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Monetizing Natural Gas by Optimizing Transport

Xiuli Wang
Minerva Engineering Inc
World Natural Gas

Price inequality

![Price of Natural Gas Chart]

- Asia
- Europe
- USA
- Russia

$20 / MMBtu

$20

$15

$10

$5

$0
Agenda

• Background information on natural gas
  – Demand
  – Resources
• Transportation means
• Natural gas transportation optimization
Future Demand of Natural Gas

Global: 1.8%/yr
Non-OECD: 2.5%/yr
OECD: 0.9%/yr

Data source: IEA World Energy Outlook 29 May 2012
World Natural Gas Reserves vs. Ultimate Recovery

Share of World's Proven Gas Reserves, 187Tcm (6,609Tcf) 22%

Rest of World's Recoverable Gas, >662Tcm (23,390Tcf) 78%

Data source: EIA International Energy Outlook, 2010
Who Has the Natural Gas?

Data source: BP, 2013

<table>
<thead>
<tr>
<th>Country</th>
<th>Proved Reserves, Tcf</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iran</td>
<td>1186.8</td>
<td>18.0%</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>1162.1</td>
<td>17.6%</td>
</tr>
<tr>
<td>Qatar</td>
<td>884.8</td>
<td>13.4%</td>
</tr>
<tr>
<td>Turkmenistan</td>
<td>617.9</td>
<td></td>
</tr>
<tr>
<td>US</td>
<td>299.9</td>
<td></td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>290.7</td>
<td></td>
</tr>
<tr>
<td>United Arab Emirates</td>
<td>215</td>
<td></td>
</tr>
<tr>
<td>Venezuela</td>
<td>196.3</td>
<td></td>
</tr>
<tr>
<td>Nigeria</td>
<td>181.9</td>
<td></td>
</tr>
<tr>
<td>Algeria</td>
<td>159</td>
<td></td>
</tr>
</tbody>
</table>
Top Ten Gas Production/Consumption Countries

**2012 Production, Tcf/yr**

- US: 24.0
- Russian Federation: 20.9
- Iran: 5.7
- Qatar: 5.5
- Canada: 5.5
- Norway: 4.0
- China: 3.8
- Saudi Arabia: 3.6
- Algeria: 2.9
- Indonesia: 2.5

**2012 Consumption, Tcf/yr**

- US: 25.4
- Russian Federation: 14.7
- Iran: 5.5
- China: 5.1
- Japan: 4.1
- Saudi Arabia: 3.6
- Canada: 3.5
- Mexico: 2.9
- United Kingdom: 2.8
- Germany: 2.6
Stranded Gas

Data Source: IHS, EIA, and IEA, 2011
Natural Gas Transportation Modes

• Compression
  – Pipeline: most onland
  – Compressed natural gas (CNG)

• Convert gas to liquid
  – Liquefied natural gas (LNG)
  – Gas-to-liquids (GTL)

Key for transportation: reduce gas volume economically
2012 World Major Gas Trade Movements
in Billion Cubic Meters

BP, 2013

(~32%)

(~68%)
Offshore Pipelines

Source: www.nord-stream.com
## Offshore Pipeline Examples

<table>
<thead>
<tr>
<th>Pipeline Name</th>
<th>Greenstream</th>
<th>Nord Stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>2003</td>
<td>2012</td>
</tr>
<tr>
<td>Route</td>
<td>Libya to Italy through Mediterranean Sea</td>
<td>Russia to Europe through the Baltic Sea</td>
</tr>
<tr>
<td>Maximum Water Depth</td>
<td>3,698 ft (or 1,127 m)</td>
<td>689 ft (or 210 m)</td>
</tr>
<tr>
<td>Pipe Length</td>
<td>330 mi (or 531 km)</td>
<td>760 mi (or 1,224 km)</td>
</tr>
<tr>
<td>Pipe Diameter, inches</td>
<td>32</td>
<td>48</td>
</tr>
<tr>
<td>Lines</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Capacity/yr/Line</td>
<td>283 Bcf (or 8 Bcm)</td>
<td>971 Bcf (or 27.5 Bcm)</td>
</tr>
<tr>
<td>Total Cost, Billion $</td>
<td>6.6</td>
<td>11.5</td>
</tr>
<tr>
<td>Cost per Mile, MM $/mile</td>
<td>20</td>
<td>7.6</td>
</tr>
</tbody>
</table>

