Reducing GHG emissions from shipping: to be or not to be

Harilaos N. Psaraftis
Professor
Technical University of Denmark
Purpose

• Takes a critical look at recent developments as regards the decarbonization of maritime transport
• Identifies challenges and opportunities
• Tries to assess prospects for the future
Reference

• Paper at IAME 2017, Kyoto

• Extended version of IAME 2017 paper*

• Some 10 years work in this area

• *Psaraftis, H.N., Decarbonization of maritime transport: to be or not to be? Maritime Economics and Logistics, in press.
Kyoto protocol (1997)

- UNFCCC, Kyoto
- Commits State Parties to reduce greenhouse gas (GHG) emissions
- 192 signatories

- Maritime transport & aviation NOT included
Kyoto 20 years later

IAME 2017
COP21 (2015)

Brought all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so.
COP21 ii

• Hailed by many as perhaps one the most significant achievements of humankind thus far.
• Others were less enthusiastic.
• Pres. Trump: US will get out.

• Maritime transport and aviation still left outside UNFCCC mandate
  – Shipping: IMO
  – Aviation: ICAO
3 classes of measures
(to reduce emissions incl. GHGs)

• Technological
  – More efficient (energy-saving) engines and propulsion
  – More efficient vehicle designs
  – Cleaner fuels (low sulphur content)
  – Alternative fuels (fuel cells, biofuels, etc)
  – Devices to trap exhaust emissions (scrubbers, etc)
  – Energy recuperation devices
  – “Cold ironing” in ports

• Logistics-based
  – Speed reduction
  – Optimized routing
  – Fleet management
  – Network design
  – etc

• Market-based measures (MBMs)
  – Emissions Trading Scheme (ETS)
  – Carbon Tax/Levy on Fuel
  – Others
Bubbles generated by supplying air to the vessel's bottom
3E is green
3 classes of measures (to reduce emissions incl. GHGs)

• Technological
  – More efficient (energy-saving) engines and propulsion
  – More efficient vehicle designs
  – Cleaner fuels (low sulphur content)
  – Alternative fuels (fuel cells, biofuels, etc)
  – Devices to trap exhaust emissions (scrubbers, etc)
  – Energy recuperation devices
  – “Cold ironing” in ports

• Logistics-based
  – Speed reduction
  – Optimized routing
  – Fleet management
  – Network design
  – etc

• Market-based measures (MBMs)
  – Emissions Trading Scheme (ETS)
  – Carbon Tax/Levy on Fuel
  – Others
Division is artificial!

- A Market Based Measure (MBM) can induce
  - logistics-based measures in the short run and
  - technological measures in the long run
‘Logistics-based’ example

• Impose a Levy on bunker fuel
• Induces ships to slow steam
• Slow steaming will reduce CO2 emissions
• Will also reduce fuel consumption, hence is potentially a win-win proposition
‘Technological’ example

• What can an MBM induce ship owners to do in the long run?

• Build/buy a more fuel efficient ship (with better hulls, engines, propellers, etc)

• Better do this than pay the MBM
How much CO2?

2009 IMO GHG study
- (2007 data)

2014 IMO GHG study
- (2012 data)
- 2.7% reduced to 2.2%
- 796 million tonnes of CO2 in 2012, down from 885 million tonnes in 2007
- Mainly attributed to slow steaming due to depressed market conditions after 2008
IMO: the GHG track

Subtrack I

• EEDI
  (also SEEMP)

Subtrack II

• MBMs
IMO: the GHG track

Subtrack I

• EEDI

Subtrack II

• MBMs

Since 2016: The IMO Roadmap
Subtrack I: thus far the only mandated measure on GHGs

- IMO’s adoption of EEDI, July 2011
- Adopted as an amendment to MARPOL’s Annex VI
- Fierce resistance by China, India, Brazil, Saudi Arabia and other developing countries
- Matter highly political
Energy Efficiency Design Index (EEDI)

- Defined as

\[
\left( \prod_{j=1}^{M} f_j \right) \left( \sum_{i=1}^{n_{ME}} P_{ME(i)} C_{FAE(i)} S_{FCME(i)} \right) + \left( P_{AE} C_{FAE} S_{FCAE} \right) + \left( \prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{ndf} f_{df(i)} \cdot P_{AE_{df(i)}} C_{FAE} S_{FCAE} \right) - \left( \sum_{i=1}^{ndf} f_{df(i)} \cdot P_{df(i)} C_{ME} S_{FCME} \right)
\]

