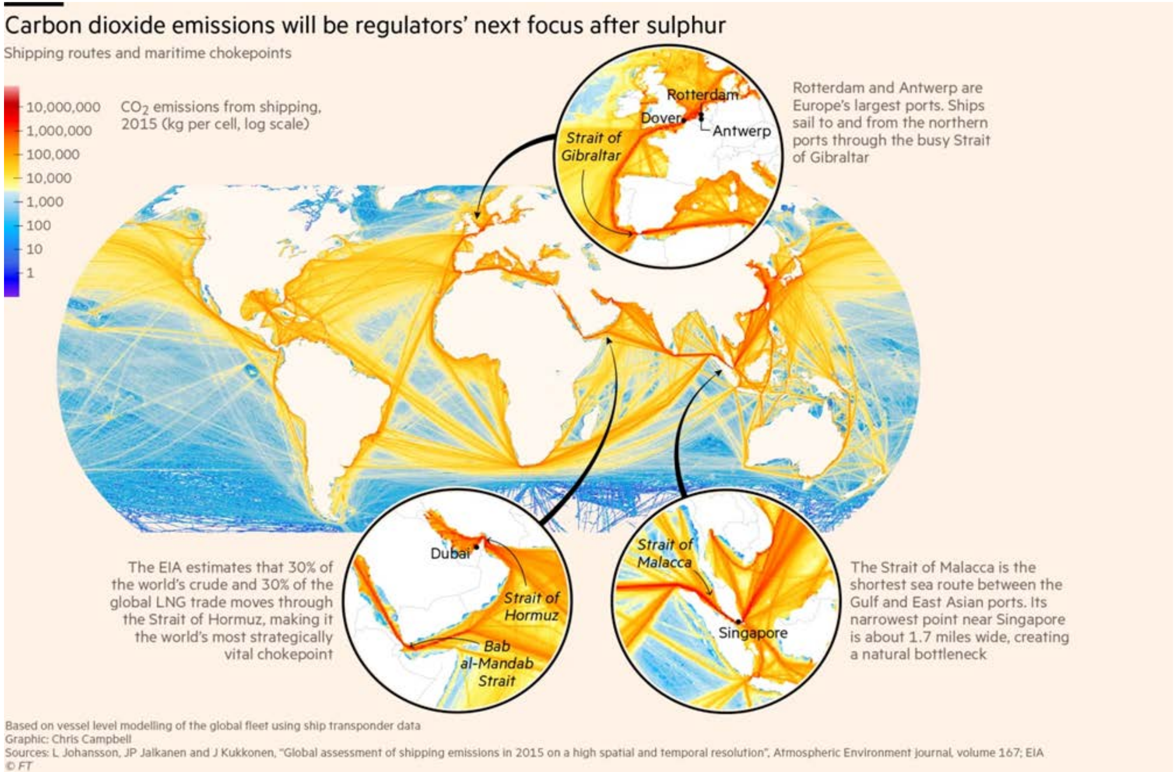
# Group Discussion on EEDI Phase 4
# 2017-2021

Chairman : Gerhard Strasser
Members : -

# $CO_2$ emissions caused by maritime sector



# Energy Efficiency Design Index (EEDI)

The Energy Efficiency Design Index (EEDI) was made mandatory for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for all ships at MEPC 62 (July 2011) with the adoption of amendments to MARPOL Annex VI (resolution MEPC.203(62)), by Parties to MARPOL Annex VI.

# Energy Efficiency Design Index

Main Engines

Auxiliary engine power

Shaft motor(s)

Output of the innovative mechanical energy efficient technology for propulsion

$$\frac{\left(\prod_{j=1}^{n} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}{*}\right) + \left(\left(\prod_{j=1}^{n} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}{**}\right)}{f_i \cdot f_c \cdot f_l \cdot Capacity \cdot f_w \cdot V_{ref}}$$

Correction factor for ship specific design elements e.g. ice class etc.

Cubic capacity correction factor

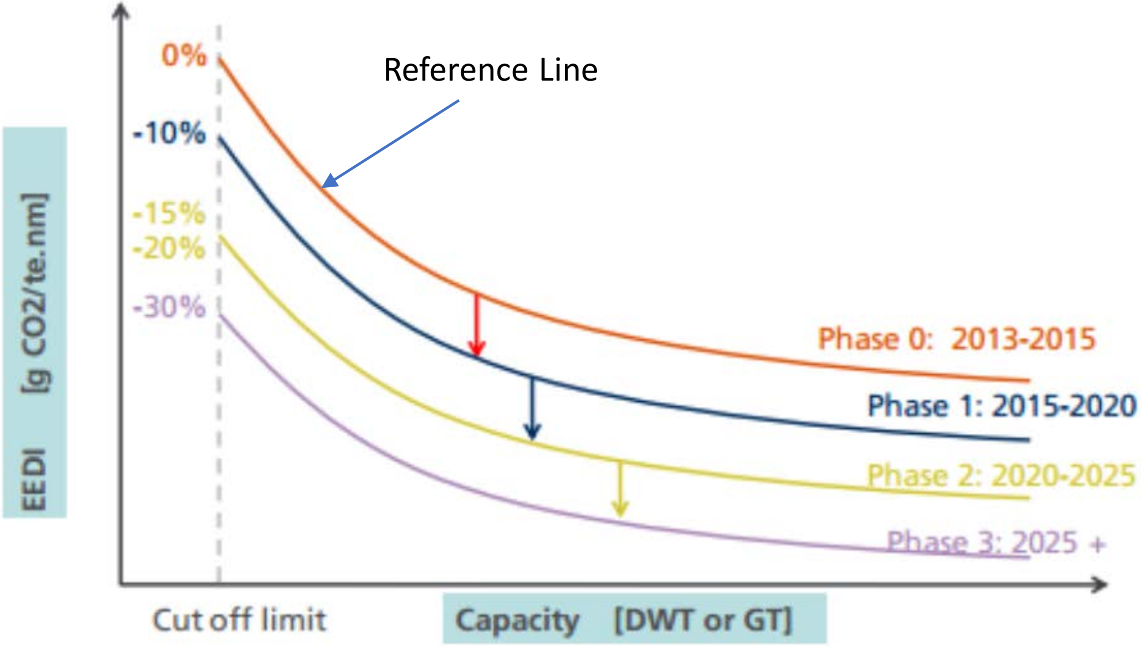
capacity factor for any technical/regulatory limitation

Deadweight, gross tonnage etc.

