Alternative Fuels

Dr. Hans J. Gätjens
Vice President
Marine Regional Chief Executive for
North - Central - Europe, Baltic Region and Russia
BUREAU VERITAS S.A.

GMEC
Global Maritime Environmental Congress
4. September 2012 / Hamburg

Move Forward with Confidence
Why Alternative Fuels?

- It took more than 100 million years to convert solar energy via biomass to coal, oil and gas
- Human beings will burn it in less than 500 years
- After 200 years burning coal, oil and gas, it is considered that there is an influence regarding global warming
- It is assumed that the oil production will reach its peak in this century
- Consequences regarding availability of fuels for shipping, prices and environmental aspects have to be investigated and solutions defined
## Fuels used for Propulsion of Ships

<table>
<thead>
<tr>
<th>Fuel type:</th>
<th>Propulsion Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>biomass</td>
<td>humans / paddle</td>
</tr>
<tr>
<td>wind</td>
<td>sails</td>
</tr>
<tr>
<td>coal</td>
<td>steamplants</td>
</tr>
<tr>
<td>oil</td>
<td>steamplants, diesel engines</td>
</tr>
<tr>
<td>gas</td>
<td>steamplants, gas engines</td>
</tr>
<tr>
<td>uranium</td>
<td>steamplants</td>
</tr>
<tr>
<td>hydrogen</td>
<td>fuel cells</td>
</tr>
<tr>
<td>sun</td>
<td>solar cells</td>
</tr>
</tbody>
</table>
Examples of fuels for Internal Combustion Engines used from 1850 ... 2012

- gun powder
- hydrogen
- coal gas
- kerosine
- gasoline
- petroleum
- biofuel
- coal dust
- residual fuel
- oil from coal liquifaction
- natural gas
- bio gas
Hydrogen as Fuel?
(source: HDW)
### Fuel Cell Efficiencies

<table>
<thead>
<tr>
<th>Fuel Source</th>
<th>Electric Power Generation</th>
<th>Propulsion</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂</td>
<td>67%</td>
<td>63%</td>
</tr>
<tr>
<td>H₂ / O₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methanol</td>
<td>47%</td>
<td>44%</td>
</tr>
<tr>
<td>H₂ / Air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane</td>
<td>41%</td>
<td>39%</td>
</tr>
<tr>
<td>H₂ / Air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diesel oil</td>
<td>41%</td>
<td>39%</td>
</tr>
<tr>
<td>H₂ / Air</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Present Situation

- World-wide the merchant fleet consists of abt. 120,000 vessels (>100 GT)
- >99% are equipped with diesel engines and burn Intermediate Fuel Oil (IFO), Marine Diesel Oil (MDO) and Gasoil (MGO)
- abt. 400 LNG tankers are burning natural gas in steamplants or dual fuel engines
- abt. 30 other vessels are using gas as fuel
- sailing ships are only used for training and cruises

Fuels used presently in shipping

- IFO abt. 80%
- MDO + MGO abt. 20%
- Natural Gas < 1%
### Production of Fuel (2011)

<table>
<thead>
<tr>
<th></th>
<th>Production per year</th>
<th>RP rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>abt. 4000 mio t</td>
<td>54,2 years</td>
</tr>
<tr>
<td>Gas</td>
<td>abt. 3000 mio t (oil equivalent)</td>
<td>63,6 years</td>
</tr>
<tr>
<td>Coal</td>
<td>abt. 4000 mio t (oil equivalent)</td>
<td>112 years</td>
</tr>
</tbody>
</table>

#### Bio Fuels

<table>
<thead>
<tr>
<th></th>
<th>Production per year</th>
<th>RP rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol, Biodiesel</td>
<td>abt. 60 mio t</td>
<td></td>
</tr>
<tr>
<td>Palmoil</td>
<td>abt. 50 mio t</td>
<td></td>
</tr>
</tbody>
</table>

(< 10% used as fuel)

- Refinery utilization: 81,2%

(source: BP)
Demand / Supply Balance
(source: IEA July 2012)
Economic context: current fuel price vs gas price

**Bunker fuel prices**

- **HFO ~ 18 $ / 10^6 Btu**
- **MDO ~ 28 $ / 10^6 Btu**

**Natural gas prices:**

- **USA:** ~ 2.3 to 3 $ / 10^6 Btu
- **Europe:** ~ 8.5 to 9.7 $ / 10^6 Btu
- **Asia:** ~ 14 $ / 10^6 Btu

**Courtesy Marine Service GmbH Hamburg**
Estimates and predictions about the annual total consumption of bunker fuel for ships vary from 220 mio t (IEA) to 330 mio t (IMO 2009). Rough Estimation for 2011 for Intermediate Fuel Oil (IFO) Consumption:

