Potential for GHG reduction from shipping

Elizabeth Lindstad and Torstein Bø
SINTEF Ocean AS
Increased Energy usage (Fossile) -> Increases CO$_2$ concentration in the atmosphere and the temperature

1971
- Residential: 30%
- Industry: 22%
- Transport: 18%
- Other: 19%
- Conversion & losses: 12%
Total: 5,523 Mtoe

2015
- Residential: 26%
- Transport: 21%
- Industry: 16%
- Other: 29%
- Conversion & losses: 9%
Total: 13,647 Mtoe
Global Development 1970 – 2012

Development of shipping emissions up to 2050 for 16 different scenarios developed by the Third IMO GHG study.

Source: Smith et al. (2014) and IPCC (2013)
Shipping & Climate change

• Emissions effect both local pollution and climate change.
• Combined regulation is an economical and technical challenge for the shipping industry.
• Alternative fuels such as LNG, LPG, Methanol or Hydrogen is one tempting option for meeting these new requirements.
• IMO aims to (April 2018):
  • Reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008 whilst pursuing efforts towards phasing them out.
  • Reduce CO2 emissions per transport work, by at least 40% by 2030, pursuing efforts towards 70% by 2050, compared to 2008.
Greenhouse gases are more than CO2

Source: Leland McInnes based on IPCC Natural Drivers of Climate Change, Figure SPM.2, in IPCC AR4 WG1 2007.
Location is important

Gram CO2 per ton km range per vessel type

- LPG
- LNG
- RoRo
- Chemical tankers
- Product tankers
- Crude oil
- Container
- Reefer
- Dry Bulk
- General Cargo
- Inland waterways
- Road transport
- Rail

Gram CO2 per ton km range

Source: Lindstad and Mørkve 2009 and Lindstad 2018
Mains options for reducing shippings GHG

Use less energy
- Hull design and other technologies (same speed, less power)
- Logistic (new speed, route, etc)

Lower GHG emission/energy
- Alternative fuels
- Renewable energy
State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping – A review

Evert A. Bouman a, *, Elizabeth Lindstad b, Agathe I. Rialland b, Anders H. Strømman a
Well to Wake (WTW) emissions for alternative versus traditional fuels in shipping

– a Review of published studies
Open Hatch Carriers & General Cargo

Conventional Designs versus – a Step Change

A parametric feasibility study
Designs analysed in the parametric feasibility study

Reference Vessel:
L = 199.99m
B = 32.3m
Draught = 11.9m
Dwt = 47000t
Disp = 60000m³
C_b = 0.8

Beam Variation
+15%
B = 37.1m
C_b = 0.7

+10%
B = 35.5m
C_b = 0.73

-7%
B = 30m
C_b = 0.86

Dwt Variation
+10%
Dwt = 51700t
C_b = 0.88

+5%
Dwt = 49350t
C_b = 0.84

-10%
Dwt = 42300t
C_b = 0.72

-20%
Dwt = 37600t
C_b = 0.64

Length Variation
+20%
L = 240m
C_b = 0.67

+10%
L = 220m
C_b = 0.73

+5%
L = 210m
C_b = 0.76
Increasing beam keeping DWT constant
Increasing length keeping DWT constant
Summary – Comparing alternative designs with same cargo capacity

- **Required voyage speed** is a main input parameter to the design process.

- Vessels are frequently pushed far beyond their boundary speeds.

- Increasing length gives largest reduction, and this advantage increases in Real SEA
Operational Speed is a function of fuel price and capex cost
Main References 2016 & 2017

- Lindstad Elizabeth, Rehn C., F., Eskeland, G., S. 2017 *Sulphur Abatement Globally in Maritime Shipping*. Accepted for publication in Transportation Research Part D


- Lindstad, H. E. 2016. *Bigger picture suggest effects of IMO emission efforts are counter productive*. TradeWinds Page 10, 5.August 2016,


Alternative Hybrid Powertrains to meet EEDI Requirements

Elizabeth Lindstad, Torstein Ingebrigtsen Bø
Case study

- Aframax tanker (110 000 dwt)
- How can EEDI requirements be met?

$$EEDI = \frac{CO_2}{\text{DWT} \times \text{Distance}}$$
Technologies

- Hybrid (PTO/PTI/Battery)
- LNG (5 – 20 % less CO$_2$-eq)
- Slender hull
Hybrid

- Downsize main engine
- Use shaft motor during severe weather
LNG

• 20 % reduction in CO₂

• Methan slip:
  • 5 - 20 % reduction in greenhouse gas emissions
Slender hull

Power Requirement including aux.

- Calm
- 4 m waves
- 7.5 m waves
- Calm and Slender
- 4 m waves and Slender
- 7.5 m waves and Slender
EEDI

\[ EEDI = \frac{CO_2}{DWT \times Distance} \]

\[ = \frac{P_{\text{installed}} \times 75\% \times SFC \times \text{Carbon factor} \times \text{time}}{DWT \times \text{speed} \times \text{time}} \]

\[ = \frac{P_{\text{installed}} \times 75\% \times SFC \times \text{Carbon factor}}{\text{speed} \times DWT} \]

\[ EEDI \geq \frac{P_{\text{installed}}}{\text{speed}} \text{ Constant} \]

\[ \frac{EEDI}{\text{Constant}} \text{ speed} \geq P_{\text{installed}} \]
Calculation of Cost and Emission
Power Requirement including aux.

![Graph showing power requirement vs. speed in knots for different conditions: Calm, Calm and Slender, 4 m waves, 4 m waves and Slender, 7.5 m waves, 7.5 m waves and Slender.](image)

- **Calm**
- **4 m waves**
- **7.5 m waves**
- **Calm and Slender**
- **4 m waves and Slender**
- **7.5 m waves and Slender**
Conclusion
MPC based control of gas engine and battery

Torstein I. Bø (SINTEF), Erlend Vaktskjold (Rolls-Royce Bergen Engine), Eilif Pedersen (NTNU), Olve Mo (SINTEF)
Otto cycle gas engine

Knocking

Metan slip

Low NOx

Image source:
Load data: removed from presentation
Case

Two gas engines
2.2 MW
Maximum rate of change 0.5%/s
Energy storage (battery)
260 kWh, 780 kW, ~3800kg
Given load series
Results: removed from presentation
## Conclusions

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<tr>
<th>Mode</th>
<th>Cycles after 10 years</th>
<th>RMS $\dot{u}$ [%/s]</th>
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<tr>
<td>Frequency barrier, baseline</td>
<td>18,432</td>
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<td>Frequency barrier, MPC</td>
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<td>Stiff frequency, baseline</td>
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<td>Stiff frequency, MPC</td>
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Questions?