TRIG™ Technology - Applications for IGCC, Refueling, and Syngas Projects

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Outline

• Low Rank Coal Utilization
• KBR / TRIG™ Advantage
• Refueling Applications
• Syngas (SNG) Business Case
• TRIG™ Commercialization Timeline
The Case for Utilization of Low Rank Coals – TRIG™ is the Premier Gasification Technology of Choice

• On a dollar per unit energy equivalent basis, Low Rank Coals are lower cost energy sources as compared to Natural Gas and Oil.

• Coal provides a more economical option than other sources of energy.

• This raw material differential with a manageable investment cost is the key business opportunity to use low rank coal as a feedstock in different applications.

Source: Annual Energy Outlook 2011, EIA & CERA
TRIG™ Lowers Investment & Operating Costs

Economies of Scale
• Gasifiers with 4,000+ MTPD coal feed capacities
• No spare gasifier required

TRIG™ Gasifier is Less Expensive
• Cold shell design (refractory-lined), no internals
• Uses inexpensive carbon steel

TRIG™ Island Maximizes Local Content
• ~ 95% of equipment sourced locally (e.g. China)

TRIG™ is a Clean Coal Technology
• Low capital costs for effluent treatment
• Simplifies treatment scheme

TRIG™ Reduces Water & Treatment Costs
• Uses less water – lowest in industry
Cost Advantages of TRIG™ IGCC

COE for Low Rank vs High Rank Coals

Additional Benefits: TRIG™ provides compact layout

Typical TRIG™ based Syngas Plant Plot Area

Coal Storage

CO Shift

AGRU

SRU

WW

Water Treat

STG

DM Water

TRIG 1

TRIG 2

CW

KBR Technology

Know-How Delivered
Environmental Advantages of TRIG™ Plants

![Graph showing environmental benefits of TRIG™ plants compared to other technologies.](image)

TRIG™ system has one of the lowest water usage due to dry coal feed and ash removal. Can be designed to be Zero Liquids Discharge (ZLD)

Refueling Diesel fired units with Low Rank Coal lowers feedstock costs:

- Approx. $100 - $200 Million / year savings for a nominal 120 MW unit
- Rapid return on investment expected since investment is lower than a new facility

TRIG™ based IGCC allows using low cost (low rank coals)

- Air-blown gasifier lowers investment cost
- Power island can operate stand-alone on a second or backup fuel

Integration captures efficiency

- About 30% of power is generated by steam from gasifier island
- Air extraction from gas turbines for gasifier reduces air compression load

*Assumes $3/gallon for Diesel and $2/MMBtu for Low Rank Coal
TRIG™ based Coal to Ammonia – Replacing Natural Gas with Low Cost Coal

Traditional Reformer based Front-End

Natural Gas → Syngas

Coal → TRIG™ Front-End

Syngas → Offsite & Utilities (OSBL)

AMMONIA
Coal to Ammonia Refueling Case Study

Feedstock: Low Grade Coal ($30/tonne or $2/MMBtu)
Coal: 4,000 MTPD (Metric Tonnes Per Day)
Ammonia Production
  - 1,200 MTPD (before revamp)
  - 1,500 MTPD (after revamp)
Ammonia Selling Price $360 per Tonne

**Coal Cost Sensitivity**
- 150% of Base
- Base Case
- 70% of Base

**Capital Cost Sensitivity**
- 125% of Base
- Base Case
- 75% of Base
Syngas Applications: KBR Coal to SNG Process

Syngas Generation using TRIG™ Technology + Syngas Purification + KBR Methanation Technology
SNG Plant Economics

- Basis: 160,000 Nm$^3$/hr SNG
- Coal Feed: 12,200 MTPD (low rank coal)
- Coal Price: $2/MMBtu (~$34/tonne)
- Target IRR: 15% with typical Project Financing terms

Gas cost using KBR process ~ $5-$8/MMBtu (typical for most locations) using low cost coal
Coal to SNG: Project Economics and Plant Capacity

Impact on Cost of Production

Base Case

SNG Capacity, Billion Nm³/year

Impact on Cost of Production

0% 30% 60% 90% 120% 150%

0.6 1.3 2.5 4.0
TRIG™ Commercialization Timeline

- **PSDF TRIG™ Demo Unit**
  - Location: Alabama, USA
  - 50 MTPD
  - 16 Years of Operational Experience
  - 1 x 50 MTPD
  - 1996

- **UND TRIG™ Pilot Plant**
  - Location: North Dakota, USA
  - 3 MTPD
  - 16 Years of Operational Experience
  - 1 x 3 MTPD

- **SKI TRIG™ Pilot Plant**
  - Location: Daejeon, South Korea
  - 1 x 3 MTPD

- **Dongguan IGCC Project**
  - Location: Dongguan, China
  - 120 MW
  - 1 x 1,600 MTPD
  - 2011

- **Kemper County IGCC Project**
  - Location: Mississippi, USA
  - 582 MW
  - 2 x 4,600 MTPD
  - In Construction

- **Berun Project**
  - Location: Inner Mongolia, China
  - 100 KTA Glycol
  - 1 x 1,000 MTPD
  - 2014

KBR TECHNOLOGY

Operating
BED Completed, In Construction
Start-up
TRIG™ Coal to Chemicals – Inner Mongolia, China

1Q 2014 Start-up
First oxygen-blown TRIG™ gasifier

<table>
<thead>
<tr>
<th>Location</th>
<th>Inner Mongolia, China</th>
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<tbody>
<tr>
<td>Design Feedstock</td>
<td>High ash lignite feedstock from adjacent mine</td>
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<tr>
<td>Design Capacity</td>
<td>35,000 Nm³/hr Syngas</td>
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<tr>
<td>Product Use</td>
<td>Feedstock to 100 KTA Grassroots Ethylene Glycol Plant</td>
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| KBR Work Scope  | • Basic Engineering  
                  | • Proprietary Equipment  
                  | • Start-up Services |
| Project Progress| Engineering Completed, Equipment on Order, Construction in progress |
TRIG™ IGCC Refueling Project – Dongguan, China

Beijing Guoneng Yinghui Clean Energy Engineering Co., Ltd

120 MW IGCC
Plant owned and operated by Dongguan Tian Ming Electric Power Co., Ltd (TMEP)
KBR Scope of Supply - Total Commitment for Success

- TRIG™ Technology License
- Basic Engineering Design
- Support Services for Critical Equipment
- Supply of Proprietary Equipment
- Training, Commissioning & Start-Up Services
- Optional Performance Monitoring after Start-Up
For more information…

Visit coal.kbr.com or email coal@kbr.com