UTICAJ BRODOVA NA ZAGAĐENJE VAZDUHA

PANEL @ UCG/PFK 27.11.2024.

Prof. dr Danilo Nikolić

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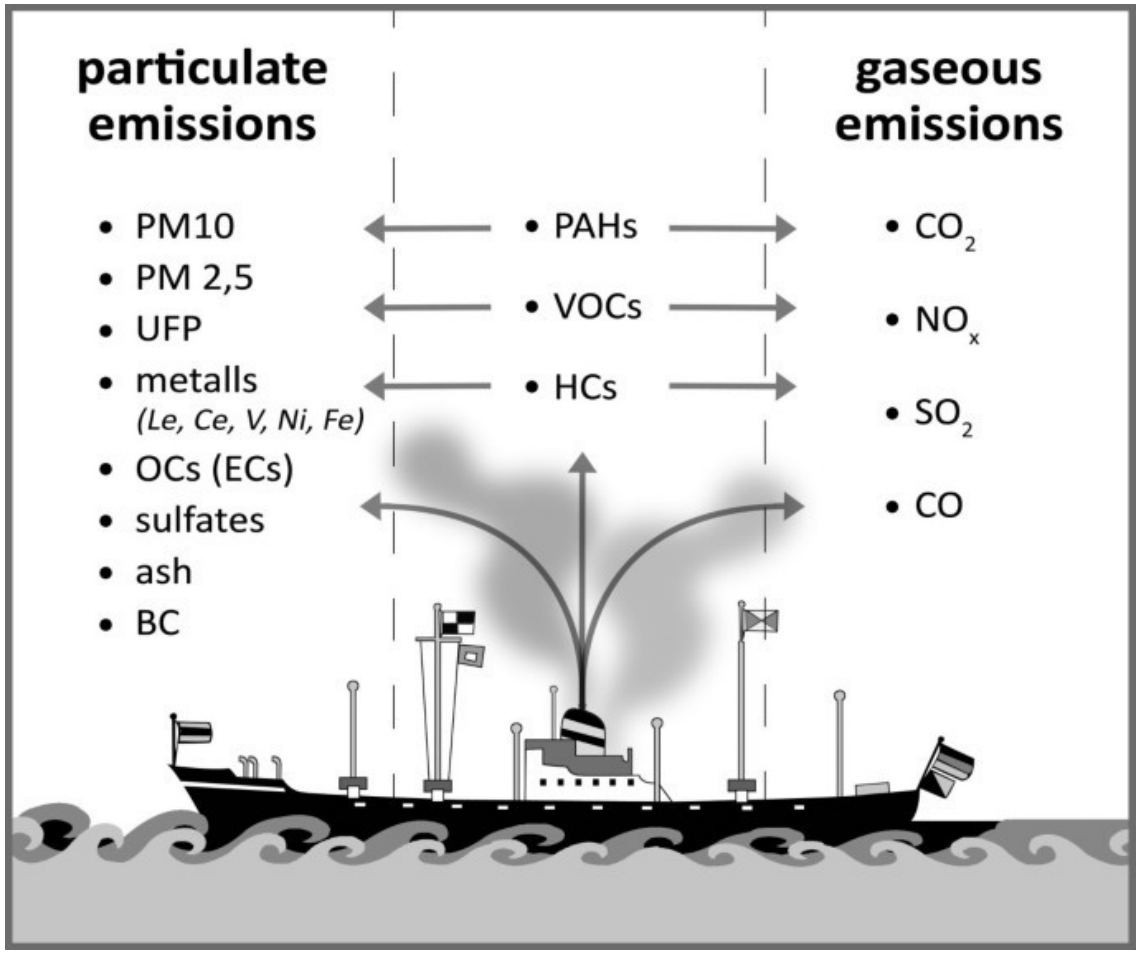
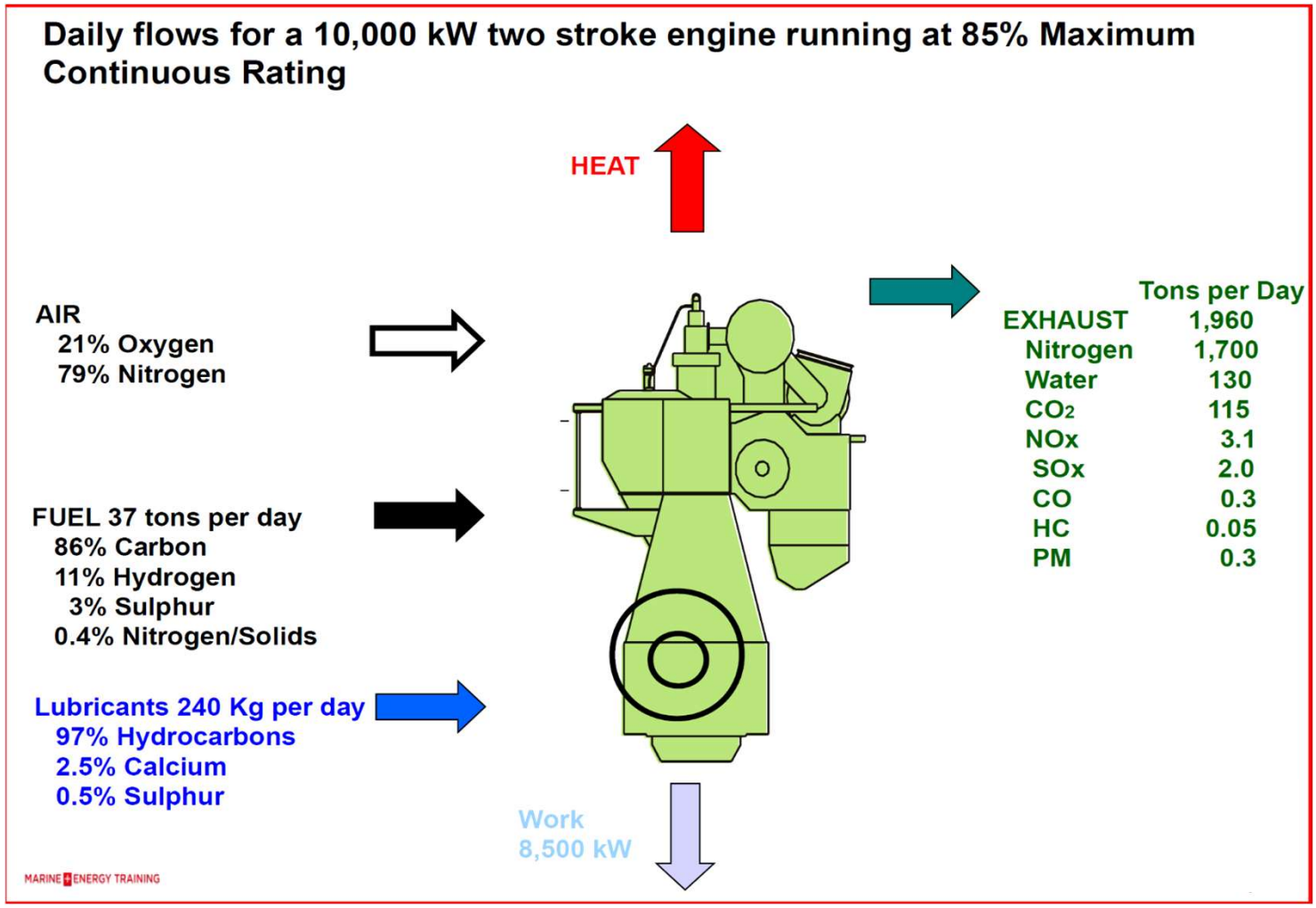
COMPOSITION OF EXHAUST GAS EMISSIONS FROM SHIP ENGINE

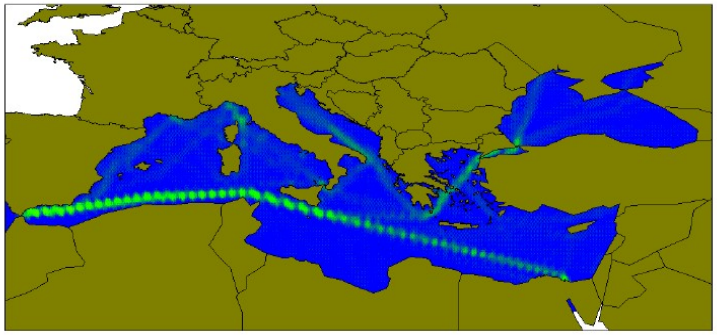


https://doi.org/10.1186/1745-6673-6-31



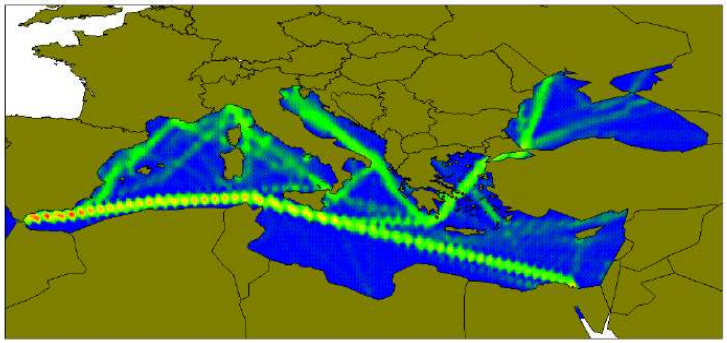
Izduvna emisija iz brodskih dizel motora

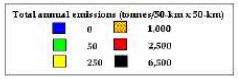
Estimated emissions of hydrocarbons from shipping operating in the Mediterranean & Black Sea regions, 1990



HC

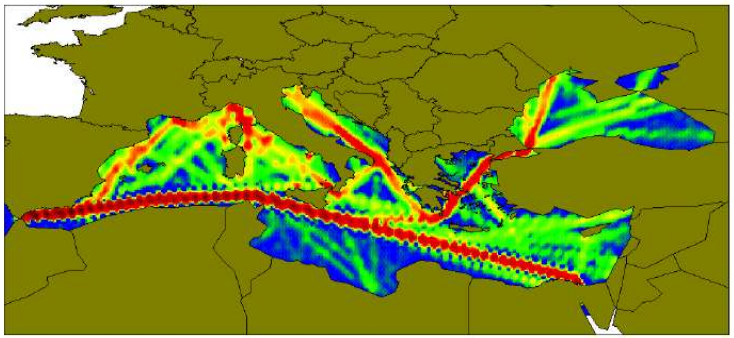
Estimated emissions of carbon monoxide from shipping operating in the Mediterranean & Black Sea regions, 1990

