Gasification of lignite coal in North America; Past experience and future opportunities

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Outline

- Key Properties of North American Lignite
- History of Lignite Gasification in North America
- Technology Options
- Current Activities
- Future Opportunities
Unique Properties

- Molecular and physical structure
- high moisture content
- low heating value
- dissimilar contents and forms of oxygen
- Sulfur and nitrogen
- higher porosity and surface area
- higher reactivity in oxidizing and reducing atmospheres
- high gas and low tar yields in pyrolysis
- distinctive (alkaline) inorganic forms and mineral contents
- uniquely different physical and chemical transformations of char and inorganic intermediates in combustion and gasification systems; and distinctive ash deposition mechanisms, slag viscosity behavior, and corrosion mechanisms.
Enhanced Reactivity

Reactivity
- Organic structure
- Inorganic components

Catalytic Activity
Na, Ca, Mg

Carbon Content of Raw Coal, % d.a.f.
Fate of Lignite Impurities

- Vaporization
- Nucleation
- Coagulation
- Condensation
- Reaction
- Char or Mineral Fragmentation, Shedding, and Coalescence
- Particle Size Distribution
- Cenosphere Formation
- Fick Diffusion (vapors) <1 µm
- Inertially Impacting Particles >5-10 µm
- Heat-Transfer Surface
- Gas Boundary Layer

Viscosity, log₁₀ poise vs. Temperature, °C
- Non-Newtonian Flow
- Newtonian Flow

T_{cv}
T_{250}
History of Gasification of Lignite

Technologies that have been applied to gasify lignite for over 100 years:

- Retorts
- Fixed bed
- Catalytic
- Entrained flow
- Fluidized bed
- Transport reactor
Current Commercial Lignite Gasification Facilities

- Dakota Gasification Company
- Kemper County IGCC
A Look at the Past

- Plant origin: ‘70s energy shortages
- $2.1 billion cost

First Synthetic Natural Gas (SNG) produced in July 1984

Dakota Gasification Company (DGC) began operating facility in 1988 as a subsidiary of Basin Electric Power Cooperative
Products

- Naphtha
- Carbon Dioxide
- Anhydrous Ammonia
- Liquid Nitrogen
- Krypton/Xenon
- Natural Gas
- Cresylic Acid
- Ammonium Sulfate
- Phenols
Lurgi Mark IV Gasifier
Ammonium Sulfate

- Started in 1996
- Created to utilize the sulfur removed from the plant boiler flue gas in order to be compliant with the Clean Air Act of 1990
- Capacity to produce 60,000 tons per year
- DGC’s flue gas desulfurization unit is removing 93% of the sulfur
- On site storage for 40,000 tons
- Truck loading facility
- Ammonia: 21% as N
- Sulfur: 24% as S
Naphtha

- Started in 1993
- Capacity of 8 million gallons per year
- Used as:
  - Gasoline blend stock
  - Paint thinner & other solvents
  - Feedstock for benzene production
Anhydrous Ammonia

• Capacity to produce 400,000 tons annually
• Truck loading facility
• Fertilizer for farming & as chemical feedstock
Weyburn and Midale, Saskatchewan
12.6 Million Metric Tons Net Sequestered Through The End of 2010

240 mmscf/d
Pipeline capacity

Current flow rate: 153 mmscf/d

World’s Largest Carbon Capture and Sequestration Project
DGC’s CO$_2$ Pipeline

- 205 miles
- Featured on the History Channel’s “Modern Marvels”
- 14” & 12” carbon steel pipe
- Strategically routed through Williston Basin oil fields
- Pipeline take offs already installed
Kemper County IGCC Project Overview

- **2x1 Integrated Gasification Combined Cycle (IGCC)**
  - 2 TRansport Integrated Gasifiers (TRIG™)
  - 2 Siemens SGT6 - 5000F CTs
  - 1 Toshiba Steam Turbine (Tandem Compound Double Flow)
  - 582 MW peak and 524 MW on syngas
  - Heat Rate 11,708 Btu/kWh (29.5% HHV Efficiency w/ CO₂ control and 40+% moisture coal)
  - Selexol for H₂S and CO₂ removal
  - 65+% CO₂ capture (~800 lb/mWh emission rate)
  - Mine Mouth Lignite
- **Owner & Operator:** Mississippi Power
- **Over $2 billion capital investment**
- **Commercial Operating Date:** May 2014
- **Use treated effluent from Meridian as makeup water**
- **By-Products (TPY)**
  - ~3,000,000 - Carbon dioxide used for EOR
  - ~135,000 - Sulfuric acid
  - ~20,000 - Ammonia