Weather factor as reduction of speed

Ship's speed at EEDI power

# EEDI Concept



# Paris Agreement (12 December 2015)

## Central Aim

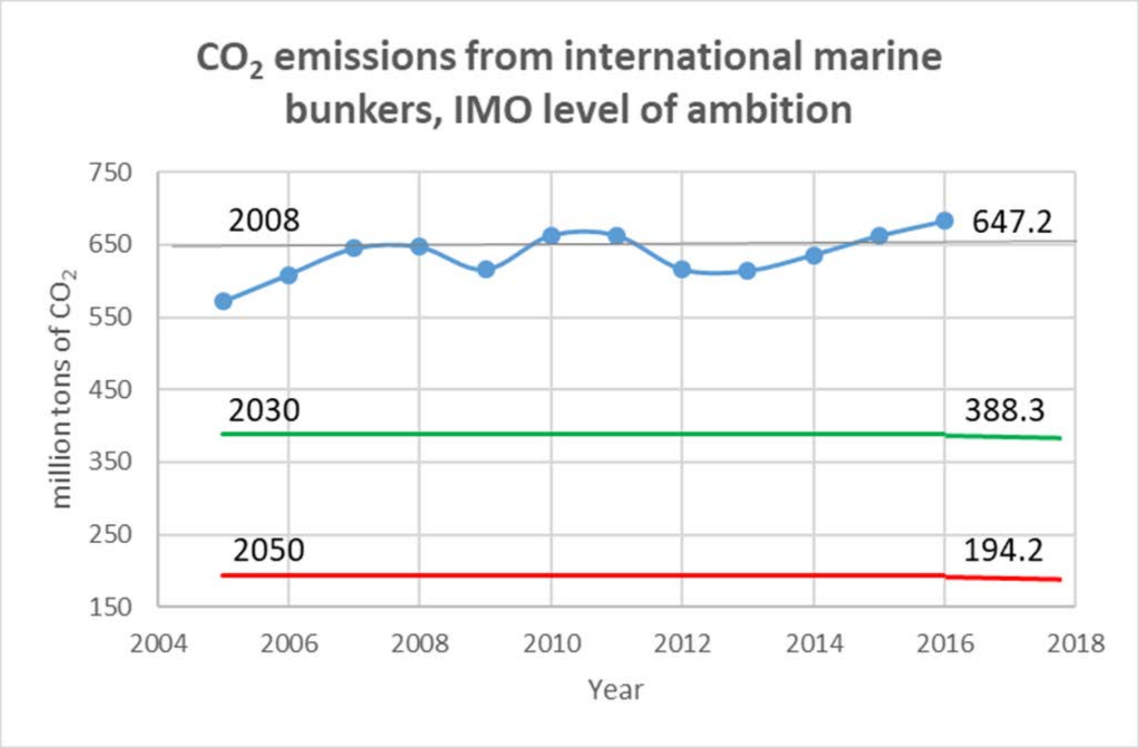
to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2°Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5° Celsius

# Initial IMO strategy on reduction of GHG emissions from ship

## Levels of Ambition

1. **carbon intensity** of the ship to decline through implementation of further phases **of the energy efficiency design index (EEDI)** for new ships
2. **carbon intensity** of international shipping **reduce $CO_2$** emissions per transport work, **by at least 40% by 2030,** pursuing **efforts towards 70% by 2050, compared to 2008**
3. **GHG emissions** from international shipping to peak and decline GHG emissions from international shipping as soon as possible and to **reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008**

# Level of ambition of IMO strategy



# IMO / EEDI Phase 3

Phase 3 of the EEDI rules were scheduled to come into effect in 2025 and require a reduction of power of 30% over the baseline. Now it was decided in MEPC 75 to bring forward the next phase of EEDI reductions for gas carriers, containerships, general cargo vessels, LNG carriers and cruise ships to 2022.

# IMO/ EEDI Phase 3

The suggestions at MEPC 74 was that
gas tankers above 15 000 tdw
general cargo ships above 3 000 tdw
LNG carriers above 10 000 tdw
cruise ships above 25 000 grt
should be considered to come into effect 2022.
For containerships between 1 500 tdw and 40 000 tdw the reduction rate of 30% remains
containerships above 40 000 tdw will be subject to a sliding scale to a reduction rate up to 50%.

