Small Scale Pilot Plant for the Gasification of Coal and Coal/Biomass Blends and Conversion of Derived Syngas to Liquid Fuels Via Fischer-Tropsch Synthesis

Project Number: FE0010482 and FE0005988

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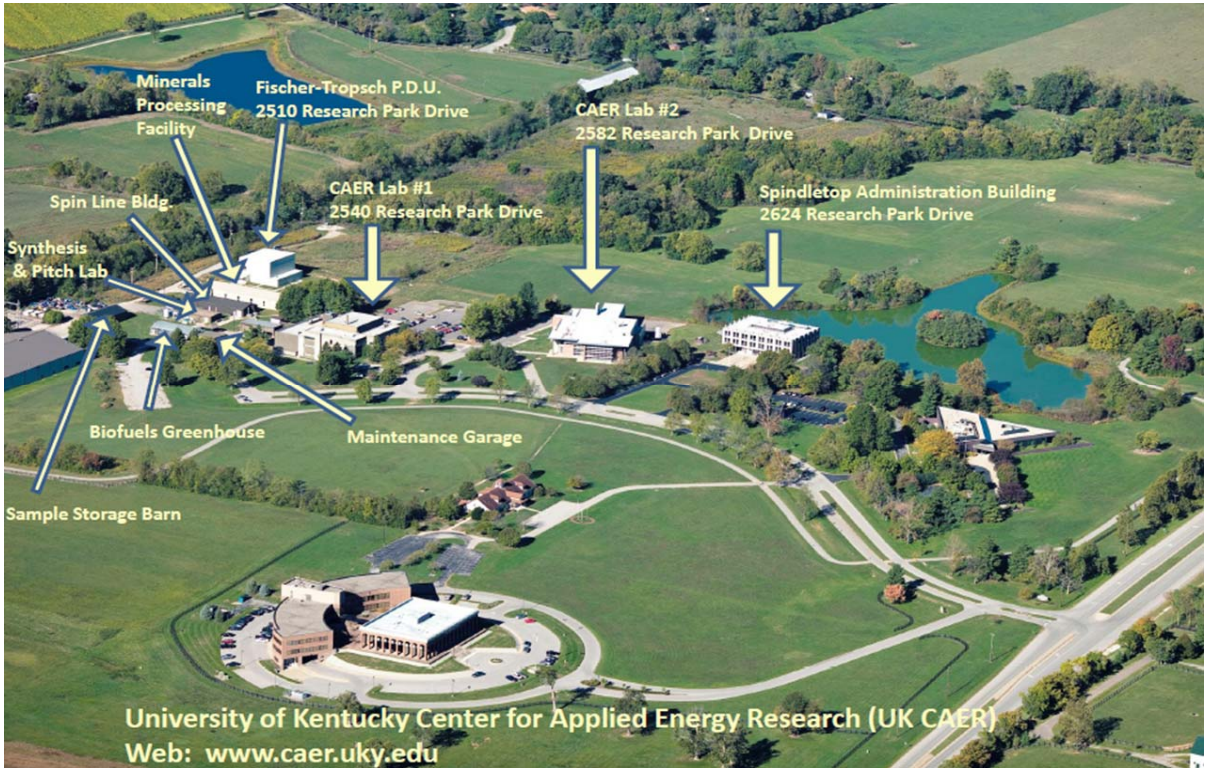


RESEARCH AREAS

- **Biofuels and Environmental Catalysis**
  - Catalytic Converters, Catalytic Upgrading for Fuels, Algae based CO2 utilization.
- **Carbon Materials**
  - Carbon Fibers, Nanotubes
- **Clean Fuels and Chemicals**
  - Fischer-Tropes, Indirect Coal Liquefaction
- **Electrochemical Power Sources**
  - Low cost capacitors, batteries, and hybrids
- **Environmental and Coal Technologies**
  - Post Combustion Byproduct Beneficiation, Advanced Concretes
- **Power Generation and Utility Fuels**
  - Chemical Carbon Capture, Chemical Looping, Demonstration Projects

