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is funded principally through a grant of the

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The Society gratefully acknowledges those companies that support the program by allowing their professionals to participate as Lecturers.

And special thanks to The American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) for their contribution to the program.
Transforming Stranded Gas Resources into Profitable Assets

Enabling technologies and the status of their commercialization

By Joe T. Verghese
ABB Lummus Global Inc.
Overview

- Stranded Conventional Gas
  - The Geography and Key Drivers
- Principal Technology Options
  - NGLs Extraction
  - Pipelines
  - Baseload and Mid-Scale LNG
  - GTL
  - CNG
  - Gas to Wire
  - Hydrates
- Technology Maturity & Delivery to Commercialization
- Conclusions
The Energy Mix

The Energy Mix is getting lighter

Gas now 25% of Primary Energy Consumption
Stranded Gas – The Components

Non-Associated Gas Prospects
- Remote from markets and pipeline infrastructure

Associated Gas Produced
- Gas Produced from existing crude oil production operations but quantities sub-economic for transport to market

Flared Gas
- Associated gas flared from mature oil production operations
Non-Associated Gas Reserves – Barriers to Monetization

- Stranded Gas Resource
- Substantial Contaminants CO₂/H₂S
- Lack of Pipeline Infrastructure
- Geographic Constraints
- Political Risks to Development
Associated Gas – Barriers to Monetization

- Sub-Economic production volumes
- High Capex for gas capture/export
- Production rate swings
The LPG FPSO Concept

NGL EXTRACTION OFFSHORE
- Extract Value from:
  - Flared Gas
  - Reinjected Gas

PRODUCTS
- NGLs (Propane and Butane)
- Mixed LPG
- Condensates
Pathways to Gas Utilization

- Compressed Gas Transport
- Liquefaction
- Chemical Conversion

- Pipelines
- CNG
- LNG
- GTL
- Methanol
- DME

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Gas Value Chain

Options:
- Removal/Stabilization of Condensates
- Dewpointing/Conditioning of Gas
- Removal of Acid Gas & other contaminants (N2, Hg, etc)
- NGL Extraction/ Fractionation

Alternative Transportation Modes:
- HVDC - Light
- GTL
- CNG
- Hydrates

Gas to Chemicals:
- MeOH
- DME
- NH3

Baseload LNG
- Mid-Scale or Niche LNG

Production & Gathering

Treating & Processing

LNG

Pipelines
Technology Application Bands

Stranded Gas

FIELD RESERVES (TCF) | PRODUCTION RATE (MMscfd)
---|---
6.6 | 1000
4.6 | 700
3.3 | 500
0.3 | 50

Baseload LNG

Niche LNG

CNG

DME

GTL

Methanol

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Gas Transportation Options

Distance to eventual markets, kms

- Gas Conversion
- LNG
- CNG
- Onshore Pipeline
- Offshore Pipeline
Mini/Mid-Scale LNG Technologies

Methane Expansion + Propane Refrigeration
LNG-Pro Scheme
U.S. Patent 5,755,114

Dual Expansion Methane / Nitrogen
U.S.Patent 6,412,302

Propane Pre-Cooled Dual Expansion Methane / Nitrogen
U.S.Patent 6,412,302

This scheme is the intellectual property of the Randall Division of ABB Lummus Global Inc.
Mini/Mid-Scale LNG Technologies

Dual Expansion Methane / Nitrogen
US Patent 6,412,302

Suitable for offshore deployment
Gas Liquefactionaction

UTILITY TARGET PROCESS COMPOSITE CURVES
COLD Utility Target — 0.0 Btu/F
Minimum Approach — 5.3 F

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Equipment Components

Plate Fin Heat Exchanger

Turbo-Expander

Gas Turbine Compression String

Methane Cycle

Nitrogen Cycle

Methane to BAHX

Nitrogen To BAHX
Development Concept – Niche LNG

Oil Development

- OIL
- FPSO

Associated Gas Feed Stock

Niche LNG Chain

- NICHELNG FPSO
- LNG TRADE CARRIER
- LPG CARRIER FOR SMALL PARCELS

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LNG Processes - Specific Energy

Cascade Refrigeration

- Pretreated Feed Gas
- Mixed Refrigerants
- LNG Product Pumps
- LNG Product to Storage