Decided in MEPC 75

# Reduction factors (in percentage) for the EEDI relative to the EEDI reference line

6 The existing table 1 (Reduction factors (in percentage) for the EEDI relative to the EEDI reference line) and the associated footnotes are replaced by the following:

"

| Ship Type | Size | Phase 0 1 Jan 2013 – 31 Dec 2014 | Phase 1 1 Jan 2015 – 31 Dec 2019 | Phase 2 1 Jan 2020 – 31 Mar 2022 | Phase 2 1 Jan 2020 – 31 Dec 2024 | Phase 3 1 Apr 2022 and onwards | Phase 3 1 Jan 2025 and onwards |
|---|---|---|---|---|---|---|---|
| Bulk carrier | 20,000 DWT and above | 0 | 10 | | 20 | | 30 |
| | 10,000 and above but less than 20,000 DWT | n/a | 0-10* | | 0-20* | | 0-30* |
| Gas carrier | 15,000 DWT and above | 0 | 10 | 20 | | 30 | |
| | 10,000 and above but less than 15,000 DWT | 0 | 10 | | 20 | | 30 |
| | 2,000 and above but less than 10,000 DWT | n/a | 0-10* | | 0-20* | | 0-30* |
| Tanker | 20,000 DWT and above | 0 | 10 | | 20 | | 30 |
| | 4,000 and above but less than 20,000 DWT | n/a | 0-10* | | 0-20* | | 0-30* |
| Containership | 200,000 DWT and above | 0 | 10 | 20 | | 50 | |
| | 120,000 and above but less than 200,000 DWT | 0 | 10 | 20 | | 45 | |
| | 80,000 and above but less than 120,000 DWT | 0 | 10 | 20 | | 40 | |
| | 40,000 and above but less than 80,000 DWT | 0 | 10 | 20 | | 35 | |
| | 15,000 and above but less than 40,000 DWT | 0 | 10 | 20 | | 30 | |

# Reduction factors (in percentage) for the EEDI relative to the EEDI reference line

| Ship Type | Size | Phase 0<br>1 Jan 2013<br>–<br>31 Dec 2014 | Phase 1<br>1 Jan 2015<br>–<br>31 Dec 2019 | Phase 2<br>1 Jan 2020<br>–<br>31 Mar 2022 | Phase 2<br>1 Jan 2020<br>–<br>31 Dec 2024 | Phase 3<br>1 Apr 2022<br>and onwards | Phase 3<br>1 Jan 2025<br>and onwards |
|---|---|---|---|---|---|---|---|
| | 10,000 and above but less than 15,000 DWT | n/a | 0-10* | 0-20* | | 15-30* | |
| General Cargo ships | 15,000 DWT and above | 0 | 10 | 15 | | 30 | |
| | 3,000 and above but less than 15,000 DWT | n/a | 0-10* | 0-15* | | 0-30* | |
| Refrigerated cargo carrier | 5,000 DWT and above | 0 | 10 | | 15 | | 30 |
| | 3,000 and above but less than 5,000 DWT | n/a | 0-10* | | 0-15* | | 0-30* |
| Combination carrier | 20,000 DWT and above | 0 | 10 | | 20 | | 30 |
| | 4,000 and above but less than 20,000 DWT | n/a | 0-10* | | 0-20* | | 0-30* |
| LNG carrier*** | 10,000 DWT and above | n/a | 10** | 20 | | 30 | |
| Ro-ro cargo ship (vehicle carrier)*** | 10,000 DWT and above | n/a | 5** | | 15 | | 30 |
| Ro-ro cargo ship*** | 2,000 DWT and above | n/a | 5** | | 20 | | 30 |
| | 1,000 and above but less than 2,000 DWT | n/a | 0-5*,** | | 0-20* | | 0-30* |
| Ro-ro passenger ship*** | 1,000 DWT and above | n/a | 5** | | 20 | | 30 |
| | 250 and above but less than 1,000 DWT | n/a | 0-5*,** | | 0-20* | | 0-30* |
| Cruise passenger ship*** having non-conventional propulsion | 85,000 GT and above | n/a | 5** | 20 | | 30 | |
| | 25,000 and above but less than 85,000 GT | n/a | 0-5*,** | 0-20* | | 0-30* | |

* Reduction factor to be linearly interpolated between the two values dependent upon ship size. The lower value of the reduction factor is to be applied to the smaller ship size.

** Phase 1 commences for those ships on 1 September 2015.

*** Reduction factor applies to those ships delivered on or after 1 September 2019, as defined in

# IMO / EEDI Phase 4 Correspondence Group, some statements

- The EEDI is a statistical instrument that is best suited for large numbers of reasonably homogenous ships. It is not well-suited for segments with small populations or with a large variety between the designs within the population.
- For segments, where design requirements are still considered necessary, an equivalency approach should be developed

# IMO / EEDI Phase 4 Correspondence Group, some statements

- There is a discussion whether it should still be based on the ship types used for the previous phases.
- Many contributions stress that the introduction of Phase 4 should be based an **adequate number of data.**
- Present EEDI only considers $CO_2$ , not Green House Gases (GHG)
- The requirements for „minimum power“ in adverse seas is still a topic.

.

# Safety Considerations (in many comments of the correspondence Group)

- **Minimum manoeuvrability in adverse sea conditions (minimum power)**

    - Waves (bulk carriers, tankers)
    - Wind (container ships, cruise ships

# Achievement of IMO Levels of Ambition

**The IMO levels of ambition cannot be reached by energy efficiency improvement only**.
Therefore, there has started an investigation in

- alternative fuels
- Electrical drives ( also Hybrid)
  - chemically stored electricity (batteries)
  - solar panels
  - Fuel cells (hydrogen)
- different propulsion engine units (nuclear)
- additional propulsion aids (sails, Flettner Rotor)

# TABLE OF FUEL/TECHNOLOGY OPTIONS FOR POSSIBLE EEDI PHASE 4

**Different Fuels**
Hydrogen
Ammonia
Biofuel
Ethane
Methanol (Methane Slip!)
Synthetic fuels
LOHC (Liquid Organic Hydrogen Carrier)
Fuel cell
Battery electric / Hybrid
Wind power
Nuclear
Solar power