Assumptions:
- IFO consists of Residual Fuel blended with destillates
- abt. 12% of the oil production are residuals
- abt. 35 % is used in shipping
- annual oil production 2011 = 4000 mio t
  - abt. 480 mio t residuals
  - abt. 170 mio t for shipping
  - blended with 17 mio t destillates (10%)
  - annual IFO consumption abt. 187 mio t
MDO and GO Consumptions

Estimation of DO / GO consumption in shipping:

- abt. 27% of the oil production are Diesel Oil and Gas Oil
- abt. 4% of the DO / GO production is used for shipping

- abt. 1080 mio t DO / GO
- abt. 43 mio t for shipping

Total Consumption:

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>IFO</td>
<td>abt. 187 mio t</td>
</tr>
<tr>
<td>DO / GO</td>
<td>abt. 43 mio t</td>
</tr>
<tr>
<td>Total:</td>
<td>abt. 230 mio t</td>
</tr>
</tbody>
</table>

Shipping is responsible for 2%-3% of all hydrocarbons burned.
Use of Heavy Fuel Oil

Production of Residual Fuel Oil will decline because it is commercially more attractive for producers to sell destillates than desulferized Heavy Fuel Oil.

- old refineries will close down
- some new refineries produce no Residual Fuel Oil at all – the residual is petrol coke
- existing refineries will be upgraded by installation of crackers and flexi cokers

If the percentage of RFO production decrease as in the last century and oil production will remain on 2011 level:

- 160 mio t less RFO production per year in 2020 compared to 2011

The present RFO consumption in shipping is abt. 170 mio t.
Residual Fuel Oil as a Percentage of all Oil Products

(BP Statistical Review 2010, TUHH)
Consequences for shipowners

- Prices for HFO will increase
  - 2005: 60% of crude oil price
  - 2011: 80% of crude oil price
  - 2020: 100%?

For ECA’s

- Use of MGO from 2015 onwards
- Use of natural gas from 2015 onwards + for newbuilding 2016
- Installation of scrubbers from 2015 onwards
- Installation of SCR for newbuildings 2016
- Exhaust gas recirculation for newbuildings 2016
IMO and other regulations are becoming more and more stringent:

► Progressive reduction of air emissions (SOx, NOx, particulate matters, greenhouse gases including CO2).
► Trend to extend the Emission Control Area (ECA for SOx, NOx or particulate matters or all three types of emissions).
► Trend of local or regional legislations to reduce SOx emissions at port, e.g. in the US, in the EU.

Existing ECAs: Baltic Sea (May 2006); North Sea & English Channel (Nov 2007), for SOx
Newly designated ECAs: US and Canadian coastal waters, for NOx, SOx and PM (adoption MEPC 59, Jul 2009)
EU ECAs (SOx only)
Future ECAs may include: Mediterranean Sea, Black Sea, port areas with heavy traffic, etc.
<table>
<thead>
<tr>
<th>Regulations</th>
<th>Sulphur Content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010</td>
</tr>
<tr>
<td>IMO - Global</td>
<td>4.5%</td>
</tr>
<tr>
<td>IMO - ECA</td>
<td>1.5%</td>
</tr>
<tr>
<td>EU ports</td>
<td>0.1%</td>
</tr>
<tr>
<td>California (&lt; 24 nm)</td>
<td>1.5%</td>
</tr>
<tr>
<td></td>
<td>0.5%</td>
</tr>
</tbody>
</table>

(*) Subject to 2018 feasibility study

Residual fuels
Distillate fuels
Regulations for NOx emissions

- Applicable to Diesel engines with power output $\geq 130$ kW
- Entry into force: 1 July 2010

<table>
<thead>
<tr>
<th>Engine fitted on a ship constructed at date D *</th>
<th>Applicable standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1/2000 ≤ D &lt; 1/1/2011</td>
<td>Tier I</td>
</tr>
<tr>
<td>1/1/2011 ≤ D &lt; 1/1/2016</td>
<td>Tier II</td>
</tr>
<tr>
<td>1/1/2016 ≤ D</td>
<td>Tier III in ECA **</td>
</tr>
<tr>
<td>“existing engines”</td>
<td>Tier II elsewhere</td>
</tr>
<tr>
<td>1/1/1990 ≤ D &lt; 1/1/2000</td>
<td>Tier I</td>
</tr>
<tr>
<td>cylinders ≥ 90 l &amp; output &gt; 5,000 kW</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Engine rpm</th>
<th>N &lt; 130</th>
<th>130 ≤ N &lt; 2000</th>
<th>N ≥ 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>17.0 g/kWh</td>
<td>45 N^{-0.20} g/kWh</td>
<td>9.8 g/kWh</td>
</tr>
<tr>
<td>Reg. 13(3)(a)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tier II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>~ 80% Tier I</td>
<td>14.4 g/kWh</td>
<td>44 N^{-0.23} g/kWh</td>
<td>7.7 g/kWh</td>
</tr>
<tr>
<td>Tier III</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>~ 20% Tier I</td>
<td>3.4 g/kWh</td>
<td>9 N^{-0.20} g/kWh</td>
<td>2.0 g/kWh</td>
</tr>
</tbody>
</table>

