Marine fuels - Today and Tomorrow
What has been achieved
What needs to be done

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Agenda

- Regulatory developments
- Fuel oil availability
- Alternative fuels
Shipping by the numbers

- Majority of total international trade is transported by sea

Source: SEAS BBXX database of the Global Ocean Observing System Center from the Atlantic Oceanographic and Meteorological Laboratory of the National Oceanic and Atmospheric Administration
Global marine fuel consumption was expected to grow up to 350-400 Mtons/year by 2020 (source: BLG12/6/1)

- Slow steaming and efficiency measures will moderate marine fuel demand

Fuels represent a significant part of seaborne transportation costs
Shipping by the numbers

- Shipping is the most fuel-efficient mode of transportation: international maritime transport emissions account for ± 3% of global CO₂ emissions (source: EU Commission)

Comparison of CO₂ emissions between different modes of transport

Source: NTM, Sweden

- Cargo vessel over 8,000 dwt: 15 gr/tonne-km
- Cargo vessel 2,000-8,000 dwt: 21 gr/tonne-km
- Heavy truck with trailer: 50 gr/tonne-km
- Air freight: 747-400 1,200 km flight: 540 gr/tonne-km

Source: Shipping, World Trade and the Reduction of CO₂, United Nations Framework Convention on Climate Change; International Maritime Organization Marine Environment Protection Committee
First decades of 21st century characterised by regulations to reduce impact of shipping emissions on human health, environment and climate change

Current fuel oil sulphur levels do not impose major supply and fuel quality issues

– Occasionally some uncharacteristic fuel qualities have been observed when ECA entered into force

Unprecedented future sulphur regulations call for massive investments by ship owners, technology suppliers and fuel suppliers
Legislation to limit SO$_x$ emissions from shipping

Marpol Annex VI sets internationally agreed regulations to limit SO$_x$ emissions from shipping

- Fuel used on board ships shall not exceed:
  - 3.50% S on and after January 1, 2012
  - 0.50% S on and after 2020 or 2025 subject to 2018 review
- Emission Control Area (ECA)
  - 1.00% S, July 1, 2010
  - 0.10% S, January 1, 2015
  - Equivalent measures are permitted

EU SLFD 2012/33/EU amending 1999/32/EC

- ECA: 0.10% S, January 1, 2015
- 0.50 % S max in 2020 in EU waters outside ECA
- 0.10 % S max when at berth for more than 2 hours
- Fuel S restrictions for passenger ships on regular schedule between EU ports: 1.50% S until 2020
- Inland waterways gasoil 10 ppm S as of 2011, as per FQD

California: auxiliary and main engines + auxiliary boiler of OGV within Californian coastline

- July 1, 2009: use MGO (DMA) or MDO 0.5% S max
- August 2012: DMA: max 1 % S
- January 1, 2014 use MGO/MDO 0.1% S max
Emission controlled areas

North American Coasts ECA-SO\textsubscript{x}
- from August 1, 2012
- August 1, 2012 to January 1, 2015: Max. 1.00% 
- After January 1, 2015: Max. 0.10%

Baltic and North Sea ECA-SO\textsubscript{x}
- Now to January 1, 2015: Max. 1.50%
- After January 1, 2015: Max. 0.10%

North American ECA-NO\textsubscript{x}\textsubscript{2} comes into effect in 2016, using the same co-ordinates as the ECA-SO\textsubscript{x}.

MARPOL Annex VI fuel oil maximum sulphur content outside of ECA-SO\textsubscript{x} reduces from 4.50% to 3.50% from January 1, 2012.

