WORKSHOP ON “RISK AND SAFETY SCENARIOS IN THE ADRION PORT ENVIRONMENTS”

Environmental Risk Scenarios for Ports and Maritime Transport in the Era of Climate Change

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University of Montenegro, Faculty of Maritime Studies Kotor

7.06.2023, Taranto, Italy

”PrOmoting Resilient, Sustainable, and Smart Transport and logistic activities in the South Adriatic Area - PORTS PLUS/No. 552/SMALL/CAPITALIZATION restricted procedure”

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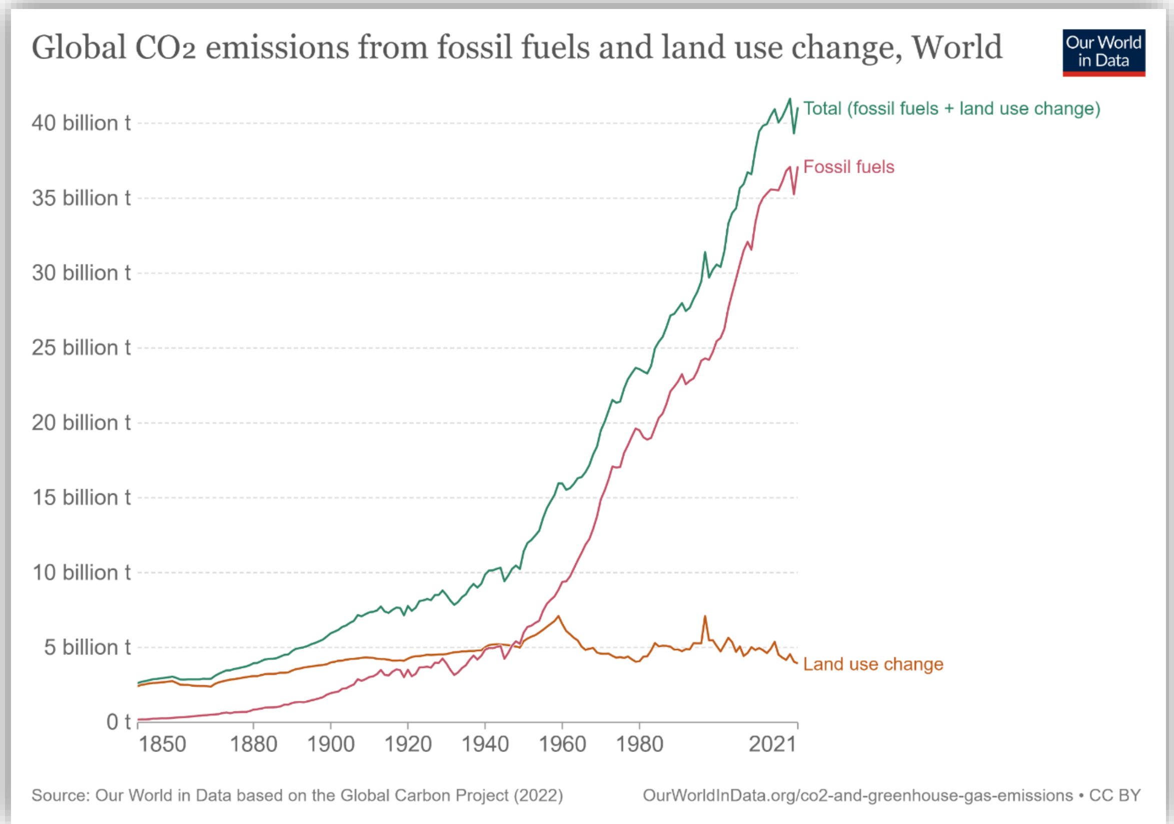
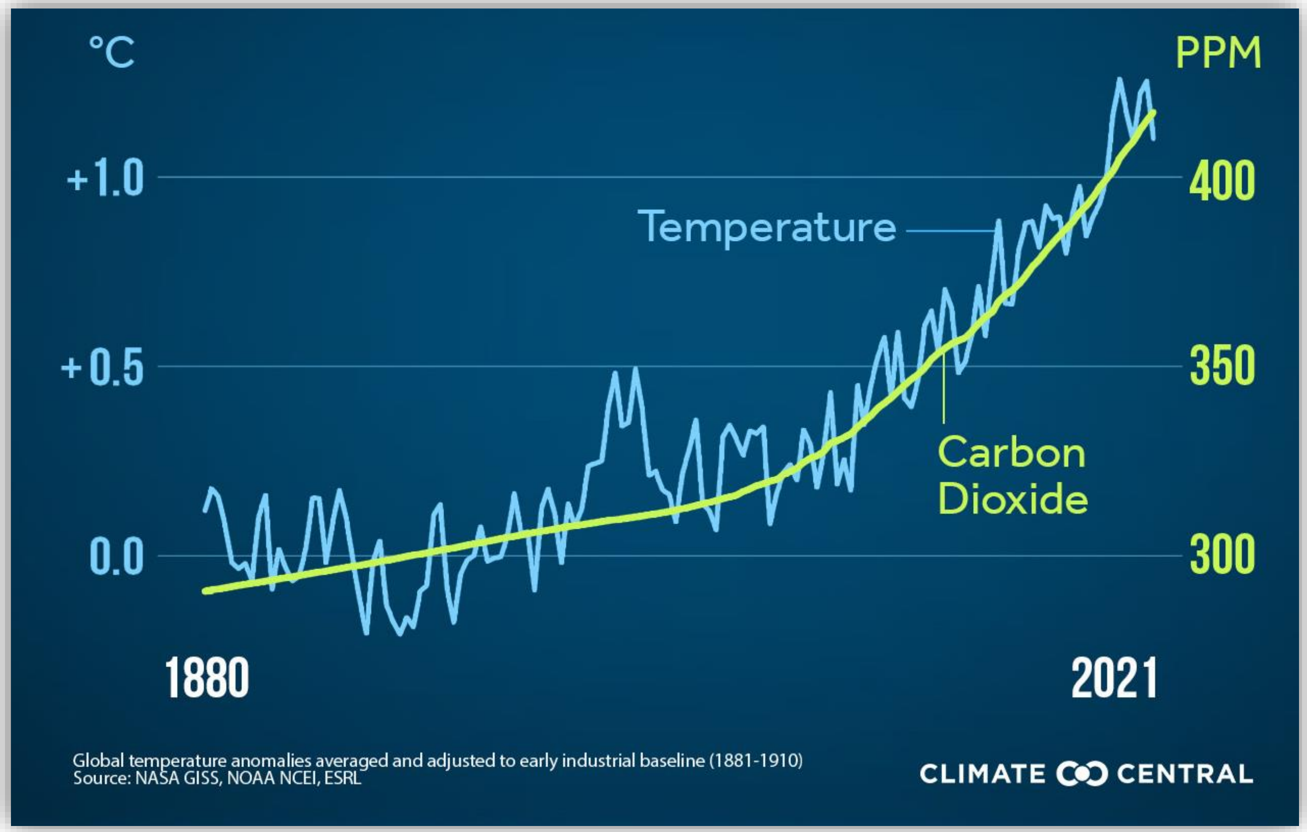
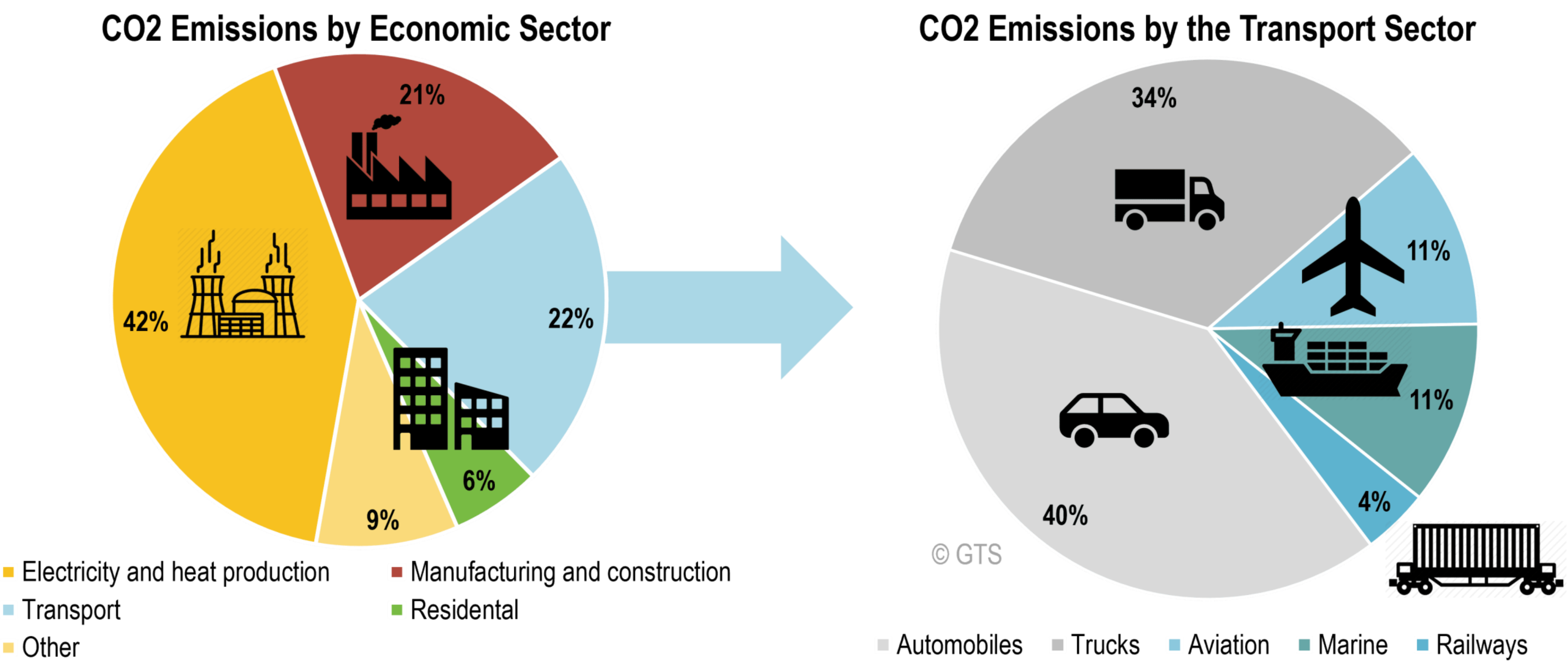
Global CO_2 Emission





