

Clean energy solutions towards zero emissions for maritime applications

Low Emission Advanced Power – LEAP Workshop, 1-5th November 2021

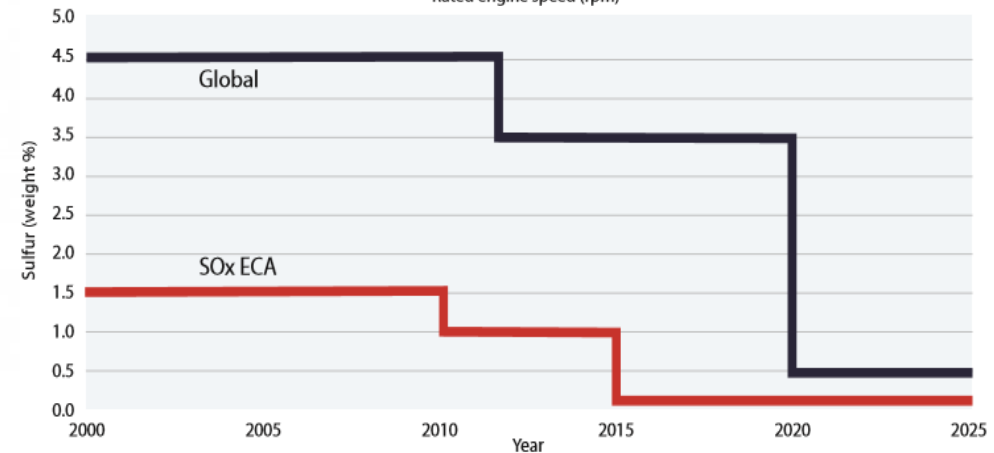
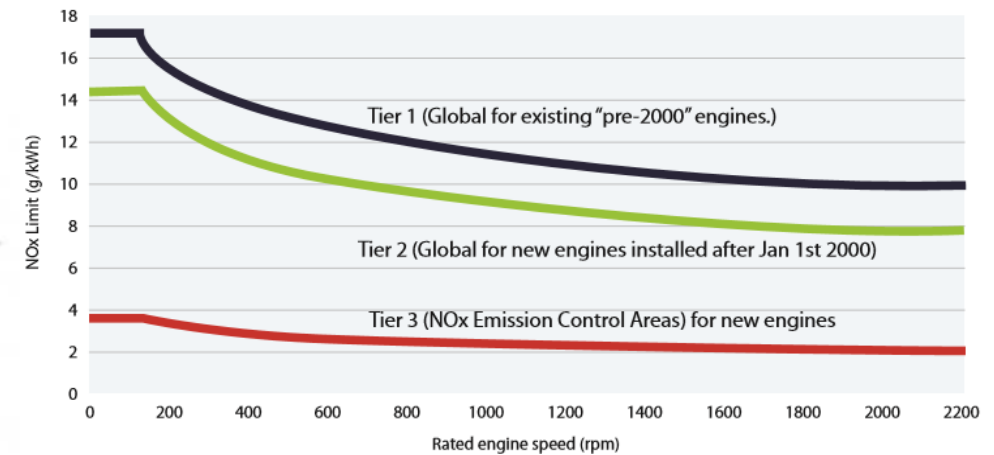
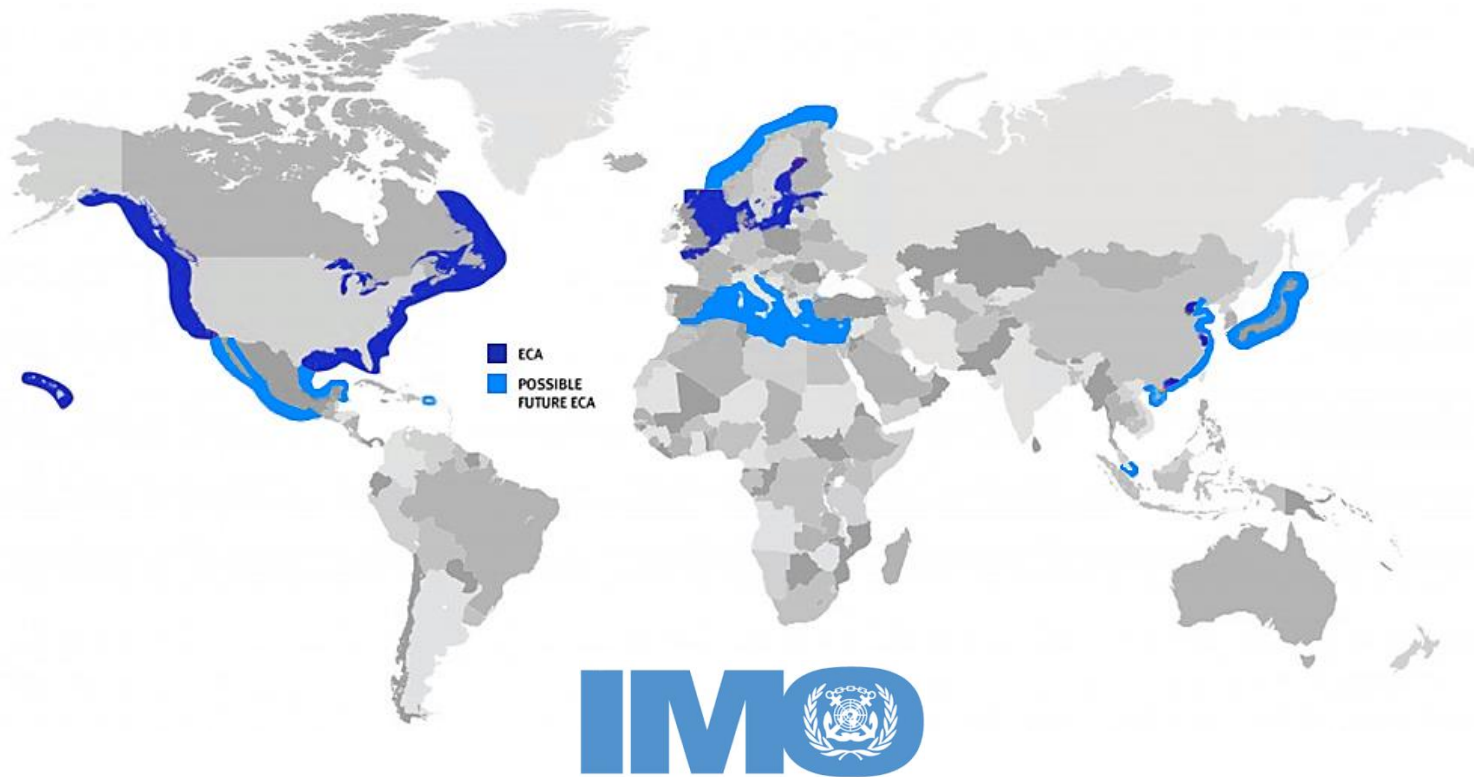
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Introduction