14 kW/ton LNG day

Mixed Refrigerants

- SMR
- DMR
- CMR
- Prico
- APCI

12.2 to 16.8 kW/ton LNG day

Turbo-Expander Cycles

- Methane Expander
- Nitrogen Expander
- Liquid Expander

12.5 to 16.5 kW/ton LNG day

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# ABB LNG Turbo-Expander Technologies

<table>
<thead>
<tr>
<th><strong>We Achieved:</strong></th>
<th><strong>Benefits:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Simplicity</td>
<td>Safe Operation - Simplicity of Operation - High Reliability - Cost Effective</td>
</tr>
<tr>
<td>Low Equipment Count</td>
<td>Lower CAPEX</td>
</tr>
<tr>
<td>Use of proven standard equipment (compressors, expanders, plate-fins)</td>
<td>Optimized Procurement Cycle</td>
</tr>
<tr>
<td>High Degree of Modularization</td>
<td>High Operational Availability (~ 3 years)</td>
</tr>
<tr>
<td>No Refrigerant Inventory</td>
<td>Reduced Plot Area</td>
</tr>
<tr>
<td></td>
<td>Minimal Flare Requirements</td>
</tr>
<tr>
<td></td>
<td>No Motion Impact</td>
</tr>
</tbody>
</table>
Gas to Liquids Value Chain

GTL CORE PROCESS

Conditioning

Reforming

FT Conversion

Hydrocracking

Syncrude Fractionation

Storage/Export

Associated Gas

Oil Production

Or

Stranded Gas

CH₄ + H₂O = CO + 3H₂
2CH₄ + O₂ = 2CO + 4H₂
CH₄ + 2O₂ = CO₂ + 2H₂O
CH₄ + CO₂ = 2CO + 2H₂

n CO + 2nH₂ = [-CH₂⁻] n + H₂O
n CO + (2n+1) H₂ = CnH₂n+2+nH₂O
Natural Gas Reforming Technologies

Typical Steam Methane Reforming
- Fuel
- Fired Heater
- Burners
- Catalyst Tubes
- Convective Heat Recovery
- Effluent Gas
- Steam
- Hydrocarbon Feed
- Stack

Typical Partial Oxidation
- Hydrocarbon Feed
- Oxygen
- Burner
- Refractory Lined Vessel
- Effluent Gas

Typical Autothermal Reforming
- Oxygen or Enriched Air
- Hydrocarbon Feed and Steam
- Burner
- Refractory Lined Vessel
- Catalyst
- Effluent Gas

Typical Gas Heated Reforming / O2 Reforming
- Oxygen
- Natural Gas
- Refractory Lined Vessel
- Effluent from Secondary Reforming
- Catalyst
# Fischer Tropsch Plants

<table>
<thead>
<tr>
<th>Installation</th>
<th>Operator</th>
<th>Age (years)</th>
<th>Capacity (bpd)</th>
<th>Plant Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sasol 1, Sasolberg (South Africa)</td>
<td>Sasol</td>
<td>47</td>
<td>5,000</td>
<td>Commercial</td>
</tr>
<tr>
<td>Sasol II and III, Sasolberg</td>
<td>Sasol</td>
<td>22/20</td>
<td>150,000</td>
<td>Commercial</td>
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<tr>
<td>Moss Gas, Mossel Bay, South Africa</td>
<td>Mossgas</td>
<td>11</td>
<td>22,700</td>
<td>Commercial</td>
</tr>
<tr>
<td>Shell, Bintulu (Sarawak), Malaysia</td>
<td>Shell</td>
<td>9</td>
<td>12,500</td>
<td>Commercial</td>
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<tr>
<td>Rentech</td>
<td>Fuel Processes Development Company</td>
<td>2</td>
<td>275*</td>
<td>Commercial</td>
</tr>
<tr>
<td>Baton Rouge</td>
<td>ExxonMobil</td>
<td>9</td>
<td>200</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Cherry Point</td>
<td>BP (Arco)</td>
<td>1999-2000</td>
<td>70**</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Ponca City</td>
<td>ConocoPhillips</td>
<td>Started up 2003</td>
<td>400</td>
<td>Demonstration</td>
</tr>
<tr>
<td>Nikiski</td>
<td>BP</td>
<td>Started up 2003</td>
<td>300</td>
<td>Demonstration</td>
</tr>
</tbody>
</table>

* Plant decommissioned/redeployed.  
** Plant decommissioned/redeployed to Tulsa (DOE’s Ultra-Clean Fuels Project)
Capex Trends For Fischer Tropsch GTL Technology

