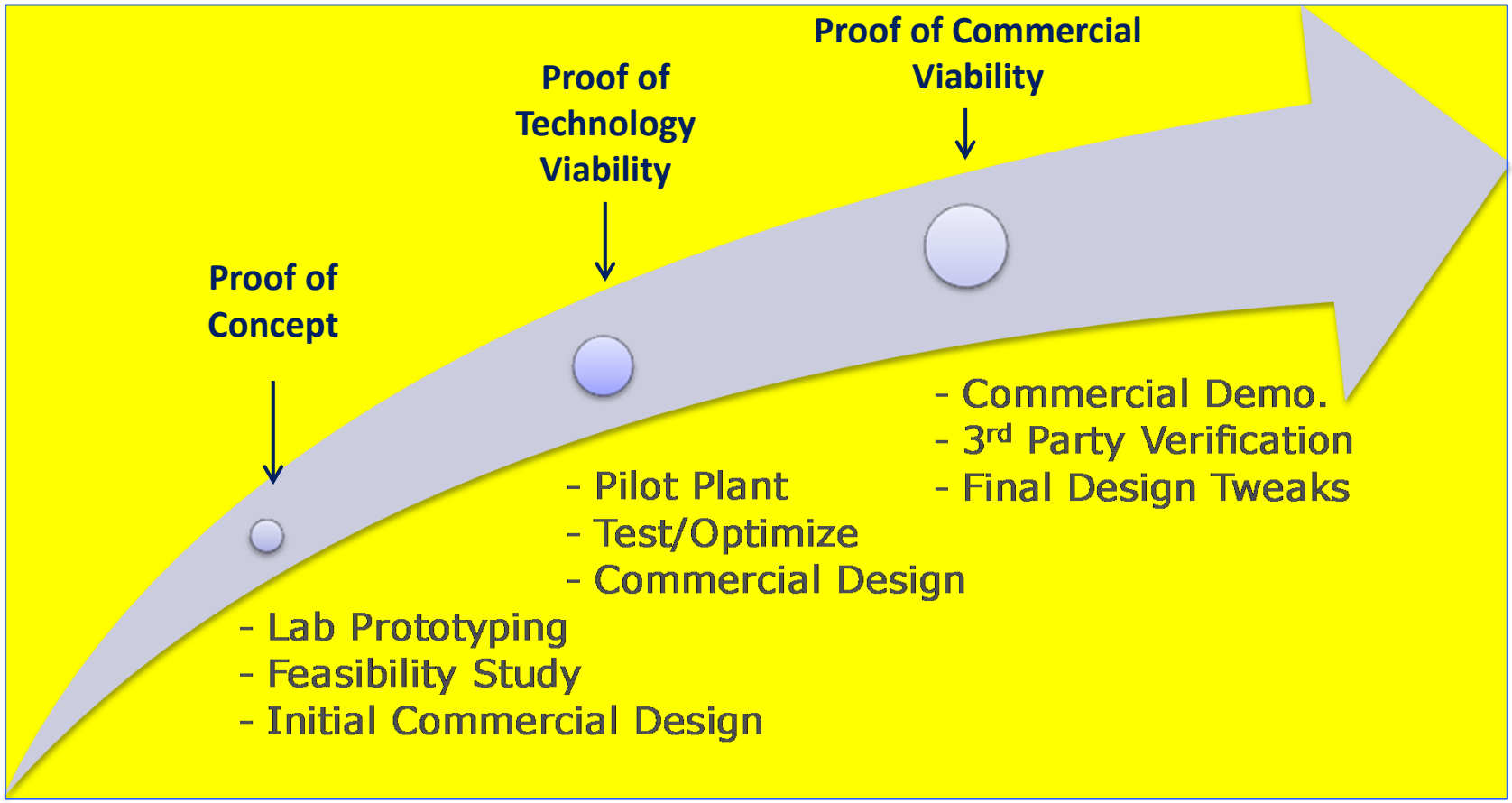
SR Supports The Full Pathway to Energy Technology Commercialization



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Examples of Ongoing Projects

- **Lab-Scale Projects**
  - Hydrogen production using palladium membranes
  - Direct liquefaction of biomass
  - High temperature syngas reforming
  - Biomass sugar conversion to acrylonitirile
  - CO2 capture using functionalized amines
- **Bench-Scale Projects**
  - Autothermal reforming
  - Thermochemical energy storage for solar plants
  - Coal and biomass feeding against high pressure without lockhoppers
  - Selective FT catalyst testing
  - Water cleanup from shale fracturing operations
- **Pilot-Scale Projects**
  - Conventional FT synthesis
  - Biomass gasification (gasifiers range from 2 to 4 ton/day, fixed and fluidized bed)
  - MSW gasification and conversion to power and liquid fuel
- **Field Demonstration Projects**
  - Thermal oxidizer- based microturbine for converting very low BTU gas to power
  - Solar-energy based adsorption chiller
  - Engine waste heat conversion to power using an organic Rankine cycle system
  - Slipstream testing of coal/biomass to liquids