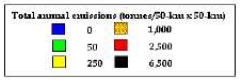




CO

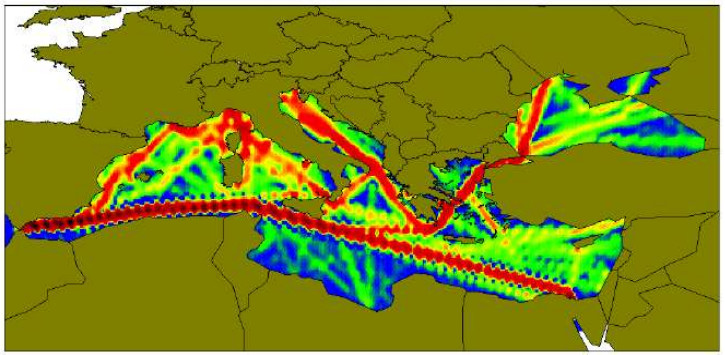
Estimated emissions of sulphur dioxide from shipping operating in the Mediterranean & Black Sea regions, 1990

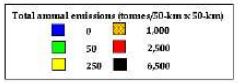




SO_2

Estimated emissions of oxides of nitrogen from shipping operating in the Mediterranean & Black Sea regions, 1990



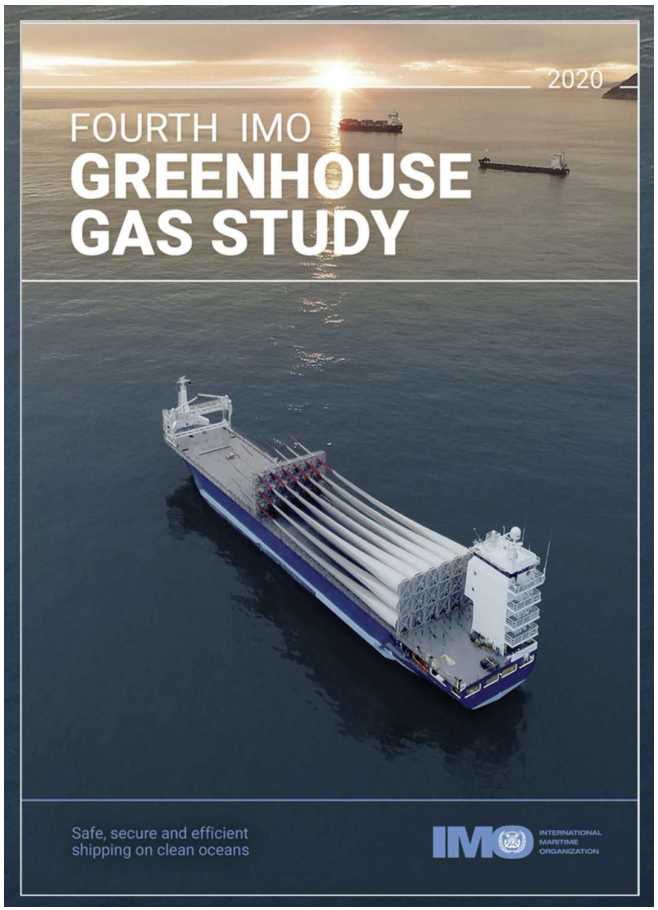


NOx

Emission of GHG and Pollutants

Substance	
CO_2	Climate Change
SOx	Air quality (smog - health problems) Acidification Climate change
NOx	Air quality (smog - health problems) Acidification Climate change
PM	Air quality (health problems)

Global CO_2 Emission from Maritime Transport



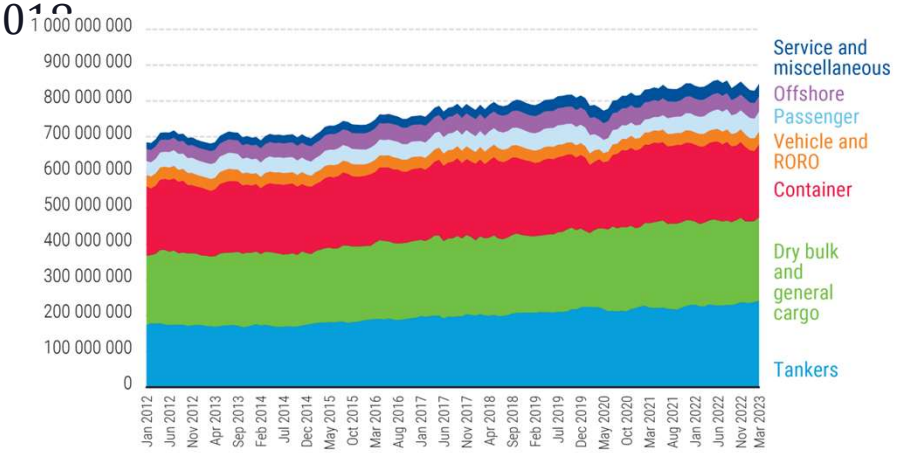
- ✓ Total amount of GHG emissions from shipping have increased from 977 million tonnes in 2012 to 1,076 million tonnes in 2018 (9.6% increase).
- ✓ The share of shipping emissions has increased from 2.76% in 2012 to **2.89%** in 201[illegible]

1st IMO GHG Studija 2000.

2nd IMO GHG Studija 2009.

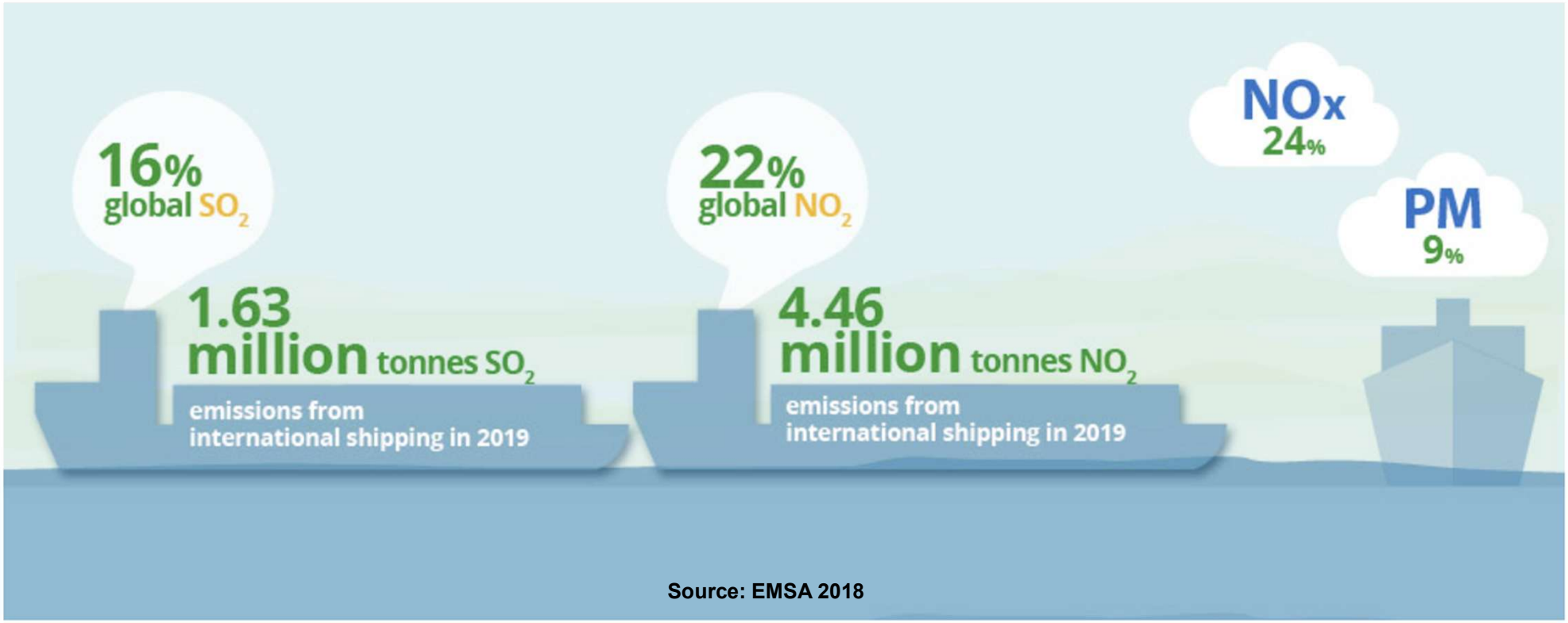
3rd IMO GHG Studija 2014.

4th IMO GHG Studija 2020.