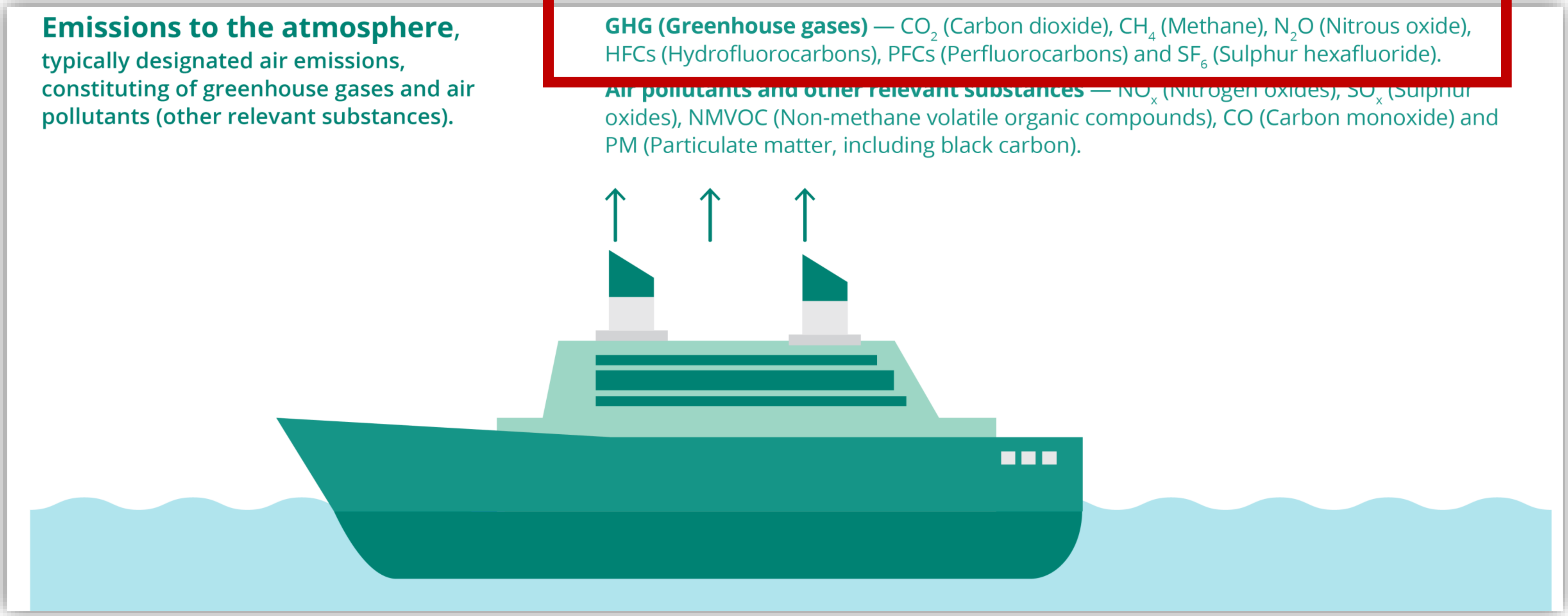
Global CO_2 concentrations set a new record in 2022 of 417.2(ppm), up 2.5ppm from 2021 levels.

Fossil Fuel CO_2 Emission by Sector



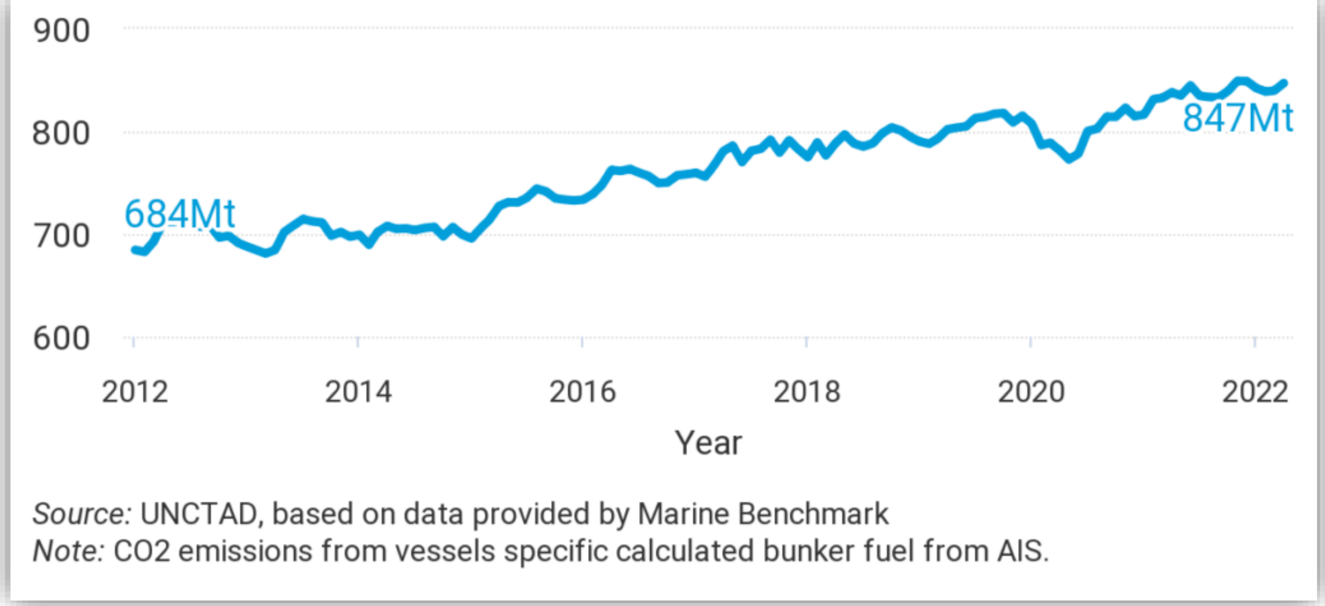
Source: International Energy Association

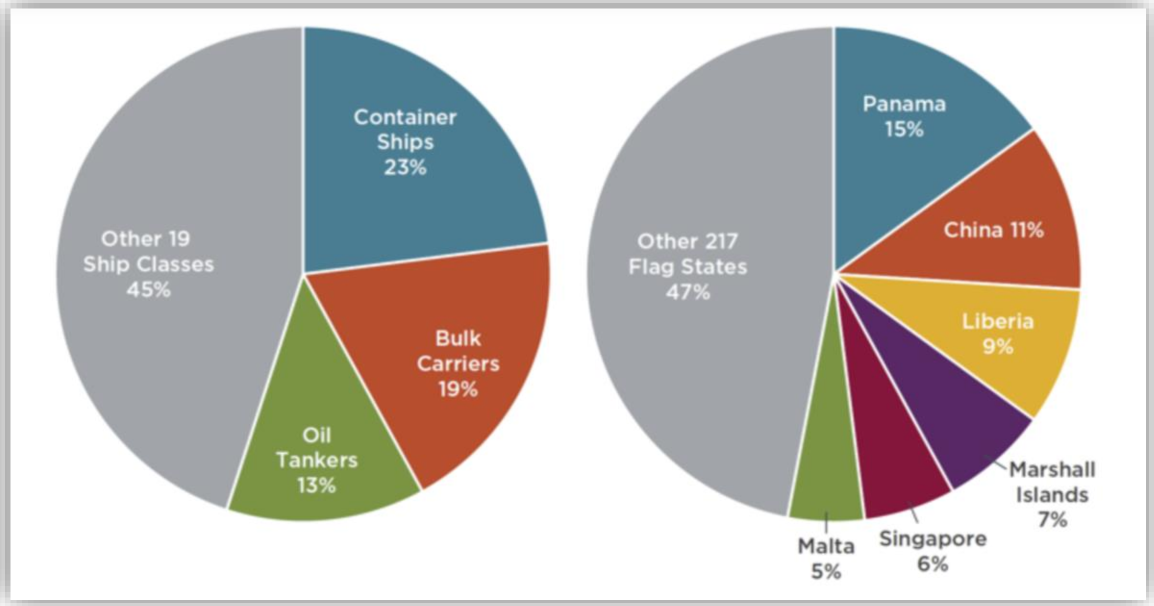
Ship-Related GHG Emission Sources



Source: EMSA/EEA (2021).