# TABLE OF FUEL/TECHNOLOGY OPTIONS FOR POSSIBLE EEDI PHASE 4

**Machinery and Equipment**
Waste heat recovery
Boiler configuration Design with burner having Variable Frequency Drive (VFD) plus damper
Power take-off (PTO)
Efficiency improvement of main engine auxiliary systems

**Different Fuels**
Hydrogen
Ammonia
Biofuel
Ethane
Methanol (Methane Slip)
Synthetic fuels
LOHC (Liquid Organic Hydrogen Carrier)
Fuel cell
Battery electric / Hybrid
Wind power
Nuclear
Solar power

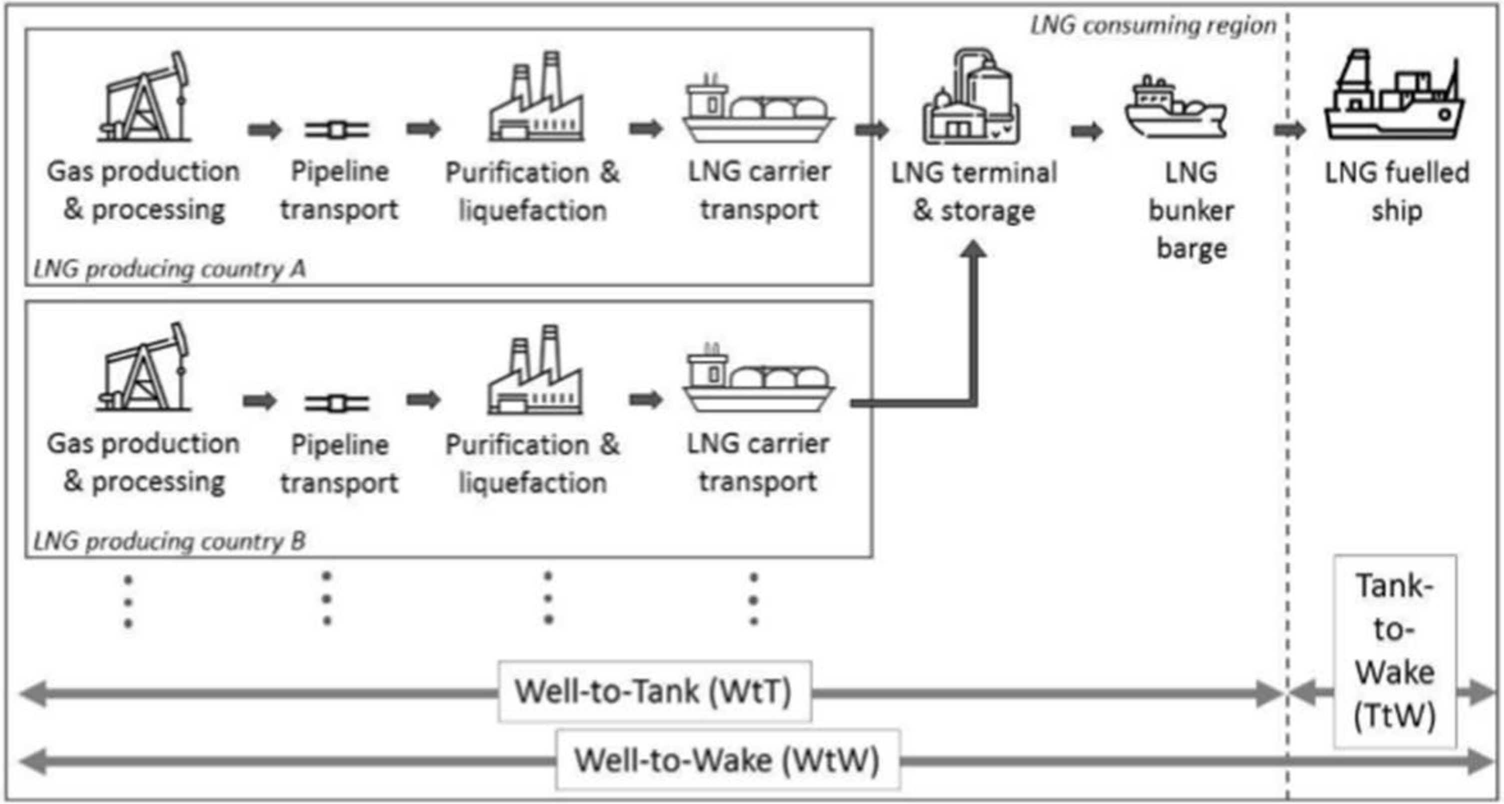
# TABLE OF FUEL/TECHNOLOGY OPTIONS FOR POSSIBLE EEDI PHASE 4

**Hydrodynamics**
Hydrodynamic innovative technology (in general)
Air cavity / Air lubrication systems
Energy saving device (in general)
Propeller optimization (compared to traditional design)