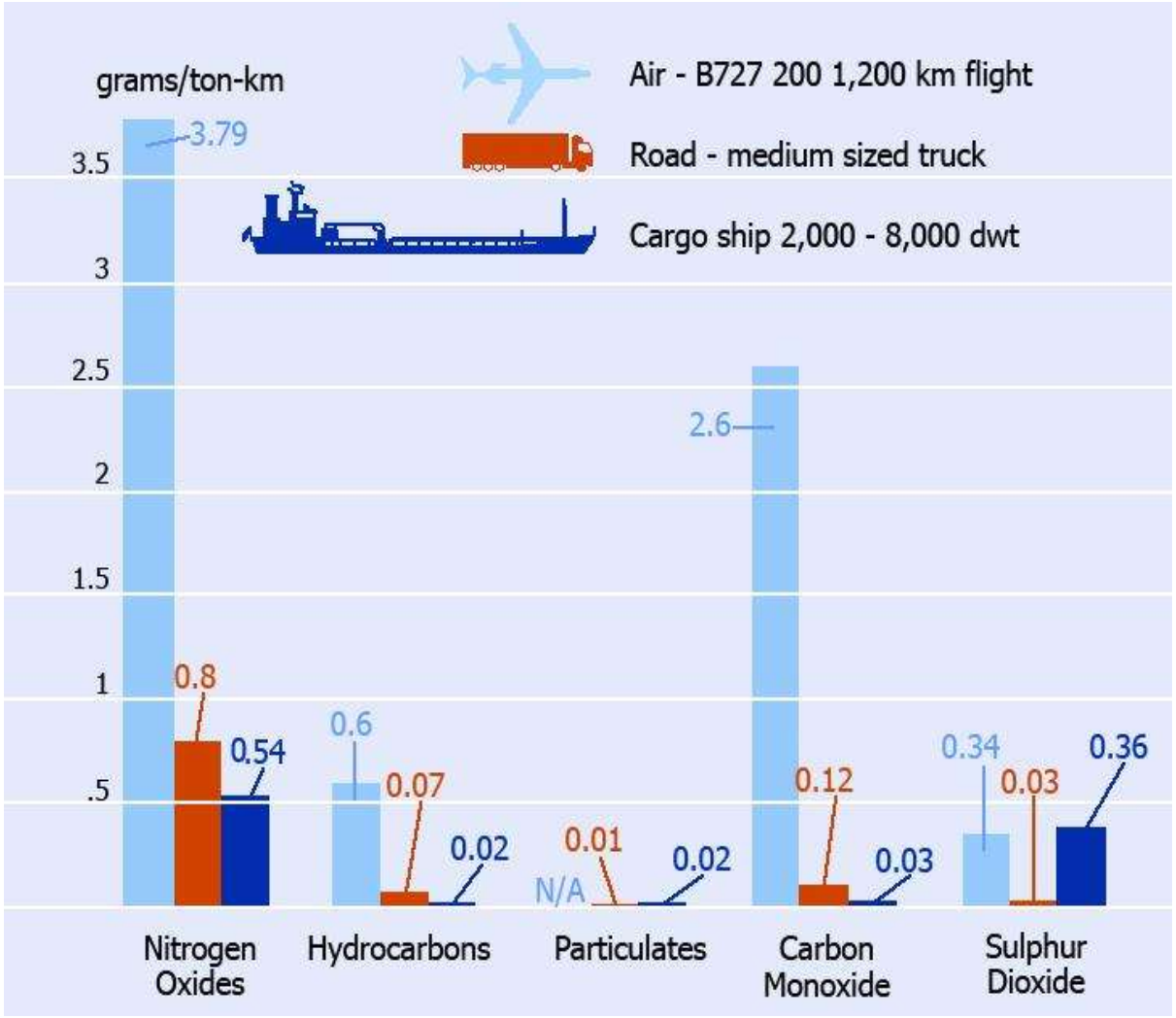


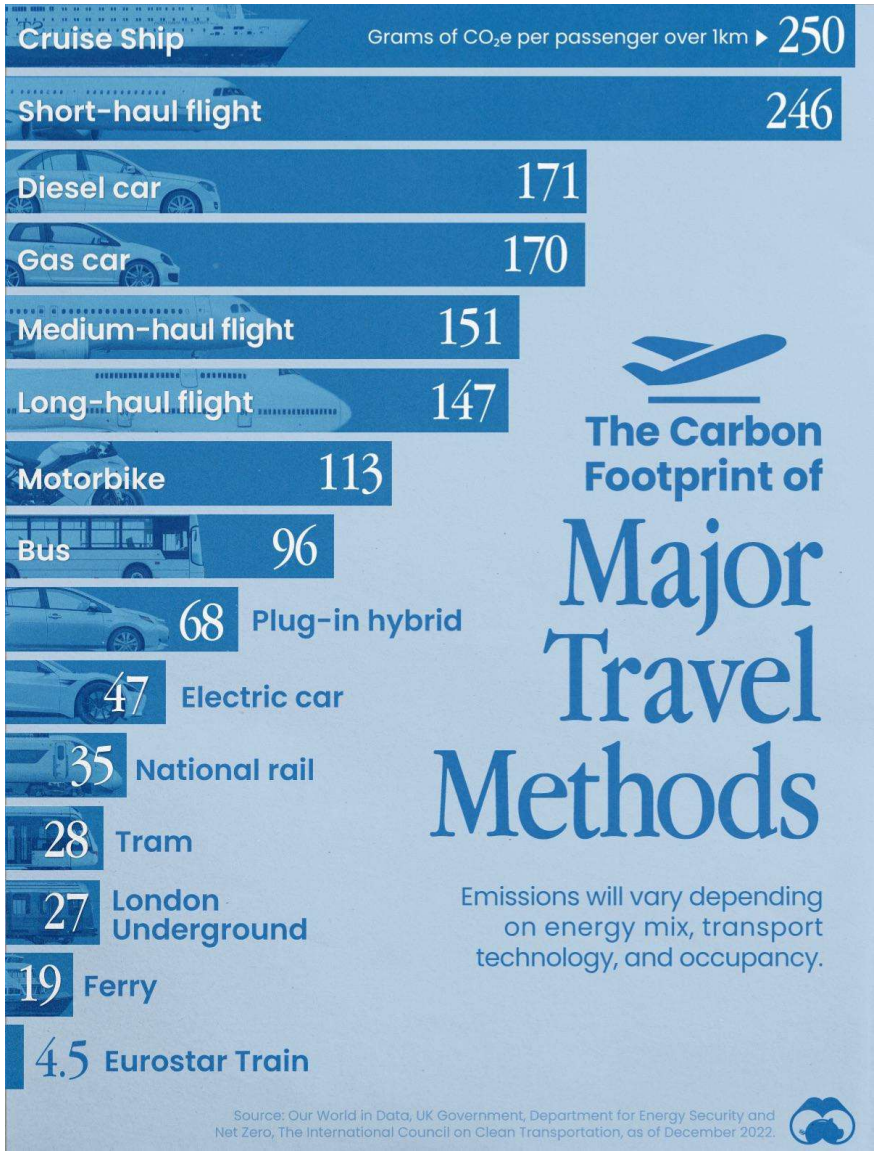
Source: UNCTAD, based on data provided by Marine Benchmark, July 2023.
Note: RORO means roll-on/roll-off vehicle carrier.

Total carbon dioxide emissions by vessel types, tons, January 2012—March 2023 (**684 mil t CO_2 - 850 mil t CO_2**)



Source: EMSA 2018


grams/ton-km
Air - B727 200 1,200 km flight
Road - medium sized truck
Cargo ship 2,000 - 8,000 dwt
3.5
3
2.5
2
1.5
1
.5
3.79
0.8
0.54
0.6
0.07
0.02
0.01
N/A
0.02
2.6
0.12
0.03
0.34
0.03
0.36
Nitrogen Oxides
Hydrocarbons
Particulates
Carbon Monoxide
Sulphur Dioxide

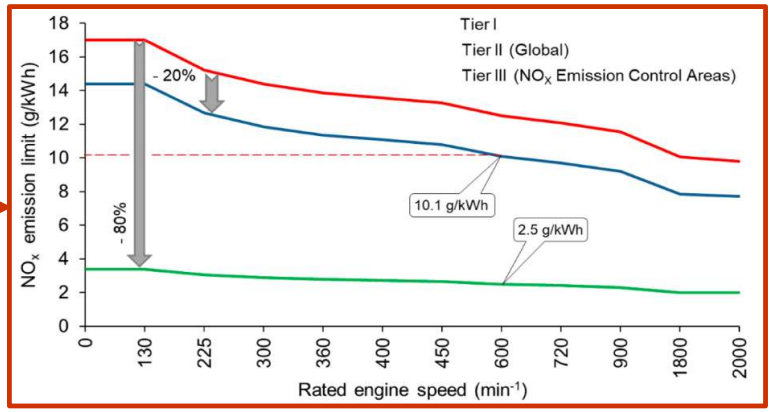

Cruise Ship
Grams of CO_2e per passenger over 1km ▶ 250
Short-haul flight 246
Diesel car 171
Gas car 170
Medium-haul flight 151
Long-haul flight 147
Motorbike 113
Bus 96
68 Plug-in hybrid
47 Electric car
35 National rail
28 Tram
27 London Underground
19 Ferry
4.5 Eurostar Train
The Carbon Footprint of
Major Travel Methods
Emissions will vary depending on energy mix, transport technology, and occupancy.
Source: Our World in Data, UK Government, Department for Energy Security and Net Zero, The International Council on Clean Transportation, as of December 2022.

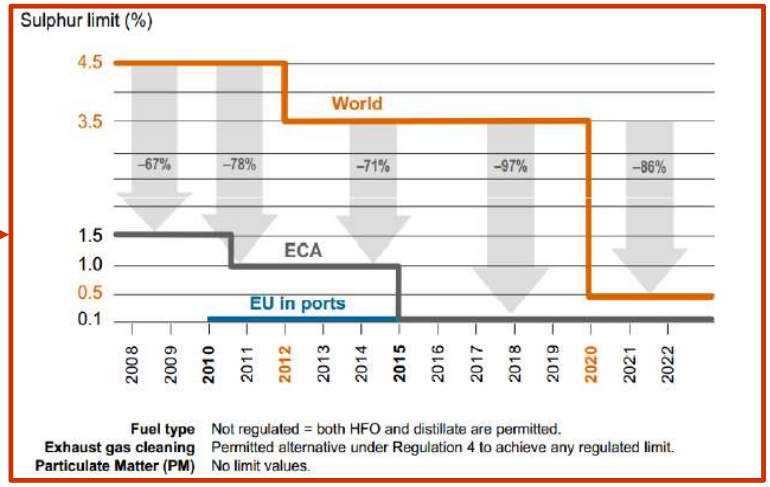
LEGISLATION

IMO Legislation – MARPOL Annex VI

Chapter 3 - Requirements for Control of Emissions

Ozone depleting substances	Reg.12
Nitrogen oxides (NOx)	**Reg.13**
Sulphur oxides (SOx) and PM	**Reg.14**
Volatile organic compounds (VOC)	Reg.15
Shipboard incineration	Reg.16
Reception facilities	Reg.17
Fuel oil availability and quality	Reg.18

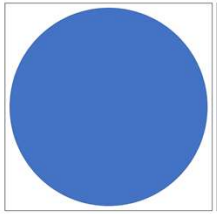
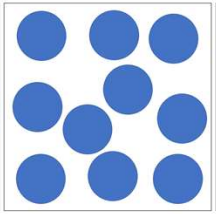
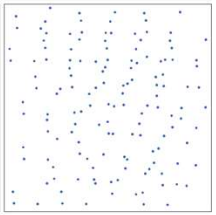




https://doi.org/10.3390/jmse8100820

Shipping Emissions Contain Nanoparticles

By **Mfame Team** - November 24, 2015

	10 µm (Coarse)	2.5 µm (Fine)	0.1 µm (Ultrafine)
			
Total mass	1	1	1
Particle number	1	64	1,000,000
Surface area per particle	1	0.0625	0.0001
Total surface area per mass	1	4	100
	• Filtered in proximal airway • May irritate skin, mucosa	• Reaches peripheral airway • Cannot enter systemic circulation	• Higher adsorbed toxic material on surface • May enter systemic circulation

ShippingEmissions * Ultrafine * ParticleNumber * YourResearch

Shipping is a significant source of ultrafine particles in coastal areas.