Contribution of Maritime transport to GHG emission and Climate change





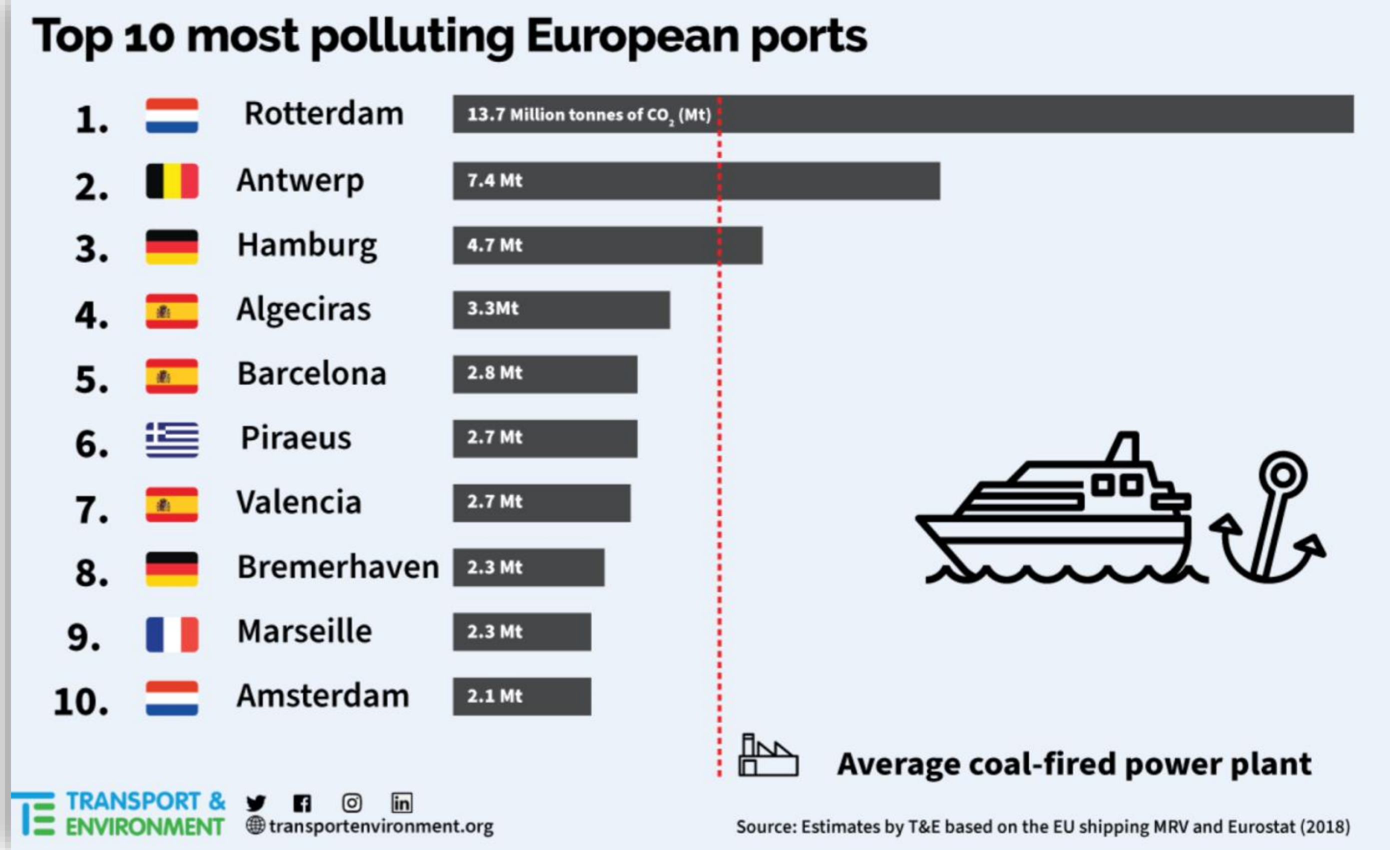
https://cleantechnica.com/2017/10/24/icct-shipping-industrys-greenhouse-gas-emissions-rise/

Port-Related GHG Emission Sources

Source type	Emissions source category	Energy types
Mobile	Seagoing vessels	fuel oil, diesel, natural gas (NG), methanol
	Domestic vessels	fuel oil, diesel, NG
	Cargo handling equipment	diesel, NG, propane, gasoline, methanol, electricity
	Heavy-duty vehicles	diesel, NG, electricity
	Locomotive	diesel, NG, electricity
	Light-duty vehicles	diesel, NG, propane, gasoline, electricity
Stationary	Electrical grid	coal, NG, diesel, renewable
	Power plant	coal, NG, diesel, renewable
	Industrial facilities	electricity, renewable, diesel
	Manufacturing facilities	electricity, renewable, diesel
	Administrative offices	electricity, renewable, diesel

Source: Port Emissions Toolkit

Contribution of Port operations to GHG emission and Climate change



Top 10 ports (CO_2 emissions)	Share of total
1. Singapore	5.9%
2. Hong Kong	2.2%
3. Rotterdam	2.0%
4. Port Klang	1.9%
5. Tianjin	1.8%
6. Shanghai	1.7%
7. Fujairah	1.7%
8. Busan	1.4%
9. Kaohsiung	1.4%
10. Antwerp	1.2%
Total Top 10	**19.0%**

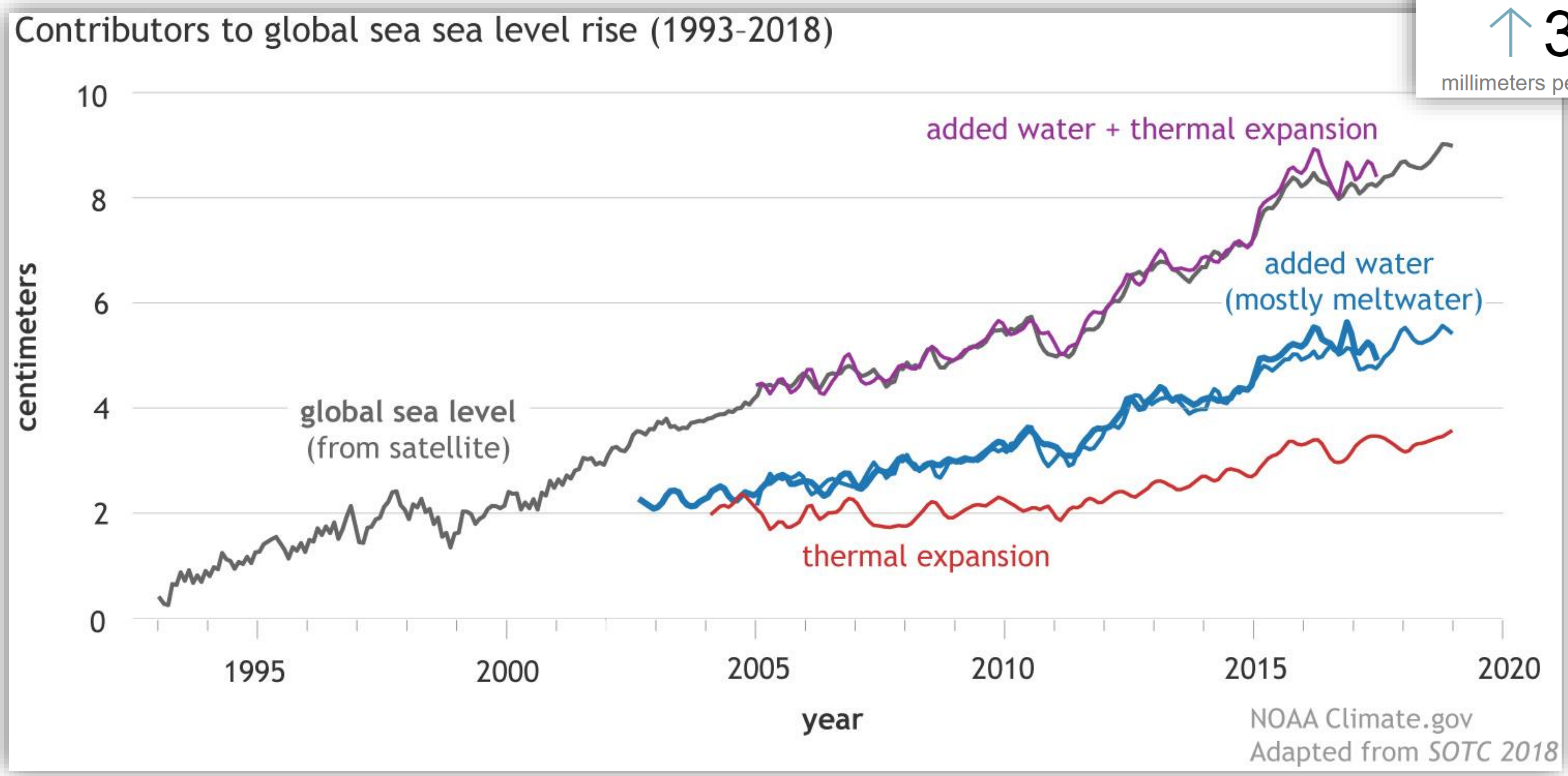
Source: OEBS

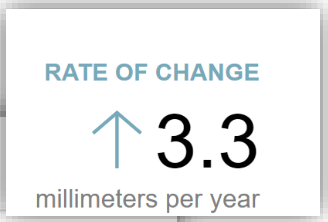
Climate Change and its Potential Impacts on Transportation

	Operations	Infrastructures
Heat waves	• Limits on periods of construction activity. • More energy for reefer transportation and storage.	• Thermal expansion of piers. • Pavement integrity and softening. • Deformation of rail tracks.
Rising sea levels	• Frequent interruptions of coastal low-lying road and rail due to storm surges. • Flooding of terminal areas.	• More frequent flooding of infrastructure (and potential damage) in low lying areas. • Erosion of infrastructure support. • Changes in harbor facilities to accommodate higher tides and surges.
Intensity of precipitation	• Increase in weather related delays and disruptions.	
Increasing hurricane intensity	• Frequent interruptions of air services. • Frequent and extensive evacuations of coastal areas. • Debris on road and rail infrastructures.	• Greater probability of infrastructure failure. • Greater damage to port infrastructures. • More significant flooding on hinterland infrastructures.