- Numerator: Ship’s CO2 emissions
- Denominator: Ship’s transport work
- Units: Grams of CO2 per ton-mile
Energy Efficiency Design Index (EEDI)

• Defined as

\[
\left( \prod_{j=1}^{M} f_j \right) \left( \sum_{i=1}^{n_{PM}} P_{ME(i)} C_{FME(i)} \cdot SFC_{ME(i)} \right) + \left( P_{AE} \cdot C_{FAE} \cdot SFC_{AE} \right) + \left( \prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{n_{PPL}} P_{PPL(i)} - \sum_{i=1}^{n_{eff}} f_{eff(i)} \cdot P_{AE_{eff(i)}} \right) C_{FAE} \cdot SFC_{AE} \right) - \left( \sum_{i=1}^{n_{eff}} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME} \right)
\]

\( f_i \): Capacity \( V_{ref} \), \( f_w \)

Ship’s capacity (usually DWT)

Ship’s reference speed: Speed corresponding to 75% of MCR
EEDI contd

• Mandatory for newbuildings as of 2013
• Attained $\text{EEDI} \leq \text{Required EEDI}$
• Required $\text{EEDI} = (1-\frac{X}{100}) aDWT c$

- $X=0\%$ for ships built from 2013-2015
- $X=10\%$ for ships built from 2016-2020
- $X=20\%$ for ships built from 2020-2025 and
- $X=30\%$ for ships built from 2025-2030.
Coefs a and c: determined by regression from world fleet database

<table>
<thead>
<tr>
<th>Ship type</th>
<th>a</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk carrier</td>
<td>961.79</td>
<td>0.477</td>
</tr>
<tr>
<td>Gas carrier</td>
<td>1120.00</td>
<td>0.456</td>
</tr>
<tr>
<td>Tanker</td>
<td>1218.80</td>
<td>0.488</td>
</tr>
<tr>
<td>Container ship</td>
<td>174.22</td>
<td>0.201</td>
</tr>
<tr>
<td>General cargo ship</td>
<td>107.48</td>
<td>0.216</td>
</tr>
<tr>
<td>Reefer</td>
<td>227.01</td>
<td>0.244</td>
</tr>
<tr>
<td>Combination carrier</td>
<td>1219.0</td>
<td>0.488</td>
</tr>
</tbody>
</table>
Reference line EEDI

Figure 1: Dry bulk carriers
All data: 2,259 ships. Without outliers (shown in blue): 2,218 ships
A closer look at the EEDI formula

**ATTAINED EEDI** (of a specific ship)

\[
\left( \prod_{j=1}^{M} f_j \right) \left( \sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)} \right) + \left( P_{AE} \cdot C_{FAE} \cdot SFC_{AE} \right) \]

\[
\left( \prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} \cdot f_{eff(i)} \cdot P_{AEeff(i)} \cdot C_{FAE} \cdot SFC_{AE} \right) - \left( \sum_{i=1}^{nPTI} P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME} \right)
\]

- \( f_i \): Capacity
- \( V_{ref} \): Reference speed
- \( f_w \): Weight factor

Ship’s capacity (usually DWT)

Ship’s reference (design) speed: Speed corresponding to 75% of MCR
Attained EEDI is a ratio

• If V is the ref. speed corresponding to 75% MCR (the speed at the denominator)

• Numerator typically grows like $V^3$
• Denominator grows like $V$

• Hence, attained EEDI grows like $V^2$
EEDI compliance

• Attained EEDI $\leq (1 - X/100) aDWT^{-c}$

• Attained EEDI grows like $V^2$

• Required EEDI is independent of $V$

• Therefore EEDI compliance implies an upper bound on $V$!
  (and a corresponding upper bound on MCR)
The horsepower limit deficiency

• To be EEDI compliant, the correct solution would be to optimize hull, engine and propeller

• The easy solution would be to reduce installed power
The horsepower limit deficiency ii

• Any energy inefficient design can be made EEDI compliant by reducing installed power
• The existence of this easy way out is hardly an incentive for more fuel efficient ships

• This could also lead to underpowered ships
• More CO2 to maintain speed in bad weather
Compromise on safety?