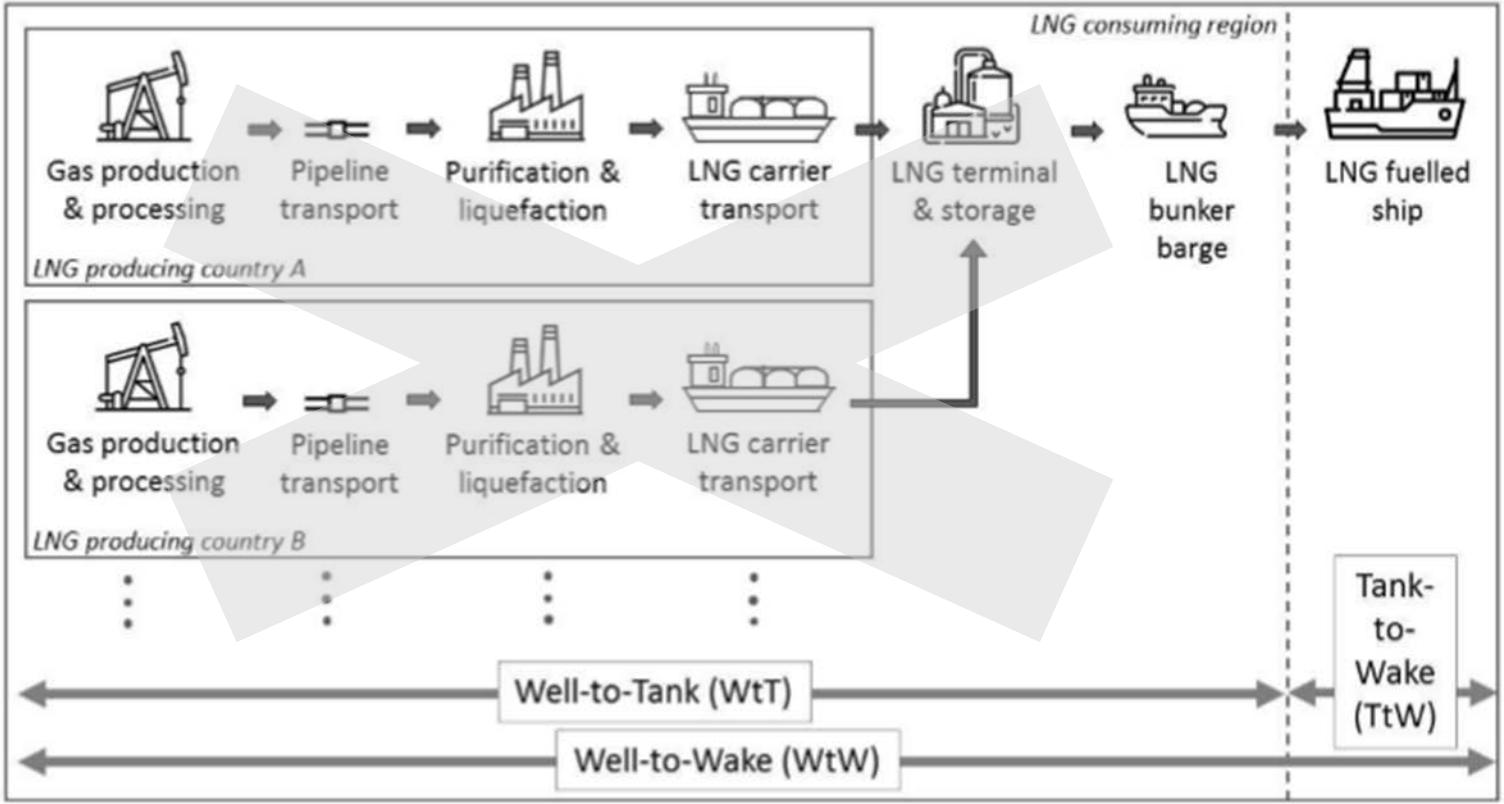
**Machinery and Equipment**
Waste heat recovery
Boiler configuration Design with burner having
Variable Frequency Drive (VFD) plus damper
Power take-off (PTO)
Efficiency improvement of main engine auxiliary systems

**Different Fuels**
Hydrogen
Ammonia
Biofuel
Ethane
Methanol (Methane Slip)
Synthetic fuels
LOHC (Liquid Organic Hydrogen Carrier)
Fuel cell
Battery electric / Hybrid
Wind power
Nuclear
Solar power