Source: Lloyd’s Register
## Solutions to comply with sulphur regulations

<table>
<thead>
<tr>
<th>Option</th>
<th>Notes</th>
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<tbody>
<tr>
<td><strong>Switch to low sulphur HFO</strong></td>
<td>• After 2015: no option when in ECA</td>
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<td>• 2020/2025:</td>
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<td>• Availability ? Operating cost ?</td>
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<tr>
<td><strong>Switch to distillate fuel</strong></td>
<td>• 2015: 0.10 % S in ECA</td>
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<td>• 2020/2025:</td>
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<tr>
<td></td>
<td>• Availability ? Operating cost ?</td>
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<tr>
<td><strong>Operate on HFO with exhaust cleaning system</strong></td>
<td>• Efficient for PM/(\text{SO}_x), but wat about (\text{NO}_x)</td>
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<td>• Different systems, handling of waste/sludge !</td>
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<td>• ROI depends on price differential HSFO/LSFO &amp; time spent in ECA</td>
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<td><strong>Alternative fuel: LNG</strong></td>
<td>• Efficient for (\text{CO}_2), (\text{NO}_x), PM and (\text{SO}_x)</td>
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<td>• Low LNG price favors investing in gas engines</td>
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<td>• Availability ?</td>
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2009 worldwide average : 2.60%
2010 worldwide average : 2.61 %
2011 worldwide average : 2.65 %

Residual fuel oil S content,
% m/m

Source: Rudi Kassinger, DNVPS, MEPC 56/4
2006 S monitoring, MEPC 57/4/24 2007 S
monitoring,MEPC 59/4/1, MEPC 61/4,MEPC62/, MEPC 64/4
Middle distillates are key driver of refining and refined product market

- Demand influenced by drive to increase energy efficiency and substitution of fossil fuels by other fuels (renewables, natural gas)

Source: OPEC Oil Outlook, 2012
Changes in marine fuel sulphur specifications will create massive demand for lower sulphur fuel oils

Refinery production by product
(IEA, 2007 & IMO/BLG12/6/1)

- Middle distillates
- Heavy fuel oil

Source: IEA 2007, BLG12/6/1
Future marine fuels demand

- Changes in marine fuel sulphur specifications will create massive demand for lower sulphur fuel oils
  - Existing shortage in distillates in some areas already
  - Crude oils become heavier and “souring” trend expected to continue
  - Will require large refinery investments
  - Quality changes will have significant impact on refineries’ energy consumption and CO$_2$ emissions
  - Onboard scrubbers are a potential alternative to meet S regulations with low overall incremental CO$_2$ emissions
Basic steps in the refining process

- **Distillation**: separation of the light/heavy material in crude oil
  - Atmospheric/vacuum distillation

**Straight run refinery**: comparison with (world wide) demand barrel
Basic steps in the refining process

- **Distillation**: separation of the light/heavy material in crude oil
  - Atmospheric/vacuum distillation

- **Conversion**: middle distillate, gasoil and residuum (the heavy asphalt-like material) are converted into gasoline, jet and diesel fuels, fuel oil …
  - Cracking: large, heavy hydrocarbon molecules are converted into smaller, lighter ones
    - Catalytic (FCC)
    - Thermal (Visbreaker/coker)
    - Hydrocracking

- **Treatment**: removal of e.g. S
Typical refinery with thermal and catalytic cracking

- Crude oil
- Atmospheric distillation
- Gases
  - Naphta
  - Kerosene
  - Gasoil
  - Atmospheric residue
- Treatment
  - Vacuum distillation
  - Vacuum gasoil
- Catalytic cracking
  - Catalytic cracked distillates
- Thermal cracking
  - Thermally cracked residue
- Residual fuel oil
Residue desulfurisation (RDS)

- Primarily used as feed treatment for refinery conversion units
- Lower S specifications change nature of product
- Higher investment risk, lower return
- Energy intensive (increase of refinery CO₂ emissions)

- Resid desulfurisation
  - < 0.50 % S can be achieved on most of the atmospheric residue
  - About 100 % conversion

- Vacuum resid desulfurisation (VRDS)
  - Difficult to achieve < 0.75 % S
  - Metals may constrain application of VRDS
Conversion of residual streams into distillates

- Coking & resid hydrocracking
  - Cokers produce only ±50% distillates and heavier, shifting bunker volume into gasoline, lighter products and cokes
  - Lower investment risk, higher return
  - Energy intensive

- Probably driven by refineries’ economics with conversion likely more attractive than RDS
Call on refiners - Marine fuels: 2015 and beyond