IMO Regulation

The International Maritime Organization (IMO) in 1997 introduced the Emission Control Areas (ECAs) to control pollutant emissions from ships (NO_x, SO_x, PM) but not CO₂. In 2018 IMO launched a strategy that aims to **reduce** CO₂ emissions by at least 50% by 2050 compared to 2008.



Source: IMO

Introduction

Current Scenario



90% of world transportation in weight terms (11,000 Mtons) by vessels



99% of ships is currently powered by ICE with conventional fuels

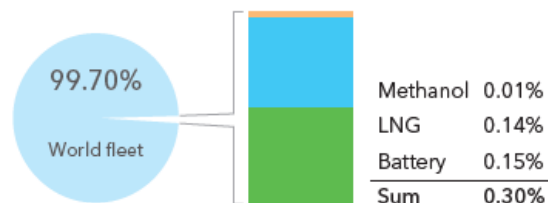


Need for
alternative fuels
and innovative
technologies

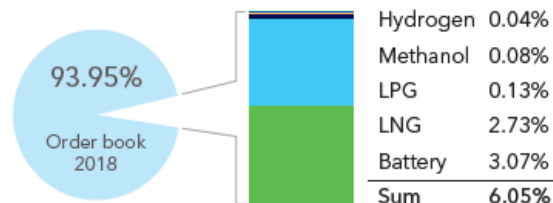


2.8% of global CO₂ emissions due to maritime sector (in 2018 about 870 million tons of CO₂)

