



# Calculated EEOI improvements using ship energy efficiency methods

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# Objectives

- To provide state-of-the-art opportunities for reducing the CO<sub>2</sub> emissions for an MR Tanker
- To examine what technical and operational CO<sub>2</sub> emission reduction methods are technically feasible for today's MR Tanker
- To present:
  - a holistic ship design process, and
  - a range of efficiency gains, represented as changes in the EEOI





# **Efficiency Methods**

- An efficiency method is any way of reducing energy consumption on board:
  - This could be by using any technology (or a combination of technologies) and/or by operation
  - Speed reduction is **not** taken as an efficiency method but used as a variable

[2]

**Electric Turbocompound** 



**Organic Rankine Cycle** 







# **Efficiency Methods**

- An efficiency method is any way of reducing energy consumption on board:
  - This could be by using any technology (or a combination of technologies) and/or by operation
  - Speed reduction is **not** taken as an efficiency method but used as a variable
- Refined based on feedback:
  - From work carried out for the Danish Shipowners Association and Lloyd's Register
  - From equipment manufacturers to check the mechanism for the Energy Efficiency





- Based on physics:
  - Comparisons with sea trials
  - PhD Research
  - Operational Experience
  - Published data (Academic and Industry)
- Secondary effects on ship (engine, propeller, etc.) from efficiency methods are calculated

– e.g. 2% + 2% ≠ 4%



### 

# **Calculation process**

- Whole Ship Model:
  - Complex sub-models.
  - Both a design process and an operational performance evaluation process.

			Whole Ship M	odel (WSM)				
	Select a (	Container S	ihip:		~			
	Select	a Bulk Car	rier:					
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EEOI and design speed



From the Third GHG Study (MEPC 67/Inf. 3, 2014)

Ship specification used (2010):

- 14.8 kn MR Tanker
- EEOI speed of 11.7 kn
- 46249 dwt
- Length = 174 m
- Beam = 32 m







- The baseline ship specifications (without efficiency methods) also include:
  - a 9% fouling and degradation factor
  - bulbous bows and a standard autopilot
  - exhaust gas boiler/economizer
- EEOI was used to measure transport efficiency because it measures actual emissions:

Average EEOI = 
$$\frac{\sum_{i} \sum_{j} (FC_{ij} \times CF_{j})}{\sum_{i} (m_{cargo,i} \times D_{i})}$$





# EEOI and design speed

2010 data [MEPC 67/INF.3] [MEPC 68/INF.24]

Survey on the use of efficiency methods

2015 survey [MEPC 69/INF.8]

- Survey of ship owners and operators on energy efficiency measures [4]:
  - Largest of its kind (covering around 5000 ships)
  - Carried out in 2015
  - Survey confirmed some preconceptions:
    - Widespread use of bulbous bows, pre/post-swirl devices, engine modifications and waste heat recovery, and,
    - generally, adoption is small.











#### Technology Efficiency Method combinations

Current technologies comb	pination	Future technologies combination				
Rudder Bulb		Contra rotating propeller				
End-plated Propeller						
Engine Derating		Engine Derating				
Speed control of pumps an	d fans	Speed control of pumps and fans				
Energy saving lighting		Energy saving lighting				
WHR Steam		WHR Steam				
		WHR Organic Rankine Cycle (ORC)				
		WHR series turbocompounding				
Technologies		High cost hull coating				
that are not		Air lubrication				
widely used		Block coefficient reduction				
		Optimistic Flettner Rotors				
+						



#### **EEOI** Reductions for a MR Tanker

EEOI change due to hydrodynamic and renewable methods (compared to 2010)