**Kemper Lignite Composition**

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<tr>
<th>Heat Content</th>
<th>Average</th>
<th>Min</th>
<th>Max</th>
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<tr>
<td>Moisture %</td>
<td>45.5</td>
<td>42</td>
<td>50</td>
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<tr>
<td>Ash %</td>
<td>12.0</td>
<td>8.6</td>
<td>17</td>
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<tr>
<td>Sulfur %</td>
<td>1.0</td>
<td>0.35</td>
<td>1.7</td>
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**Kemper County IGCC Project Site**

- Distribution of coal-bearing units in the Gulf Region
- Plant Site

**Kemper County IGCC Project Map**

- Mississippi River
- Big Black River
- Boswell
- Meridian
- Plant Site

**5/31/2012**
Kemper County IGCC Project Map

- ~70 miles transmission
- ~60 miles CO₂ pipeline (for EOR)
- ~5 miles natural gas pipeline
- ~31,000 acre mine site
- ~2,900 acres plant site
- ~30 miles treated effluent line

Plant Site
Meridian
New CO₂ Pipeline

5/31/2012
Visual Comparison of Main Gasifier Types
(Not to Scale)

GE
Phillips 66
Shell
Siemens
MHI
TRIG™

Oxygen-blown
Air-or $O_2$-blown
Burner-type, slagging
No-burner
Non-slagging

5/31/2012
Development of the TRIG™ for Power and Chemical Production

TRIG™ Leverages Long History of KBR Fluid Catalytic Cracking (FCC) Expertise

- **First Commercial FCC Unit for Exxon**
- **Orthoflow™ A Design**
- **Orthoflow™ C Design**
- **Resid FCCs**
- **Orthoflow™ F Design**

- **Late 30's**
- **1942**
- **1951**
- **Early 1960's**
- **1976**
- **1980's**
- **1990**
- **1996**
- **1996 China**
- **2011 USA**
- **2014**

- **1980's**
- **Design Based on FCC Technology**
- **Pilot Plant Tech Center**
- **Grand Forks, ND 2,600 Hours Test Run**
- **PSDF at Wilsonville, AL. >14,600 hrs in gasification >2,200 hrs on Mississippi Lignite thru Dec '09**
- **TRIG™ In Kemper County, MS, USA & Dong Guan, China**
TRIG™ Attributes / Advantages

- Simple, well established design
  - Based on technology in use for 70 years
- Either Air- or Oxygen-blown
  - Air for power
  - Oxygen for liquid fuels and chemicals
- High Reliability Design
  - Non-slagging design:
    - Provides 10-20 year refractory life,
    - Eliminates black water system
    - Provides non-fouling syngas cooler operation
  - No burners to fail and be replaced
  - Dry dust removal eliminates gray water system
- Lower Fuel Costs
  - Coarse, dry coal feed allows:
    - Fewer, lower power pulverizers, and
    - Less drying than other dry-feed gasifiers
  - Cost-effective using high moisture, high-ash, low rank coals (PRB and lignite).
- Excellent Environmental Performance
  - Lower water use compared to pulverized coal (PC)
  - Excellent emissions performance
Kemper Construction - March 2012
Completed Facility Superimposed
What’s next in Lignite Gasification in North America?