Key Personnel

PI: Rodney Andrews
Co-I: Don Challman
Co-I: Andrew Placido

Other Key Personnel

Kunlei Liu
Burt Davis
Gary Jacobs
Dennis Sparks

DOE Project Manager

Arun Bose

Process Components

Gasification

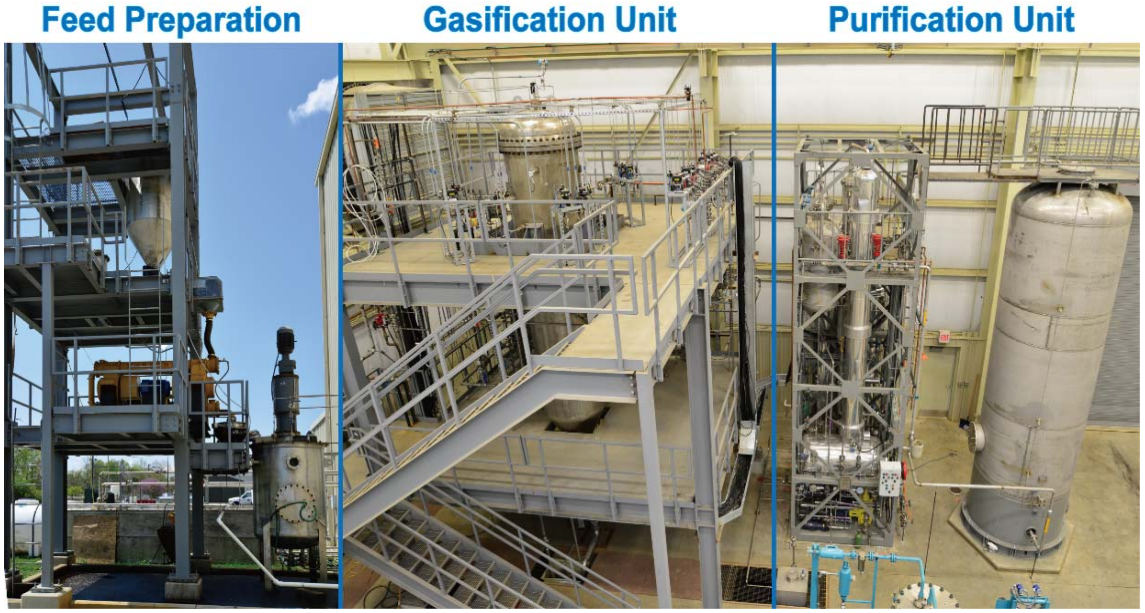
- Coal and Coal/Biomass Integrated Feed Preparation
- Entrained flow, oxygen blown, molten slag, OMB gasifier
- 1 ton dry coal/day
- 160 lb/hour syngas production

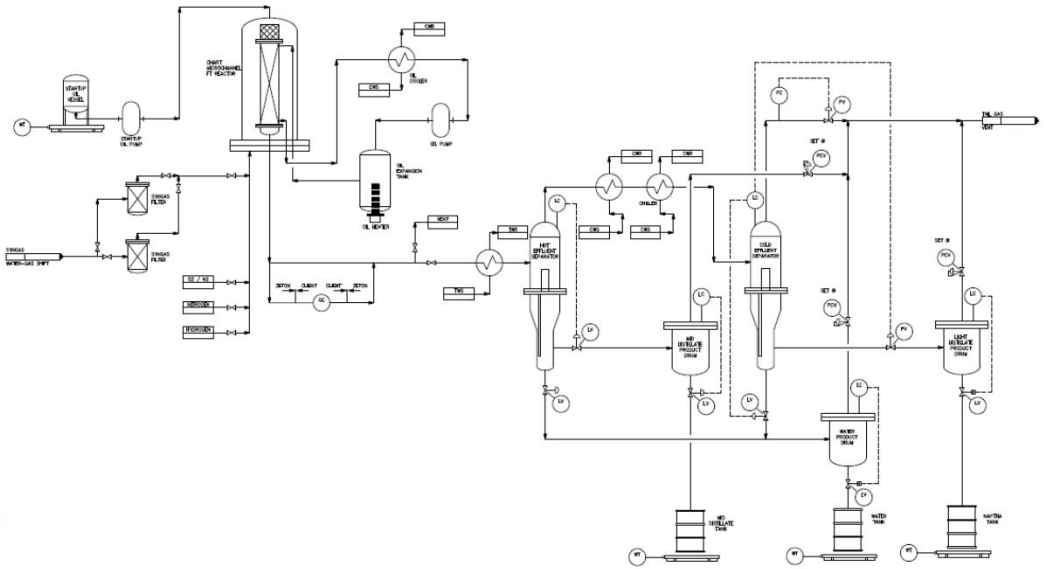
Acid Gas

- Aqueous Amine system with absorber and stripper
- Pressurized system (400 psi)
- Sulfur treatment on both rejected and clean gas (<1ppmv sulfur)