* MARPOL: construction date = keel laying date
** ECA = Emission Control Area
Principles of the SCR System
(source: MAN)

Exhaust gas → NO₂ → NO → NO₃ → NH₃

40% urea solution
CO(NH₂)₂ • 5(H₂O)

SCC Reactor

N₂ + H₂O

4NO + 4NH₃ + O₂ = 4N₂ + 6H₂O
6NO₂ + 8NH₃ = 7N₂ + 12H₂O
Flow Chart - DryEGCS
(source: Couple Systems)
EGR System Layout on Alexander Maersk (MAN)
Reduction of emissions of NO\textsubscript{x}, SO\textsubscript{x}, PM and CO\textsubscript{2}

Effectiveness of natural gas fuel versus abatement technologies:

<table>
<thead>
<tr>
<th>Technique / Reduction of</th>
<th>NO\textsubscript{x}</th>
<th>SO\textsubscript{x}</th>
<th>PM</th>
<th>CO\textsubscript{2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combinations of engine modifications</td>
<td>30-40%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCR</td>
<td>&gt;90%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emulsified fuel</td>
<td>10-20%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Humid Air Motors</td>
<td>25-50%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct Water Injection</td>
<td>~50%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exhaust Gas Recycling</td>
<td>35-60%</td>
<td></td>
<td>20-60%</td>
<td></td>
</tr>
<tr>
<td>Filters</td>
<td></td>
<td>~95%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scrubbing</td>
<td></td>
<td>85-100%</td>
<td>70-100%</td>
<td></td>
</tr>
<tr>
<td>1.5% Sulphur fuel</td>
<td></td>
<td>~40%</td>
<td>~18%</td>
<td></td>
</tr>
<tr>
<td>0.5% Sulphur Fuel</td>
<td></td>
<td>~80%</td>
<td>~20%</td>
<td></td>
</tr>
<tr>
<td>Natural Gas Fuel</td>
<td>80 to 90%</td>
<td>100%</td>
<td>~100%</td>
<td>20 to 25%</td>
</tr>
</tbody>
</table>

IMO Tier 3 standard is achieved

Reduction of EEDI
### Natural Gas as Fuel

#### Different fuel types in comparison (April 2012)

<table>
<thead>
<tr>
<th>Fuel type:</th>
<th>MGO</th>
<th>MDO</th>
<th>IFO 380</th>
<th>LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Calorific Value: [MJ/kg]</td>
<td>42</td>
<td>42</td>
<td>39,5</td>
<td>48,5</td>
</tr>
<tr>
<td>Density [t/m³]:</td>
<td>0,89</td>
<td>0,9</td>
<td>0,95</td>
<td>0,41</td>
</tr>
<tr>
<td>Bunkerprice [US$/ton]:</td>
<td>997</td>
<td>960</td>
<td>684</td>
<td>439</td>
</tr>
<tr>
<td>Fuel conditioning:</td>
<td>Heating</td>
<td>Heating</td>
<td>Purifying + Heating</td>
<td>Heating</td>
</tr>
</tbody>
</table>
Selected BV references in gas fuelled ships


- 23 LNG C classed with BV with single gas fuel, dual or triple fuel Diesel Electric propulsion classed with BV since that date.

- “Coral Methane”, 7,500m3 LNG C built in 2009 by Remontowa for Anthony Veder

- 15,000m3 LNG C Hull 665 ordered by Anthony Veder in 2011 at Meyerwerft

- 6,500m3 LNG / LEG / LPG C at for Anthony Veder at Dingheng Jiangsu.

- Classification of series of Ethylene Carriers with gas fuel Gen Sets built in Korea for Lauritzen Kosan.

- Technical discussions with KHI in 2003 about “Shinyu Maru”, 2.500m3 LNG C.
Selected BV references in gas fuelled ships

- **Ultra large container ship**
  - 2-stroke dual fuel propulsion engine supplied with high pressure gas
  - Auxiliary engines supplied with low pressure gas
  - Storage in type B tanks (~20,000 m³ LNG)

- **1,000 teu container feeder**
  - Propulsion and auxiliary engines supplied with low pressure gas
  - Storage in containerized cryogenic tanks
Selected BV references in gas fuelled ships

► Ferries for current operation on gas fuelled engines
► Cruise vessels design for operation on gas at berth
► Inland navigation tanker
► Deep sea oil tanker
► AiP of LNG bunker ship design
► Assistance to Port Authorities for risk assessment / management of LNG bunkering operations.

