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- TGE Company Profile
- Sources of LNG for use as ship’s fuel
- Small scale LNG shipping
- Distribution & Bunkering
- Cost overview
- Conclusions
TGE Marine is a long established market leader in the design and construction of cargo handling systems for ships and offshore units carrying liquefied cryogenic gases (LNG, LPG and petrochemical gases).

- Personnel: approx. 60 engineers & specialists plus temporary staff
- Main Office: Mildred-Scheel-Str. 1, 53175 Bonn, Germany
- Branch Office in Shanghai, China

Business activities and expertise

Cargo handling systems and cargo tanks for Gas Carriers
- LPG carriers, CO₂ carriers
- Ethylene carriers
- LNG carriers

Cargo handling systems for Offshore units
- FSO/FPSO for LPG
- FSRU and FPSO for LNG
- CO₂ liquefaction, storage and offloading units

Fuel Gas Systems for seagoing vessels
- Fuel gas supply systems
- Fuel gas tanks
- RoRo, Container, Ferries, …
- Bunker Barges, Bunker Boats
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LNG Bunker market potential North Sea/Baltic Sea

- Study of MAGALOG (Maritime Gas Fuel Logistic) for LNG as clean fuel has identified RoRo-ships, RoPax-ships and container-feeder as potential candidates for LNG propulsion systems

Table: North + Baltic Sea annual fuel consumption (HFO,MDO):

<table>
<thead>
<tr>
<th>No.</th>
<th>Type</th>
<th>Power</th>
<th>Consump. HFO/MDO</th>
</tr>
</thead>
<tbody>
<tr>
<td>182</td>
<td>RoRo ships</td>
<td>12,000 kW</td>
<td>1,200,000 t/a</td>
</tr>
<tr>
<td>189</td>
<td>RoPax + super fast</td>
<td>20,000 kW</td>
<td>1,900,000 t/a</td>
</tr>
<tr>
<td>215</td>
<td>Container-Feeder</td>
<td>8,000 kW</td>
<td>1,200,000 t/a</td>
</tr>
<tr>
<td>586</td>
<td>Total</td>
<td></td>
<td>4,300,000 t/a</td>
</tr>
</tbody>
</table>
LNG Market potential for North Sea/Baltic Sea

- MAGALOG study predicts a potential of 10 new ships (RoRo + RoPax) per year fuelled by LNG, considering age profile and market growth; retrofitting technically not easy
- Similar potential for new container-feeders fueled by LNG, hence for this study we have assumed 10 new ships per year

Annual consumption of LNG based on 10 new ships/a each of RoRo+RoPax and container feeder:

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>RoRo + RoPax</td>
<td>85,000 t/a</td>
<td>170,000 t/a</td>
<td>255,000 t/a</td>
<td>340,000 t/a</td>
</tr>
<tr>
<td>Container-feeder</td>
<td>60,000 t/a</td>
<td>120,000 t/a</td>
<td>180,000 t/a</td>
<td>240,000 t/a</td>
</tr>
<tr>
<td>Total</td>
<td>145,000 t/a</td>
<td>290,000 t/a</td>
<td>435,000 t/a</td>
<td>580,000 t/a</td>
</tr>
</tbody>
</table>

Potential LNG sources for bunker market

- Three options have been evaluated:
  - Supply from small scale LNG production (Norway):
    Liquefaction of pipeline gas in small liquefaction plant, gas price level NBP/ZIG minus transport; LNG production cost rather expensive due to low energy efficiency in small scale; short transport to LNG bunkering terminal only; potentially available in many locations all over Europe
  - Supply from re-export terminal (Zeebrugge, Gate)
    LNG FOB price: NBP/ZIG plus premium, depending on agreement with LNG Owners/shareholders of terminals (no spot market)
  - Supply from MED LNG production
    LNG FOB price: NBP/ZIG plus small premium, depending on agreement with LNG Owners/shareholders of terminals (no spot market)
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Small LNG carriers

19-May-2010 „Coral Methane“ loading at Zeebrugge, First loading of a small carrier at a large import terminal.
Small LNG Carriers

- Up to 10,000 cbm cylindrical tanks
- Up to 20,000 cbm bilobe tanks (patented supports)
- Ship sizes up to 75,000 cbm have been studied
- Tank pressure 2.7 to 4.0 barg
- BOG handling by pressure increase or fuel gas consumption

Main aspects for design of small LNG carriers

- Tank design: IMO type C to allow for:
  - Partial loading, no secondary barrier
  - High loading rates
  - Pressure build-up possible
  - Separate erection and easy installation
- Tank insulation:
  - PS or PU panels
  - PU spray foam
  - Improved insulation panels
- Dual fuel, pressure build-up or reliquefaction for boil-off handling
- Combination with other cargoes possible
TGE’s Tank fabrication expertise

Fabrication 8,200 m³ and 8,400 m³ Bilobe and Cylindrical Tanks for Ethylene Service

Fabrication Bilobe Cargotanks for 5×22,000 m³ Ethylene Carriers

Transportation of Stainless Steel cargo tanks for a 7,500 m³ LNG carrier on a heavy lift carrier to a shipyard in Europe

Cargo tanks type A for a 23,000 m³ Fully Refrigerated LPG Carrier

Freight cost from Re-export terminal

- TGE has estimated freight cost from Zeebrugge to Rostock:
  - Distance: 760 nm, speed: 14 kn; BOG-cost: 6 USD/mmbtu
    - Zeebrugge terminal call cost estimation is included.
    - based on 100 % utilization

