LNG as a Sustainable Fuel of the Future

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Presented by:
Abul Bashar
Asst. Principal Research Engineer
KOMtech
Keppel Offshore & Marine (KOM) is the global leader in providing solution for-

- **Technology**
  Provider of innovative and cost-effective solutions for the offshore and marine industry.

- **Specialised Shipbuilding**
  Builder of distinction for advanced vessels serving all frontiers.

- **Offshore**
  Leader in the design, construction and repair of mobile offshore rigs.

- **Marine**
  Trusted name for the repair, conversion and upgrading of a diverse range of vessels.
LNG as a Sustainable Fuel of the Future

Sustainable Energy

Any energy generation, efficiency & conservation source where:

- Resources are available to enable massive scaling of energy generation for long term, preferably 100 years.
- Low to zero Carbon footprint
- Energy independence from one main region or country is fostered.
- It helps fuel a long term vibrant economy and significant job opportunities.

Sustainable Fuel

If any fuel produces such energy may consider as sustainable fuel.
LNG as a Sustainable Fuel of the Future

LNG will only be sustainable fuel, if-

• It has enough reserve
• It is environmentally friendly
• It is cost effective,
• It has proven technology, and moreover,
• Users are confident in using it

But, the confidence depends the understanding of LNG as a safe fuel and the above parameters
What is Natural Gas (NG)

Natural gas is a fossil fuel; a flammable gas, consisting largely of methane (CH4) and other hydrocarbons with a traceable amount of CO₂, N₂, and hydrogen sulfide (H₂S); occurring naturally underground.

In the 19th and early 20th century, such unwanted gas was usually burned off at oil fields. Today, that unwanted gas is economically transporting from a well site to an end user via pipelines or exporting to far end as Liquefied Natural Gas (LNG).
**Composition of Natural Gas (NG)**

<table>
<thead>
<tr>
<th>Composition</th>
<th>H/C Ratio</th>
<th>Source-A (%)</th>
<th>Source-B (%)</th>
<th>Source-C (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1% mol</td>
<td>4.00</td>
<td>93.75</td>
<td>91.85</td>
<td>90.28</td>
</tr>
<tr>
<td>C2% mol</td>
<td>3.00</td>
<td>6.17</td>
<td>5.57</td>
<td>6.33</td>
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<tr>
<td>C3% mol</td>
<td>2.67</td>
<td>0.05</td>
<td>2.04</td>
<td>2.49</td>
</tr>
<tr>
<td>iC4% mol</td>
<td>2.50</td>
<td>0.00</td>
<td>0.27</td>
<td>0.49</td>
</tr>
<tr>
<td>nC4% mol</td>
<td>2.50</td>
<td>0.00</td>
<td>0.19</td>
<td>0.00</td>
</tr>
<tr>
<td>iC5% mol</td>
<td>2.40</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>nC5% mol</td>
<td>2.40</td>
<td>0.00</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>H₂S</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>CO₂% mol</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>N₂% mol</td>
<td>0.03</td>
<td>0.07</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>Methane Number</td>
<td>99.8</td>
<td>96.2</td>
<td>92.90</td>
<td></td>
</tr>
</tbody>
</table>

Natural gas from different reserves are with different composition.
What is LNG

Liquefied Natural Gas (LNG) is the liquid form of natural gas (predominantly methane, CH₄) cooled at (-)162°C.

- Natural Gas (NG) is turned into liquid, called LNG, for mass transportation and storage.
- It takes up about 1/600th the volume of natural gas.
- LNG is not used directly in any case. It is turned back to gas and then used for various purposes.
Basic Property of LNG

- The “boiling point” of LNG is -162°C, a cryogenic temperature. LNG evaporates at this temperature.
- LNG is odorless, colorless, non-toxic, non-corrosive.
- While natural gas is flammable, LNG is not.
- Auto ignition temperature of LNG (599°C) is much higher compared to conventional liquid fuels, such as MDO (260~371°C), Gasoline (226~471°C).
- LNG vapour is lighter than air. If LNG spills on the ground or on water and the resulting flammable mixture of vapour and air does not encounter an ignition source, it will warm, rise and dissipate into the atmosphere.
- LNG leaves no residue when evaporates.
**LNG as a Cleaner Fuel**

The liquefaction process of LNG eliminates the impurities of natural gas.