Slipping IV Changing Changing

EEOI<sub>base</sub> < 30%

**EEOI Speed** 

	Operating Speed (knots)	Baseline	Rudder bulb	Vane wheel	Contra rotating propeller (CRP)	End plated propeller	Air lubrication (AL)	Min. Flettner rotor	Max.Flettner rotor
	4.4	80.2%	80.0%	79.9%	80.9%	80.0%	86.2%	71.3%	73.0%
able	5.9	72.0%	71.7%	71.4%	72.8%	71.7%	75.9%	55.5%	57.0%
newa	8.8	77.6%	77.1%	76.6%	77.6%	77.1%	78.6%	56.5%	49.1%
nd re	9.6	82.6%	82.0%	81.4%	81.9%	82.0%	83.0%	60.5%	52.6%
ic an	10.4	88.0%	87.3%	86.6%	86.5%	87.3%	87.8%	65.0%	56.7%
nam	11.1	94.2%	93.4%	92.6%	91.7%	93.4%	93.6%	70.4%	61.8%
rody	11.5	98.1%	97.2%	96.4%	95.0%	97.2%	97.3%	73.8%	65.1%
Hyd	11.7	100.0%	99.1%	98.2%	96.6%	99.1%	99.1%	75.5%	66.7%
(er –	11.8	101.5%	100.6%	99.7%	97.9%	100.6%	100.5%	76.8%	68.0%
Tank	12.6	110.2%	109.2%	108.2%	105.4%	109.2%	108.8%	84.4%	75.3%
MR	14.1	135.7%	134.3%	133.0%	129.0%	134.3%	133.5%	104.7%	94.7%
	14.8	157.0%	155.4%	153.8%	152.0%	155.4%	154.5%	119.0%	108.0%

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#### **EEOI** Reductions for a MR Tanker

**EEOI change using** Waste Heat Recovery (WHR) and machinery modifications (compared to 2010)

70% < EEOI <sub>base</sub> > 30%

EEOI<sub>base</sub> < 30

< EEOI <sub>base</sub> > 30%	
EOI <sub>base</sub> < 30%	
EEOI Speed	

	Operating Speed (knots)	Baseline	WHR steam (conventional)	WHR organic Rankine cycle (ORC)	WHR series turbocompounding	WHR parallel turbocompounding	Engine tuning	Engine derating	Speed controlled pumps and fans	
	4.4	80.2%	80.4%	80.2%	76.9%	80.2%	79.6%	79.9%	79.6%	
	5.9	72.0%	72.2%	72.0%	69.5%	72.0%	71.4%	71.5%	71.5%	
n methods	8.8	77.6%	78.1%	77.6%	76.0%	77.6%	77.0%	76.8%	77.3%	
	9.6	82.6%	83.2%	82.6%	81.1%	82.6%	82.0%	81.6%	82.3%	
	10.4	88.0%	88.6%	88.0%	86.6%	88.0%	87.3%	86.8%	87.7%	
	11.1	94.2%	94.9%	94.2%	92.9%	94.2%	93.4%	92.8%	94.0%	
catio	11.5	98.1%	98.9%	96.6%	96.8%	98.1%	97.3%	96.6%	97.8%	
lodifi	11.7	100.0%	100.8%	98.4%	98.7%	100.0%	99.2%	98.5%	99.8%	
	11.8	101.5%	102.3%	99.8%	100.2%	101.5%	100.7%	99.9%	101.2%	
	12.6	110.2%	107.6%	108.0%	109.0%	107.8%	109.3%	108.5%	110.0%	
	14.1	135.7%	132.3%	132.1%	134.6%	132.6%	134.6%	133.4%	135.5%	
	14.8	157.0%	153.0%	152.3%	156.0%	153.8%	155.7%	154.3%	156.8%	14





#### **EEOI** Reductions for a MR Tanker

EEOI change when using block coefficient reduction and combinations of methods (compared to 2010).