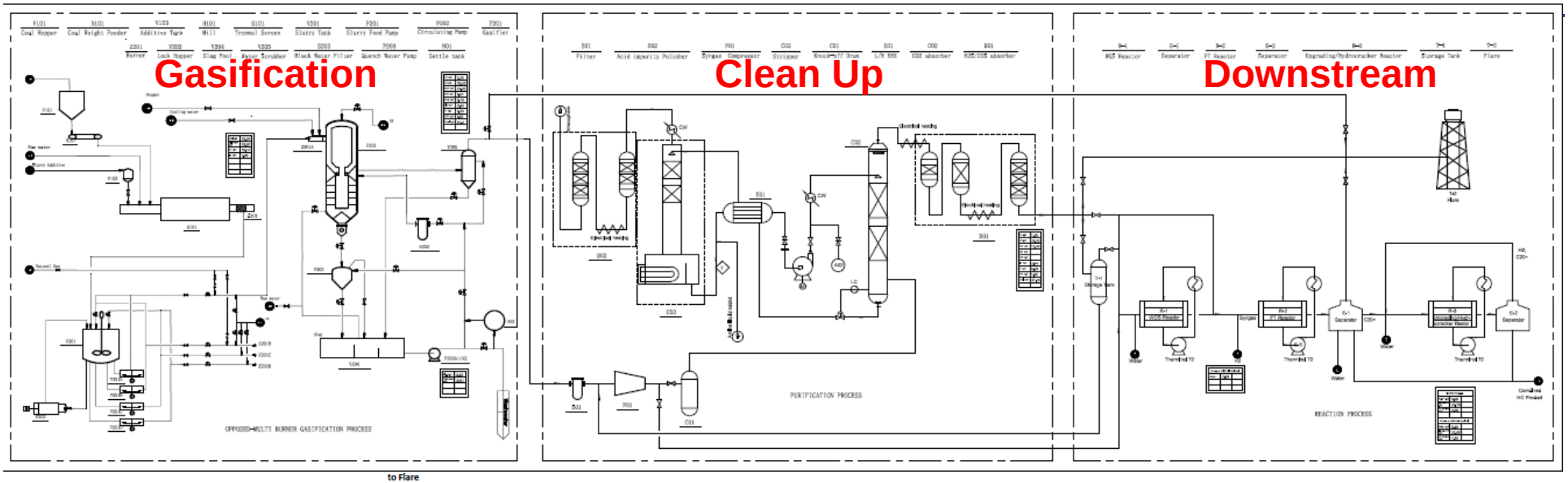
FT and WGS

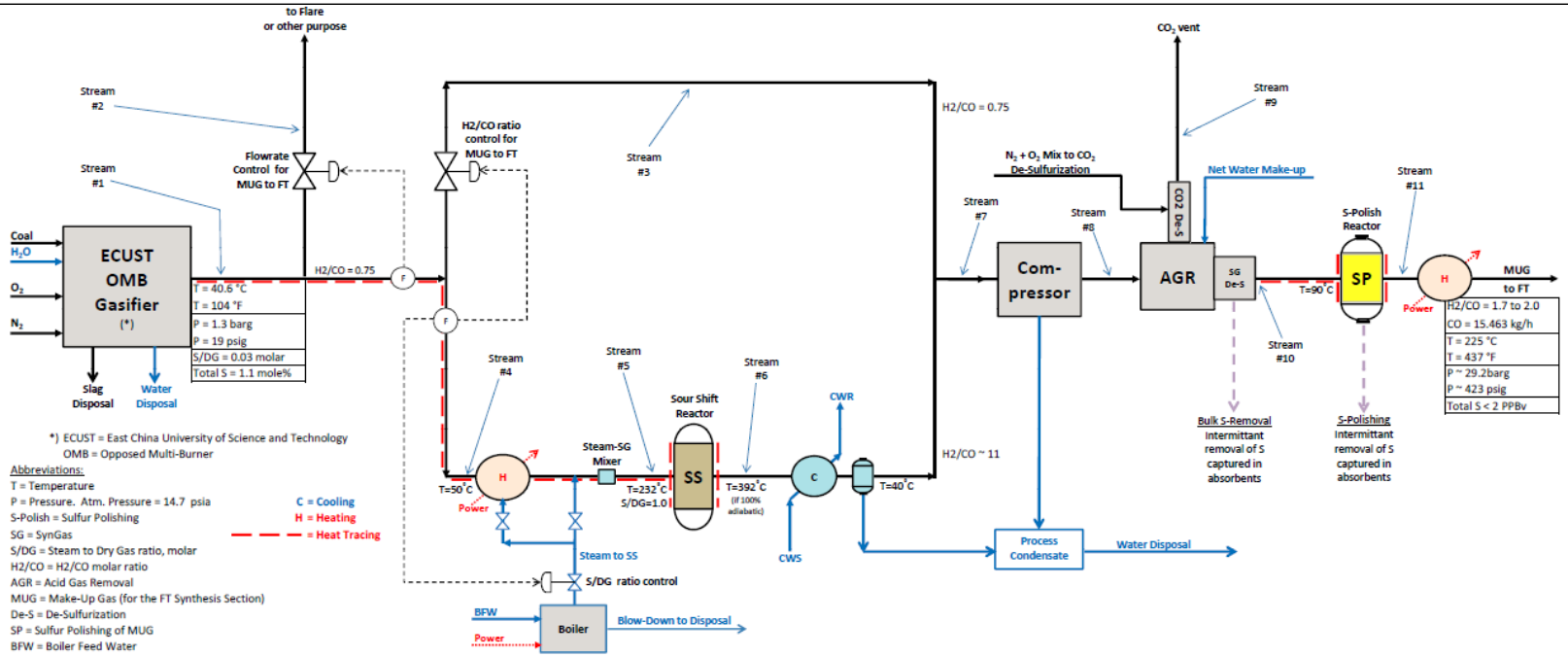
- WGS will increase H_2/CO ratio from ~0.7 to ~2.0
- Chart Energy Microchannel reactor
- Pressurized hot oil system (coolant and process side need to be similar)
- Co or Fe Catalyst





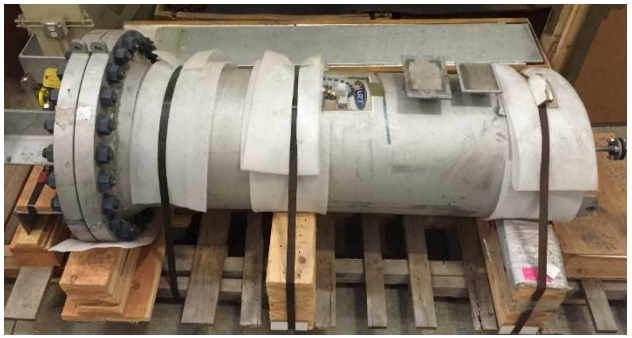
Plot Plan


Gasification
Clean Up
Downstream
OPPOSED-MULTI BURNER GASIFICATION PROCESS
PURIFICATION PROCESS
REACTION PROCESS


to Flare
or other purpose
Stream #2
Stream #1
Flowrate Control for MUG to FT
H2/CO ratio control for MUG to FT
Stream #3
H2/CO = 0.75
Coal
H2O
O2
N2
ECUST OMB Gasifier (*)
T = 40.6 °C
T = 104 °F
P = 1.3 barg
P = 19 psig
S/DG = 0.03 molar
Total S = 1.1 mole%
Slag Disposal
Water Disposal
H2/CO = 0.75
Stream #4
Stream #5
Stream #6
Steam-SG Mixer
Sour Shift Reactor
SS
T=232°C
S/DG=1.0
T=392°C
(if 100% adiabatic)
T=50°C
T=40°C
CWR
CWS
Power
Steam to SS
S/DG ratio control
BFW
Power
