LNG Basics and status of LNG fuelled ships

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FOUNDED
• DNV in 1864 and GL in 1867 with purpose of Safeguarding Life, Property & the Environment

PEOPLE
• 16,000 employees with 400 offices in 100 countries (almost 600 years of experience)
• Highly qualified surveyors & engineers with extensive knowledge in all disciplines

TECHNOLOGY
• 5% Revenue (MUSD170) devoted to R&I => Leadership in Standards & Innovation

Maritime Services:
 o Ship & Offshore Classification
 o Advisory Services
 o Verification
Agenda

A. The background and drivers for the use of LNG as a marine fuel

B. Safety challenges, risks and hazards with LNG

C. Rules and regulations on vessels and bunkering

D. Innovation in vessel design and concepts

E. LNG Ready
The drivers for alternative fuels in shipping are interlinked

<table>
<thead>
<tr>
<th>Fuel prices and competiveness</th>
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<tbody>
<tr>
<td>More stringent environmental regulations</td>
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<tr>
<td>Availability of new energy sources</td>
</tr>
<tr>
<td>Stakeholder pressure to manage environmental and climate risks</td>
</tr>
</tbody>
</table>
Possible developments towards 2030 -

**Adopted**
- EU Recycling Regulation
- US BW requirements
- EEDI phase 1
- 0.1% ECA sulphur limit
- NOx tier III for new builds in North America
- EU CO₂ monitoring, reporting and verification
- EU 0.5% sulphur cap
- EEDI phase 2
- Operational requirements on CO₂
- Additional ECAs established
- HK Recycling convention ratified
- Global CO₂ monitoring, reporting and verification
- 0.5% global sulphur cap
- EEDI phase 3
- BC, noise, biofouling and VOC regulation
- 0.5% global sulphur cap
- EEDI phase 4

**Possible**

2015 2016 2018 2020 2025 2030
More stringent regulations on emissions to air

**Existing fleets**

**Requirement**
- 2012: SOx < 1.0%
- 2015: SOx < 0.1%

**Compliance options**
- HFO + scrubber
- Distillate fuels
- LNG

**Newbuilds**

**Requirement**
- 2016: NOx Tier 3

**Compliance options**
- Scrubber + SCR
- LNG, NOx abatement
Current status of LNG fuelled ships
Gas for propulsion - before year 2000

- CNG as fuel in ships in Russia, Netherlands, US, Canada, Australia
- Gas engine installations offshore (FPSOs)
- LNG carriers (dual fuel boiler / steam turbine propulsion)
- Today about 420 LNG Carriers in operation
Market Change
150 confirmed LNG fuelled ship projects + Abt 40 Gas Ready

Development of LNG fuelled fleet

Number of ships

Year of delivery

Ships in operation
Ships on order
LNG ready ships

Updated Aug 2015
Excluding LNG carriers and inland waterway vessels
LNG uptake by vessel segment

<table>
<thead>
<tr>
<th>Vessel Segment</th>
<th>In operation</th>
<th>On order</th>
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</thead>
<tbody>
<tr>
<td>Specialized vessel</td>
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<tr>
<td>Tug</td>
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<td>Ro-Ro</td>
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<td>RoPax</td>
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<td>PSV</td>
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<td>Patrol vessel</td>
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<tr>
<td>Oil/chemical tanker</td>
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<td>HSLC</td>
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<tr>
<td>General Cargo</td>
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<td>Gas carrier</td>
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<td>Cruise ship</td>
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<tr>
<td>Container ship</td>
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<tr>
<td>Car/passenger ferry</td>
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<td>25</td>
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<tr>
<td>Car carrier</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Bulk ship</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Updated Aug.2015
Excluding LNG carriers and inland waterway vessels
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Contents

- Properties of Natural Gas
- LNG Hazards and Safety issues
- Risk mitigation
Why is natural gas better?