Ships in operation

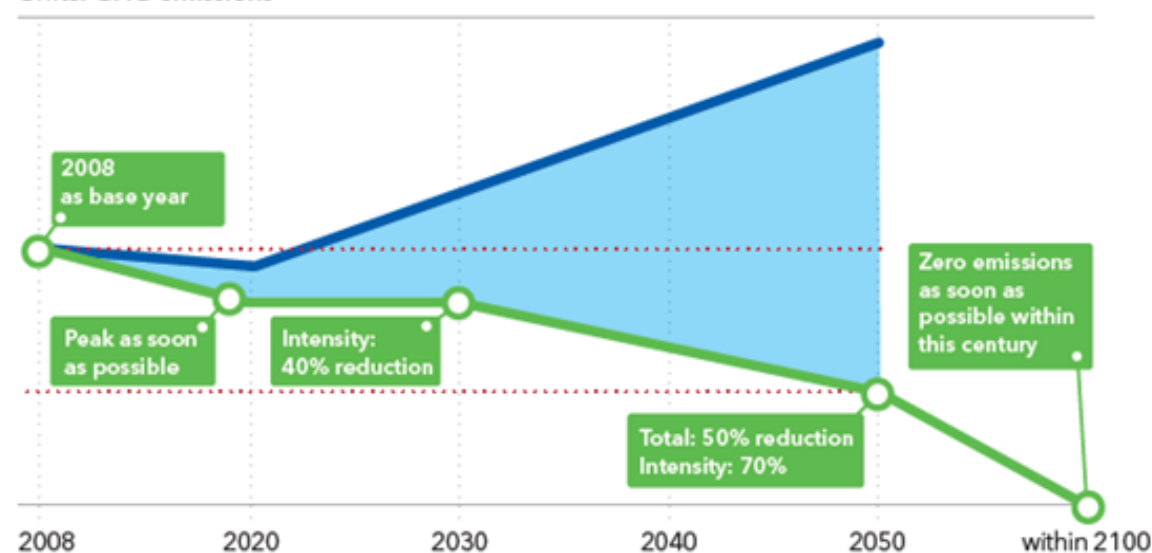


Ships on order



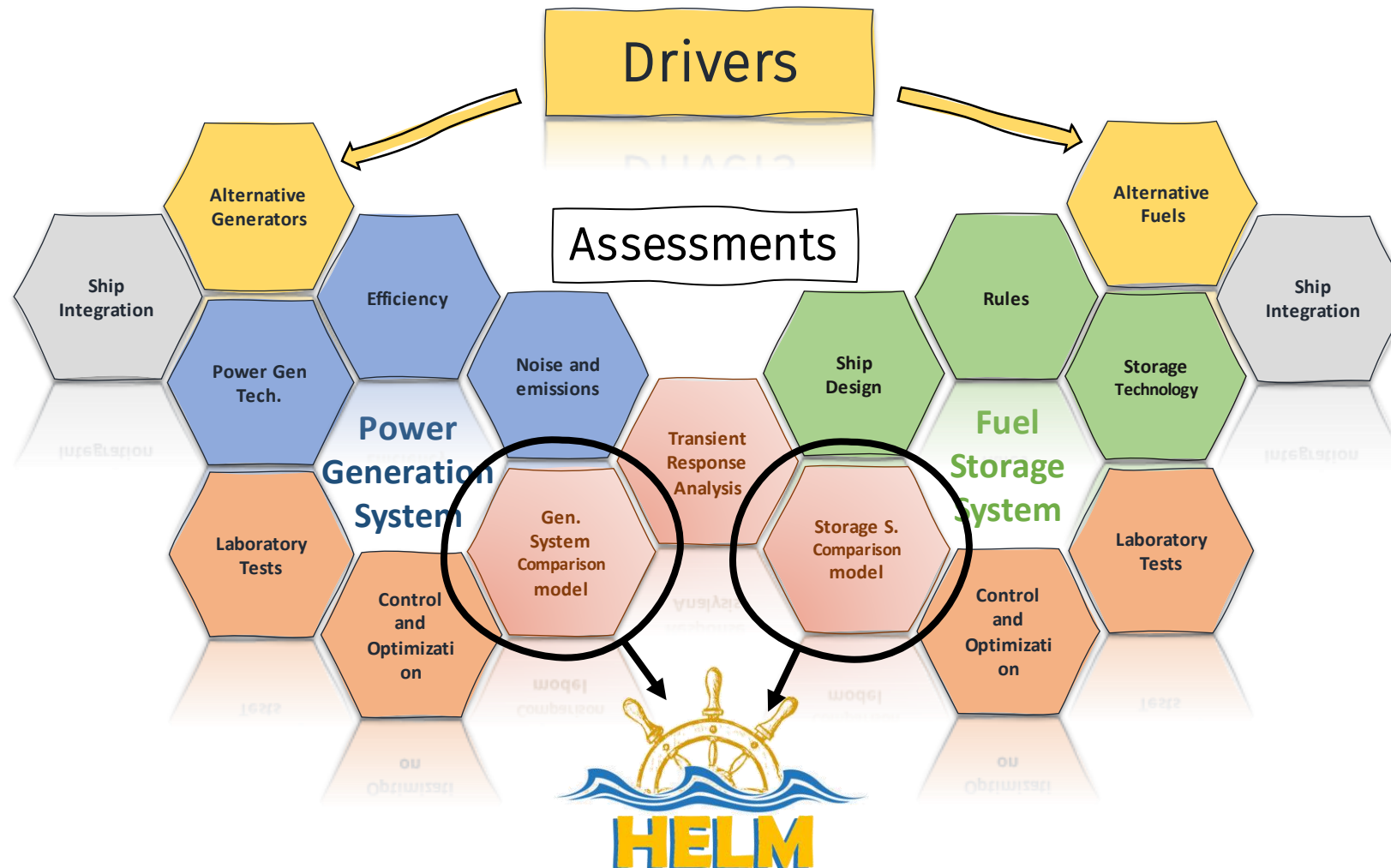
^{a)}Source: DNV GL's Alternative Fuels Insight (AFI) portal, <https://www.dnvgl.com/services/alternative-fuels-insight-128171>

Units: GHG emissions



Introduction

Alternative Fuels and innovative technologies



HELM Tool Description

HELM (Helper for Energy Layouts in Maritime applications)



HELM compares different solutions for energy production in maritime applications considering the **relevance** of:



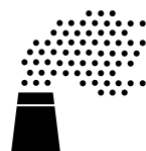
Weights



Volumes



Costs

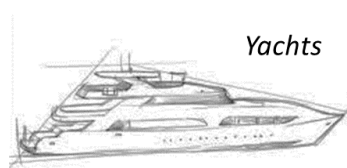


Emissions

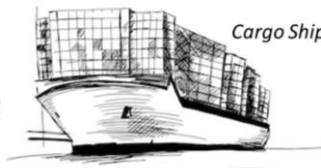
$$X = \frac{V_i}{V_{best}}$$

Value	Score	Value	Score
$1 < X \leq 1.1$	10	$3 < X \leq 4$	5
$1.1 < X \leq 1.3$	9	$4 < X \leq 5$	4
$1.3 < X \leq 1.6$	8	$5 < X \leq 6$	3
$1.6 < X \leq 2$	7	$6 < X \leq 8$	2
$2 < X \leq 3$	6	$X > 8$	1