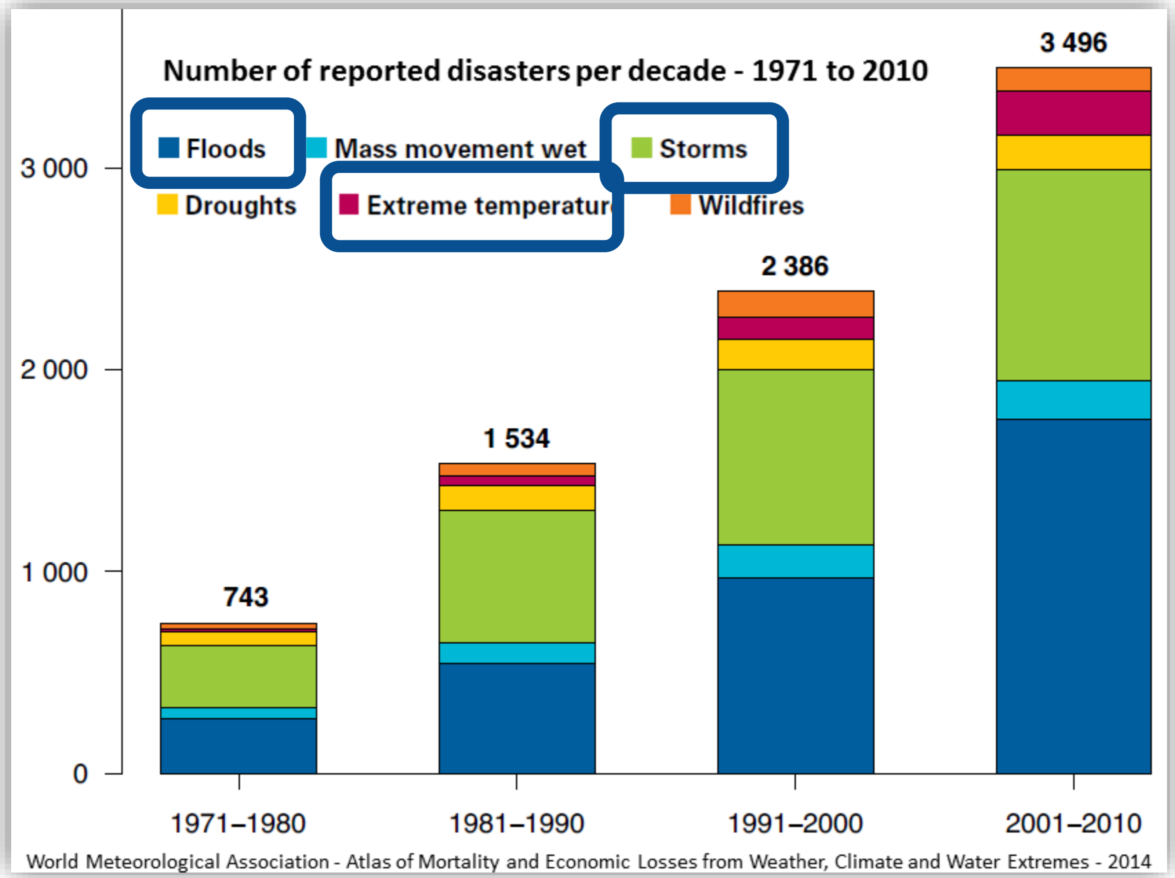
National Research Council (2008) Potential impacts of climate change on U.S. Transportation

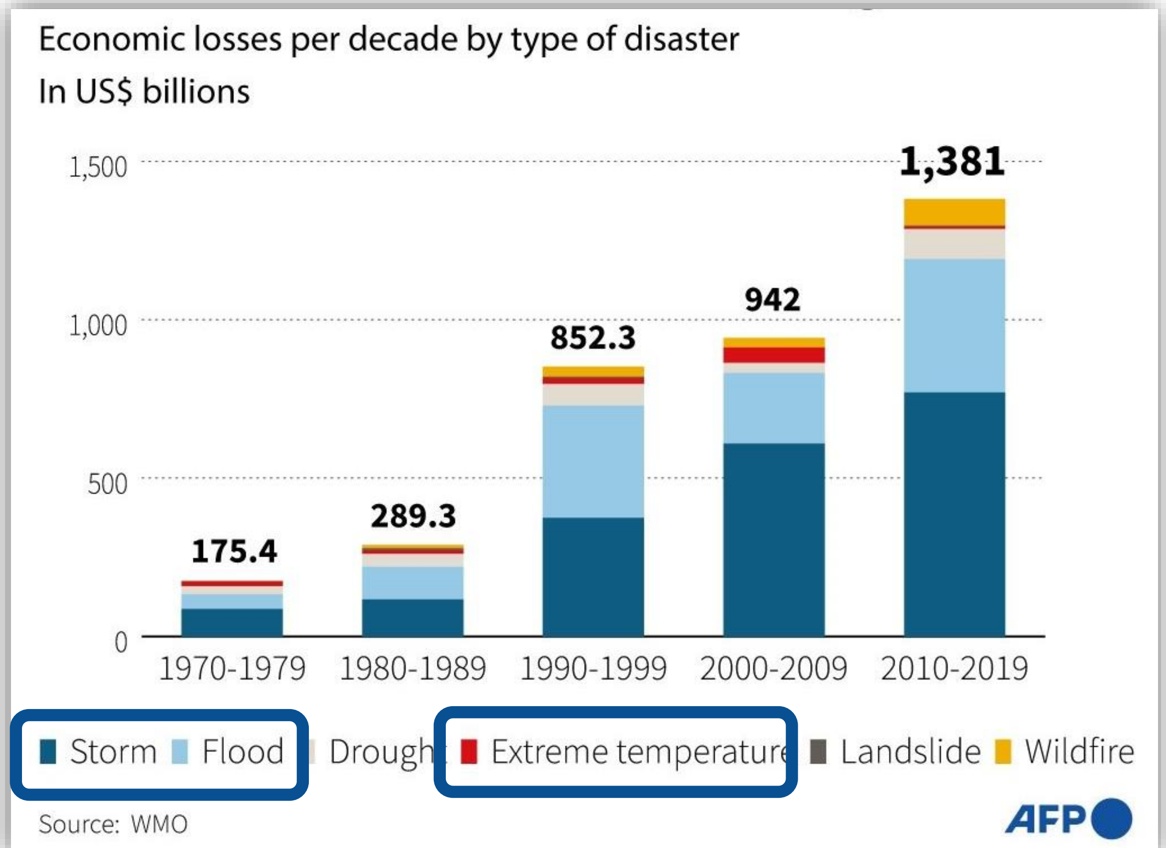
Climate change indicators: Global sea level rise





Climate change indicators: Natural disasters





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Maritime transport and Ports - Impacts from Sea Level Rise and Tropical Storms

- **Losses from Damages to Port Infrastructure (examples):**
  - ✓ Damage estimates to US ports from previous hurricanes range from 46 million US$ for Hurricane Florence in 2018 to about **2.2 billion US$ for Hurricane Katrina** in 2005.
  - ✓ If sea level and storm surge had been as high as some **2100 projections**, the study estimates that the damage would have been **5.5 times larger**.

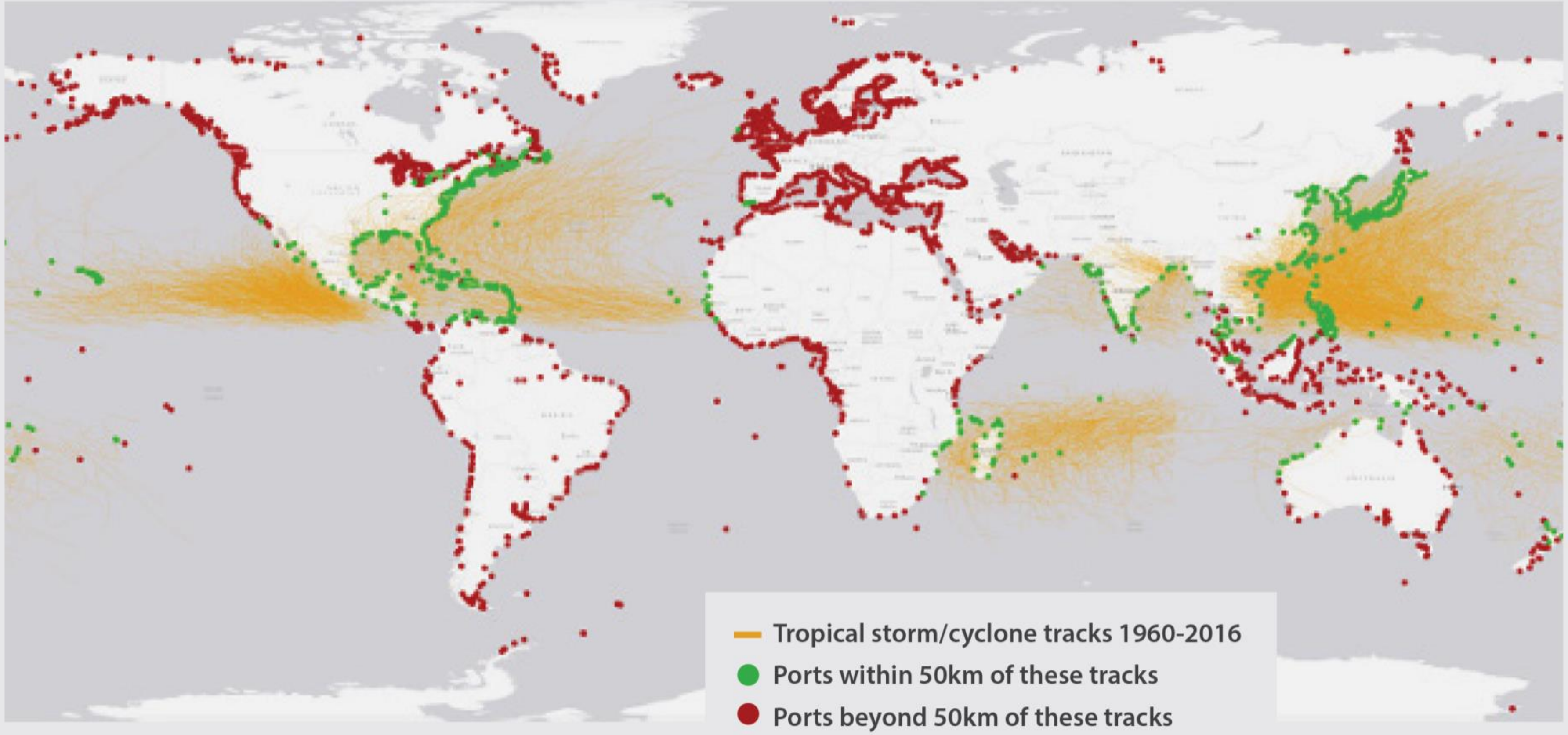
- **Losses from Disruptions to Port Operations (examples):**
  - ✓ Economic loss estimates due to previous storm-related disruptions range from **10 million US$** at the **Port of Shanghai**, caused by a 2-day disruption due to Typhoon Haikui in 2012, to **65 million US$** at the **Port of Dalian**, caused by a 5-day disruption due to Typhoon Lekima in 2019.

