Modular Gasification – New Markets for Coal Use

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David Lyons
Technology Manager, Gasification Systems and Coal & Coal-Biomass to Liquids
Why the Interest in Coal Gasification?

Energy Diversity and Security
Gasification can:

- Convert coal to power
- Convert coal to valuable products (chemicals/fuels)
- Superior environmental performance, including GHG
- Feasible for carbon capture

U.S. Coal Resources
18.3 Recoverable Reserves at Active Mines
255 Estimated Recoverable Reserves
477 Demonstrated Reserve Base
1,669 Identified Resources
3,906 Total Resources

Why the Interest in Coal Gasification?
U.S. Has A Lot of Coal!

U.S. Has A Lot of Coal!

https://www.eia.gov/energyexplained/index.cfm?page=coal_reserves
Benefits and Products of Gasification

Gasification can be

- Used to make: hydrogen, fertilizer, chemicals (methanol, plastics, etc.) and transportation fuels
- Lowest cost option to make power with almost total carbon dioxide (CO₂) capture and storage

Gasification can play in the global market, including developing countries
Modular/Small Scale Approach

- Identify emerging markets for coal via modular/small scale technology implementation
- Perform cold flow tests & perform system analyses
- Determine what manufacturing & balance-of-plant R&D can reduce capital costs

NETL-Internal Research Strategy: develop a software toolbox for unit operation & plant optimization, component characterization, advanced manufacturing, solid/liquid carbon capture & re-use, and performance modeling via systems analysis. The toolbox will lower the risk and cost of implementation.
## Potential Economic Benefits of Modular/Small Scale

### Results of early screening study

<table>
<thead>
<tr>
<th>Location</th>
<th>Available Fuels</th>
<th>Primary Need</th>
<th>Possible Markets</th>
</tr>
</thead>
</table>
| Rural Alaska              | • Subbituminous coal  
                          • Woody biomass (southern region)  
                          • Peat (northern region)  
                          • MSW?                                                            | • COE reduction  
                          • Transport/heating fuel cost  
                          • Job creation  
                          • GHG reduction                                           | • Diesel – make use currently available infrastructure  
                          • Power                                               |
| Rural Appalachia          | • Bituminous coal  
                          • Woody biomass  
                          • Natural gas  
                          • MSW or prep plant coal fines                           | • Job creation  
                          • Increased coal sales  
                          • GHG reduction                                           | • Chemicals  
                          • Tar  
                          • Power Plants                                         |
| Rural Southwest U.S.      | Solar +  
                          • Subbituminous coal  
                          • Bituminous coal                                             | • Lower-cost power w/o transmission line expense | • Power  
                          • DC Micro-grid                                         |
| U.S. Military Installations | • Biomass  
                          • Fossil Fuels  
                          • MSW                                                      | • Meet lifecycle GHG requirements of EISA 2007 §526  
                          • Supply fuel/power w/o power lines                      | • Jet fuel  
                          • Power (both for bases and humanitarian aid needs)     |
Gasification Portfolio Locations

26 Projects in 14 States (Primes' business locations)

<table>
<thead>
<tr>
<th>State</th>
<th>Projects</th>
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<tbody>
<tr>
<td>AK</td>
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<tr>
<td>WV</td>
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</table>
Locations of Awarded Projects (FY17)

9 projects in 6 states (Prime business location)

Thermosolv
Performance Locations
Associated with projects selected in FY17, includes partner locations.
Total DOE funding: ~$16M.
Three Main Areas for FY17 Selections

• Modularization of Emerging Gasification Technologies

• Modularization of Advanced Air Separation Technologies

• Small Field Pilot FEED Study
Questions?

Thank You
Additional Slides
Current Focus: Looking at Modular/Small Scale with Advanced Technology to Achieve Cost Reduction Goals

- Achieving advantageous economies via mass production, instead of economy of scale, is counter to the historical convention employed in utility sector power generation.
- Examples of modular technologies in other technologies that achieved capital cost reduction:
  1. Addition of cylinders to reciprocating internal combustion engines
  2. Stacking batteries in DC electric power
- Opportunities to exploit modular/small scale philosophy in Distributed Power Generation via advanced manufacturing.
Financial Assistance Projects Awarded in FY17

• DOE/NETL selected 9 projects to support the development of advanced technologies that will foster early adoption of small-scale modular coal-gasification.

• Focus on the development of emerging gasification technologies that can be scaled down to modularization to support program goals using the modular/small scale concept.

• Total DOE funding: ~$16M.
Advance Syngas Cleanup for REMS
Research Triangle Institute-FE0031522

Project Strategy
Address knowledge gaps to develop modular sorbent-based warm syngas cleanup to be cost-competitive with state-of-the-art commercial plants.