Despite stricter regulations and lower fuel sulphur content, ships still emit considerable amounts of ultrafine particles.
This was proven by scientists from Tampere University, FMI and VTT measuring at sea and in engine laboratories.

https://airmodus.com/shipping-ultrafine-emissions/

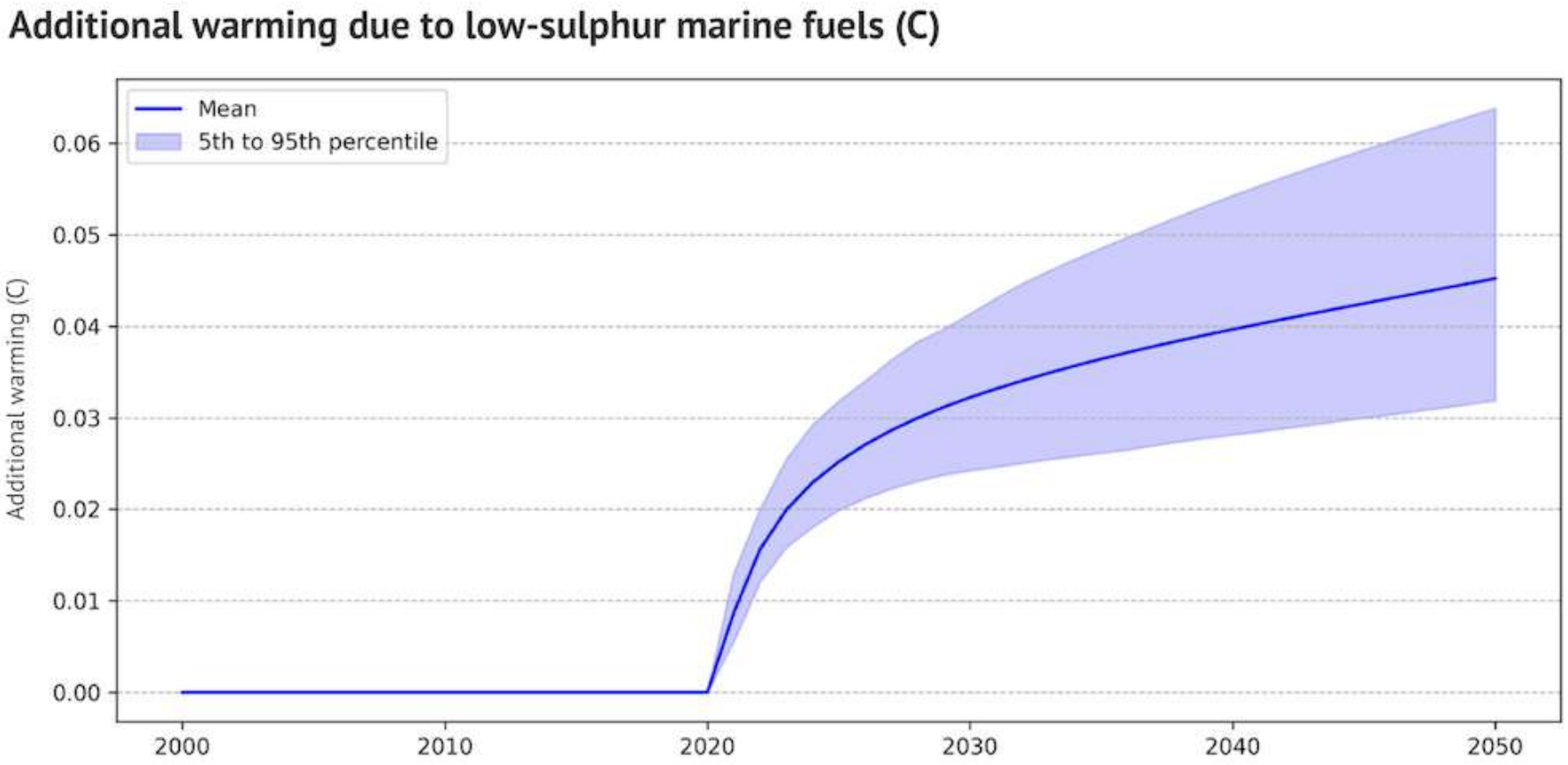
NEWS RELEASE 30-MAY-2024

Climate change: Reduced sulphur content in shipping fuel associated with increased maritime atmospheric warming

Peer-Reviewed Publication

SCIENTIFIC REPORTS

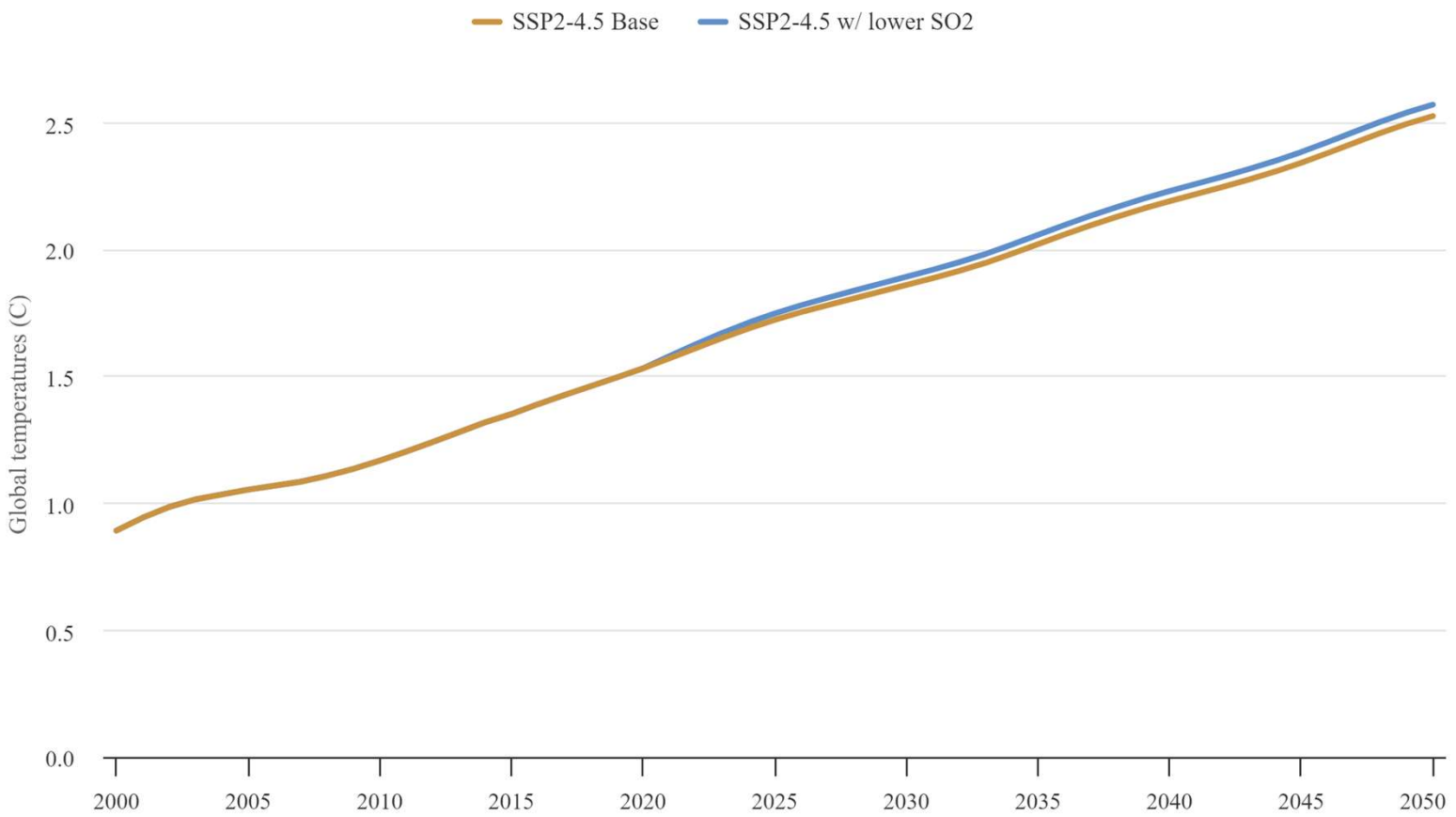
http://dx.doi.org/10.1038/s43247-024-01442-3



Global mean temperature change from the FaIR model simulating the effects of a reduction in SO2 emissions equivalent to 8.5MtSO2 per year after 2020, relative to the SSP2-4.5 scenario across 66 different CMIP6 models. The solid line shows the average of all model runs, while the shaded area shows the 5th to 95th percentile range. Chart by Zeke Hausfather for Carbon Brief.