Increased exposure to coastal flooding will test the integrity of port infrastructure and operations. (Getty Images)

Maritime transport and Ports - Impacts from Sea Level Rise and Tropical Storms

- Around **1/3 of the world's ports** are located in **areas prone to tropical storms** and, between 1960 and 2010, at least one tropical storm passed within a **radius of 50 km from 32% of the world's seaports**.

Figure 4. Map of Ports Worldwide in Relation to Historical Tropical Storm Tracks[22]



Maritime transport and Ports - Impacts from Sea Level Rise and Tropical Storms

- **Losses from Vessel Incidents at Sea**
  - ✓ Weather-related conditions were responsible for **at least 20%** of the roughly 400 total vessel losses that occurred worldwide **from 2015-2019**.
  - ✓ Total vessel loss incidents over these **5 years have resulted in the death at sea of 142 crew members, many due to extreme weather events.**

- **Adapting to Avoid Losses**
  - ✓ For ships at sea, **stronger storms will require adaptation through re-routing, which increases delays and operating costs**. For a containership consuming 150 tons of fuel per day, each additional day at sea can cost roughly 75,000 US$.
  - ✓ **Most research on port adaptation costs has focused on elevation approaches, with unit costs ranging from 30 million US$ to over 200 million US$ per km^2 of port area.**

Table 6. Estimated Port Adaptation (Elevation) Costs Against Sea Level Rise and Increased Storm Surge

YEAR	2050	2100
ELEVATION (M)	0.27	0.84
INCREASED STORM SURGE HEIGHT (M)	0.38	0.76
Average unit cost (US$ per square km)	US$89 - US$129	US$111 - US$150
Investment cost (US$ billions)	US$121 - US$176	US$151 - US$205
Annualized cost (US$ billions/ year)[a]	US$4.0 - US$5.8	US$5.0 - US$6.8

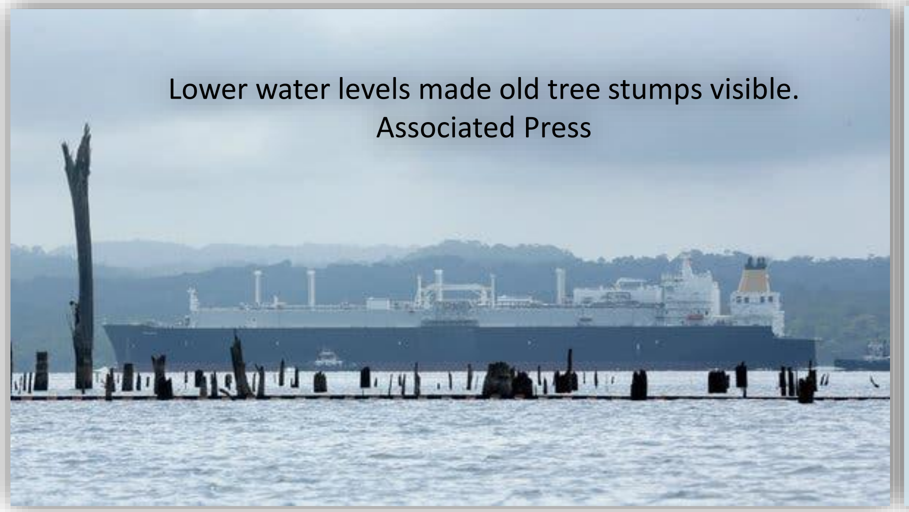
[a] assuming 80 year life and 3% discount rate

George Van Houtven et al.

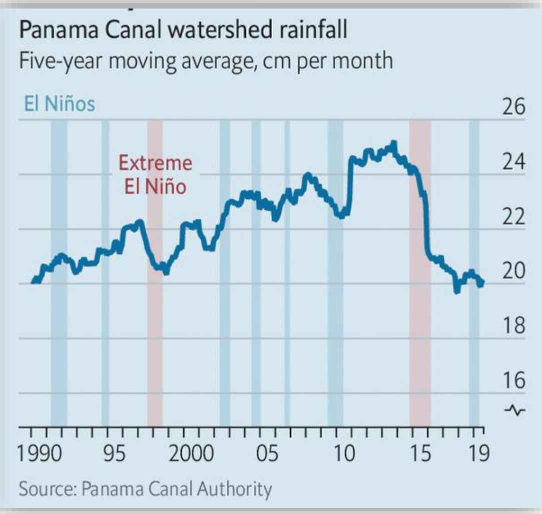
Maritime transport and Ports - Impacts from Inland Flooding and Droughts

- **Changing inland precipitation patterns**, including increased risks of flooding and drought, **can have indirect impacts on the maritime sector** through supply chain effects.
  - ✓ **Record water levels on the Mississippi River** in 2019 disrupted this key transport network for exporting US agricultural goods, causing losses valued at almost **1 billion US$**.
  - ✓ In the same year, **severe drought in the Panama Canal region required limits** on through traffic that have been estimated to cost global shipping **between 230 million US$ and 370 million US$.**

Mississippi River flooding in Davenport, Iowa in 2019



Lower water levels made old tree stumps visible.
Associated Press



Maritime transport and Ports - Impacts from Rising Temperatures and Extreme Heat Events

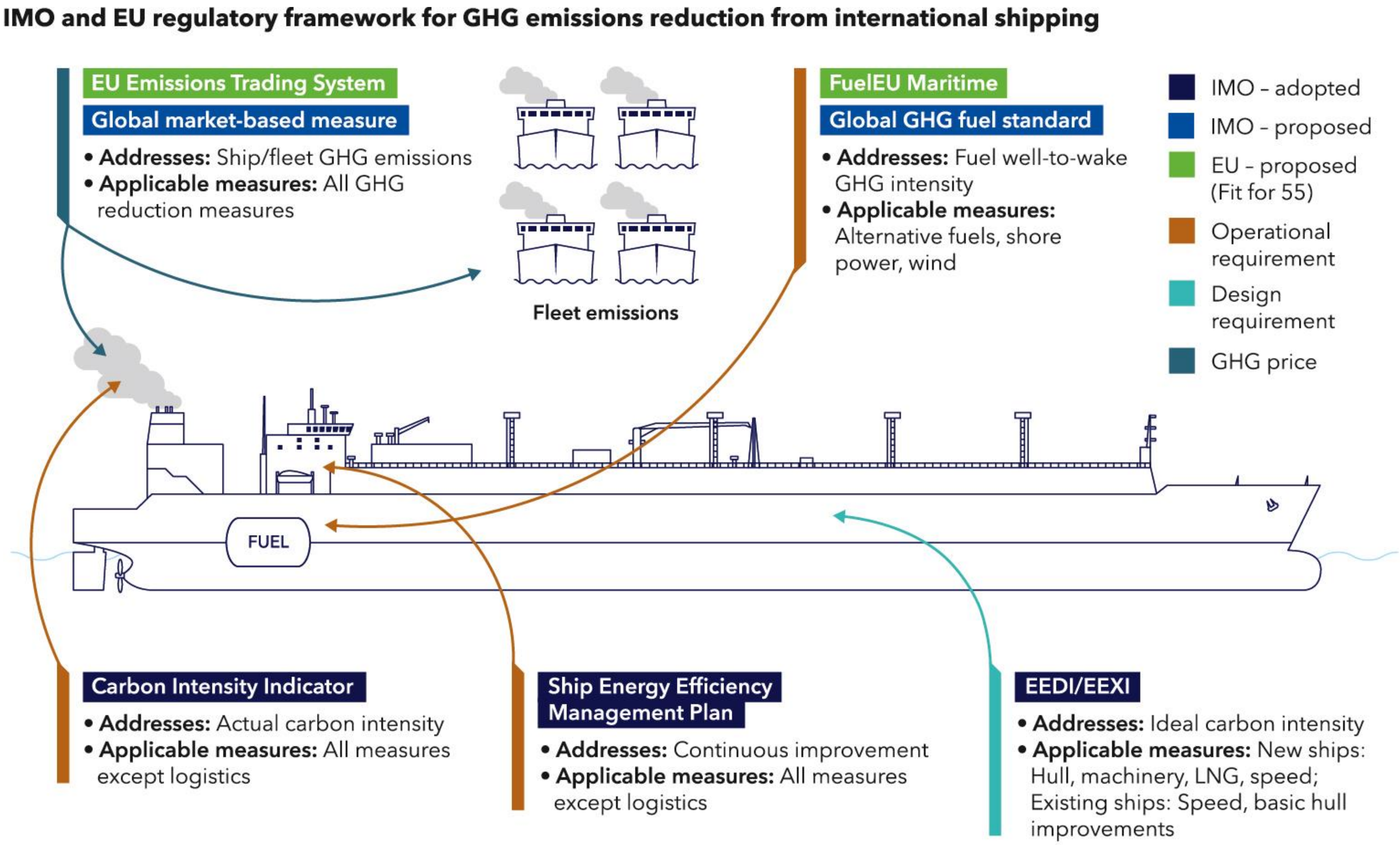
- Extreme heat can cause substantial damage to shipping vessels and port infrastructure, as well as disrupts port operations.
  - ✓ **Impacts on port infrastructure include stress on cooling systems and metal port structures**, such as container handling cranes and warehouses.
  - ✓ **In 2009, heatwaves in Australia shut down sections of the Port of Melbourne for 3 days, resulting in productivity losses due to work stoppages**.

