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and Petroleum Engineers (AIME) for their contribution to the program.
LNG – What’s Happening – and Why!

John Morgan

John M. Campbell & Company
$5 Billion Entry Fee
WHAT IS LNG

LPG – Liquid Petroleum Gas
NGL – Natural Gas Liquids
LNG – Liquid Natural Gas
Example LNG Properties
-162°C [-235°F] at atmospheric pressure

<table>
<thead>
<tr>
<th></th>
<th>Rich</th>
<th>Lean</th>
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<tbody>
<tr>
<td>nitrogen</td>
<td>0.3</td>
<td>0.5</td>
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<tr>
<td>methane</td>
<td>88.7</td>
<td>97.5</td>
</tr>
<tr>
<td>ethane</td>
<td>8.0</td>
<td>1.5</td>
</tr>
<tr>
<td>propane</td>
<td>2.0</td>
<td>0.5</td>
</tr>
<tr>
<td>butanes</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>approx. kg/m³</td>
<td>465</td>
<td>435</td>
</tr>
<tr>
<td>CV (higher) MJ/m³</td>
<td>42</td>
<td>38.5</td>
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</table>
An LNG Export Terminal with Multiple Expansions - Bontang, Indonesia
The Basic LNG Chain

Gas Production

LNG Production

Shipping

LNG Reception

Gas Utilization
Natural Gas Transportation Options

- Pipeline
- LNG
- Gas-to-liquids
- Electricity
- Uneconomic

Distance to market, km

MMscfd
Nominal Gas Transportation Efficiency

Ref. OG&J (May 15, 2000), p.64
Historical Development of LNG Trade – Last 25 Years

- Projects grow from less than 1 mta to 4-6 mta
- New supplies to Japan,
  first imports to Korea, 1987,
  and Taiwan, 1990
- Late 1990s – present
  - Slower growth in Asian LNG demand – economic upsets
  - Growth in LNG demand in Europe, USA and Caribbean
  - New supply projects in Atlantic Basin and Middle East
  - Today’s LNG trade
LNG Industry Growth

Source: CERA, CEDIGAZ
Demand is Met from Diverse Sources of Supply

© 2005 Source NPC
LNG Imports Are Needed, but Face Obstacles
The Basic LNG Chain

Gas Production

LNG Production

Shipping

LNG Reception

Gas Utilization
The Contract Chain

1. Exploration licenses, production-sharing contracts
2. Gas sales to LNG Producer
3. LNG production joint venture agreement
4. Condensate/LPG production and sale
5. Government and local authority agreements
6. LNG sale and purchase agreement between LNG producer and LNG buyers
Gas Production Platform
North Rankin A
North-West Shelf Project, Australia
The Basic LNG Chain

1. Gas Production
2. LNG Production
3. Shipping
4. LNG Reception
5. Gas Utilization
Contaminants

What’s in gas (besides light hydrocarbons)?

H₂O  CO₂  H₂S  S  He  N₂  Cl  Hg  As

Waxes  Asphaltenes etc.

Sand  Dinosaur Dust

Lubricants  Corrosion Inhibitors

Mystery Stuff, etc.
Mixed Refrigerant LNG Process
Overview of LNG Production Facilities Technologies

• Established Technologies
  – ConocoPhillips (Optimized Cascade)
  – APCI (Propane Precooled)

• New Process Technologies
  – APCI (AP-X)
  – Linde (MFC)
  – Shell (PMR)
  – IFP (Liquefin)
ConocoPhillips Optimized LNG Process
Overview of LNG Production Facilities Trends

• Larger facilities
  – Bigger Trains
  – Bigger Turbines

• Reduce Environmental Impact
  – \( \text{CO}_2 \)
    • Produced with gas
    • Developed by turbines
  – \( \text{NO}_x \)
  – Marine Environment
Typical Project Schedule