<table>
<thead>
<tr>
<th>Ship size</th>
<th>6,000 m³</th>
<th>12,000 m³</th>
<th>20,000 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundtrips/ month</td>
<td>4,4</td>
<td>4,4</td>
<td>4,4</td>
</tr>
<tr>
<td>Annual delivery</td>
<td>145,000 t</td>
<td>290,000 t</td>
<td>480,000 t</td>
</tr>
<tr>
<td>Shipping cost (USD/t)</td>
<td>98</td>
<td>63</td>
<td>45</td>
</tr>
<tr>
<td>Shipping cost (USD/mmbtu)</td>
<td>1,9</td>
<td>1,2</td>
<td>0,9</td>
</tr>
<tr>
<td>Shipping cost (€/MWh)</td>
<td>4,5</td>
<td>2,9</td>
<td>2,1</td>
</tr>
</tbody>
</table>
Freight cost ex LNG export terminal MED

- TGE has estimated freight cost from Damietta (Egypt) and Skikda (Algeria) to Hamburg: Distance: 3,600 resp. 2,300 nm, speed: 17 kn; BOG-cost: 6 USD/mmbtu
  - LNG terminal call cost estimation included
  - 100 % utilization

<table>
<thead>
<tr>
<th></th>
<th>Damietta</th>
<th>Skikda</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship size (m³)</td>
<td>20,000 m³</td>
<td>40,000 m³</td>
</tr>
<tr>
<td>Roundtrips/ month</td>
<td>1,4</td>
<td>1,4</td>
</tr>
<tr>
<td>Annual delivery (t)</td>
<td>158,000 t</td>
<td>317,000 t</td>
</tr>
<tr>
<td>Shipping cost (USD/t)</td>
<td>112</td>
<td>75</td>
</tr>
<tr>
<td>Shipping cost (USD/mmbtu)</td>
<td>2,2</td>
<td>1,5</td>
</tr>
<tr>
<td>Shipping cost (€/MWh)</td>
<td>5,2</td>
<td>3,6</td>
</tr>
</tbody>
</table>

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Design options for LNG Bunkering Terminals

There are two alternatives for LNG bunkering terminals:

- **Onshore solution with either:**
  - Flat bottom storage tanks:
    - Capacity: 10,000 – 50,000 m³
    - More economic > 8,000 m³
  - Bullet type pressure vessels
    - Capacity: 3,000 – 8,000 m³
  - Both options may be equipped with regasification equipment in order to supply gas to the local grid
  - Local utilities may book additional capacities

- **Offshore floating solution:**
  - Barge type LNG floater with cylindrical type C cargo tanks
  - Capacities from 5,000 m³ up to 80,000 m³ possible
  - Barge may be jetty moored, but offshore floating solution is technically possible
  - LNG floater may also be equipped with regasification equipment and connected to local grid
  - Redeployment possible

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Capacity: 20,000 m³
Send-out rate: 50 t/h
Dimensions: L=100 m; B=34.4m
Bunkering

- Requirements for future operations:
  - High loading rates due to tight time schedule
  - Large total amount of LNG for larger vessels
  - Safe but easy handling of heavy equipment
  - Dry-break emergency couplings
  - Bunkering during cargo operations
- This will only be possible with bunker vessels (small LNG carriers) coming alongside
- Regulations and standards for the bunker interface and related operations are under preparation by several international working groups
LNG Bunkering Operation

Three options for LNG bunkering are viable:

- Bunkering from LNG trucks
  - Only possible for small quantities; performed in Norway

- Bunkering from LNG bunker vessel/barge
  - TGE has designed a 3,000 m³ LNG bunkering ship to serve RoRo and container feeders at the corresponding terminals
  - Service cost estimation: 0.5 – 1.5 USD/mmbtu on top of terminalling cost depending on distance from satellite terminal

- Bunkering at the LNG bunkering terminal
  - Technically safest solution, but not applicable for most shipping areas due to timing issues
  - Service cost included in terminalling cost

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**Cost Overview** (Result of TGE study)

- Basis for LNG bunker price estimation:
  - 20,000 m³ floating bunker terminal
  - about 0.5 mtpa
  - NBP 9.3 USD/mmbtu

<table>
<thead>
<tr>
<th></th>
<th>Liquefaction</th>
<th>Zeebrugge</th>
<th>Skikda</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG FOB price [USD/mmbtu]</td>
<td>13.1</td>
<td>11.2</td>
<td>10.2</td>
</tr>
<tr>
<td>Shipping cost</td>
<td>0.7</td>
<td>0.9</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>truck/ship</td>
<td>1x20k</td>
<td>2x12k</td>
</tr>
<tr>
<td>Bunker service cost incl. terminal [USD/mmbtu]</td>
<td>1.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>truck/shore</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total [USD/mmbtu]</td>
<td>14.8</td>
<td>14.1</td>
<td>14.6</td>
</tr>
<tr>
<td>Total [€/MWh]</td>
<td>35.2</td>
<td>33.6</td>
<td>34.8</td>
</tr>
<tr>
<td>Total [USD/ton]</td>
<td>770</td>
<td>733</td>
<td>760</td>
</tr>
</tbody>
</table>

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- LNG as fuel for merchant ships is a viable option for future applications
- Norway is already operating small LNG bunkering terminals
- The technology for the complete chain of LNG bunkering services is available
- LNG bunker prices have potential to decrease with established infrastructure by re-export resp. direct import, expected price level even below HFO in midterm, clearly below low sulphur alternatives
- Considerable economical advantages in shipping OPEX can be achieved, if gas pricing will be further disconnected from oil price

Thank you for your kind attention