Data source: ENI, Nord Stream, Gazprom
Liquefied Natural Gas (LNG)

• Volume reduction ~600:1
  – By liquefaction @ -162° C (-260° F), ~1 atm
• Development since 1960s
• Capital investments:
  – Liquefaction and regasification terminals (~60%)
  – LNG ships (~40%)
• Energy-intensive
  – Energy-efficiency improving
Why Transport Natural Gas?

Data source: BP, 2013
Before and after earthquake (March 2011):
- LNG import quantity jumped 26%.
- Price: $550/t in 2010, jumped to >$850/t ($17.5/MMBtu) in 2012.
#4 LNG Consumer - China

- Average growth rate:
  - Production: 11.8%. **Consumption: 17.5%**

Wang et al., 2014
2012: 12% of the world total gas trades, 32% LNG movements. LNG: 63% to Asia Pacific. 29% to Europe and Eurasia. Rest: 8%.
#3 LNG Supplier - Australia

AUSTRALIA TO LEAD LNG FUTURE
BY MICHAEL J. ECONOMIDES AND XIULI WANG
Facts

- #13 in natural gas reserves (133 Tcf) in the world.
- #3 in exporting LNG (0.99 Tcf in 2012) after Qatar and Malaysia. Major buyers: China, Japan, South Korea.
- By 2017: LNG export capacity: 3 Tcf/yr

Industry prediction: **#1 LNG exporter by 2020.**
New Player in LNG – U.S.

U.S. LNG Export A Reality

US LNG?
LNG Cost Example

- Cost of delivered LNG from Sabine Pass to Europe/Americas & Asia = $8 - $10 / MMBtu.

<table>
<thead>
<tr>
<th></th>
<th>Europe/Americas</th>
<th>Asia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Henry Hub</td>
<td>$4.00</td>
<td>$4.00</td>
</tr>
<tr>
<td>Capacity Charge</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>Shipping</td>
<td>1.00</td>
<td>2.80</td>
</tr>
<tr>
<td>Fuel/Basis</td>
<td>0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>Delivered Cost</td>
<td>$8.10</td>
<td>$9.90</td>
</tr>
</tbody>
</table>

Data source: Cheniere, February 2012
New Players in LNG - Israel and Cyprus

(17-20 Tcf)
New Player in LNG - Mozambique
Compressed Natural Gas (CNG)

- Volume reduction ~200:1
  - At 200 atm (3,000 psi), ambient temperature
  - At 140 atm (2,000 psi), -20 °C (~0 °F)

- Capital investment example:
  - For 2.8 MMcm/d (100 MMscf/d), 100 miles, capital cost: $250 million, tariff: $3.2/MMBtu.
New Generation of CNG with Composite Containment
New Efficient and Scalable Ship Design

- Composite material – 60% lighter than steel and much stronger.
- Containment - larger diameter and at least twice as much pressure as metal container. Shrinkage: ~400:1.
- Higher ship design efficiency.
Containment System Capable of Carrying Raw Gas

- Liner: Anti-corrosion coating – handle raw gas with H$_2$S.
- Opportunities:
  - Monetize stranded gas – midstream.
  - Enhance oil production through raw gas disposal – upstream.
Gas-to-Liquids (GTL)

- Volume reduction: >700:1
- Requires large capital investments
- Qatar: major player
- Likely to account for small percentage of natural gas consumed
Offshore Natural Gas Transport Optimization
Conclusions

- Gas Demand Projection to 2035: sharply elevated.
- Monetize stranded gas: transportation optimization is the key.
- Pipelines and LNG: continue to grow and play a vital role.
- New generation of CNG: allow the gathering raw gas from offshore location.
Questions?
Your Feedback is Important

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http://www.spe.org/dl/