- Coal Drying
- SHED (South Heart Energy Development)
- E-STR Gasifier
- Pratt-Whitney Rocketdyne Gasifier
DryFining

Coal → Dryer → Exhaust Gas → Bag House

- Fines → To Silos
- Refined Coal → To Silos
- Rejects → To Pyrite Disposal

Waste Energy
Lignite Drying and Gasification

- **As-Received Lignite** (37.5% moisture)
  - 35,000 STPD
  - 5,300 MW\textsubscript{th} HHV

- **Hot water** + LP Steam
  - 330 MW\textsubscript{th}

- H\textsubscript{2}O + N\textsubscript{2} + air

- **DryFining x 22**

- **Pulverizer x 9+1**

- **ASU x 4**

- **As-Fed Lignite** (8% moisture)
  - 23,800 STPD

- **Gasifier x 9+1**

- CO + H\textsubscript{2}
  - 1,000 MMSCFD
  - 4,000 MW\textsubscript{th} HHV
GRE dryer/segregator
South Heart Overview
2+1 BGL Hydrogen Power

OUTPUTS
- Power Production
  - 167 MW net
  - < 200 Pounds CO$_2$/MWhr net; approaches renewable standard

- CO$_2$ Captured:
  - 100 MMSCF/day, > 2,000,000 tons/yr.
  - Translates into over 10,000 barrels of oil per day (from EOR)
  - 94% of carbon from coal
  - Can achieve zero net CO$_2$ emissions with approximately 10% biomass feed

INPUTS
- Lignite – 5,144 tons/day raw lignite; 3,464 tons/day briquetted lignite
- Oxygen – 1,600 tons/day
Why the BGL Gasifier?

- BGL Gasifier is based on the lignite proven Lurgi Gasifier (Over 75% of global gasification is based on Lurgi technology)

- British Gas and Lurgi spent over 25 years and $500 million improving the efficiency, reliability and environmental footprint of the original Lurgi design

- The BGL Gasifier has been in commercial operation since 2000 at the SVZ facility in Schwarze Pumpe, Germany

- The BGL Gasifier predecessor, the Lurgi Mark IV gasifier, has been in commercial operation at the Dakota Gas plant for nearly 25 years and in Sasol’s Secunda facility for 40 years

- Commercially demonstrated and bankable (Schwartz Pumpe and Dakota Gas)
BGL Gasifier Differences from Lurgi Mk IV Gasifier

- Higher conversion efficiency of coal to gas
- Increased fines tolerance
- Higher plant throughput
- Significantly lower steam (water) usage
- Lower aqueous liquor production
- Recycling of by-products to extinction via tuyeres
- Less $\text{CO}_2$ in the syngas
- Ash converted to non-leachable vitrified slag
South Heart Project Status

- Feasibility & Development
  - Preliminary development work substantially complete
  - Conceptual design complete
  - Mine plan complete
- Major Technologies Have Been Selected
- Incorporated GTL Coal Beneficiation Technology Into Plant Configuration
- Transmission
  - Multiple interconnect options available with little or no upgrades required
- Pre-FEED performed for the Hydrogen Power Configuration
- Mine permit is underway with expected issuance of final permit in 4Q 2012
E-STR Gasifier Configuration

INTERNAL FEEDSTOCK UPGRADER

Lower temp 2nd stage, 400-750°C

Up to 100% slurry to 2nd stage

O₂ → Residence Vessel → Syngas Cooler → Syngas

No syngas cooler

Cylindrical for Hi-pressure

Slurry

No residence vessel

Char

Dry feed 1st stage

Slag

Catalytic tar conversion & CO shift
E-STR Technology Advantages

- **Reduced CAPEX**
  - Elimination of Residence Vessel and Syngas Cooler
  - Up to 40% smaller ASU from dry feeding 1st stage
  - Up to 20% smaller downstream systems due to higher syngas and methane yield from gasifier
  - Low cost slurry-based feed system; dry solid recycle to 1st stage with no lock-hoppers

- **Reduced OPEX**
  - Lower fuel and oxygen consumption
  - Lower maintenance cost

- **Improved Operability**
  - Less equipment; simpler design
  - Simple and reliable slurry-based feed system
  - High pressure cylindrical gasifier design and slurry-based feed system allows delivery of SNG at pipeline pressure without added compressors
PWR Gasifier

- 90 percent size reduction (gasifier)
- 50 percent lower cost (gasification system)
- 80-85 percent cold gas efficiency
- 99 percent carbon conversion
- 99 percent availability (gasification system)
- Capability for near-zero emissions
Conclusions

 Lignite properties need to be considered in selection of gasification
  • Lignite reactivity
  • Moisture levels
  • Inorganics content
 Long history of gasification
 New options that take advantage of the unique properties of lignite coal are being developed
 Critical challenge is having government policies in place that will allow lignite gasification to continue to move forward