Greenfield LNG Export Project

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>9</th>
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<td>design</td>
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<td>LNG Plant</td>
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<td>concept design</td>
<td>FEED</td>
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<td>ship building</td>
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<td>Project Structure &amp; Evaluation</td>
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<td>negotiations -j.v.</td>
<td>evaluation</td>
<td>first LNG exports</td>
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<td>Markets</td>
<td>artanalysis</td>
<td>marketing, sales agreements</td>
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<td>Financing</td>
<td>advice and analysis</td>
<td>securing financing</td>
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</tbody>
</table>
The Basic LNG Chain

Gas Production

LNG Production

Shipping

LNG Reception

Gas Utilization
1959 – The Methane Pioneer
Partial Loading of LNG Cargoes

Photo Courtesy of ABS
The Basic LNG Chain

Gas Production → LNG Production → Shipping → LNG Reception → Gas Utilization
Reduce Environmental Impact

• Reduce CO2
  – Inject Produced CO2
  – Install most efficient drivers
    • Cogeneration
    • Larger Turbines
    • Electric Motor Drivers

• Reduce NOx
  – Install “Clean-burn” technology

• Effect on Marine Environment
  – Use of air coolers
Negishi Terminal, Japan: Single Containment Tanks (background) Inground Tanks (foreground)
## Costs in an LNG Project

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost Range</th>
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<tbody>
<tr>
<td>Gas Gathering</td>
<td>US$ 1 – 1.5 billion</td>
</tr>
<tr>
<td>Liquefaction (1 train)</td>
<td>US$ 1 – 1.5 billion</td>
</tr>
<tr>
<td>Ships 5 @ $180 m</td>
<td>US$ 0.9 billion</td>
</tr>
<tr>
<td>Regasification</td>
<td>US$ 0.5 billion</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>US$ 3.4 – 4.4 billion</strong></td>
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</table>

Could easily reach $5,000,000,000
The Basic LNG Chain

- Gas Production
- LNG Production
- Shipping
- LNG Reception
- Gas Utilization
Seasonal Demand Pattern
Europe & North America

Winter

Maximum Capacity

Annual Average

Take or Pay Quantity

Actual Demand/Take

Summer

January

December
**Gas Markets**

- **Residential & Commercial**
  - Heating demand highly seasonal (low load factor)
  - No fuel switching capabilities

- **Industrial**
  - Fuel for factories, chemical plants, steel mills, etc.
  - Power generation for factories, chemical plants, steel mills, etc.
  - Chemical feedstock – ammonia, methanol, GTL
  - High load factor
  - Fuel switching capability
Gas Markets

- Power Generation
  - Combined cycle most popular
    - GT + waste heat boiler  Eff.~55%
    - Low CO$_2$ emissions
      - 7 – 8 tonnes/MW compared to
        - 25 – 27 tonnes/MW for coal
  - Higher load factor than residential & commercial
  - Quick response to demand swings
  - Summer demand higher than winter (A/C)
  - Fuel switching capability
The 9EC's 18-stage compressor was derived from the MS9001E through a combination of scaling and limited radial extension of the outer annulus.
GE GAS TURBINES
H-Technology

400-480 MW combined cycle output

Firing at 2600°F, 1430°C

23:1 compressor, 18 stages

4 stage turbine

60% combined cycle efficiency
Example Heating Values

- Japan – Power Plant
- USA - Florida
- UK

Adapted from: Bramoulle, Morin and Capelle, “LNG Quality and Market Flexibility Challenges and Solutions”, LNG 14, Doha, Qatar 2004
Commercial Trends

- Continued downward pressure on LNG costs
- More competition, more risk-taking. Global supply strategies
- Building ships/terminals in advance of firm supply/sales contracts. Merchant facilities
- Increasing power generation market
- Regional market trends
  - Europe. Open access. Market related prices. LNG and pipeline supplies.
  - Central/South America.
- Market niches: small-scale supply projects, reception, satellites.
LNG – What’s Happening – and Why!
UK Gas Supply and Demand

Note: supply represents UKCS producing, UKCS proposed and existing UK imports

Adapted from: David Haynes & Paul Martin
LNG is Coming Home
GASTECH 2005, Bilbao, Spain
Some of Today’s Challenges in LNG…..Many

- Permits for US Imports
- Crews for LNG Carriers
- LNG quality variations
- Security
- Materials and Staffing
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