Boiler
Blow-Down to Disposal
H2/CO ~ 11
CO2 vent
Stream #9
N2 + O2 Mix to CO2 De-Sulfurization
Net Water Make-up
Stream #7
Stream #8
Com-pressor
CO2 De-S
AGR
SG De-S
T=90°C
Stream #10
Bulk S-Removal
Intermittant removal of S captured in absorbents
S-Polish Reactor
SP
Stream #11
S-Polishing
Intermittant removal of S captured in absorbents
MUG to FT
H2/CO = 1.7 to 2.0
CO = 15.463 kg/h
T = 225 °C
T = 437 °F
P ~ 29.2barg
P ~ 423 psig
Total S < 2 PPBv
Process Condensate
Water Disposal
*) ECUST = East China University of Science and Technology
OMB = Opposed Multi-Burner
Abbreviations:
T = Temperature
P = Pressure. Atm. Pressure = 14.7 psia
S-Polish = Sulfur Polishing
SG = SynGas
S/DG = Steam to Dry Gas ratio, molar
H2/CO = H2/CO molar ratio
AGR = Acid Gas Removal
MUG = Make-Up Gas (for the FT Synthesis Section)
De-S = De-Sulfurization
SP = Sulfur Polishing of MUG
BFW = Boiler Feed Water
C = Cooling
H = Heating
= Heat Tracing