- Sulphur free
  - SO\textsubscript{x} emissions 100 % reduction

- Burned in lean mixture in combustion engine
  - Low temperature $\rightarrow$ NO\textsubscript{x} emissions substantially reduced ($\sim 90\%$ reduction)
  - Lean burn engine - efficient engine without “engine knocking” (uncontrolled self-ignition)
  - Gas diesel: Also some reduction in NO\textsubscript{x}

- Clean combustion – particles almost eliminated

- Methane, CH\textsubscript{4}, has less carbon to hydrogen than oils
  - CO\textsubscript{2} emissions reduced compared to oil combustion ($\sim 20\%$ reduction)

VS
**LNG Properties**

- 96% methane (CH4) => Cleanest burning fuel
- Flammable 5 to 15% conc. in air => burns with lazy flame
- Liquefied at -259 deg F (-162 deg C) => Stored in Cryogenic materials
- Density 42% of water
- Expands 600 times
- Colorless
- Odorless
- Non Toxic
- Non Corrosive

**Facts**

- In liquid, not flammable or explosive
- In gaseous state is not explosive if unconfined
- Is flammable, but with high auto ignition temp of 595 C (vs 210 C for diesel)
- If released will initially settle to bottom and rise as it warms up.
- Is lighter than air, and vaporise and disperse with prevailing wind
- Ignited cloud will not burn back to source, unless its concentration is in flammable range
Main safety challenges using natural gas as fuel

• Fire/ explosion risk

• Low temperature (Cryogenic spill)

• Tank high energy content
Main safety challenges using natural gas as fuel

- Explosion/ fire risk
  - High auto ignition temperature: around 600°C (~ 210°C for diesel)
  - Ignitable by sparks in mixture with air: 5-15%
LNG Basics and Risk

Main safety challenges using natural gas as fuel

- Low temperature of liquid gas / cold jets from compressed natural gas
  - LNG at -163°C
  - Normal steel will become brittle
- Human exposure – Frost burns
LNG Basics and Risk

Main safety challenges using natural gas as fuel

• What are potential consequences of an LNG tank failure?

• Gas tank large energy content
  - Protection from ship side and bottom (collision and grounding)
  - Protection from external fire
  - Protection from mechanical impact
Risk Mitigation and Safety measures
Risk Mitigation and Safety Measures

Principle: Equivalent safety as with diesel fuel

Measures

- Containment and protection
- Design, analysis and material selection
- Segregation of spaces - Area classification
- Removal of ignition sources
- Monitoring, safety systems, ESD
- Ventilation
- Active and passive fire protection
- Training and competence
Materials for LNG

1. What is special about materials related to LNG?

- Low temperature; steels may become brittle (break like glass)
- Shrinkage when cooling down
Metallic materials for Low Temperature Service

- Fine grained C-Mn Steels
- Ni - alloy steels
- Invar (36% Ni)
- Austenitic (stainless) steels
- Aluminium

with good toughness properties at low temperatures
Segregation
Arrangement of Engine Room

Gas safe machinery space

- Machinery space considered gas safe under all conditions
- Fully enclosed gas tight double gas pipes in engine room, all the way to the combustion chamber
- Double pipes with extraction ventilated 30 air changes and gas detection or inert gas filled with pressure monitoring (same as IGC code)
- The concept is mandatory for high pressure piping (>10 bar), but can also be used with low pressure installations
ESD Protected machinery space

- ESD protected machinery spaces are considered non-hazardous under normal conditions, but under certain abnormal conditions may have the potential to become hazardous
- Single wall gas piping
- Pressure in gas supply lines shall be less than 10 bar
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Overview on applicable Regulations and Rules
LNG as a fuel for ships - the rules and regulations

- 2001 first DNV Class rules for gas fuelled ships
- 2004 NMD proposal to develop the IMO IGF Code
- 2010 IMO MSC.285(86) issued
- DNV GL RP-0006: Recommended Practice for the development and operation of LNG bunker facilities (published Nov 2013)
- ISO TS 18683, Jan 2015: ISO Guidelines for systems and installations for supply of LNG as fuel to ships
- DNV GL rules for LNG bunker ships (June 2015)
- DNV GL class notation on GAS READY(June 2015)

August 2015:
In operation: 65 ships (2000/2015)
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More real life examples supporting innovation [1/2]

Fjord1 (Ferry)
MF ‘Glutra’ is the world’s first gas ferry to operate on LNG. The vessel is DNV GL classed and marked the first development of rules for gas-fuelled vessels. The company started operating ‘Glutra’ in Møre and Romsdal County in 2000. The ferry route serving the coastal trunk road in Rogaland and Hordaland Counties has since 2007 been served by five such ferries from Fjord1. The magazine “Skipsrevyen” awarded the prize “Ship of the Year 2000” to Glutra’s owner and operator Møre og Romsdals Fylkesbåtar and to the Langstein Yard of Tomrefjord, Norway for their newbuilding of M/F Glutra.