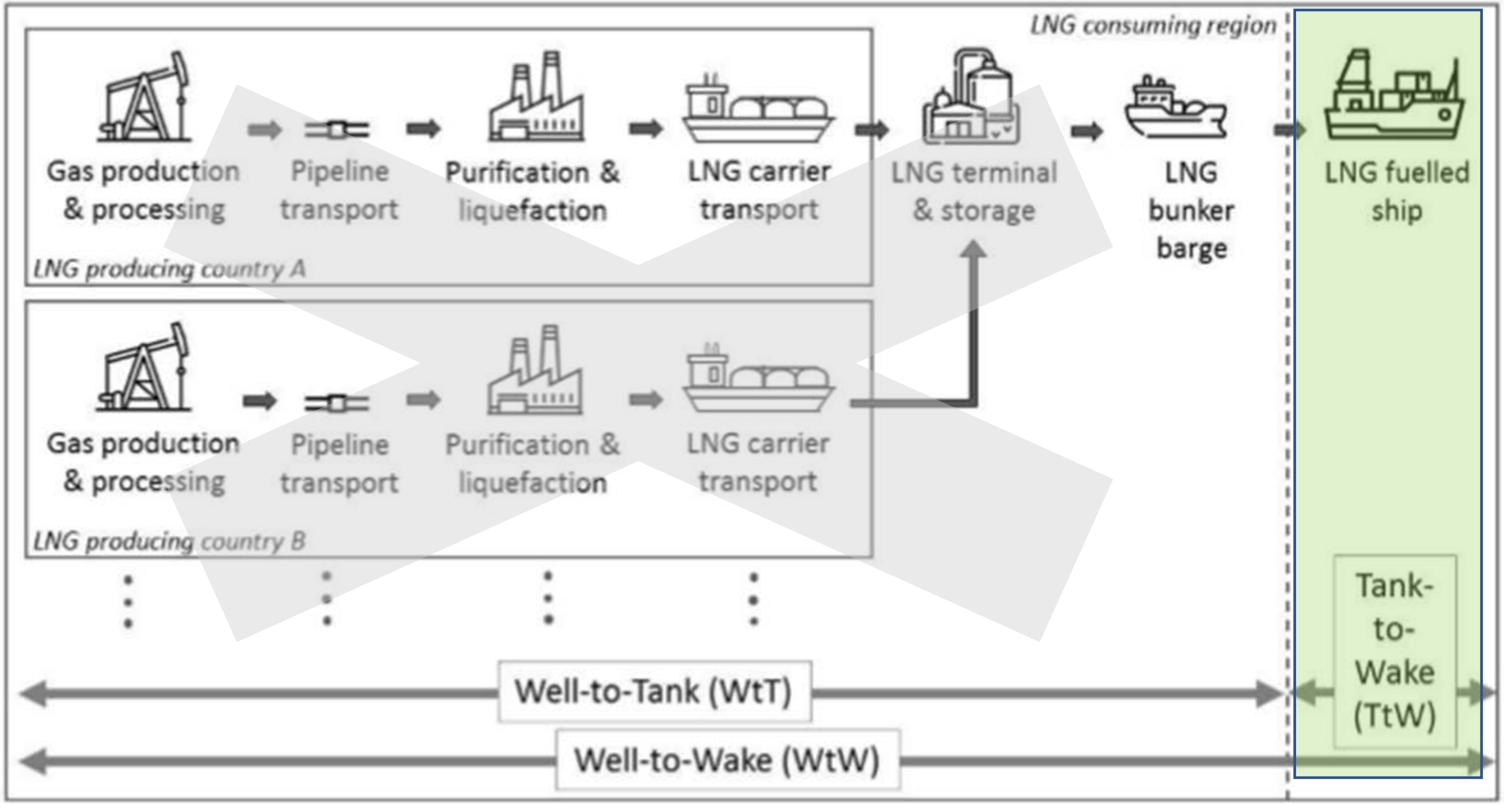
# Life Cycle Perspective of Alternative Fuels excluded



# Life Cycle Perspective of Alternative Fuels excluded



# Life Cycle Perspective of Alternative Fuels excluded



# Relevant for Ship Fluid Dynamics

$$\sum_{i=1}^{nME} \frac{P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}}{f_i \cdot f_c \cdot f_l \cdot Capacity \cdot f_w \cdot V_{ref}}$$

***P*** is the power of the main and auxiliary engines, measured in kW. The subscripts $_{ME}$ and $_{AE}$ refer to the main and auxiliary engine(s), respectively.

$\boldsymbol{C_F}$ is a non-dimensional conversion factor between fuel consumption measured in g and $CO_2$ emission also measured in g based on carbon content.(No GHG)

***SFC*** is the certified specific fuel consumption, measured in g/kWh, of the engines. The subscripts $_{ME(i)}$ and $_{AE(i)}$ refer to the main and auxiliary engine(s), respectively.

$\boldsymbol{V_{ref}}$ is the ship speed, measured in nautical miles per hour (knot), on deep water in the condition corresponding to the Capacity as defined in paragraphs 2.3.1 and 2.3.3

# Reducing EEDI value

Reduce while keeping the speed

$$\frac{\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + }{f_i \cdot f_c \cdot f_l \cdot Capacity \cdot f_w \cdot V_{ref}}$$

Increase while keeping power low

Increase factor i.e. reduce added resistance

Increase while keeping power low

# Possibilities for Reducing the EEDI Value

| Measure | Effect on |
|---|---|
| Speed Reduction | $V_S$ |
| Capacity Increase | *Capacity* |
| Drag Reduction | $P_{ME}$, $f_w$ |
| Reduction of Propulsive Losses | $P_{ME}$, $P_{eff}$ |
| Operational Measures | EEOI |
| Ship Maintenance | EEOI |
| Innovative technologies | $P_{eff}$, $f_{eff}$ |
| Improvement of efficiency of engine plant | $P_{ME}$ of main engines and $P_{AE}$ auxiliary engines |

- Effect on Power and Capacity

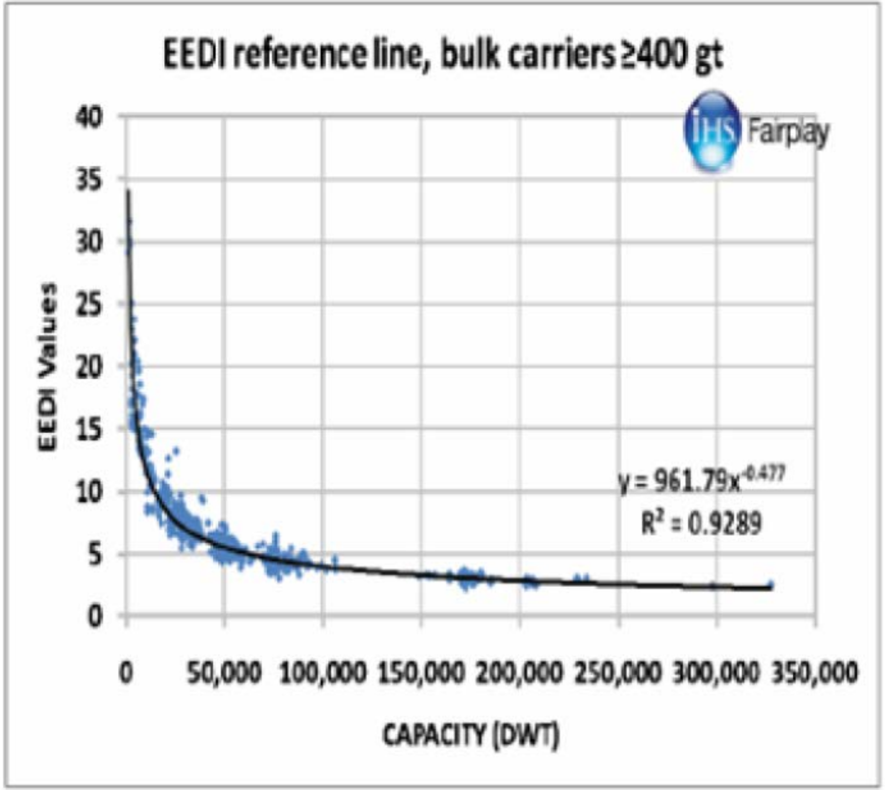
$$P_p = \frac{\Delta_p^{2/3} V_p^3}{A_p}$$