Pilot Facility Research Platform

Integrated CTL/CBTL Pilot Facility- Research Platform

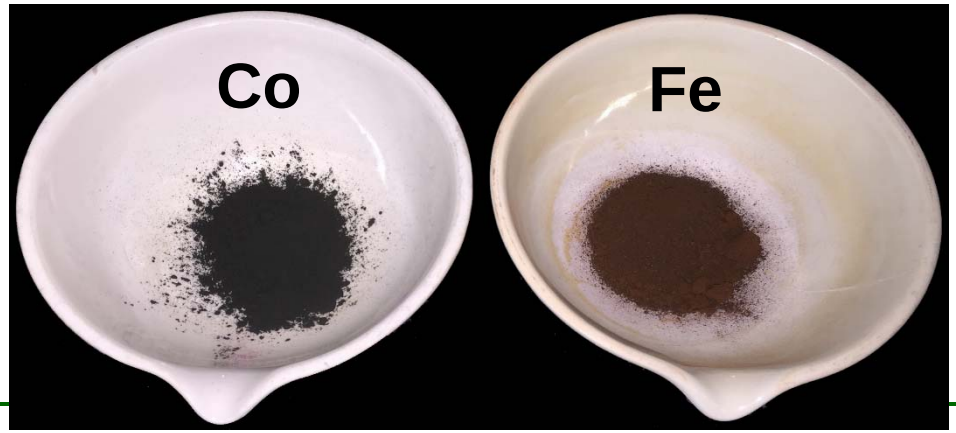


Auxiliary R&D Needed

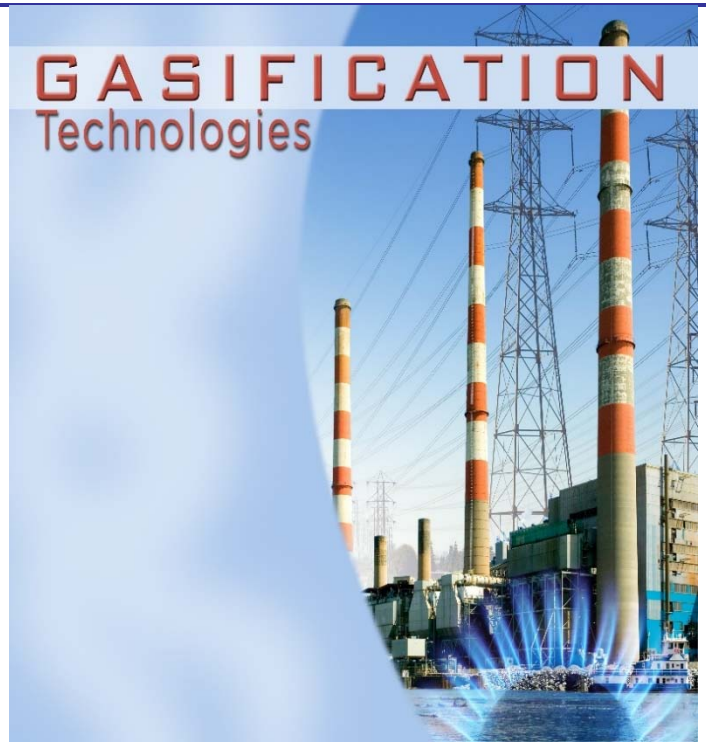
- Hosting new technologies at pilot scale