In relation to a specific scenario and application



Yachts



Cargo Ships



Cruise ships

Technologies implemented in HELM

Energy generation	PEMFC		SOFC	micro GT	Internal Combustion Engine		
Fuel storage	CH ₂	LH ₂	LNG	LNG	Methanol	LNG	MDO Ammonia

Case study (small ferry boat) and results

Installed power: 500 kW

Autonomy: 8 hours



Volumes



3/5



KG

Weights



1/5



Costs

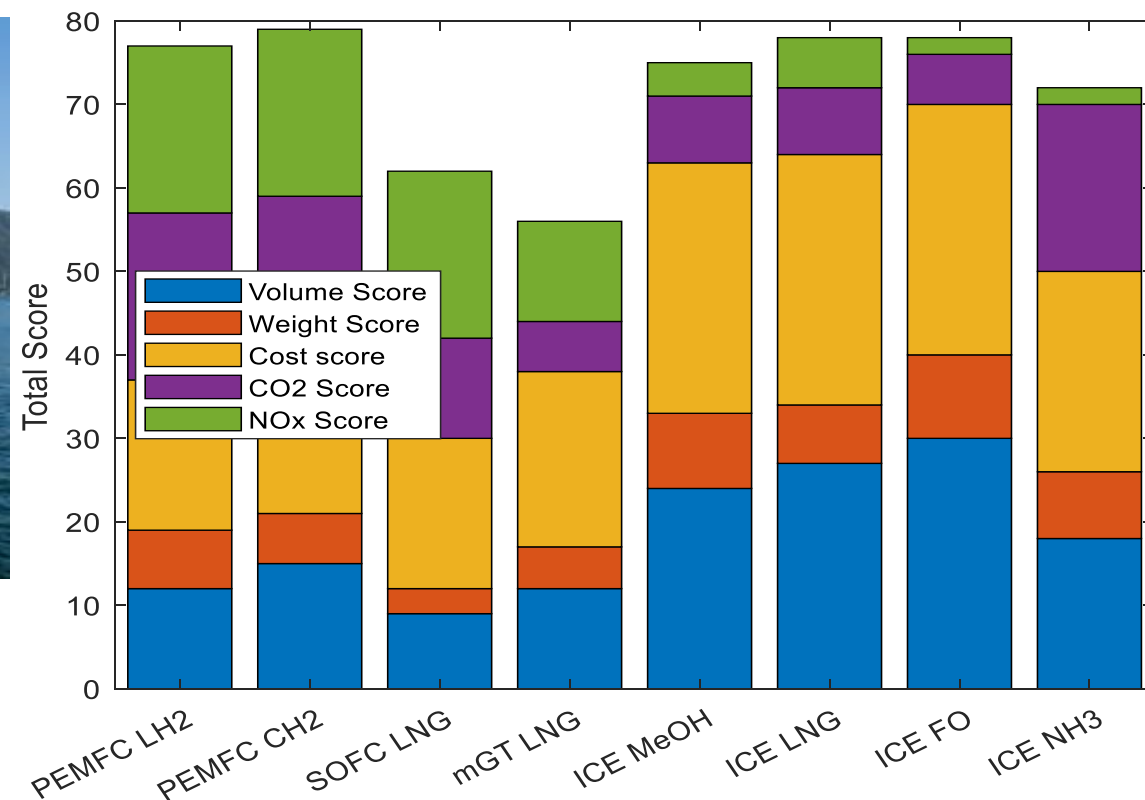


3/5



4/5

Emissions



Technology	Total Volume [m^3]	Total Weight [tons]	Total Cost [k\$]	CO2 [kg]	NOx [kg]
PEMFC LH2	40.8	6.6	682	0	0
PEMFC CH2	33.3	9.4	664	0	0
SOFC LNG	58.9	31.5	655	1685	0
mGT LNG	49.7	15.2	468	3186	1.0
ICE MeOH	12.7	5.2	272	2839	16.5
ICE LNG	10.2	7.1	283	2407	7.4
ICE FO	9.2	4.1	261	3298	38.9
ICE NH3	18.8	6.1	342	0	38.6