• A ship needs to have adequate power to maintain speed in bad weather, manoeuvering, etc.
• Big discussion at the IMO (MSC & MEPC), how to reconcile these 2 issues
• Issue STILL UNRESOLVED
• Impasse imminent?
Alternative EEDI formulations

• Can we eliminate the “easy way out”?

• CONSIDER:

EEDI (reference line) = aDWT^{-c}V^k

(with k=2 or 3)
Modified regressions with $k=2$ or $3$

Table 2. Regression results for EEDI (reference line)

<table>
<thead>
<tr>
<th>Ref. line</th>
<th>Reference</th>
<th>Bulk carriers</th>
<th>Tankers</th>
<th>Containerships</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard eq. (2)</td>
<td>IMO (2011a)</td>
<td>$961.79\text{DWT}^{-0.477}$ ($R^2 = 0.93$)</td>
<td>$1,218.80\text{DWT}^{-0.488}$ ($R^2 = 0.96$)</td>
<td>$186.52\text{DWT}^{-0.200}$ ($R^2 = 0.62$)</td>
</tr>
<tr>
<td>Modified eq. (4), $k=2$</td>
<td>IMO (2010a)</td>
<td>$10.913\text{DWT}^{-0.555}V^2$ ($R^2 = 0.91$)</td>
<td>$19.164\text{DWT}^{-0.599}V^2$ ($R^2 = 0.96$)</td>
<td>$12.74\text{DWT}^{-0.534}V^2$ ($R^2 = 0.92$)</td>
</tr>
<tr>
<td>Modified eq. (4), $k=3$</td>
<td>This paper</td>
<td>$1.1712\text{DWT}^{-0.594}V^3$ ($R^2 = 0.89$)</td>
<td>$2.3366\text{DWT}^{-0.652}V^3$ ($R^2 = 0.95$)</td>
<td>$3.5918\text{DWT}^{-0.707}V^3$ ($R^2 = 0.93$)</td>
</tr>
</tbody>
</table>

EEDI/$V^2$ - Containerships
Modified regressions with k=2 or 3

Table 2. Regression results for EEDI (reference line)

<table>
<thead>
<tr>
<th>Ref. line</th>
<th>Reference</th>
<th>Bulk carriers</th>
<th>Tankers</th>
<th>Containerships</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard eq. (2)</td>
<td>IMO (2011a)</td>
<td>$961.79\text{DWT}^{-0.477}$ ($R^2 = 0.93$)</td>
<td>$1,218.80\text{DWT}^{-0.488}$ ($R^2 = 0.96$)</td>
<td>$186.52\text{DWT}^{-0.200}$ ($R^2 = 0.62$)</td>
</tr>
<tr>
<td>Modified eq. (4), k=2</td>
<td>IMO (2010a)</td>
<td>$10.913\text{DWT}^{-0.555}V^2$ ($R^2 = 0.91$)</td>
<td>$19.164\text{DWT}^{-0.599}V^2$ ($R^2 = 0.96$)</td>
<td>$12.74\text{DWT}^{-0.534}V^2$ ($R^2 = 0.92$)</td>
</tr>
<tr>
<td>Modified eq. (4), k=3</td>
<td>This paper</td>
<td>$1.1712\text{DWT}^{-0.594}V^3$ ($R^2 = 0.89$)</td>
<td>$2.3366\text{DWT}^{-0.652}V^3$ ($R^2 = 0.95$)</td>
<td>$3.5918\text{DWT}^{-0.707}V^3$ ($R^2 = 0.93$)</td>
</tr>
</tbody>
</table>
Fate of modified regressions

• $k=2$ case submitted by Greece to the IMO in 2010

• (abt 1 yr before EEDI was finalized)
Fate of modified regressions

- k=2 case submitted by Greece to the IMO in 2010

(RESEARCH MEETS REALITY)
Fate of modified regressions

- $k=2$ case submitted by Greece to the IMO in 2010
- Stated reason: Ship owner should retain the power reduction option
- Real reason: discussion would detract from finalization of EEDI

(RESEARCH MEETS REALITY)
Subtrack II: Market Based Measures (MBMs)

• 11 MBM proposals at MEPC 60 (March 2010)
• Expert Group formed by IMO Sec. General
• Feasibility study (300-page report)
• Work: May- August 2010
• Report presented at MEPC 61 (Sep. 2010)
• Various discussions since then
Spot the speaker!
How does an MBM work?