Elidesvik Shipping AS (PSV/OSV)
Designed by Wärtsilä ship Design, classed by DNV GL and built by Kleven Verft AS in Norway, the ‘Viking Energy’ is the world’s first LNG-powered supply vessel. The vessel was delivered in April 2003, and is chartered to Statoil for delivering supplies to oil and gas platforms in the North Sea. The vessel has dual-fuel engines installed and can operate both on LNG and liquid fuel.

Buquebus (High Speed Craft)
‘Francisco’, classed in DNV GL, entered service with Buquebus in South America in 2013. The vessel operates between Buenos Aires and Montevideo at 50 knots fully loaded (1,000 passengers and 150 cars). It is the first vessel to have been built under the HSC (High Speed Craft) Code with power by gas turbines using natural gas as the primary fuel.
More real life examples supporting innovation [2/2]

Tarbit Shipping AB (Tanker)
The 25,000 dwt product tanker Bit Viking was the first vessel ever to undergo a conversion from Heavy Fuel Oil (HFO) to Liquefied Natural Gas (LNG) operation. The vessel is DNV GL classed, has Wärtsilä engines two 500 m³ LNG fuel tanks and is most environmentally friendly product tanker in the world.

Fjord Line (Cruise ferry)
MS Stavangerfjord (2013) and MS Bergenfjord (2014), both classed to DNV GL, are cruise ferries with a capacity of 1,500 people and 600 cars. Both vessels operate between Norway and Denmark and perform LNG bunkering operations in both ends.

Crowley (Con-Ro vessels)
Crowley Maritime is building two con-ro vessel (2400 TEU + abt. 400 vehicles) at VT Halter with US flag and to DNV class. The ships will enter service in 2017 and engage in Jones Act trade between Jacksonville, FL and Puerto Rico. The vessels have a single low speed dual fuel engine.
LNG Fuelled Kamsarmax Bulk Carrier (Oshima & DNV GL)
**The innovative Oshima solution – vessel design**

**Key challenges:**
- Keep the same cargo capacity
- Limited space on deck
- Accommodate up to 3,000 m$^3$ of LNG

**Solution:**
- Unique U-shaped superstructure
- LNG tank protected by a steel cover forming a box which is part of the hull structure and provides additional safety
LNG Fuelled Bulk Carrier concept by GTT
FSG Sea Road LNG-powered 181-meter RoRo ferry
Portable LNG fuel tanks
The number of LNG bunker vessels is growing rapidly – bunkering by ship seems to be a preferred solution

<table>
<thead>
<tr>
<th>LNG bunker vessel overview</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG bunker vessels in operation</td>
<td>1</td>
</tr>
<tr>
<td>Existing small scale LNG carriers capable of performing bunkering</td>
<td>2</td>
</tr>
<tr>
<td>LNG bunker vessels on order</td>
<td>4</td>
</tr>
<tr>
<td>LNG bunker barges on order (US)</td>
<td>1</td>
</tr>
</tbody>
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There are four steps to become LNG ready

1. FUEL DECISION SUPPORT
   - Operational profile
   - Concept design (tank size & location)
   - Financial assessment (CAPEX, OPEX, pay-back time and sensitivity analysis)
   - Fuel availability
   
   Basis for investment decision and outline specification

2. CONCEPT REVIEW
   - Review of engine and tank type selection
   - Concept Design Review
     - Rules and regulations
     - Fit for purpose and best practice
   - Concept HAZID

   Basis for yard/designer negotiations

3. APPROVAL IN PRINCIPLE
   - For novel designs
   - For LNG Ready designs

   Basis for contract

4. RISK ASSESSMENT
   - Assessment of safety level of LNG fuel system (mandatory by IMO)

   Basis for acceptance by administration

CLASS APPROVAL
(after vessel is ‘LNG Ready’)
DNV GL believe that LNG will become a major fuel

LNG as a fuel is now a proven and available solution and potential to be the most relevant fuel for environmental sustainable shipping.

The barriers to using LNG as fuel are being dismantled.

LNG as a fuel must be seriously considered for all new builds.

Partnerships and close cooperation is vital for commercial projects to succeed in this early phase.

The (commercial) risk of choosing LNG is still perceived high – but what is the risk of not considering LNG as a fuel?
Your questions!
Thank you for your kind interest!

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