- LNG is free from higher order hydro-carbon elements
- No Carbon-di-Oxide, CO$_2$
- No sulfur components
- No Nitrogen components, and
- No solid particles present in LNG

LNG is inherently a cleaner fuel and thus, burning LNG-
- *Reduces Carbon Emissions*
- *Reduces NOx Emissions*
- *Zero Particulate Matter (PM) Emissions*
- *Zero Sulfur Emissions*
Prevention of Air Pollution By Ship

As per MARPOL Annex-VI, IMO imposes stricter limits on NOx, SOx, PM emission from ship’s exhaust.

- Most of the engines with conventional liquid fuels (HFO, MDO) can not meet IMO’s Tier-III requirement.
- IMO’s NOx requirement in ECAs will delay from 2016 to 2021. But, The US and Canada adopted IMO Tier III equivalent NOx limits within the North American ECA, effective from 2016.
Various Options to deal with ECA requirements

- LNG, as a single fuel, has the properties to satisfy all Annex-VI requirements.
- Supremacy of LNG fuel over other solutions to meet Annex-VI, reduces the risk part as compared to other solution.
LNG is supreme for SOx, NOx & PM removal from engine exhaust

- SOx $\rightarrow$ 0%
- NOx $\rightarrow$ 20%
- PM $\rightarrow$ 0%
- CO2 $\rightarrow$ 70%

Compared to other solutions, LNG perfectly meets MARPOL Annex-VI with no doubts.
Worldwide proven conventional gas reserves are estimated at around 187 trillion cubic meters (tcm) or about 56 times current annual global gas production. However, recoverable gas resources are estimated at around 440 tcm. Estimated recoverable unconventional resources are around 240 tcm. Altogether, this would last around 220 years, based on current rates of gas consumption.

International Energy Agency
http://www.iea.org/aboutus/faqs/gas/

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country/Region</th>
<th>Natural gas proven reserves ( m^3 \times 10^9 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>World</td>
<td>187.3</td>
</tr>
<tr>
<td>1</td>
<td>Russia</td>
<td>48.7</td>
</tr>
<tr>
<td>2</td>
<td>Iran</td>
<td>33.6</td>
</tr>
<tr>
<td>3</td>
<td>Qatar</td>
<td>24.7</td>
</tr>
<tr>
<td>4</td>
<td>Turkmenistan</td>
<td>17.5</td>
</tr>
<tr>
<td>5</td>
<td>United States</td>
<td>9.9</td>
</tr>
<tr>
<td>6</td>
<td>Saudi Arabia</td>
<td>8.6</td>
</tr>
<tr>
<td>7</td>
<td>Iraq</td>
<td>6.4</td>
</tr>
<tr>
<td>8</td>
<td>Venezuela</td>
<td>5.7</td>
</tr>
<tr>
<td>9</td>
<td>Nigeria</td>
<td>5.1</td>
</tr>
<tr>
<td>10</td>
<td>Algeria</td>
<td>4.5</td>
</tr>
</tbody>
</table>
LNG Price Compared to Conventional Fuel

**Henry Hub Natural Gas Spot Price**

- Mar 13 '15: HHNGSP 2.72

**Bunkerworld Oil Prices**

- 1mt of 0.1%S Fuel: US$630.00
- 1 Gallon of 0.1%S Fuel: US$2.03

<table>
<thead>
<tr>
<th>1MMBTU of LNG</th>
<th>US$2.72</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Gallon of LNG</td>
<td>US$0.89</td>
</tr>
</tbody>
</table>
LNG Price Compared to Conventional Fuel

Fuel Cost Saving in using LNG

\[ \frac{2.02 - 0.89}{2.02} \times 100\% = 56\% \]

So, How much is the total fuel cost saving-

• Per day?
• Per year??
• In the life-cycle of the ship???

Natural gas prices (including LNG) has been reduced the last two years due to the introduction of shale gas in the US market. Hence, LNG has improved its competitiveness to conventional fuel, especially on ECA areas where exhaust gas cleaning is necessary.
LNG Fueled Engines

Single Fuel (SF) Gas Engine

- Rolls-Royce
- MTU
- MHI

Dual Fuel (DF) Gas Engine

- Niigata
- Caterpillar
- Wartsilla
- Anglo Belgian Corporation (ABC)

Other engine manufacturers are also coming up with LNG fuel engines.