- **2015**: 0.10 % S in ECAs; projected global demand ± 40 MT
  - Hydroteated middle distillates
  - Challenge to supply will grow when new ECAs are established
  - Estimated EU refineries investments at ± 13 billion USD

**Source**: PGI 2009 study prepared for DG Environment
Call on refiners -
Marine fuels: 2020/2025 0.50 % S global cap

- Probably driven by refineries’ economics, with conversion likely to be more attractive
  - Lower investment risk, higher return
  - Energy intensive
  - Estimated EU refineries investments at ± 18 billion USD

Source: PGI 2009 study prepared for DG Environment
Shipping is under extreme pressure to reduce its GHGs

- Design-based, technical and operational measures offer significant potential for reduction of CO₂ per tonne kilometer

- Mandatory measures to reduce GHGs from international shipping were adopted at MEPC 62 (MARPOL Annex VI, Chapter 4)
  - Energy Efficiency Design Index (EEDI)
  - Ship Energy Efficiency Management Plan (SEEMP) for all ships:

- EU recently abandoned idea of regional measures to reduce GHG emissions, rather it prefers global legislation. But they plan to introduce measure to monitor GHG emissions.

- Alternative fuels ??
Many countries have already legislated renewable fuel mandates in some segments of the transportation sector

- Limited marine experience in the use of biodiesel (e.g. Fatty Acid Methyl Ester based - FAME).
- Lessons learnt from the ‘Auto-industry’ experience to be considered for guidance
- In some ports only FAME containing diesel is available and cross-contamination of marine fuels with biodiesel (FAME based) in multi-product pipeline systems can not entirely be excluded

Trials and research into use of biodiesel in large diesel engines are being conducted
Biodiesel/FAME – A viable future alternative?

- FAME: benefits:
  - Reduced emissions
  - Good lubricity
  - Free of S and aromatics
  - Good ignition quality
  - Blends well with fossil diesel

Biodiesel/FAME – A viable future alternative?

- The critical technical aspects for marine use:
  - At higher blending ratios NO\textsubscript{x} increases
  - FAME is surface active: sticks to metal, glass
  - FAME related material may deposit on filters etc
  - Water separation properties
  - Affinity to water and increased risk for microbiological growth
  - Long term storage stability
  - Low temperature flow properties
  - Material compatibility

- CIMAC guide under development

Source: Concawe
LNG – A viable future alternative?

- LNG is already being used successfully by smaller ships, sometimes driven by national incentives.
- LNG tankers have gas burning propulsion system to burn cargo Boil Off Gas (BOG).

Ship emission reduction potential with increasing share of LNG in Baltic

Source: DNV, Greener Shipping in the Baltic Sea
LNG – A viable future alternative?

- LNG contains approximately 87 vol % of methane CH₄
  - Methane is a more potent GHG than CO₂

- LNG ageing due to heat, with lighter fractions evaporating first (CH₄ is main component of BOG)
  - Composition of LNG on barge will not be the same as the composition of LNG in the fuel tank after loading.
    - Composition may effect the Methane Number (MN) of the fuel

- Methane slip and BOG to be accounted for

- LNG has low flashpoint
LNG – A viable alternative?

- Compared to HFO:
  - Reduced emissions (SO$_x$, NO$_x$, PM, CO$_2$)
  - LNG contains about 1.25 times more energy content per mass, but about 1.8 times less energy content per volume
  - Lower $/mBtu$ cost (regional differences)
  - Ship design changes due to extra space requirements of LNG tanks resulting in cargo space loss
  - Less maintenance

- Dual-fuel engines require a pilot fuel to start the ignition but offer the possibility to select most suitable fuel
LNG – A viable alternative?

- Current distribution is geared toward large-scale operations, not supply of small parcels to end users

- Bunkering infrastructure and practices need to be developed
  - LNG supply and availability
  - Bunkering procedures & product quality control
  - Cargo loading/unloading
  - Personnel training

- LNG will primarily prevail on newbuilds

- Future LNG prices?