Global surface temperatures in the SSP2-4.5 scenario

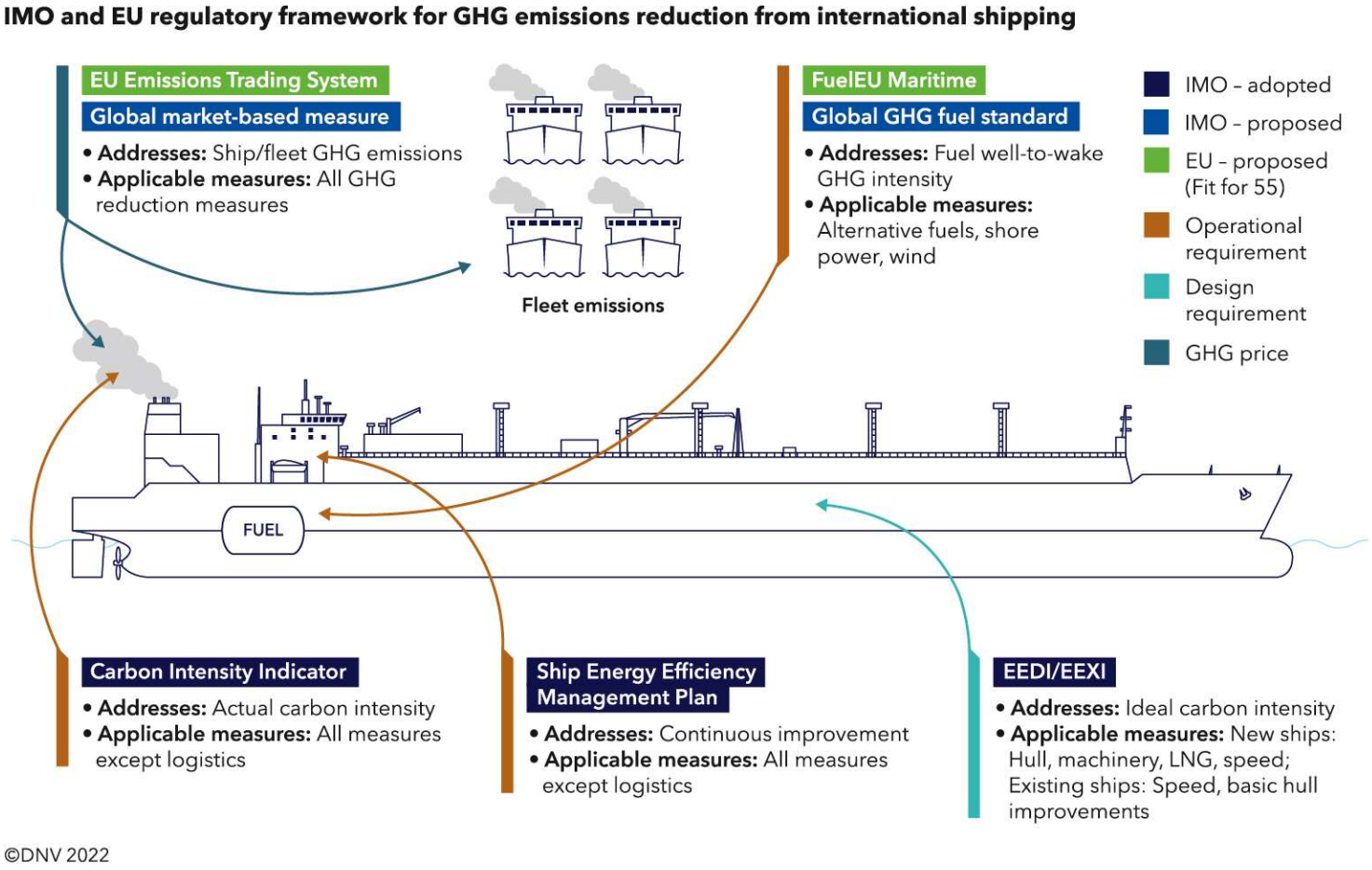
With and without the additional effects of marine SO2 reductions.



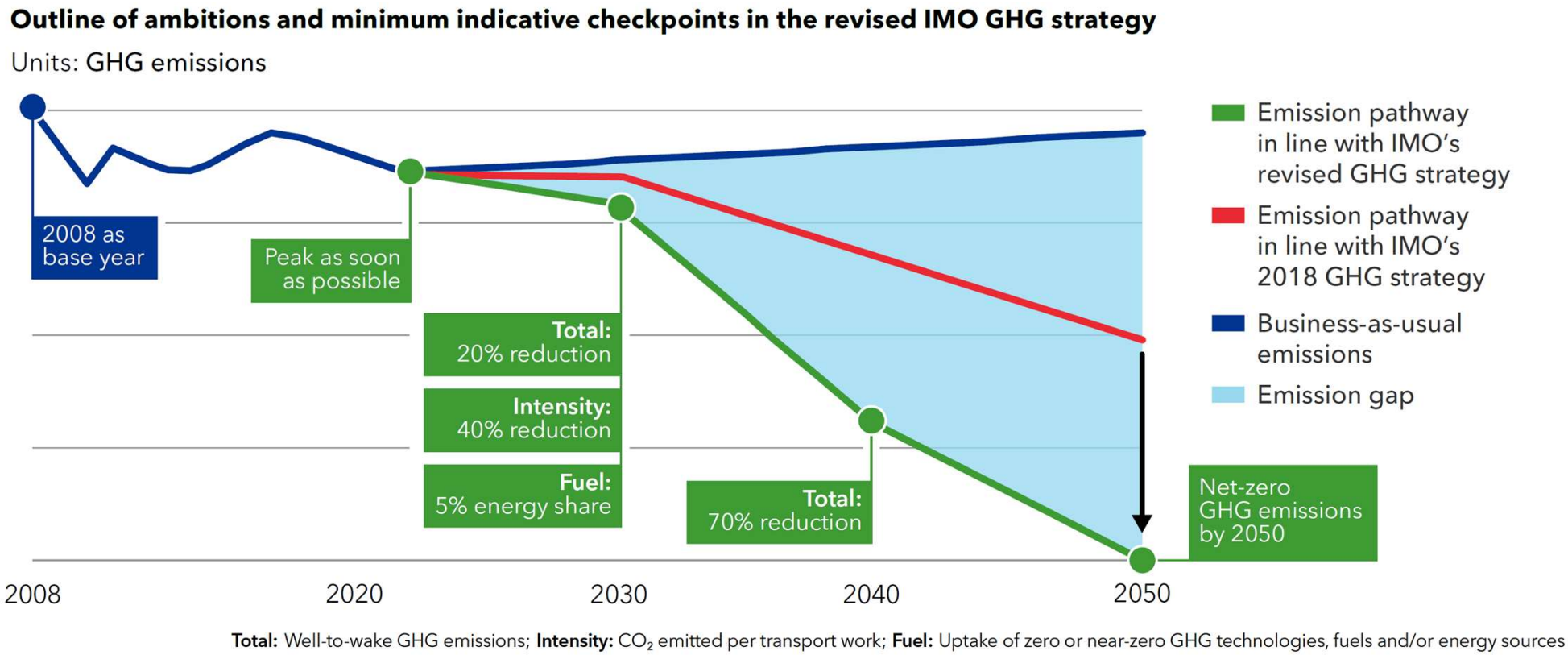
Source: Carbon Brief / FaIR model.

CarbonBrief
CLEAR ON CLIMATE

EU and IMO regulatory framework for GHG emission reduction

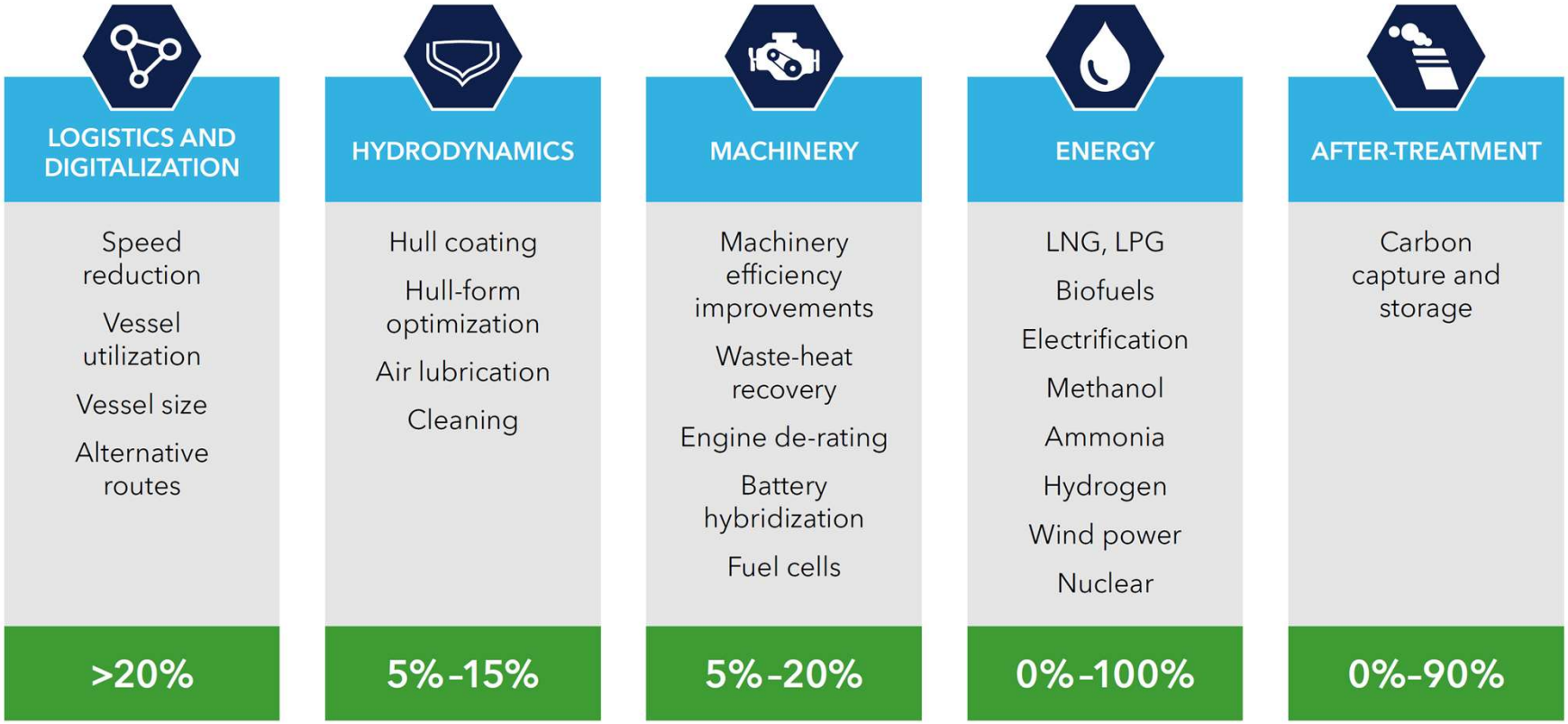


Revised IMO Strategy on GHGs in shipping



DNV: Maritime Forecast to 2050

Solutions that can contribute Decarbonisation of shipping



DNV: Maritime Forecast to 2050

Center for Research, Innovation and Entrepreneurship @UoM/PFK

Activities within Center:

- **Research and Innovation;**
- **Project activities;**
- **Provider of Life Long Learning;**
- **Supporting student start ups;**
- **Supporting activities between academia and industry, etc.**

Labs/equipment:

- **SMART BAY Lab;**
- **Marine fuels laboratory;**
- **3D Lab;**
- **Underwater ship archeology, etc**

Personnel:

- **Prof. dr Danilo Nikolić, coordinator**
- **MSc Radmila Gagić**
- **PhD Maja Škurić**
- **Dijana Radović**

Interreg Danube – GREEN-PRO project

PROJECT TITLE	Possibilities of Establishing Green Propulsion Shipping Routes on Rivers and Seas
ACRONYM	**GREEN-PRO**
CO-FUNDING PROGRAM	Interreg DANUBE SMF
COORDINATING INSTITUTION	University of Montenegro, Faculty of Maritime Studies Kotor (UoM)
PARTNERS	University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture; Lviv Polytechnic National University, Department of Chemical Engineering; Energy Institute at the J ohannes Kepler University Linz
PROJECT BUDGET	118.496,00 €
BUDGET FOR THE UoM	38.192,00 €
PROJECT COORDINATOR	Prof. dr Danilo Nikolić
PROJECT DURATION	01/09/2024- 31/08/2025

Interreg Danube – GREEN-PRO project

PROJECT DESCRIPTION/OVERALL OBJECTIVE

The addresses the pressing challenges faced by both river and sea shipping sectors in meeting stringent emission reduction targets set by initiatives like the European Green Deal and the Energy Taxation Directive (FuelEU Maritime). The focus of this endeavour is on tackling the geographical complexities within the EUSDR region, with a specific emphasis on the imperative need for decarbonizing these sectors.