- Lean burn engine ensures complete combustion of fuel, hence higher efficiency.
- LNG fueled engine burns 10~15% less fuel than conventional fuel engines.
- LNG fueled Engines meet IMO Tier III requirements without any after treatment.
Fuel LNG Containment

- **Type C Tank**
  - Can be installed within hull or on deck

- **GTT Exoskeleton - Self Supporting Tank**
  - Developed to be installed on deck

- **IHI (SPB) Tank**
  - Type B tank installed within hull

- **GTT Membrane Tank**
  - Hull Integrated tank
LNG Vaporizer-The Fuel Treatment System

Numerous companies have come-up with proven and patented LNG vaporizers suitable for marine application. These vaporizers are mostly using engine waste heat to heat-up the LNG into gas, as required for burning into the engine. Some of these companies are:

- KOMtech
- Wartsila
- Cryonorm
- Taylor Wharton
- Cryostar
- TGE
- Charts

KOMtech’s patented LNG vaporizer design
Statistics of LNG Fuel Ship Past-Present-Future

LNG fueled ships are feasible

LNG - The Sustainable Fuel in the Future
NORWAY: A Look at Recent LNG Marine Fuel Developments

Norway has built natural gas powered vessels to support the North Sea oil and gas industry. Simultaneously, they are investing for LNG bunker and LNG Transportation system.

LNG fueled Platform Supply Vessel ‘MV Viking Princess’. 500 m³ Onshore LNG Bunker Station at Halhjem ferry terminal. Resupply of LNG storage tanks from a road truck.

LNG fuel supply chain is working efficiently in Norway.
EU Co-financed Projects for Marine LNG Fuel Developments

European Union via **European Maritime Safety Agency (EMSA)** is co-funding in different projects for developing Marine LNG Fuel Application

<table>
<thead>
<tr>
<th>LNG Projects</th>
<th>Project Purposes</th>
<th>Funding (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modernizations of Dunkirk Port</td>
<td>Technical design for the construction of LNG bunkering station</td>
<td>2,200,000</td>
</tr>
<tr>
<td>Make a difference</td>
<td>To identify and minimize the barriers and operating a LNG fuelled vessel</td>
<td>1,247,000</td>
</tr>
<tr>
<td>BLUE CHANGE</td>
<td>Conducting studies to evaluate use of Liquefied Natural Gas (LNG) as fuel in Gijon</td>
<td>1,108,000</td>
</tr>
<tr>
<td>Costa</td>
<td>Develop a harmonized approach towards LNG bunker filling practice in the Baltic Sea region</td>
<td>1,697,020</td>
</tr>
<tr>
<td>Infrastructure for ship’s LNG filling stations</td>
<td>Feasibility study of LNG filling station infrastructure as well as a full scale pilot action</td>
<td>9,569,500</td>
</tr>
<tr>
<td>LNG network in the eastern Mediterranean</td>
<td>Studies to support the use of liquefied natural gas (LNG) as marine fuel in the eastern Mediterranean</td>
<td>2,500,000</td>
</tr>
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</table>
LNG Fuel & Bunkering- Singapore MPA’s Efforts

Singapore's effort in support of LNG as a marine fuel

- Singapore MPA has discussed with European Port Authorities on harmonizing LNG bunkering standards and procedures.
- MPA will provide funding of up to $2 million per vessel for up to 6 LNG-fueled vessels to encourage marine industries for adopting LNG as a fuel.
- MPA will be commencing work on a pilot programme by early 2017 with interested parties of the LNG bunker supply chain.

In MPA’s pilot programme, MPA is evaluating the most cost-effective method of supplying fuel LNG to the LNG fueled ships.
Summary

Shipping industries are focusing on LNG as a marine fuel, preparing the ground for rapid introduction of LNG as a fuel for ships in the future, because:

- LNG is safe to use as a fuel either in marine or onshore facilities
- LNG reserves are enough to ensure its sustainability
- LNG fuel perfectly meets MARPOL Annex-VI with no doubts compared to other solutions.
- LNG fuel is much cheaper than conventional fuel
- LNG technology is matured to use in marine industry.
KOM’s 65T BP LNG Fueled ASD Tug

MPA’s ‘Outstanding Maritime R&D and Technology Award-2015’ winner
THANK YOU