| | |
|---|---|
| $P_P$ | power necessary for propulsion of the ship |
| $\Delta_P$ | displacement |
| $V_P$ | ship speed |
| $A_P$ | admiralty coefficient for the particular ship |

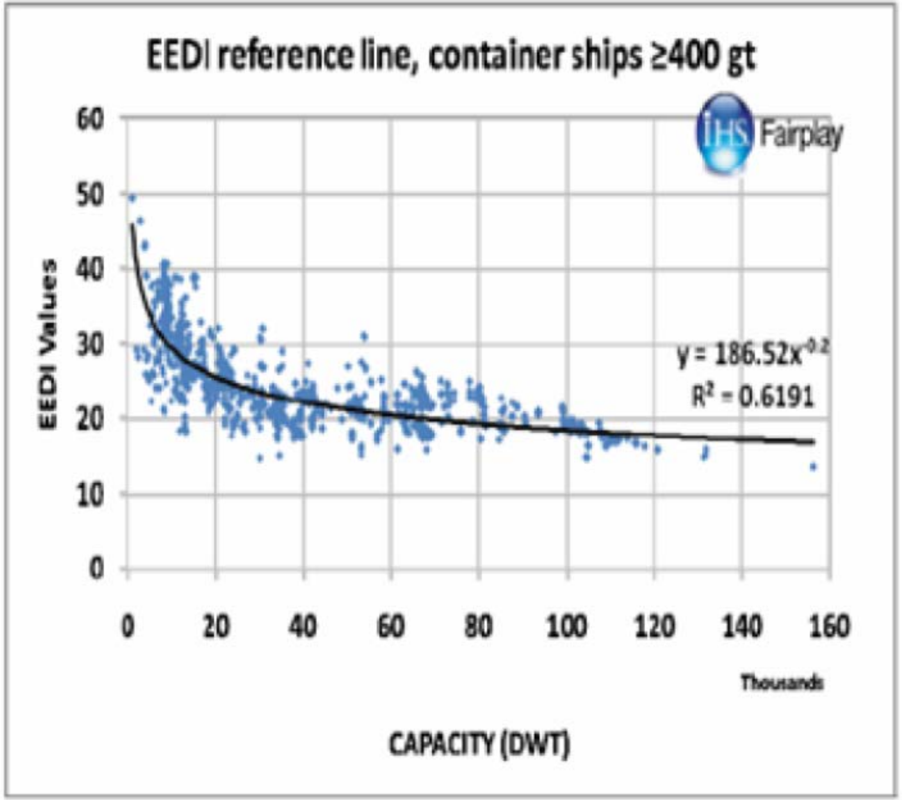
# Possibilities for Reducing the EEDI Value

| Measure | Effect on |
|---|---|
| Speed Reduction | $V_S$ |
| Capacity Increase | *Capacity* |
| Drag Reduction | $P_{ME}$, $f_w$ |
| Reduction of Propulsive Losses | $P_{ME}$, $P_{eff}$ |
| Operational Measures | EEOI |
| Ship Maintenance | EEOI |
| Innovative technologies | $P_{eff}$, $f_{eff}$ |
| Improvement of efficiency of engine plant | $P_{ME}$ of main engines and $P_{AE}$ auxiliary engines |

# EEDI Reference Line Bulk Carriers



# EEDI Reference Line Container Ships



# Possibilities for Reducing the EEDI Value

| Measure | Effect on |
|---|---|
| Speed Reduction | $V_S$ |
| Capacity Increase | *Capacity* |
| Drag Reduction | $P_{ME}$, $f_w$ |
| Reduction of Propulsive Losses | $P_{ME}$, $P_{eff}$ |
| Operational Measures | EEOI |
| Ship Maintenance | EEOI |
| Innovative technologies | $P_{eff}$, $f_{eff}$ |
| Improvement of efficiency of engine plant | $P_{ME}$ of main engines and $P_{AE}$ auxiliary engines |

# Direct Drag Reduction

| Principle | Mechanism | Technique | Methodology |
|---|---|---|---|
| Direct drag reduction | Frictional resistance | Wetted surface area | Air lubrication |
| | | Reduce sheer force | Low friction paint |
| | Viscous pressure resistance | Boundary layer control | Generate local vortices |
| | | | Constrain flow via a duct |
| | | | Hull optimisation |
| | Wave-making resistance | Bow shaping | Bulbous bow |
| | | | Hull optimisation |
| | Aero drag reduction | Shaping of upper structures | Corner rounding |
| | | | Downsizing of upper structure |
| | Added wave resistance | Incident wave reflection | Bow shaping |
| | | Ship motion | Hull shape |