https://www.politico.eu/article/heat-wave-europe-temperature-frontline-workers-at-risk/

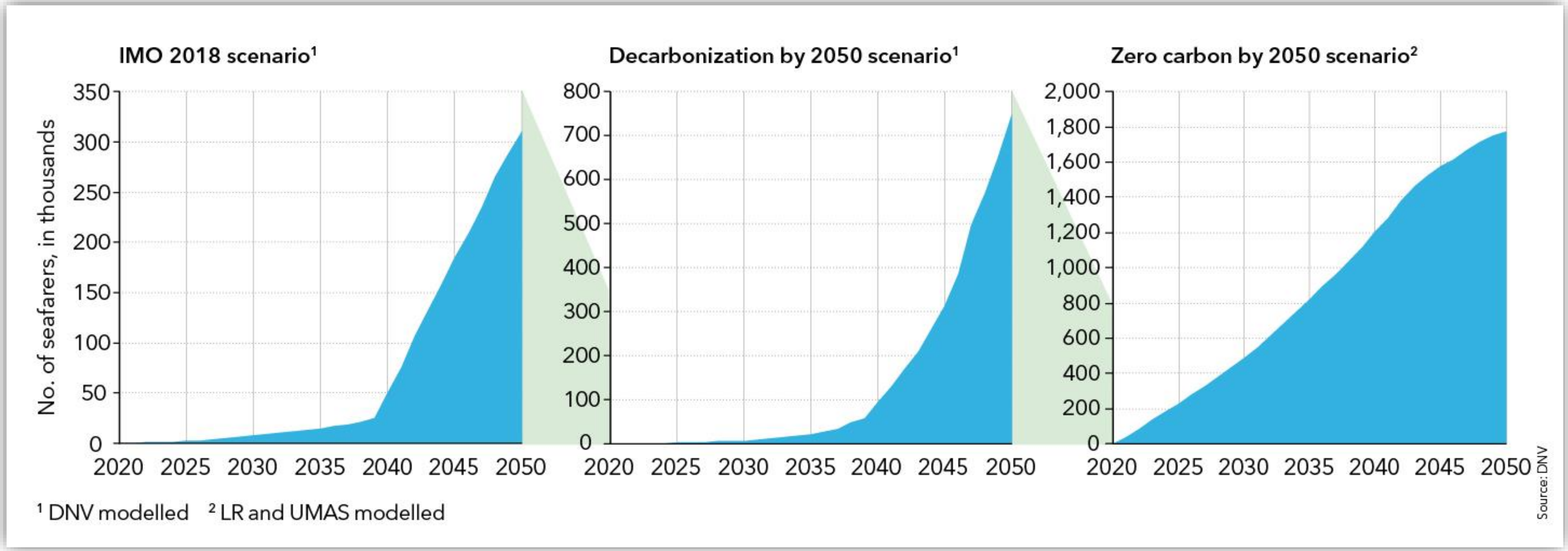
Decarbonisation of Maritime transport and Ports

- In 2015, the **Paris Agreement on climate change** was agreed by parties to the United Nations Framework Convention on Climate Change (UNFCCC). It entered into force on 4 November 2016. Its goal is **to keep global temperature rise below 2°C above pre-industrial levels, and preferably limited to 1.5°C**.
- EU Green Deal – **EU to be carbon neutral until 2050.**
- **Decarbonization of maritime transport and ports** is essential to achieve the goals of the Paris Agreement. **It requires a combination of strategies**, including:
  - ✓ transitioning to low-carbon or zero carbon fuels,
  - ✓ improving energy efficiency,
  - ✓ electrification and shore power,
  - ✓ integrating renewable energy,
  - ✓ fostering technological innovation,
  - ✓ implementing policy measures, and
  - ✓ fostering collaborative approaches among stakeholders.
- **By implementing these strategies in a holistic and coordinated manner, shipping and ports can significantly reduce their GHG emissions and contribute to global efforts to combat climate change**.

IMO and EU regulatory framework for GHG emission reduction



Estimates of the # of workforce requiring specific trainings in future



Key finding: The number of seafarers working on alternative fuel technologies ships increases slightly until the late 2030s. After, the number increases dramatically, so in 2050, it is estimated that 310,000 seafarers would be working aboard those ships.

Key finding: Similar trend to previous scenario. By 2050, 750,000 seafarers would require additional training to handle alternative fuels and technologies.

Key finding: In the 'Zero Carbon by 2050 scenario', the number of seafarers requiring additional training rises steeply from the 2020s until 2050. By 2030 some 450,000 seafarers would require some additional training, while 800,000 seafarers by the mid-2030s.

UPSKILLING/RESKILLING OF WORKFORCE FOR ACHIEVING DECARBONISATION GOALS @ UoM/Faculty of maritime studies

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University of Montenegro - Faculty of Maritime studies Kotor

LLL programs for professionals and students

- STCW programs for seafarers (Certified by Croatian Register of Shipping a member of International Association of Classification Societies (IACS)
- Summer school for students and professionals (2 ECTS)

Undergraduate programs, BSc (3y)

- Navigation and sea transportation (STCW program certified by CRS)
- Marine engineering (STCW program certified by CRS)
- Marine electrotechnics (STCW program certified by CRS)
- Maritime management and logistics

Postgraduate programs MSc (2y)

- Maritime sciences
  - ✓ modul Navigation and transportation
  - ✓ modul Marine engineering
- Maritime management and logisticss

Doctoral programs (3y)

- Maritime sciences
  - ✓ modul Navigation and transportation
  - ✓ modul Marine engineering
- Maritime management and logistics

http://www.pfkotor.ucg.ac.me/

Joint MSc in Maritime Environmental Protection and Management

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Programma Sviluppo lavoro • formazione • welfare

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INSTITUTI TRANSPORTIT

Joint MSc in Maritime Environmental Protection and Management

#	Sem.	Course title	# of hours	ECTS	O/E
I	I	**Research Skills, Methods and Tools**	2+2+0	10	O
2	I	**Fundamentals of Environmental Science and Sustainability**	2+2+0	10	O
3	I	**Introduction to the Blue Economy**	2+2+0	10	O
4	II	**Marine Ecology and Conservation**	2+1+1	10	O
5	II	**Marine Environmental Pollution and Prevention**	2+1+1	10	O
6	II	**GHG Emission and Climate Change Mitigation Policies**	2+1+1	10	O
7	III	**Environmental Management Standards and Impact Assessment**	2+2+0	10	O
8	III	**Elective Course #1**	2+1+1	10	E
9	III	**Elective Course #2**	2+1+1	10	E
		Sustainable Development of Maritime Transport and Ports			
		Sustainable Development of Coastal Tourism			
		Management of Offshore Energy and Mineral Resources			
		Fisheries Management			
		Integrated Coastal Management			
		Management of Protected Marine Areas And Species			
		Maritime Safety and Security			
		Entrepreneurship and Innovation			
13	IV	Professional Practice/Research		12	
14	IV	Master Degree Thesis		18	

Lifelong learning/Summer school @UoM/Faculty of maritime studies Kotor

6-day accredited summer school providing 2 ECTS

SUSTAINABLE DEVELOPMENT OF YACHTING AND CRUISE INDUSTRY

Date: July 3rd – July 8th, 2023
Place: University of Montenegro, Faculty of Maritime Studies Kotor
Address: Put I Bokeljske brigade 44, 85330 KOTOR, MONTENEGRO

BACKGROUND

The summer school (Lifelong Learning Program) on "Sustainable development of yachting and cruise industry" started in 2022 as a part of the Erasmus+ CBHE project "Fostering Internationalization at Montenegrin HEIs through Efficient Strategic Planning (IESP)", project No. 609675-EPP-1-2019-1-ME-EPPKA2-CBHE-SP.

It is Montenegrin first accredited lifelong learning program, as determined by Decision No. 02-607/22 – 51/74P of the national Agency for Control and Quality Assurance of Higher Education on 21.4.2022.

The summer school provides students with 2 ECTS and is conducted in English.

It is organized by the Center for Research, Innovation, and Entrepreneurship at the University of Montenegro, Faculty of Maritime Studies in Kotor.

The lecturers are eminent professors and professionals from Montenegro, Albania, and the European Union.