• It induces operators and investors to adopt measures that will reduce CO2 emissions

• These measures can be
  – Operational (short run) or
  – technological (long run)
What else can an MBM do?

• Collect money to be used for various purposes (even for the environment!)
In-sector vs out-of-sector

In-sector

- **Direct** reduction of emissions (e.g., reduce speed due to a fuel tax)

Out-of-sector

- **Indirect** reduction of emissions (e.g., use the money to build a wind farm in New Zealand)
9 Criteria for evaluation

.1 Environmental effectiveness

.2 Cost-effectiveness and potential impact on trade and sustainable development

.3 The potential to provide incentives to technological change and innovation

.4 Practical feasibility of implementing MBM

.5 The need for technology transfer to and capacity building within developing countries, in particular the least developed countries (LDCs) and the small island development states (SIDS)
9 criteria cont’d

.6 The relation with other relevant conventions (UNFCCC, Kyoto Protocol and WTO) and the compatibility with customary international law

.7 The potential additional administrative burden and the legal aspects for National Administrations to implement and enforce MBM

.8 The potential additional workload, economic burden and operational impact for individual ships, the shipping industry and the maritime sector as a whole, of implementing MBM

.9 The compatibility with the existing enforcement and control provisions under the IMO legal framework.
MBM proposal groups

• International GHG Fund (Denmark et al) (LEVY)
• 4 distinct Emissions Trading Schemes (ETS) (Norway, UK, France, Germany)
• Various hybrids, based on EEDI (Japan, USA, WSC)
• Port-based (Jamaica)
• Rebate mechanism (IUCN)
• Bahamas proposal
# Emission reductions in 2030

Modelled emission reductions across various scenarios

<table>
<thead>
<tr>
<th></th>
<th>SECT</th>
<th>VES</th>
<th>Bahamas</th>
<th>GHG Fund</th>
<th>LIS</th>
<th>PSL</th>
<th>ETS (Norway France)</th>
<th>ETS (UK)</th>
<th>RM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mandatory EEDI (Mt)</strong></td>
<td>123-299</td>
<td>123-299</td>
<td>123-299*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MBM In sector (Mt)</strong></td>
<td>106-142</td>
<td>14-45</td>
<td></td>
<td>1-31</td>
<td>32-153</td>
<td>29-119</td>
<td>27-114</td>
<td>27-114</td>
<td>29-68</td>
</tr>
<tr>
<td><strong>MBM Out of Sector (Mt)</strong></td>
<td></td>
<td></td>
<td></td>
<td>152-584</td>
<td></td>
<td></td>
<td>190-539</td>
<td>190-539</td>
<td>124-345</td>
</tr>
<tr>
<td><strong>Total reductions (% BAU)</strong></td>
<td>19-31%</td>
<td>13-23%</td>
<td>10-20%</td>
<td>13-40%</td>
<td>3-10%</td>
<td>2-8%</td>
<td>13-40%</td>
<td>13-40%</td>
<td>13-28%</td>
</tr>
<tr>
<td><strong>Potential supplementary reductions (Mt)</strong></td>
<td>45-454</td>
<td></td>
<td></td>
<td>104-143</td>
<td>232-919</td>
<td>917-1232</td>
<td>696-870</td>
<td>187-517</td>
<td></td>
</tr>
</tbody>
</table>

* Included if the mandatory EEDI is adopted by the committee
Assumptions, assumptions, & more assumptions!

- 300-page report
- No recommendation!
MEPC 63: Greece’s proposal

- Keep on table only Levy and ETS proposals
- Put on hold hybrid MBMs* (US, Japan, WSC)
- Discard all others (Bahamas, Jamaica, IUCN)

- *MBMs embedding EEDI
MEPC 63: Greece’s proposal

- Keep on table only Levy and ETS proposals
- Put on hold hybrid MBMs (US, Jap., WSC)
- Discard all others (Bahamas, Jamaica, IUCN)

• KEEP ALL ON THE TABLE
MEPC 63

• Draft Resolution on Technical Co-operation and Transfer of Technology

• Brought forward by developing countries (China, India, Brazil, etc)
MEPC 63

• Draft Resolution on Cooperation and Transfer of Technology

• Brought forward by developing countries (China, India, Brazil, etc)

• NO CONSENSUS
MEPC 63

- Proposal for an Impact Assessment Study on MBMs
- Brought forward by the Chairman of MEPC
- Supported by developed countries
MEPC 63

- Proposal for an Impact Assessment Report Study on MBMs
- Brought forward by Chairman during MEPC
- Supported by developed countries

- NO CONSENSUS
Opposition
Q: Main reason for failure?