In this context, alternative fuels emerge as pivotal solutions for emission reduction. These include zero carbon options such as hydrogen, ammonia, and electricity, low carbon variants like methanol, LNG, LPG, and carbon-neutral alternatives such as biofuels like Hydrogenated Vegetable Oil (HVO). The retrofitting of existing vessels or the construction of new ships designed to utilize these alternative fuels can substantially impact decarbonization efforts. However, a significant obstacle lies in the inadequate development of port infrastructure, particularly storage and handling facilities for a diverse range of alternative fuels.

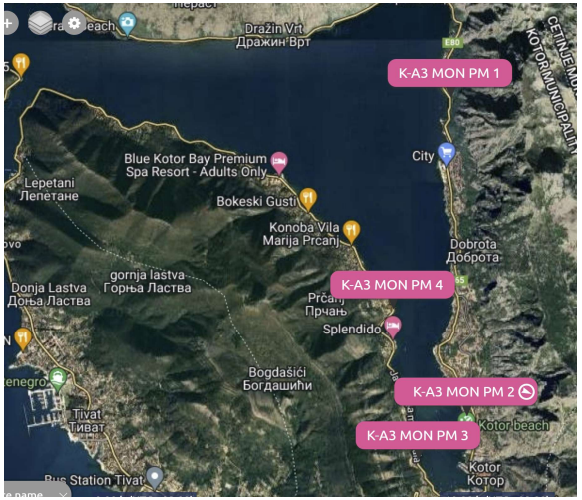
Thus, the primary objective of the GREEN-PRO project is to provide inputs for the main project in order to facilitate the transition of the river and sea shipping sectors towards adopting alternative fuels, ensuring a seamless supply chain from ports with adequate infrastructure within the Danube river and East Adriatic coastline regions.

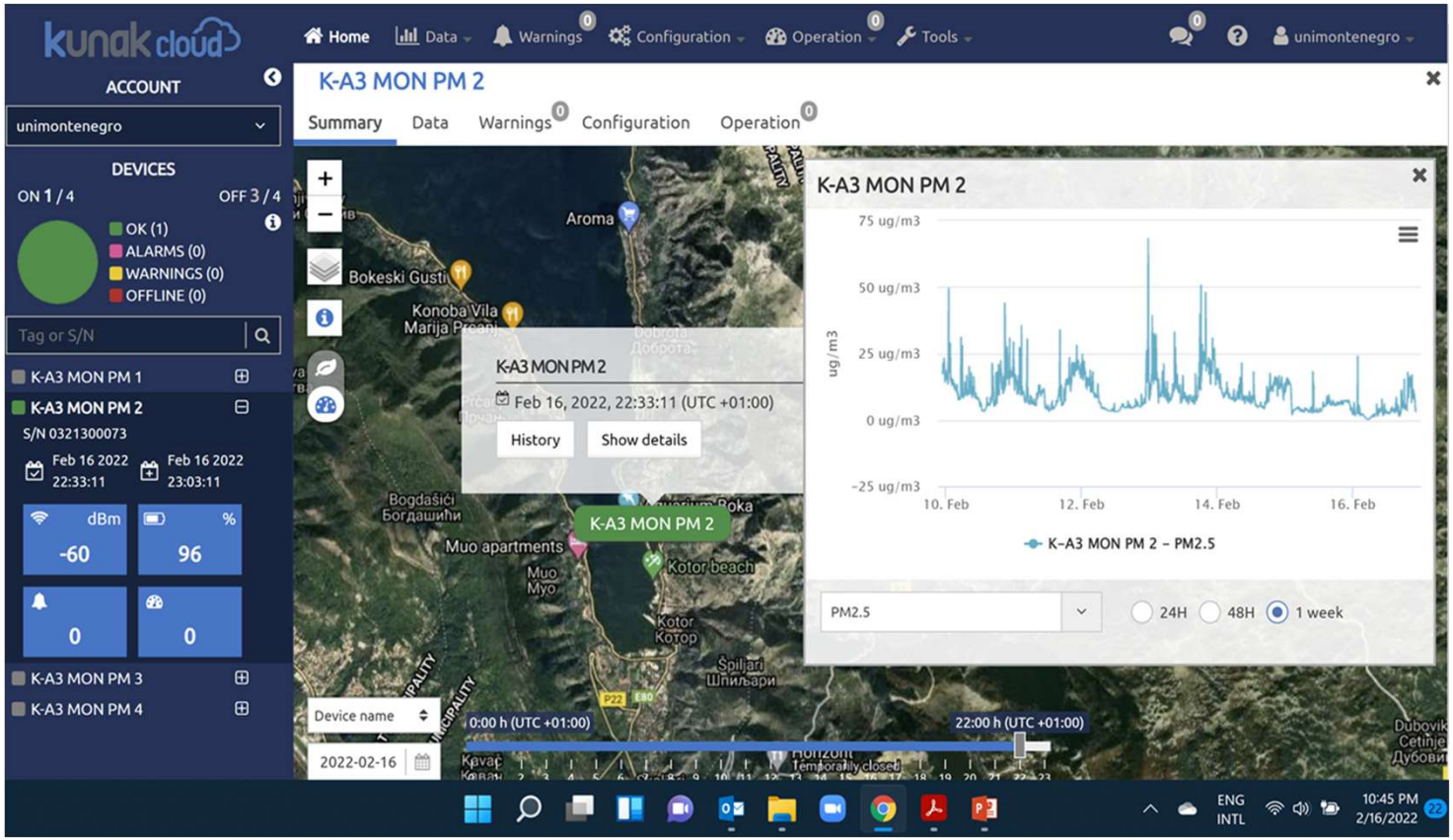
SPECIFIC OBJECTIVES

- Report on the current state of alternative fuels for ships. This activity aims to assess the current state of alternative fuels for ship propulsion in the EUSDR countries and analyze target groups for engagement.
- Main project work plan for establishing Green Propulsion Shipping Routes on Rivers and Seas. The main project will contribute to the transition towards cleaner, more efficient, and sustainable propulsion systems in rivers and seas of the EUSDR countries.
- Report on funding possibilities for Establishing Green Propulsion Shipping Routes on Rivers and Seas. For each potential source of funding, on the first place EU regional programs, as Interreges and HORIZON, following roadmap with related data will be identified.
- Additional preparatory activities needed for feasible main project planning. A wider consultation with relevant stakeholders of the region, as an additional preparatory activity needed for feasible planning of the main project will be implemented.

SMART BAY LAB

SMART BAY LAB – KUNAK PM, O_3, CO, NOx, SO_2 sensors





SMART BAY LAB – Mobile PM sizer

TSI Optical particle sizer (OPS) 3330

SMART BAY LAB – Air Drone with sensors

DJI **Mavic 3 Pro (DJI RC)**

Name
1. Sniffer4D Mini2 Base Unit
2. Inhalable Particulate Matter (PM2.5&10) Sensing Module
3. NO Sensing Module
4. Sniffer4D - Moduł wysokiej rozdzielczości do wykrywania O3+NO2 (1 miejsce)
5. O3+NO2 Sensing Module
6. CO wide range Sensing Module
7. DJI Mavic3 Enterprise Series Integration Kit
8. Wide-range SO2 Sensing Module

SMART BAY LAB - PM Concentration in Kotor bay related to cruise ships

atmosphere

MDPI

Article

Establishing Correlation between Cruise Ship Activities and Ambient PM Concentrations in the Kotor Bay Area Using a Low-Cost Sensor Network

Radmila Gagic [1,*], Maja Skuric [1], Gordana Djukanovic [2] and Danilo Nikolic [1]

[1] Center for Research, Innovation and Entrepreneurship, Faculty of Maritime Studies Kotor, University of Montenegro, 85330 Kotor, Montenegro
[2] Environmental Protection Agency of Montenegro, 81000 Podgorica, Montenegro
* Correspondence: radmilag@ucg.ac.me

Abstract: The analysis of cruise ships is focusing on port areas where they may represent a significant source of anthropogenic emissions. In order to determine the correlation between cruise ship activities (hoteling and maneuvering) in ports with the ambient concentration of pollutants associated with marine diesel fuel combustion, the low-cost sensors are finding their market share due to lower prices compared to the referent ones. In this study, a network of four low-cost PM sensors was used to determine the correlation between ambient $PM_{2.5}$ and PM_{10} mass concentrations with cruise ship activities in the Kotor Bay area during 27 days in the peak summer season, with a 10-min resolution. Recorded data and the Openair model were used to investigate the potential relationship between cruise ship operations and temporal fluctuations in PM concentrations in the ambient air. Additionally, an Tier 3 methodology developed through the European Monitoring and Evaluation Programme of the European Environmental Agency (EMEP/EEA) was applied in order to estimate the total cruise ship PM emissions. The study has shown that weather conditions play a significant role in local PM concentrations, so that, with predominant ENE wind directions, the west side of the Bay experienced on average higher concentrations of both $PM_{2.5}$ and PM_{10}. Rain precipitation and higher winds tend to decrease rapidly ambient PM concentrations. Higher PM levels are associated mainly with lower wind speeds and the inflows from neighboring berths/anchorages. During the maneuvering (arrival and departure) of cruise ships, higher spikes in PM values were detected, being more visible for PM_{10} than $PM_{2.5}$. A significant correlation between daily average PM concentrations and cruise ships' daily estimated PM emission was not found. As a result, higher temporal resolution demonstrated a stronger correlation.