# Possibilities for Reducing the EEDI Value

| Measure | Effect on |
|---|---|
| Speed Reduction | $V_S$ |
| Capacity Increase | *Capacity* |
| Drag Reduction | $P_{ME}$, $f_w$ |
| Reduction of Propulsive Losses | $P_{ME,}$ $P_{eff}$ |
| Operational Measures | EEOI |
| Ship Maintenance | EEOI |
| Innovative technologies | $P_{eff}$, $f_{eff}$ |
| Improvement of efficiency of engine plant | $P_{ME}$ of main engines and $P_{AE}$ auxiliary engines |

# Reducing Propulsive Losses

| | | | |
|---|---|---|---|
| Reducing propulsive losses | Relative rotative efficiency | Bilge vortex energy recovery | Pre swirl stators |
| | | | Vortex generators |
| | Hull efficiency | Hull-propeller interaction | Vortex generators |
| | | | Hull-propeller optimisation |
| | Rotational efficiency | Reduce rotational energy in the propeller wake | Pre swirl stators |
| | | | Contra-rotating propeller |
| | | | Reaction rudder |
| | | | Rudder fin |
| | | | Hub fins |
| | | | Overlapping propellers |
| | Axial efficiency | Hub vortex recovery | Hub fins |
| | | | Rudder bulb |
| | | Reduce tip vortex | Tip-fin propeller |
| | | | Tip-rake propeller |
| | | In-flow management | Ducts |
| | | | Overlapping propellers |
| | Frictional efficiency | Coatings | Low friction paint |
| | | Boundary Layer control | Injection |
| | Propeller design | Blade design | Area, thickness, section, tip loaded propeller |
| | | CFD, optimization | |

# Possibilities for Reducing the EEOI Value

| Measure | Effect on |
|---|---|
| Speed Reduction | $V_S$ |
| Capacity Increase | *Capacity* |
| Drag Reduction | $P_{ME}$, $f_w$ |
| Reduction of Propulsive Losses | $P_{ME}$, $P_{eff}$ |
| Operational Measures | EEOI |
| Ship Maintenance | EEOI |
| Innovative technologies | $P_{eff}$, $f_{eff}$ |
| Improvement of efficiency of engine plant | $P_{ME}$ of main engines and $P_{AE}$ auxiliary engines |

# Operational Measures

- Slow Steaming
- Optimization of Trim and Ballast
- Running at constant speed when possible

# Possibilities for Reducing the EEOI Value

| Measure | Effect on |
|---|---|
| Speed Reduction | $V_S$ |
| Capacity Increase | *Capacity* |
| Drag Reduction | $P_{ME}$, $f_w$ |
| Reduction of Propulsive Losses | $P_{ME}$, $P_{eff}$ |
| Operational Measures | EEOI |
| Ship Maintenance | EEOI |
| Innovative technologies | $P_{eff}$, $f_{eff}$ |
| Improvement of efficiency of engine plant | $P_{ME}$ of main engines and $P_{AE}$ auxiliary engines |

# Hull Cleaning (Polishing)

- Each additional 10μm to 20μm of ‘roughness’, ABS estimates, can increase the total resistance experienced by the hull by 1% for full form ships such as tankers and carriers, and by 0.5% for ships at high speeds.
- A recent report from the Clean Shipping Coalition (CSC) estimated that inadequate hull and propeller performance could reduce the entire world’s fleet efficiency by 15-20% over a typical 4 to 5 year sailing interval. This represents a serious economic liability.

# Hull Coatings

- The main issue of hull coatings is to reduce as much as possible:
  - Corrosion
  - Hull Bio-Fowling:
    - Micro Bio-Fowling
    - Macro Bio-Fowling

There is the effort to increase the fowling life time as much as possible. The friction coefficient of the new paint is hardly reduced.

# Propeller Polishing (Cleaning)

Studies carried out by the British Research Association (BSRA) have shown that a rough propeller leads to power loss that can be up to 6%. Although the surface area of the propeller is small in comparison with that of the entire hull, the effect of a rough propeller in a ship’s fuel consumption is proportionately higher.

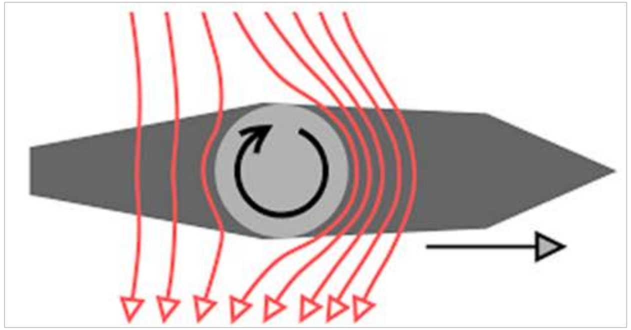
# Possibilities for Reducing the EEDI Value

| Measure | Effect on |
|---|---|
| Speed Reduction | $V_S$ |
| Capacity Increase | *Capacity* |
| Drag Reduction | $P_{ME}, f_w$ |
| Reduction of Propulsive Losses | $P_{ME}, P_{eff}$ |
| Operational Measures | EEOI |
| Ship Maintenance | EEOI |
| Innovative technologies | $P_{eff}, f_{eff}$ |
| Improvement of efficiency of engine plant | $P_{ME}$ of main engines and $P_{AE}$ auxiliary engines |

# Innovative Technologies, additional Propulsors

# Innovative Technologies, additional Propulsors

- Flettner Rotor

# Impact on Model Basins and issues (examples)

**Importance of Friction**
Slow steaming and big ship sizes lead to low Froude Numbers and consequently to high percentage of friction (which normally is calculated and not measured) in the total resistance.

**Extrapolation of power reducing devices** to full scale

**Effect of additional propulsors on the propeller**

**Manoeuvrability in heavy wind and sea conditions**
**etc.**

# Group Discussion on EEDI Phase 4

The floor is open