► Type approval of gas / dual / triple fuel engines (MAN, Wärtsilä, ABC, Bergen Engines, …)
► Approval of STS transfer systems
► Active involvement in Industry working groups (ISO, SIGTTO, AFG, …)
Use of LNG as fuel for ships: rules & regulations

► BV specific rules:
  - Rule note NR 481, Design and installation of dual fuel engines using low pressure gas
  - Rule Note NR 529, Safety of gas-fuelled engines installation on ships.
  - BV Guidance Notes for LNG ship to ship transfer

► IMO codes:
  - IGC code for reference
  - International code for the safety of gas fuelled ships (IGF Code) in preparation on the basis of the Interim guidelines (expected to come along with SOLAS 2014). It will address natural gas and other gases (butane, propane, hydrogen) and energy conversion systems (e.g. fuel cells).

► Industry guidelines
  - SIGTTO guidelines for ship to ship LNG transfer

► Other involved parties
  - Flag state, Port authorities, …
Gas fuelled ships bunkering logistics and safety
Gas fuel bunkering logistics still to be shaped.

- For small capacities, non-fixed tanks located onboard the ship may be considered, such as containerized tanks or vehicle-tanks.
- For larger capacities, bunkering from a dedicated bunker ship / barges is considered.
- Bunkering from LNG storage facility in selected port area could also be envisaged.
- Bunkering from LNG terminals looks more remote as it is quite complex to implement in practice.

Bunkering arrangement and facilities on board:

- Design to be convenient for repeated routine filling operations without disruption of the commercial operations of the vessel.
- Built-in safety of LNG transfer systems should be sensibly higher than on liquefied gas carriers.
Use of natural gas as fuel for ships: selected issues

Design of portable LNG storage tanks and equipment

- Assessment of EN 13530-1/3 standard against IGC code requirements
- Resistance to ship accelerations and shocks (collision)
- Tank pressure control and boil-off gas management
- Partial filling levels
- Discharge capacity of the safety valves
- Vacuum-insulated tanks: consequences of a failure of the external shell
- Classification and inspection
- Connections between portable tanks and fixed shipboard piping systems: LNG supply to vaporizer, safety valve discharge line, etc.
- Qualification of LNG flexible hoses (EN 12434) or equivalent.
- Compatibility between tank equipment and shipboard equipment to be addressed (electrical equipment, control, monitoring, alarms, ESD, etc.)
- Monitoring of tanks parameters: pressure, temperature and level, vacuum in vacuum insulated tanks.
Operational aspects

- LNG container can be filled in existing terminals (i.e. Zeebrugge) and transported to the desired terminal
- LNG container can be handled by standard container bridges
- 3 LNG container stacks within B/5
- Each container stack (6 or 7 containers) constitute one LNG storage tank
- Containers are connected by hose pipes to piping system of the vessel
- Containers will be disconnected before cargo operations start and connected after leaving from the terminal
- Access to container via lashing bridges
LNG Container / Lashing Bridges
Safety aspects

- Approval in principle has been carried out

- Risk analyses has to be performed for each type of vessel

- Type approval for tank container and gas treatment container is in progress

- For Vent-Mast:
  - 6m or B/3 above working or weather deck
  - 10 m from air intakes, air outlets or opening to accommodation, service and control spaces or other gas safe spaces, exhaust outlet from machinery or from furnace installations
Natural gas fuel propulsion: some conclusions

- Natural Gas appears as a quite interesting fuel,
  - Firstly for short sea shipping and navigation in ECA, to meet the most stringent environmental requirements of the international and local regulations (IMO, EU, US, …)
  - Secondly for more high sea routes due to efficiency and price competitiveness of gas

- Technical solutions
  - exist for years for gas and dual fuel engines
  - are feasible for installation on various types of vessels

- LNG bunker supply logistics to be established yet
  - Key stake holders are gas suppliers and port authorities.

- LNG bunker market expected to develop with a competitive market price.
Alternative Fuels Conclusion

- there will be no „cheap“ fuel anymore in the future for shipping
- oil products will dominate as fuel for shipping in the next generation of ships (lifetime of a vessel > 20 years)
- biofuels can be used, production is small and increase limited
- hydrogen is not an energy resource
- natural gas in form of LNG seems to be the best alternative to the HFO, MDO, GO presently used in shipping