Keywords: cruise ship emission; port air pollution; $PM_{2.5}$; PM_{10}; low-cost sensors; sensor network

Citation: Gagic, R.; Skuric, M.; Djukanovic, G.; Nikolic, D. Establishing Correlation between Cruise Ship Activities and Ambient PM Concentrations in the Kotor Bay Area Using a Low-Cost Sensor Network. *Atmosphere* **2022**, *13*, 1819. https://doi.org/10.3390/atmos13111819

Academic Editors: Yuanqing Zhu and Long Liu

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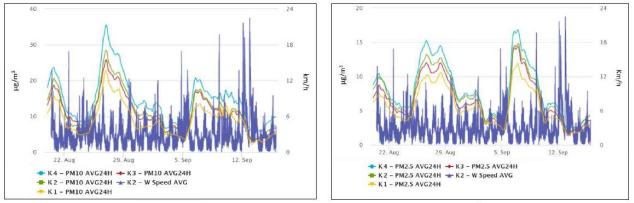
1. Introduction

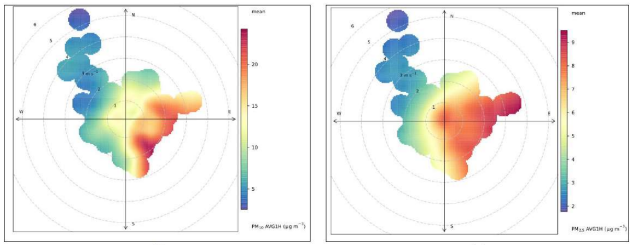
The environmental effect of shipping should be assessed in the context of port sites, since air quality in the surrounding area is significantly impacted, resulting in serious repercussions for human health for people living in coastal areas [1]. Ships produce considerable amounts of pollutants into the neighboring environment while berthed, even three to five times more than when underway [2]. In some cases, ships in ports can account for up to 77% of total emissions [3,4].

Particulate matter (PM) generated by ships' diesel engines has a range of adverse health and environmental-related consequences. It is estimated that shipping-related $PM_{2.5}$ emissions cause about 60,000 premature cardiac and lung cancer deaths worldwide each year [5]. Another study has shown that ships account for over 6 million childhood asthma cases and 250,000 deaths annually [6].



(**a**) (**b**)

Figure 8. Average wind speed vs. PM_{10} (**a**) and $PM_{2.5}$; (**b**) 24 h average over the experimental period 20 August–15 September 2022.



(**a**) (**b**)

Figure 9. Bivariate polar plot of $PM_{2.5}$ (**a**) and PM_{10} (**b**) concentrations at the K4 measuring location during experimental period from 20 August to 15 September 2022. Each plot's center indicates a wind speed of zero, which rises radially outward. The color scale indicates the concentration of PM.

Figure 10 shows both the estimated total cruise ship PM emission and $PM_{10}/PM_{2.5}$ ambient concentrations for the observed period of time. For better visibility, a 7-day period was selected, from 29 August to 4 September 2022. When evaluating the data, it is worth noting that the cruise ship activities, linked to the realization of the ship's operational phases (arrival/hoteling/departure), as described in Section 2.3, and estimated PM emissions (Table 2), affect the height of the PM ambient concentration spikes. This is more evident for PM_{10} than $PM_{2.5}$.

When observing the whole experimental period, the daily average values of both $PM_{2.5}$ and PM_{10} did not significantly correlate with the daily cruise ship's estimated total PM emission (Figure 11).

As also previously suggested by [33], a cruise ship's direct impact on PM concentration is best assessed using a higher temporal resolution.

SMART BAY LAB – Prediction of pollutant and GHG emission from ships in Kotor bay

Table 7 Total annual exhaust emission from cruise ships in the Boka Kotorska Bay in 2015 (tons/year)

Month	NOx	CO	CO_2	VOC	PM	SOx[a]	SOx[b]
January	1.017	3.374	12.097	0.772	0.045	0.0378	2.021
February	1.54	5.122	183.622	1.172	0.069	0.0574	3.064
March	1.23	4.04	145.643	0.923	0.055	0.0455	2.43
April	13.469	32.13	1,348.232	7.101	0.506	0.4213	22.499
May	34.074	74.088	3,264.452	16.175	1.224	1.0201	54.476
June	40.071	92.154	3,941.245	20.272	1.478	1.2316	65.77
July	34.48	75.709	3,318.375	16.552	1.244	1.037	55.375
August	37.082	82.632	3,593.37	18.102	1.348	1.1229	59.964
September	42.686	94.137	4,116.418	20.593	1.544	1.2863	68.693
October	32.982	71.155	3,148.458	15.518	1.181	0.9839	52.54
November	17.127	36.393	1,623.624	7.92	0.609	0.5074	27.094
December	2.74	7.86	301.208	1.774	0.113	0.0941	5.026
Total (tons/year)	258.498	578.794	24,996.744	126.874	9.416	7.8453	418.952

[a]Estimation for average sulphur content in fuel of 0.0457% m/m
[b]Estimation for average sulphur content in fuel of 2.67% m/m

Nikolic et al, DOI 10.1007/698_2016_34,

Estimation of Air Pollution from Ships in the Boka Kotorska Bay

Danilo Nikolić, Radmila Gagic, and Spiro Ivošević

Abstract The Boka Kotorska Bay, with the Port of Kotor, has become one of the most attractive cruising destinations at the Adriatic Sea. It shows not only great potential in terms of economy, but also great danger if environmental issues are taken into consideration. Emission from cruise ships represents majority of anthropogenic emissions of pollutants in this area, since there are no merchant ports and industrial plants in the bay.

In this paper exhaust emission from ships in the Boka Kotorska Bay in 2015 was calculated by using emission estimation methodology. Only cruise ships were taken for research since that is the only shipping activity in the bay, besides yachting. Cruise ship's gross tonnage, marine engine types, marine fuel types, navigation modes and retention times of the ship in the Bay were taken into consideration in the study. Total emissions from cruise ships in the Boka Kotorska Bay area in 2015 were estimated as follows: 258.50 t y^{-1} of NOx, 578.80 t y^{-1} of CO, 24,996.74 t y^{-1} of CO_2, 126.87 t y^{-1} of VOC, 9.42 t y^{-1} of PM and 7.84 t y^{-1} of SOx in the case when assumed that cruise ships burn low sulphur fuels and 418.95 t y^{-1} of SOx in the case of high sulphur fuels.

Keywords Air pollution, Boka Kotorska Bay, Cruise ships, Exhaust emission estimation

Contents

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Some Results of Air Pollution from Passenger Ferries in the Boka Kotorska Bay

Maja Škurić, Vladislav Maraš, Aleksandar Radonjić, Radmila Gagić, and Danilo Nikolić

Contents

Abstract Emission from passenger ships represents a threat especially for a population in the coastal area that is exposed to air pollution due to the port traffic throughput and other frequent activities at the seaside. Passenger ferries are one of the marine small vessels that have a primary role in connecting domicile inhabitants and serves as a favorite mode of transport for short tourist visits. In this chapter, the

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Danijela Joksimović, Mirko Đurović, Igor S. Zonn, Andrey G. Kostianoy, and Aleksander V. Semenov (eds.), *The Montenegrin Adriatic Coast: Marine Chemistry Pollution*, Hdb Env Chem, DOI 10.1007/698_2020_702,

SMART BAY LAB – Exhaust emission analyser & smoke tester

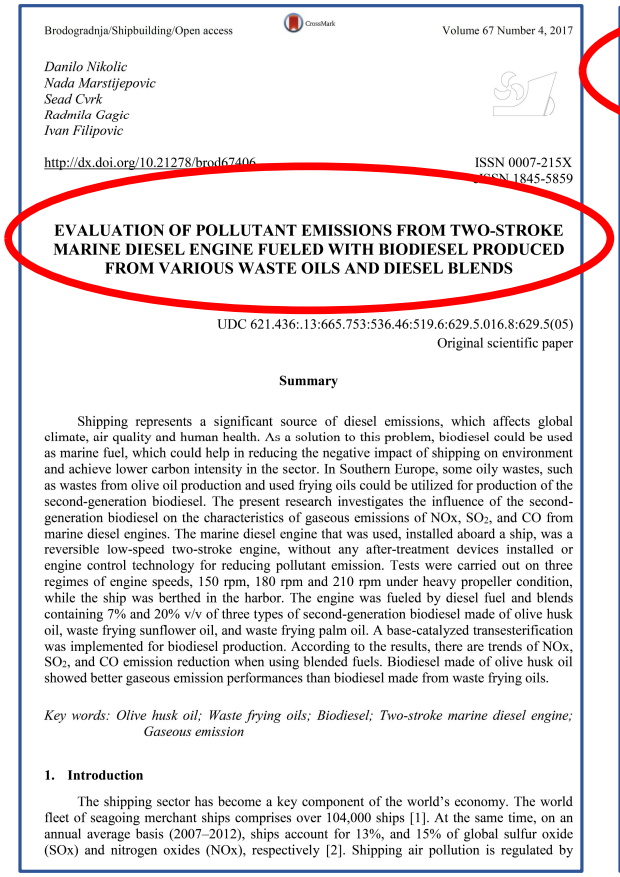
TESTO 350 MARITIME

SMART BAY LAB – Renewable fuels

Research on three types of second-generation biodiesel made from:

- Olive husk oil;
- Waste sunflower, and
- Waste palm oil from frying.

Biodiesel blends (7%, 20% and 25%) show better emission performance in regard to NOx, SO_2, CO, and CO_2 than pure low sulfur diesel.



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Sead Cvrk
Radmila Gagic
Ivan Filipovic

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EVALUATION OF POLLUTANT EMISSIONS FROM TWO-STROKE MARINE DIESEL ENGINE FUELED WITH BIODIESEL PRODUCED FROM VARIOUS WASTE OILS AND DIESEL BLENDS

UDC 621.436:.13:665.753:536.46:519.6:629.5.016.8:629.5(05)
Original scientific paper

Summary

Shipping represents a significant source of diesel emissions, which affects global climate, air quality and human health. As a solution to this problem, biodiesel could be used as marine fuel, which could help in reducing the negative impact of shipping on environment and achieve lower carbon intensity in the sector. In Southern Europe, some oily wastes, such as wastes from olive oil production and used frying oils could be utilized for production of the second-generation biodiesel. The present research investigates the influence of the second-generation biodiesel on the characteristics of gaseous emissions of NOx, SO_2, and CO from marine diesel engines. The marine diesel engine that was used, installed aboard a ship, was a reversible low-speed two-stroke engine, without any after-treatment devices installed or engine control technology for reducing pollutant emission. Tests were carried out on three regimes of engine speeds, 150 rpm, 180 rpm and 210 rpm under heavy propeller condition, while the ship was berthed in the harbor. The engine was fueled by diesel fuel and blends containing 7% and 20% v/v of three types of second-generation biodiesel made of olive husk oil, waste frying sunflower oil, and waste frying palm oil. A base-catalyzed transesterification was implemented for biodiesel production. According to the results, there are trends of NOx, SO_2, and CO emission reduction when using blended fuels. Biodiesel made of olive husk oil showed better gaseous emission performances than biodiesel made from waste frying oils.