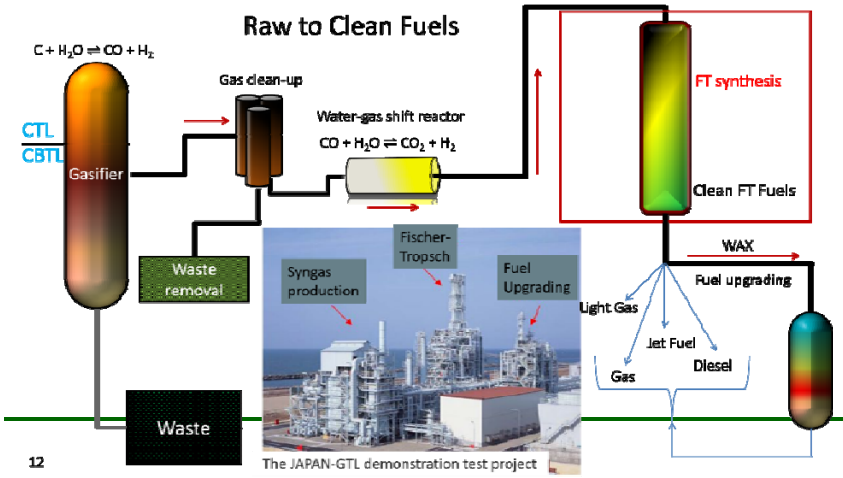
<u>Develop and Test</u>

- Improved gasification (in-situ WGS)
- New CO2 removal solvents
- New CO2 removal technologies
- Improved heat transfer fluids (FT)
- New/improved catalysts (sulfur tolerant, etc)



Overarching Project Goals





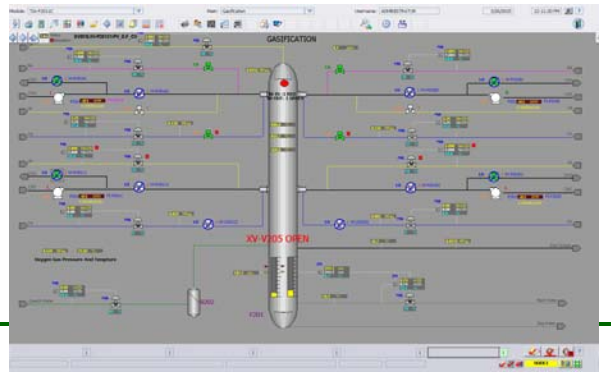
- To advance the design, construction and commissioning of a coal/biomass-to-liquids (CBTL) Process Development Unit at a capacity of 1 bbl. /day.
- To concentrate resources, create a critical mass of expertise, and provide a focal point for RD+D on fuels and chemicals derived from coal and biomass.

Project Vision

- Used as a test bed for evaluating new technologies/ concepts at a level of expenditure that is affordable. Flexible, modular for repurposing. Slipstreams available to test multiple technologies simultaneously

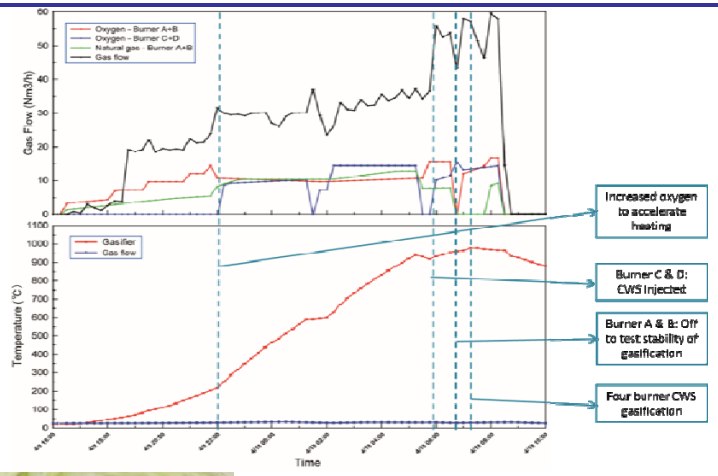
- Will provide open-access facilities, information in the public domain, and a means to independently review vendor claims.

- Used to build up human capital – to teach and train the future generation of skilled engineers, technologists, and operators.