RESEARCH ON DECARBONISATION @ UoM/Faculty of Maritime Studies

Center for Research, Innovation and Entrepreneurship @UoM/FMS

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

Permanent personnel:

- Prof. dr Danilo Nikolić, coordinator
- MSc Radmila Gagić
- PhD Maja Škurić
- MSc Darko Kovačević

Managing International Projects

PROGRAM	PROJECT TITLE	ROLE	YEAR	TOTAL BUDGET	PFK BUDGET
Erasmus + CBHE	Development of Regional Joint Master Program in Maritime Environmental Protection and Management (MEP&M)	C	2021 -2024	845,188.00 €	216,000.00 €
Interreg IPA	Protecting underwater heritage through its digitalization and valorisation as a novel touristic offer (WRECKS4ALL)	C	2020 - 2022	1,016,778.32 €	334,737.17 €
Tempus	Modernizing and Harmonizing Maritime Education in Montenegro and Albania (MArED)	C	2013 - 2017	1,154,776.80 €	316,181.47 €
Erasmus + CBHE	Sustainable development of BLUE economies through higher education and innovation in Western Balkan Countries (BLUEWBC)	P	2020 - 2023	985,755.00 €	207,766.00 €
Interreg IPA	Innovative Systems to enhance Antifraud Customs Controls (ISACC)	P	2020 - 2022	996,997.04 €	148,356.00 €
Interreg IPA	Partnership for the Observation and study of new Routes and Transnational Sea-highways (PORTS)	P	2018 - 2020	109,1053.08	136,755.00 €
Interreg IPA	Partnership for the prOmotion of a maRiTime cross-border Strategy (PORTS 4.0)	P	2020 – 2021	94,000.00 €	24,000.00 €
Interreg IPA	PrOmoting Resilient, Sustainable, and Smart Transport and logistic activities in the South Adriatic Area (PORTS PLUS)	P	2022 - 2023	94,000.00 €	11,000.00 €
Tempus	Development of Sustainable Interrelations between Education, Research and Innovation at WBC Universities in Nanotechnologies and Advanced Materials where Innovation Means Business (WIMB)	P	2013 - 2017	1,200,000.00 €	152,000.00 €
HERD	Montenegro Sustainable Maritime Competence Initiative	P	2013 – 2016	1,400,000.00€	900,000.00 €
HERIC	Knowledge transfer for increased maritime competences in Montenegro (EDUMAR)	P	2016 – 2017	55,000.00 €	55,000.00 €
TOTAL:				**8,933,548.24 €**	**2,501,795.64 €**

SMART BAY LAB

FOCUS ON AIR POLLUTION FROM CRUISE SHIPS IN KOTOR BAY

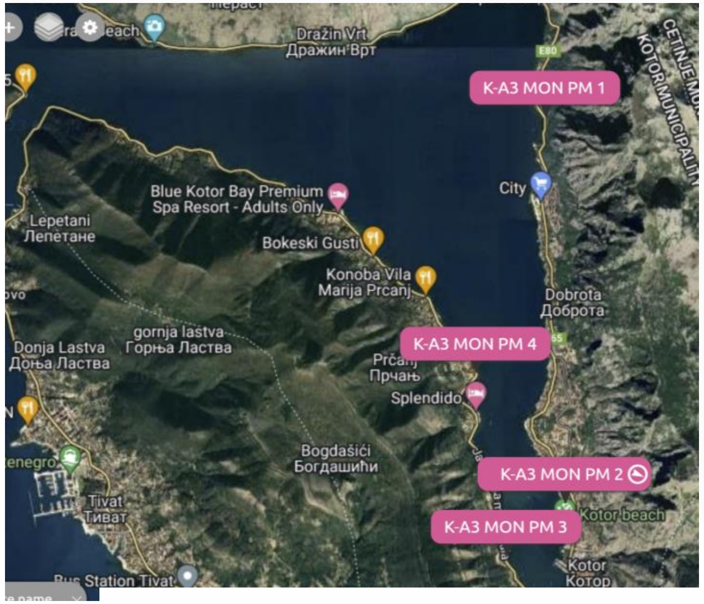
Number of calls at selected cruise ports in the Adriatic Sea in 2019*

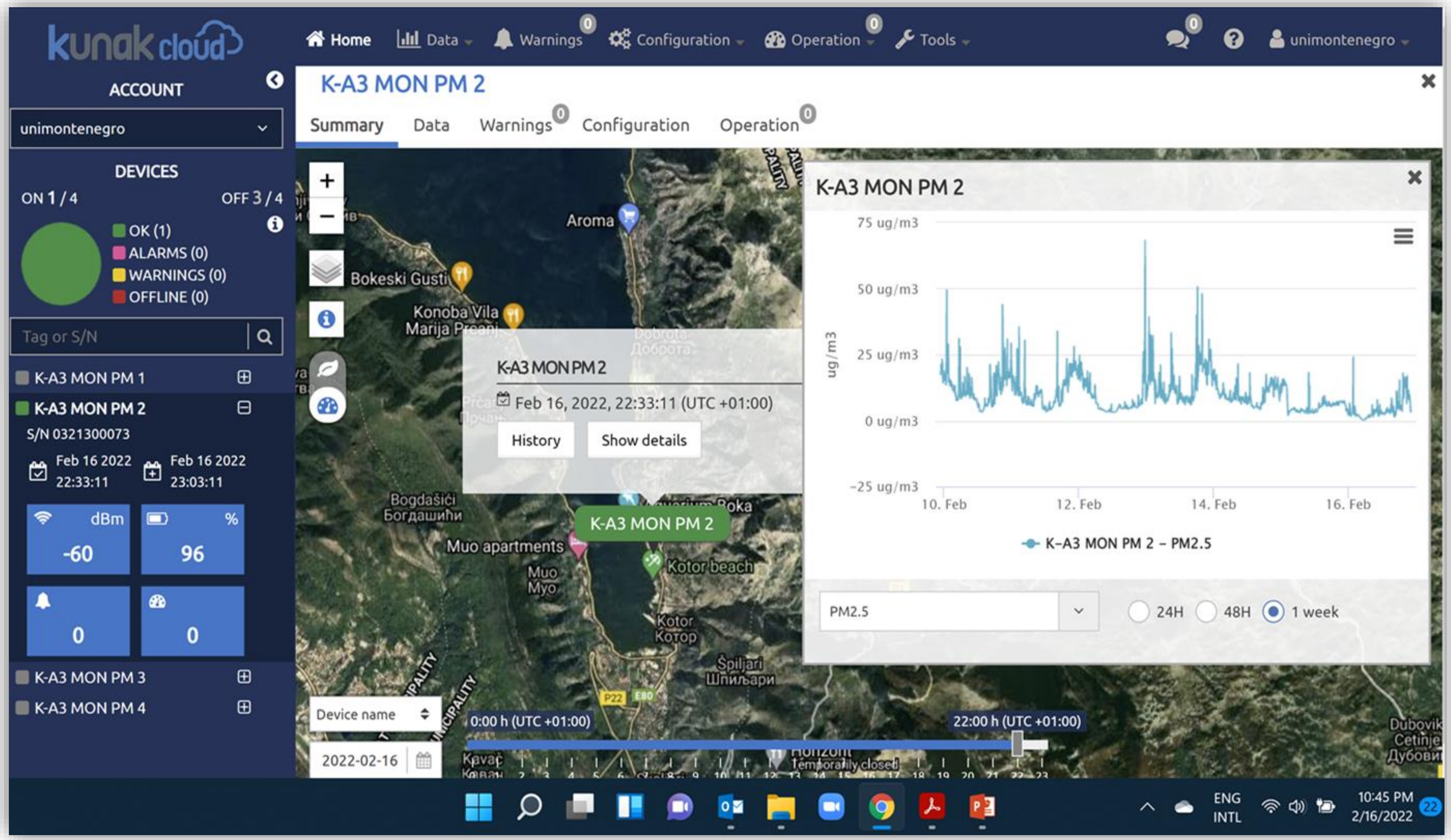
Characteristic	Number of cruise calls
Kotor	519
Venice	502
Dubrovnik	475
Corfu	416
Split	292
Bari	233
Zadar	142
Sibenik	99
Korcula	95
Koper	69
Sarande	65
Trieste	63
Rovinj	60

Showing entries 1 to 13 (20 entries in total)

See more data

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





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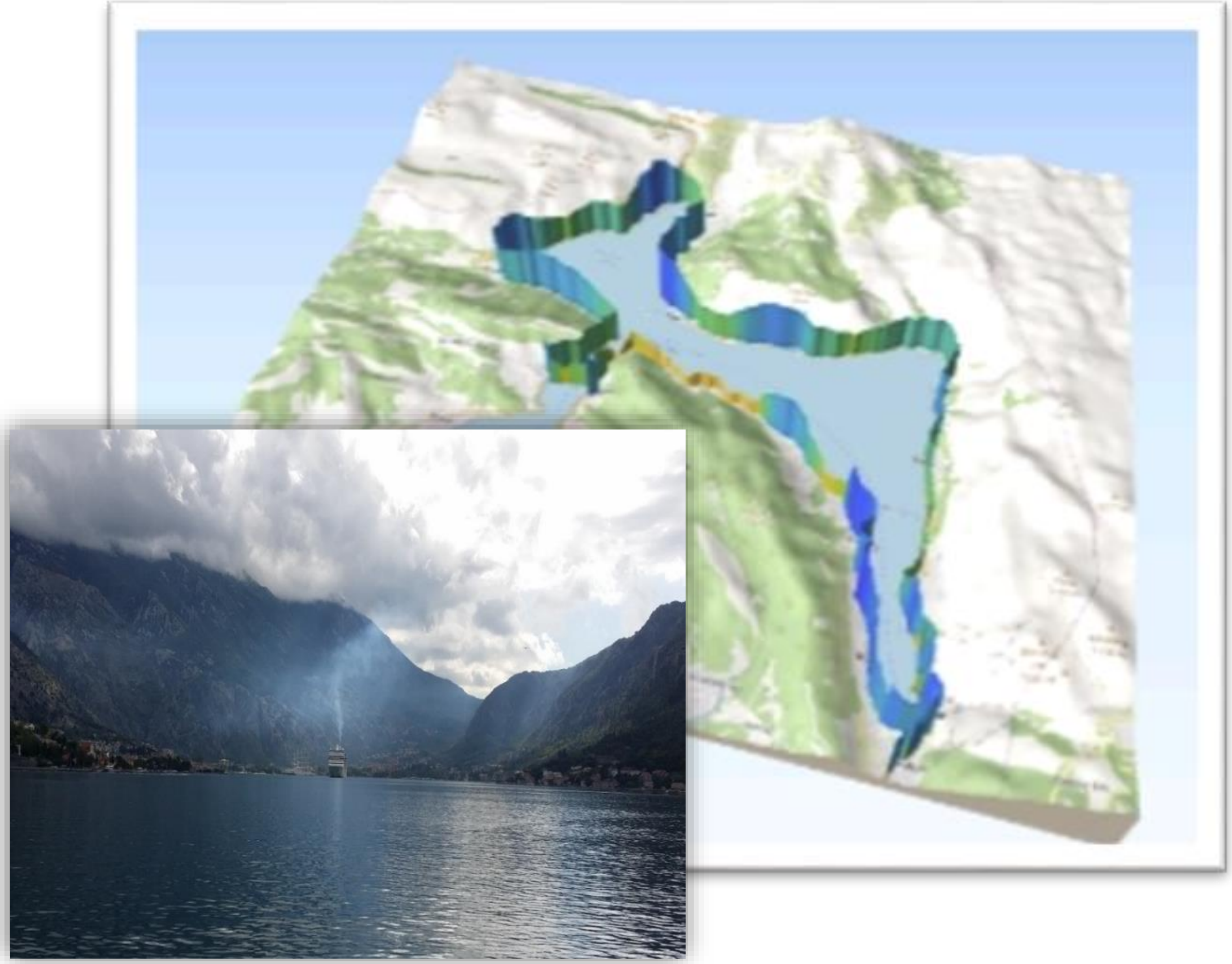
SMART BAY LAB – Mobile PM sizer