Key words: Olive husk oil; Waste frying oils; Biodiesel; Two-stroke marine diesel engine; Gaseous emission

1. Introduction

The shipping sector has become a key component of the world's economy. The world fleet of seagoing merchant ships comprises over 104,000 ships [1]. At the same time, on an annual average basis (2007–2012), ships account for 13%, and 15% of global sulfur oxide (SOx) and nitrogen oxides (NOx), respectively [2]. Shipping air pollution is regulated by

Influence of Biodiesel Blends on Characteristics of Gaseous Emissions from Two Stroke, Low Speed Marine Diesel Engines

Danilo Nikolic, Sead Cvrk, Nada Marstijepovic, Radmila Gagic and Ivan Filipovic

Abstract As a renewable source of energy, biofuels have a favourable impact on the environment and can replace fossil fuels to some extent. Biodiesel is one option for reducing the emission of pollutants and GHG in the shipping sector. By 2030, Lloyd Register predicts a global demand for about 100 million tons of biofuel in shipping, mostly biodiesel. This study investigates the influence of biodiesel blends on the characteristics of gaseous emissions from a two-stroke, low speed marine diesel engine. For this research, a reversible low-speed two-stroke marine diesel engine was used, without any after-treatment devices installed or engine control technology for reducing pollutant emission. Tests were carried out on three regimes of engine speed, 150, 180 and 210 rpm under heavy propeller condition, while the ship was berthed in the harbour. The engine was fuelled with low sulfur diesel fuel and blends containing 7 and 25% v/v of three types of second-generation biodiesel made from cast-off sunflower and palm oil waste from frying. For biodiesel production, a base-catalyzed transesterification was implemented. Biodiesel blends show better emission performance in regard to NOx, SO_2, CO, and CO_2 than pure low sulfur diesel fuel.

Keywords Used frying oils · Biodiesel · Low sulfur diesel fuel · Two-stroke low speed marine diesel engine · Gaseous emission

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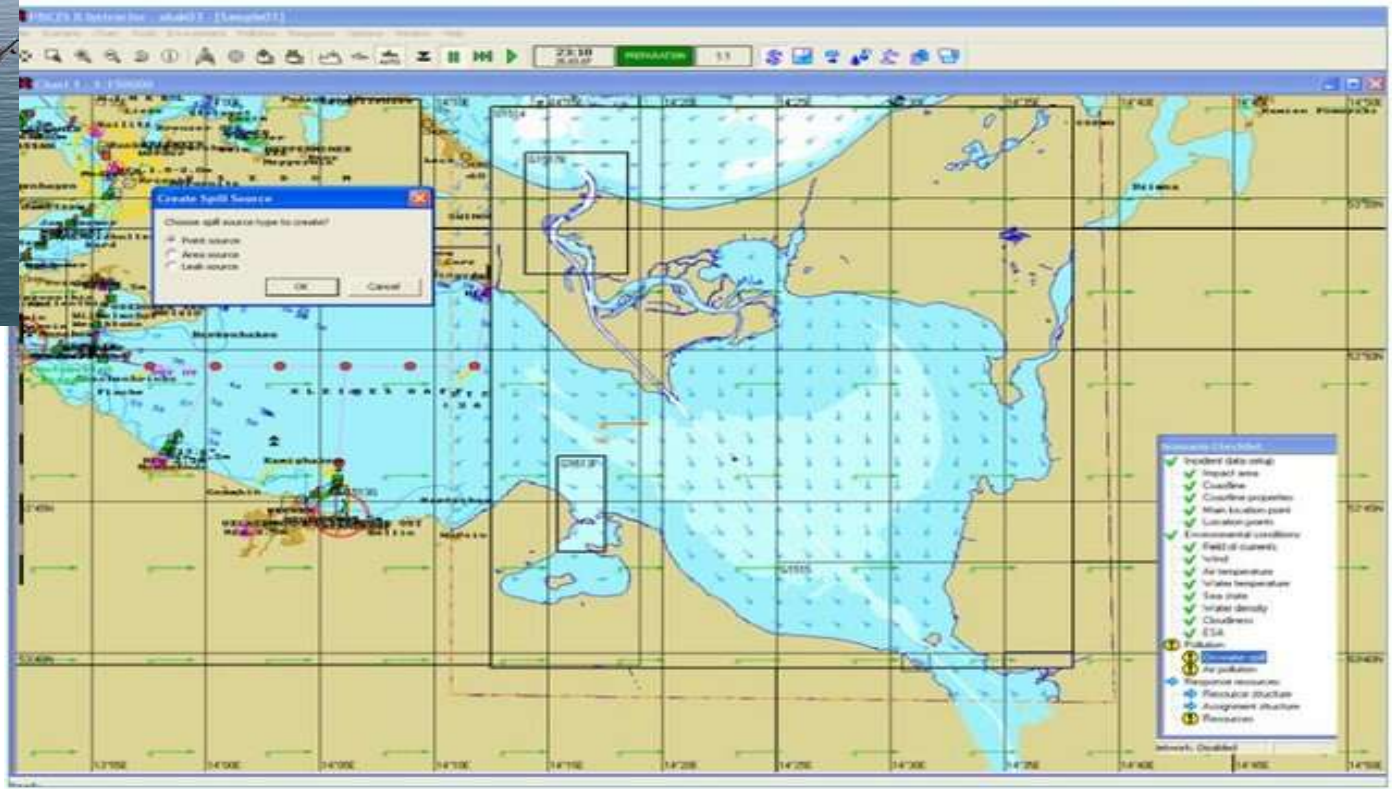
SMART BAY LAB – Simulations of oil spills

Wärtsilä Oil Spill Response Simulator



SMART BAY LAB – Equipment for underwater research

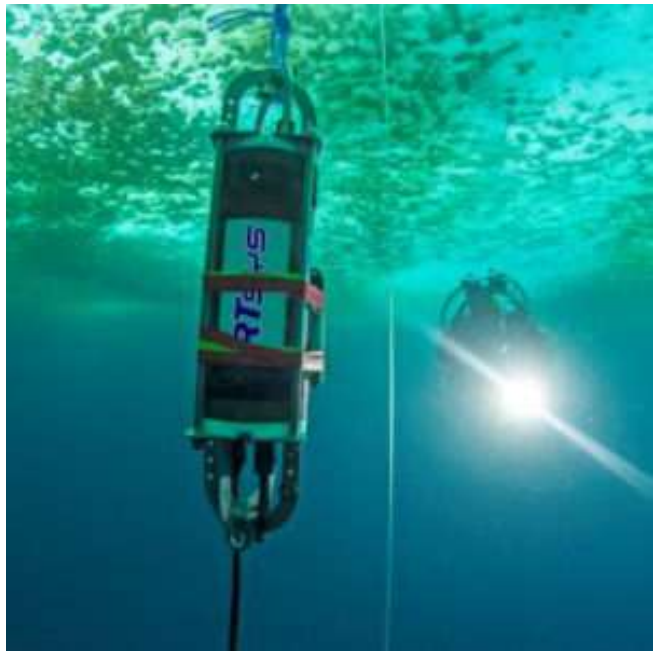
BlueROV2

SMART BAY LAB – Equipment for underwater research

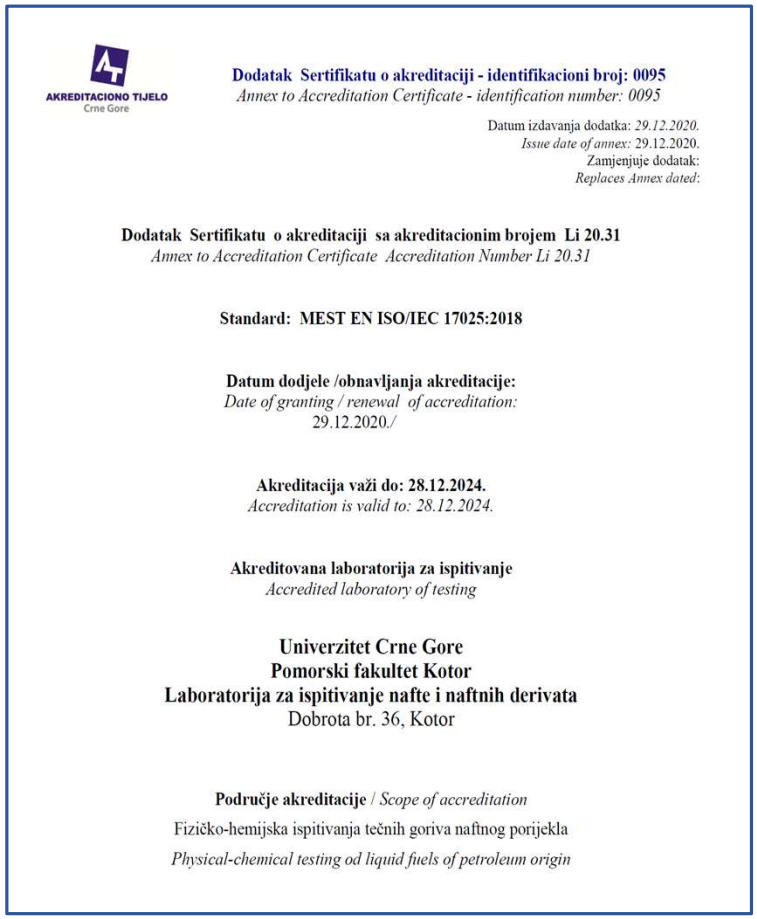
Multi-parameter Water Quality Checker

Horiba U-50 series Multi-parameter water quality checker

Underwater acoustic recorder & Hydrophone



SMART BAY LAB – Equipment for fuel and oil quality testing



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Physical-chemical testing od liquid fuels of petroleum origin

Thank you for your attention!

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