• Or: Name ONE (number=1) MAJOR obstacle in all GHG discussions

• A: CBDR!
CBDR: Common But Differentiated Responsibilities

• Widely accepted principle after the Kyoto Protocol.
• Has two aspects. The first is common responsibility, which is raised from the concept of common heritage and common concern of humankind and reflects the duty of countries to equally share the burden of environmental protection for common resources.
• The second is differentiated responsibility, which addresses different social and economic situations across countries.
MBMs

• Some proposals merged (Japan, WSC)
• Bahamas proposal reformulated and then withdrawn
• US proposal reformulated
• Basically, no real progress since 2010
MBMs

• Some proposals merged (Japan, WSC)
• Bahamas proposal reformulated and then withdrawn
• US proposal reformulated
• Basically, no real progress since 2010

MEPC 65 (May 2013):

• MBM DISCUSSION SUSPENDED!
Monitoring, Reporting and Verification (MRV)

- Only for CO2
- Discussion started when MBM discussion was suspended
- 2 different regimes (IMO, EU)
- Differences may create distortions & admin. burden

- Biggest difference is vs MRV for road transport
  - Road: Fleet level, manufacturer liable
  - Maritime: Individual ship level, operator liable
The IMO roadmap

OCTOBER 2016

• Adoption of an *initial strategy* in 2018 to meet the targets of COP21, which entered into force in November 2016.

• The strategy will be validated by actual emission figures gathered through the IMO’s *fuel data collection system* as of 2019.

• This will then lead to a final agreement on targets and measures, including an implementation plan, **by 2023.**
Enter the EU Parliament!

NOVEMBER 2016

• ENVI Committee of EU Parliament recommends to include shipping in EU ETS!
Enter the EU Parliament!

FEBRUARY 2017

• Decision of EU Parliament to include shipping in EU ETS!
Was this a good development?

• Big protests from industry circles such as
  – ECSA (the European Community Shipowners Associations),
  – ICS (the International Chamber of Shipping) and
  – many national shipowners associations.

• Big concern that an EU ETS may create
  – significant distortions and obstacles for efficient trade
  – may not be compatible with the IMO roadmap, and in fact
  – may not be a good instrument for reducing GHG emissions.
Latest

NOVEMBER 2017

• After negotiations between the EP and the EU Council of Ministers, it was agreed to **align the EU with the IMO process.**

• essentially refrain from taking action on ETS before seeing what the IMO intends to do on GHGs.

• Industry circles, concerned with the effects of an early EU ETS, welcomed this development.

• BUT! The European Commission will closely monitor the IMO process, starting from what is agreed on the initial strategy in 2018 and all the way to 2023.
IMO Roadmap progress

- MEPC 71 (June 17)
- 2 intersessional meetings (June 17, Oct. 17)
- 3rd intersessional meeting (Apr. 18)
- MEPC 72 (Apr. 18)
Shipping at COP 23 (Bonn)
Way ahead

• Q: Can we see something in the policies that are being currently pursued that would really guarantee significant fuel consumption (and hence GHG emissions) reductions?

• A: No!

• Lots of discussions
• Lots of “positive spin” press releases
• No concrete results yet
Way ahead ii

• Conceivable to reach an agreement in one of the forthcoming IMO meetings.
• Nature and level of ambition of such an agreement are pretty open at this point.
• Divergence of views is still very wide.
Thus!

• In spite of much talk about the maritime industry’s commitment toward serious GHG emissions reductions,

• it is fair to say that such reductions are, as things stand, only a wish at this point in time.
Q: any measure that might work?

• A: Investigate the impact of a significant bunker levy
• But chances of this being implemented any time soon very slim (mainly for political reasons)
VLCC emissions

- Gkonis and Psaraftis (2012)
Conclusions

• The international scene for the decarbonization of maritime transport has been rendered way too complex and fragmented, as well as political.

• Unnecessary complexity and fragmentation, coupled with factors that are mostly within the political sphere, will not help a speedy resolution of the issue.

• In fact they will definitely hinder prospects for substantial progress in the years ahead.
Maybe of interest
Thank you very much!

• hnpsar@dtu.dk