**CAPEX TRENDS**

- Installed Plant Reference
- Licensor 1 Expectation
- Licensor 2 Expectation
- Licensor 3 Expectation
- Licensor 3 Expectation (70,000 BPD)

- Conventional Refinery Benchmark
GTL Integrated Oilfield Architecture
Offshore Design Issues

Floater Based GTL Process Schemes

Vessel Motion Impact:
- Process System Performance
- Flexing of Vessel Deck and Stresses on Equipment/Piping Systems

Other Issues:
- Large Number and Complexity of Equipment in Intensified Layout
- High Equipment Weight, Weight Distribution and Point Loads
GTL Commercialization

Project Learnings

Commercialization Trajectory

Technology Development

Onshore Commercial Scale 80-150,000 BPD

Offshore Commercial Scale 15-30,000 BPD (Benign Environment)

Offshore Commercial Scale 15-30,000 BPD (Severe Environment)

Time

Pilot Plant

Onshore Demonstration Unit

Onshore Commercial Scale 20-80,000 BPD
Marine Transportation of CNG

CNG Fleet Size & Vessel Capacity = \( f \) (Gas Rate, Distance to Market)

- Modest Infrastructure at Production and Market Delivery Point
- Target Market Opportunities:
  - Gas Volume Rates of 200 - 500 MMScfd
  - Distances of 500 – 3000 kms

- Gas Transport in CNG Carriers
- Concepts offered by:
  - Coselle – Cran and Stenning, Calgary
  - Votrans – Enersea Transport, Houston
  - GTM – Transcanada Pipelines, Calgary

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Three principal approaches:
- Choice of materials to make lighter system
- Maximizing containment pressure to store more gas
- Chilling the gas to take advantage of favorable compressibility factor

CNG Containment Pressure Range:
- 1500 – 3500 psig

Use of Composite Pressure Vessels

Ship CNG Concept not commercialized to date
Gas (Energy) Transportation by HVDC

Gas Field → Power Station → Converter Station

SCALE (kilometres)

Market 1 → Market 2 → Market 3
Transmission Capability of Cables with the same Dimensions

Distance in km

Transmitted power %

Present AC
Future AC
HVDC Light
The Converter Station - Components

Converter Station

- AC bus
- Phase Reactor
- AC filters
- Converter
- DC Capacitor
- Control System

Transmission Cable

- HVDC to Markets
Gas Transportation as Hydrates

BG Group, Marathon, NTNU, Norway and others have been working on gas-to-solids technology

- Stranded gas transported to market as dry hydrates, hydrate pastes and hydrate in crude oil slurries.
- BG has laboratory tested reactor design and process schemes
- Concepts include storage and transport of gas:
  - either as atmospheric hydrates
  - or as paste in pressurized insulated containers
- Marathon has worked on proprietary process technology for production and shipping of stable slurries.
- NTNU has worked on concepts where frozen hydrates are mixed with refrigerated crude oil for atmospheric pressure transport.
Hydrates Processes for Storage & Transportation

**BG Scheme**

- Water
- Natural Gas

A series of CSTRs (10 to 15°C, 60 to 90 bar)

Gas/slurry separator

Hydrate slurry (10.5 vol/vol)

Screens and hydrocyclones

Hydrate slurry (75 vol/vol)

Shipping vessels (2 to 3°C, 10 bar)

Water back to reactor

Gas back to reactor

**NTNU Scheme**

- Fluid from production well
- Natural Gas

Separator

Pre-cooled water

Pre-cooled crude oil

Hydrate reactor (low temp. 90 bar)

Crude oil/hydrate slurry

Storage Tank (-10°C or lower, 1 atm)

Source: GasTIPS W. 2005
Technology Delivery to Commercialization

- Direct Methane Oxidation to Distillates
- Ionic Transport (Ceramic) Membranes
- Hydrates Transport
- DME
- CNG
- Fischer Tropsch
  - Shell ‘MDS’
  - Sasol ‘Synthol’
  - Rentech
  - BP
  - Exxon AGC-21
  - Syntroleum
  - ConocoPhillips
- LNG Shell ‘MDS’
- Methanol

Commercial Viability

R and D

Pilot Scale Plants

Commercial Scale Units

Technology Maturity Domains
Conclusions

Exploitation of Stranded Gas

Technology Portfolio

Stranded Gas Resources

Delivered $/MMBTU

Gas Markets

Pipelines
Gas by Wire
LNG
GTL
CNG
Hydrates