Remaining Development Work

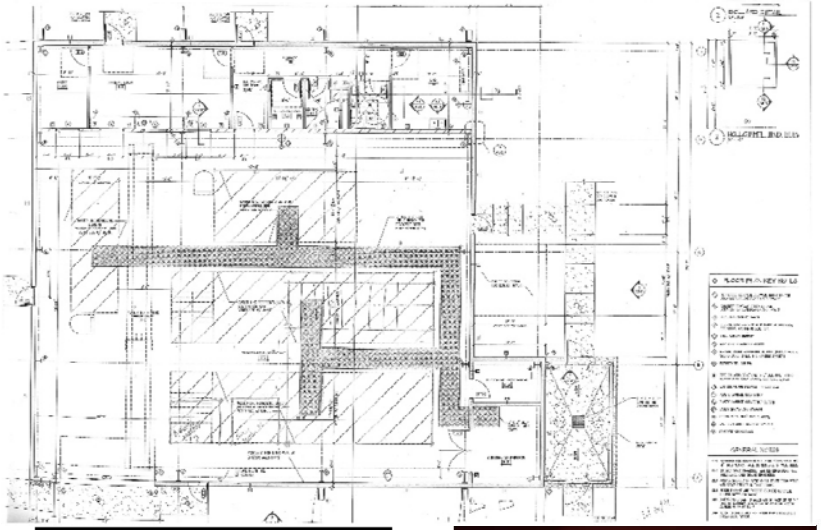
- Facility still under construction – Planned completion by end of 2016
- Host Site available for testing new technologies
- Plant units - Proven and mature technologies
  - Integration is key

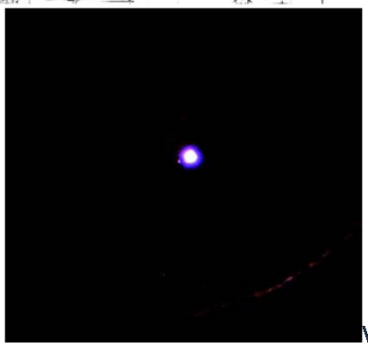


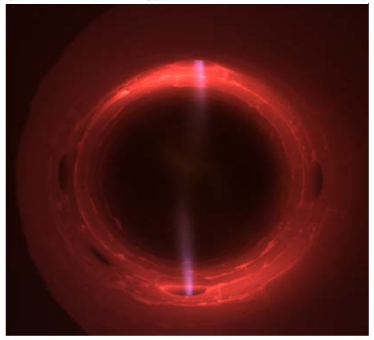
- Heat integration with CO2 capture
- Feed blending
- Biomass feedstocks
  - Algae
  - Other energy crops
- Improved heat transfer with FT reactor (CHART)
- FT Catalyst development

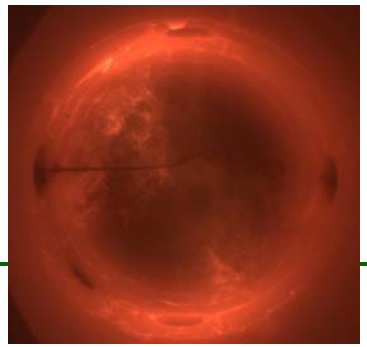
Integration Possibilities

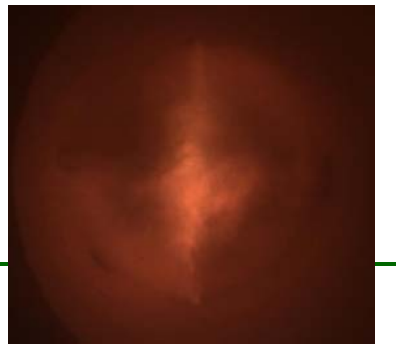
- Host site for other activities (5,000 sq. ft plus control room, office and laboratory)
- CO2 capture technologies on gasification plant
- Limited so far due to facility unfinished/under construction