HELM user interface



*Tool for innovative solutions
in maritime applications*



Max. Power Required [kW] 500

Operational hours 8

PEM Fuel Cells
+ LH2



PEM Fuel Cells
+ CH2



SOFC + LNG



mGT + LNG



Internal Combustion
Engine + MeOH



Internal Combustion
Engine + LNG



Internal Combustion
Engine + FO



Internal Combustion
Engine + NH3



PEM Efficiency 45

PEM Efficiency 45

SOFC Efficiency 50

mGT Efficiency 30

ICE Efficiency 35

ICE Efficiency 35

ICE Efficiency 35

ICE Efficiency 35

H2 Weight [tons] 0.280

H2 Weight [tons] 0.267

LNG Weight [tons] 0.613

LNG Weight [tons] 1.021

MeOH Weight [tons] 2.057

LNG Weight [tons] 0.875

FO Weight [tons] 1.029

NH3 Weight [tons] 2.198

Tot Weight [tons] 6.64

Tot Weight [tons] 9.44

Tot Weight [tons] 31.49

Tot Weight [tons] 15.19

Tot Weight [tons] 5.18

Tot Weight [tons] 7.12

Tot Weight [tons] 4.13

Tot Weight [tons] 6.06

Tot Volume [m3] 40.84

Tot Volume [m3] 33.32

Tot Volume [m3] 58.92

Tot Volume [m3] 49.72

Tot Volume [m3] 12.71

Tot Volume [m3] 10.15

Tot Volume [m3] 9.17

Tot Volume [m3] 18.81

Tot Fix Cost [kUSD] 682

Tot Fix Cost [kUSD] 664

Tot Fix Cost [kUSD] 655

Tot Fix Cost [kUSD] 468

Tot Fix Cost [kUSD] 272

Tot Fix Cost [kUSD] 283

Tot Fix Cost [kUSD] 261

Tot Fix Cost [kUSD] 342

CO2 [tons] 0.00

CO2 [tons] 0.00

CO2 [tons] 1.69

CO2 [tons] 3.19

CO2 [tons] 2.84

CO2 [tons] 2.41

CO2 [tons] 3.30

CO2 [tons] 0.00

NOx [kg] 0.00

NOx [kg] 0.00

NOx [kg] 0.00

NOx [kg] 0.98

NOx [kg] 16.46

NOx [kg] 7.35

NOx [kg] 38.86

NOx [kg] 38.62

Batteries % 0.00

Batteries % 0.00

SCORE 77

79

62

56

75

78

78

72

Volume Relevance 3

Weight Relevance 1

Costs Relevance 3

Emissions Relevance 4

Calculate

Generate
simulation report

Calculate and export
dataset with current
relevance values

Calculate and export
batteries
dataset

Show dataset 3D map

Show batteries 3D map

Zero Emission Ultimate Ship (ZEUS) - 2022

Developed in the framework of the TECBIA project (financed by Italian Government)

- First Italian Hydrogen Ship (ZEUS), lenght 25 m
- PEM Fuel Cells (140 kW) and electric batteries for propulsion
- H₂ stored in metal hydrides, autonomy 8 hours.



UNIVERSITÀ DEGLI STUDI DI NAPOLI "FEDERICO II"
DIPARTIMENTO DI INGEGNERIA CHIMICA,
DEI MATERIALI E DELLA PRODUZIONE INDUSTRIALE



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