**EEOI Speed** 

t )	Operating Speed (knots)	Baseline	Block coefficient reduction (BR)	Current combination (used in 2015)	Future combination (with CRP, AL, ORC, BR)	Future combination with wind (with CRP, AL, ORC, BC and FR)	Future combination with FR and 25% carbon factor	Future combination with FR and 50% carbon factor	Future combination with FR and 75% carbon factor
tions	4.4	80.2%	79.7%	79.3%	85.7%	70.8%	53.1%	35.4%	17.7%
lbina	5.9	72.0%	71.3%	71.0%	74.8%	53.8%	40.4%	26.9%	13.5%
t reduction and com	8.8	77.6%	76.1%	76.3%	74.8%	42.7%	32.0%	21.4%	10.7%
	9.6	82.6%	80.8%	81.1%	77.7%	45.1%	33.8%	22.6%	11.3%
	10.4	88.0%	85.8%	86.3%	81.1%	48.0%	36.0%	24.0%	12.0%
	11.1	94.2%	91.5%	92.4%	83.5%	50.1%	37.6%	25.0%	12.5%
ficien	11.5	98.1%	95.1%	96.1%	83.7%	50.1%	37.6%	25.1%	12.5%
coefi	11.7	100.0%	96.9%	97.8%	84.7%	51.0%	38.3%	25.5%	12.8%
olock	11.8	101.5%	98.2%	99.2%	85.5%	51.8%	38.8%	25.9%	12.9%
anker – b	12.6	110.2%	106.2%	103.7%	90.3%	55.9%	42.0%	28.0%	14.0%
	14.1	135.7%	129.3%	126.5%	109.3%	<mark>68.7%</mark>	51.5%	34.3%	17.2%
MR 1	14.8	157.0%	148.3%	146.1%	131.4%	79.5%	59.7%	39.8%	19.9%

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#### Efficiency methods for a MR Tanker

- For this particular ship at the EEOI speed:
  - A 2.2% reduction in EEOI from combining 6 technologies that are currently in use.
  - A **15.3%** reduction in EEOI from combining 11 possible future technologies.
  - This is potentially **49%** if Flettner rotors are included.
  - An additional 3.1% reduction in EEOI was found from operational methods (e.g. propeller polishing and hull cleaning).



# Designing ships to particular speeds and conditions

- Ships in 2010 were designed for a higher design speed, but operated at lower speeds.
- As ships operate away from their design point the efficiency of the ship and efficiency methods change:
  - For example, a conventional WHR plant is only effective close to the its design point, and
  - Hydrodynamic efficiency methods may at low speeds increase the ship resistance.



#### Charging in Charging Charging

# Conclusions

- Assuming that the same operational EEOI speed is maintained:
  - 2.2% reduction is achieved from technologies in use in 2015
  - 15.3% reduction is possible from additional technologies available at the moment
  - Higher EEOI reductions require the use of wind energy and/or fuels with a lower carbon factor (electrification, bioenergy or synthetic fuels). The EEOI becomes 87.2% (75% reduction in carbon factor) from the 2010 levels





Efficiency method decision tool with IMO paper data is at: <u>www.efficientshipdesign.com</u>

The Danish Shipowners study was carried out by U-MAS http://www.u-mas.co.uk





Image from Hans Otto Kristensen, CONTAZ units, Contra Rotating Propellers





# Thank you Questions?

**Contact Details** 

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### Modelling Process - Whole Ship Model



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# efficientshipdesign.com

Efficiency method decision tool with IMO paper data is at:

www.efficientshipdesign.com

- This includes a cost and profit calculator for a range of efficiency methods and operating speeds
- click on each efficiency method for an explanation

Efficiency method decision tool was funded by a UCL Impact Acceleration Award and was developed with the Sustainable Shipping Initiative.

#### Ship Efficiency Method Selection Decision Tool (SERVICE)

The SERVICE instruction page gives additional explanation of how this tool works and on the efficiency methods and calculations that have been carried out SERVICE version: 1.0.1 Whole Ship Model version: 0.9.5.0

click here to open the SERVICE Instructions page



click the checkboxes to select and compare methods to improve ship energy efficiency click on the name of a method for short descriptions, key assumptions and market availability none fitted rudder bulb preswirl stator duc trim optimisation vane\_wheel contra rotating propeller end plated propeller stern flap low cost hull coating high cost hull coating air lubrication block coefficient reduction wing sails minimum flettner rotors maximum flettner rotors wind kite WHRS steam WHRS ORC engine turbocompounding parallel engine turbocompounding series solar power





# Modelling Process - Whole Ship Model