Objectives
• Expand experimental database for sorbent desulfurization of low-sulfur syngas
• Determine lowest cost design

Scope of Work
• Develop potential desulfurization process designs for coal gasification CHP or polygeneration
• Develop fixed-bed sorbent formulation and fixed-bed process design
Small Scale Engineered High Flexibility Gasifier
Southern Research Institute-FE0031531

Project Strategy
Develop modular pressurized oxygen-blown gasifier that is simple to operate and minimizes tar production.

Objective
Use mathematical model to guide engineering design, construction, and pilot-scale testing.

Scope of Work
Implement experimental test plan to optimize gasifier performance and simulate a 1-5 MW power generation system.

Benefits
• Reduce coal conversion cost via a modular system
• Feed flexibility optimizing syngas make and quality
• Flexibly for site specific needs
Staged OMB for Modular Gasifier/Burner

University of Kentucky-FE0031506

Project Strategy
Test a staged opposed multi-burner (OMB) gasifier for a modular version of a commercial gasification technology.

Objective
• Test staged-OMB utilizing coal slurry feed for high-temperature gasification.
• Standardize burner design

Benefits
• Loading flexibility
• Improved fuel conversion/gasification efficiency
• Prolonged refractory/burner service life
• Demonstrate potential system gain
• Standardized burner
Radically Engineered Modular Air Separation System using Tailored Oxygen Sorbents

North Carolina State-FE0031521

**Project Strategy**
Development of modular coal gasifiers with reduced capital cost and energy consumption.

**Scope of Work**
Demonstrate REM-ASU technology at pilot-scale to generate data for commercial implementation.

**Benefits**
- Advanced O$_2$ sorbent capacity and high activity
- Oxygen generation without a vacuum desorption step
- Modular ASU that can be readily integrated
- Validate feasibility to enable future commercial sector implementation

Two potential schemes between REM-ASU and REMS gasification system
Pilot Testing of a Modular Oxygen Production System Using O\textsubscript{2} Binding Adsorbents

Research Triangle Institute-FE0031527

**Project Strategy**
Design, fabricate, and test a modular O\textsubscript{2} production system.

**Objective**
O\textsubscript{2}-purity >95% at cost equal/less than current commercial system.

**Scope of Work**
- Optimization/scale-up O\textsubscript{2} binding adsorbent
- Optimize pressure swing adsorption process
- Develop simulation tools
- Determine O\textsubscript{2} production cost

**Benefits**
- 99% pure O\textsubscript{2} for modular applications
- Reduced air separation cost
- Reduced product cost

Schematic illustration of an example of mesoporous organosilica complexed with Co (II)
Advanced Sorbents for Modular Oxygen Production for REMS Gasifiers

Thermosolv, LLC-FE0031528

Project Strategy
Develop advanced oxygen sorbents utilizing high O\textsubscript{2} storage capacity of perovskites.

Objective
Scale up perovskite manufacture to 80–250 kg per batch.

Scope of Work
• Measure sorbent capacity and rate of O\textsubscript{2} production
• Establish sorbent durability and evaluate stability
• Fabricate composite sorbent

Integrated oxygen production for IGCC with reciprocating engine and CO\textsubscript{2} capture. Oxygen production module (LCO) as schematically is immersed in a syngas “cooler”
Modularization of Ceramic Hollow Fiber Membrane Technology for Air Separation

University of South Carolina-FE0031473

Project Strategy
Develop membrane stack/module for air separation and O₂ production using ceramic hollow fiber membranes.

Scope of Work
• Characterize novel single hollow fiber membranes
• Assemble membrane stacks
• Model/analyze stacks to optimize design
• Test membrane stack permeation

Benefits
• High specific volumetric permeate performance and efficiency
• Enable scale-up to compact membrane stacks/modules
• Performance, reliability, and up-scaling improvement
Making Coal Relevant for Small Scale Applications: Modular Gasification for Syngas/Engine CHP Applications in Challenging Environments

University of Alaska Fairbanks-FE003146

Project Strategy
Provide analysis to prepare a modular Front-End Engineering and Design (FEED).

Objective
Develop cost estimates to examine potential for modular/small-scale coal gasification units.

Scope of Work
• Design gasifier, cleanup train, and plant modification components/systems
• Perform FEED level cost estimation

Benefits
• Non-baseload applications/distributed generation.
• Reduced manufacturing costs
Gasification CHP from Coal Fines
University of Kentucky-FE0031520

**Project Strategy**
Complete front-end engineering design (FEED) study for a 5 MWe equivalent polygeneration plant utilizing waste coal fines and biomass.

**Objective**
Identify appropriate main components (technology selection and operating conditions).

**Scope of Work**
- Complete design basis, including site visits, feedstock, and slurry characterization
- Complete a preliminary polygeneration process design
- Determine economic viability

**Benefits**
- Monetize coal impoundment and reduce environmental impact
- Template to spear development in coal community