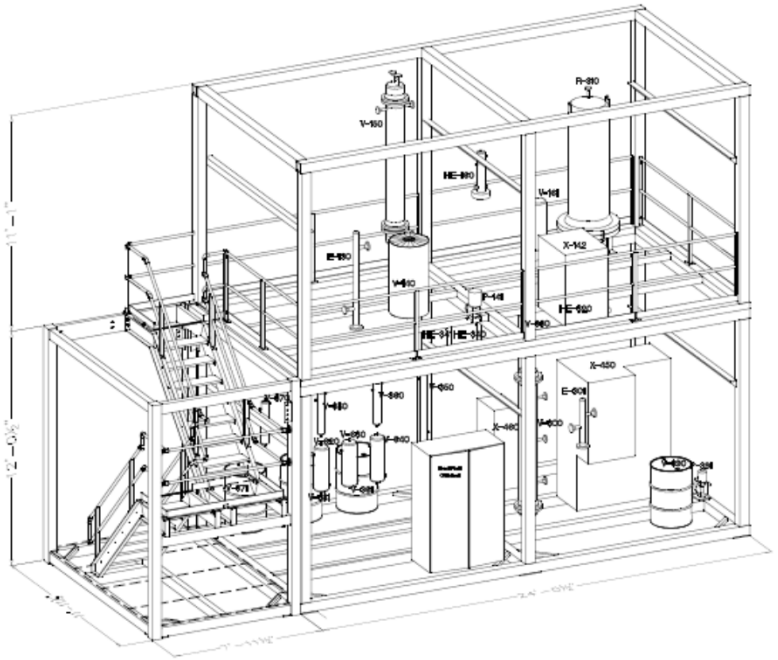


Commercial Benefits

- New modular systems
- Proving new technologies at pilot scale
- Financially prudent for testing new technologies
  - Already have infrastructure in place
  - Reduce capital costs for other projects
- Already have auxiliary unit installed (oxygen,nitrogen, compressed air, chiller, etc)
- Trained Workforce

Lessons Learned

- Design Pilot-plant Buildings for Flexibility and Re-purposing, Not Equipment Specificity
- Allow Ample Time for NEPA-EA, Permit Approvals, ESH and HAZOP Evaluations
- Professional Engineering and Construction Management Services are Vitally Important
- The Project Benefited Greatly from Strong Collaborations in China in the area of Coal Gasification



Future Research Areas

1.) Host site for technology development around CTL
- Gasification
- Carbon Capture
- FT
- WGS and Refining

2.) Gasification Technology
- High concentration CWS
- Increase H/CO ratio and Reduce Downstream Clean-up
  - In-situ WGS with warm sulfur removal
  - Collaboration with Catalyst group, ECUST
- Coal/Biomass Blending Gasification Research
- Dynamic Modeling and Controls

3.) Carbon Capture
- New Solvents
- New catalysts
- New processes and technologies

4.) Gas Conversion by F-T Synthesis
- Catalysts (Co, Fe, etc)
- Types of F-T reactors
- Fine tuning based on selectivity of desired product(s)

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- ECUST
  - Jianliang Xu, Qinghua Guo, Yan Gong and Xin Gong
- Zeton
- CEEDI

Bio Slide

- **Mr. Andy Placido** has been a Senior Research Engineer at the University of Kentucky Center for Applied Energy Research since 2010. Prior to beginning employment at CAER, he graduated with a degree in Chemistry from Centre College in 2007 and got his masters in Chemical Engineering at the University of Kentucky in 2010. He first joined UK-CAER as an undergraduate research student and then he continued as a graduate student working on his Master's degree with the Carbon Materials group. In the past he has, he has worked on biological carbon capture (algae) and polymer nanocomposites, while he currently works in the Power Generation and Utility Fuels group on coal gasification and managing the coal/biomass to liquids pilot plant facility.
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- **Dr. Rodney Andrews** has been the Director of the University of Kentucky Center for Applied Energy Research since 2007. Prior to that appointment, he served as Acting Director and was an Associate Director of CAER responsible for the Carbon Materials group since 2001. He joined the research staff at the Center in 1999. His research interests include production of pitches and heavy aromatics from coal and other fossil resources, thermochemical conversion processes for coal and biomass, carbon fiber and composites, activated carbon materials, pitch chemistry and characterization, synthesis and application of carbon nanomaterials. He is an Associate Professor for the Department of Chemical and Materials Engineering at UK. Dr. Andrews has directed major multi-university and industry-academic collaborative projects. He has published more than 50 peer reviewed journal articles and three book chapters. He has been granted four patents. In addition to his UK achievements, he is on the Executive Council of the American Carbon Society and Dr. Andrews is Program Director of Kentucky NSF EPSCoR, a statewide initiative to increase research infrastructure within the Commonwealth. He is on the Honorary Editorial Advisory Board for the journal *Carbon*. He serves on the statewide STEM Taskforce. Dr. Andrews received his Bachelor of Science degree in chemical engineering from Michigan State University and his Ph.D. in chemical engineering from the University of Kentucky. He is a licensed Professional Engineer in Kentucky.
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- **Mr. Don Challman** has broad experience in the public and private sectors, in occupations ranging from government regulator to finance manager to research administrator and entrepreneur. For the past 25 years, he has served as the Associate Director and General Manager of the University of Kentucky Center for Applied Energy Research. CAER is a nearly 40-year old world-class research institute devoted to developing technologies for the utilization of coal and biomass resources for electric power generation, and fuels and chemicals, including technologies to address associated environmental concerns. At CAER, Mr. Challman has served in various capacities: finance and HR; new business development; technology transfer and licensing; communications; facilities; energy and environmental policy; and government and international relations.
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