TSI Optical particle sizer (OPS) 3330

SMART BAY LAB – Exhaust emission analyser & smoke tester

TESTO 350 MARITIME

Equipment for fuel and oil quality testing - Accredited

AKREDITACIONO TIJELO
Crne Gore

Dodatak Sertifikatu o akreditaciji - identifikacioni broj: 0095
Annex to Accreditation Certificate - identification number: 0095

Datum izdavanja dodatka: *29.12.2020.*
Issue date of annex: 29.12.2020.
Zamjenjuje dodatak:
Replaces Annex dated:

Dodatak Sertifikatu o akreditaciji sa akreditacionim brojem Li 20.31
Annex to Accreditation Certificate Accreditation Number Li 20.31

Standard: MEST EN ISO/IEC 17025:2018

Datum dodjele /obnavljanja akreditacije:
Date of granting / renewal of accreditation:
29.12.2020./

Akreditacija važi do: 28.12.2024.
Accreditation is valid to: 28.12.2024.

Akreditovana laboratorija za ispitivanje
Accredited laboratory of testing

Univerzitet Crne Gore
Pomorski fakultet Kotor
Laboratorija za ispitivanje nafte i naftnih derivata
Dobrota br. 36, Kotor

Područje akreditacije / *Scope of accreditation*
Fizičko-hemijska ispitivanja tečnih goriva naftnog porijekla
Physical-chemical testing od liquid fuels of petroleum origin

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

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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].

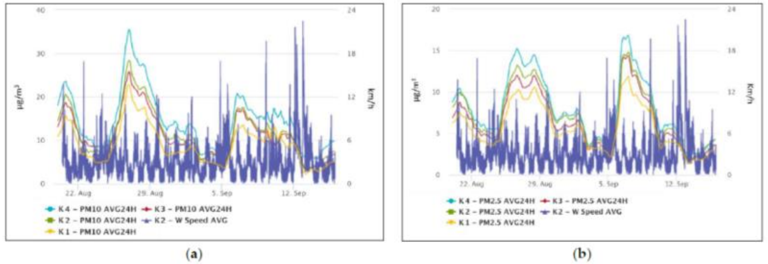

Figure 8. Average wind speed vs. PM_{10} (**a**) and $PM_{2.5}$; (**b**) 24 h average over the experimental period 20 August–15 September 2022.

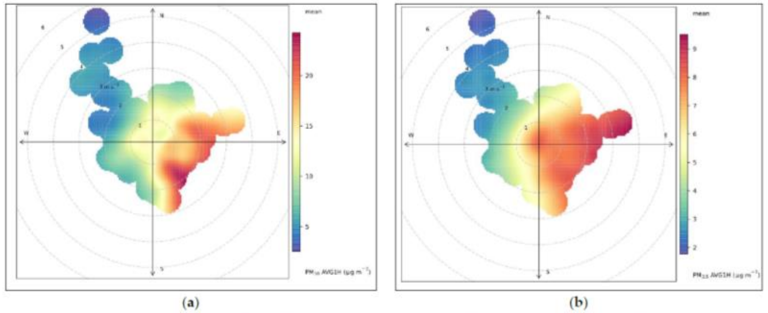

Figure 9. Bivariate polar plot of $PM_{2.5}$ (**a**) and PM_{10} (**b**) concentrations at the K4 measuring location during experimental period from 20 August to 15 September 2022. Each plot's center indicates a wind speed of zero, which rises radially outward. The color scale indicates the concentration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

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Estimation of Air Pollution from Ships in the Boka Kotorska Bay

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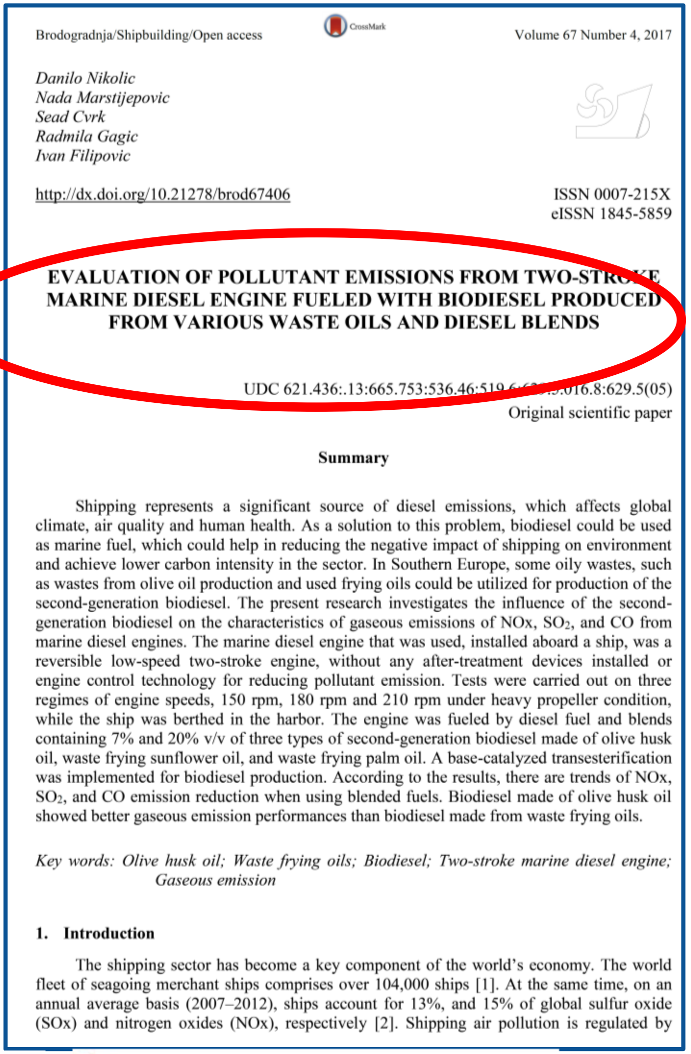
Danijela Joksimović, Mirko Đurović, Igor S. Zonn, Andrey G. Kostianoy, and Aleksander V. Semenov (eds.), *The Montenegrin Adriatic Coast: Marine Chemistry Pollution*, Hdb Env Chem, DOI 10.1007/698_2020_702,

SMART BAY LAB – 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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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 – Equipment for underwater research

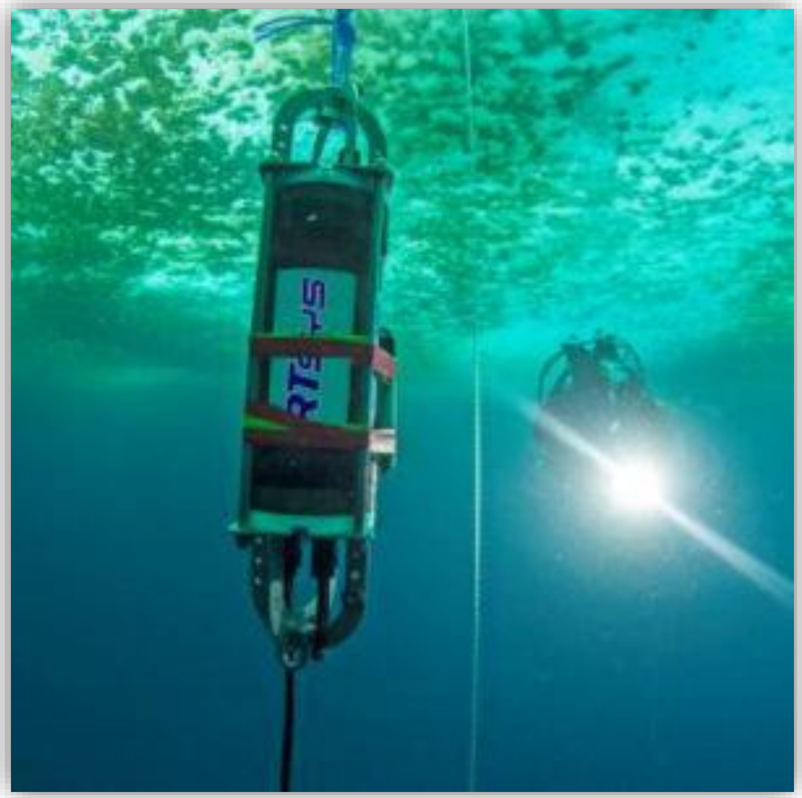
BlueROV2

SMART BAY LAB – Equipment for underwater research

Multi-parameter Water Quality Checker

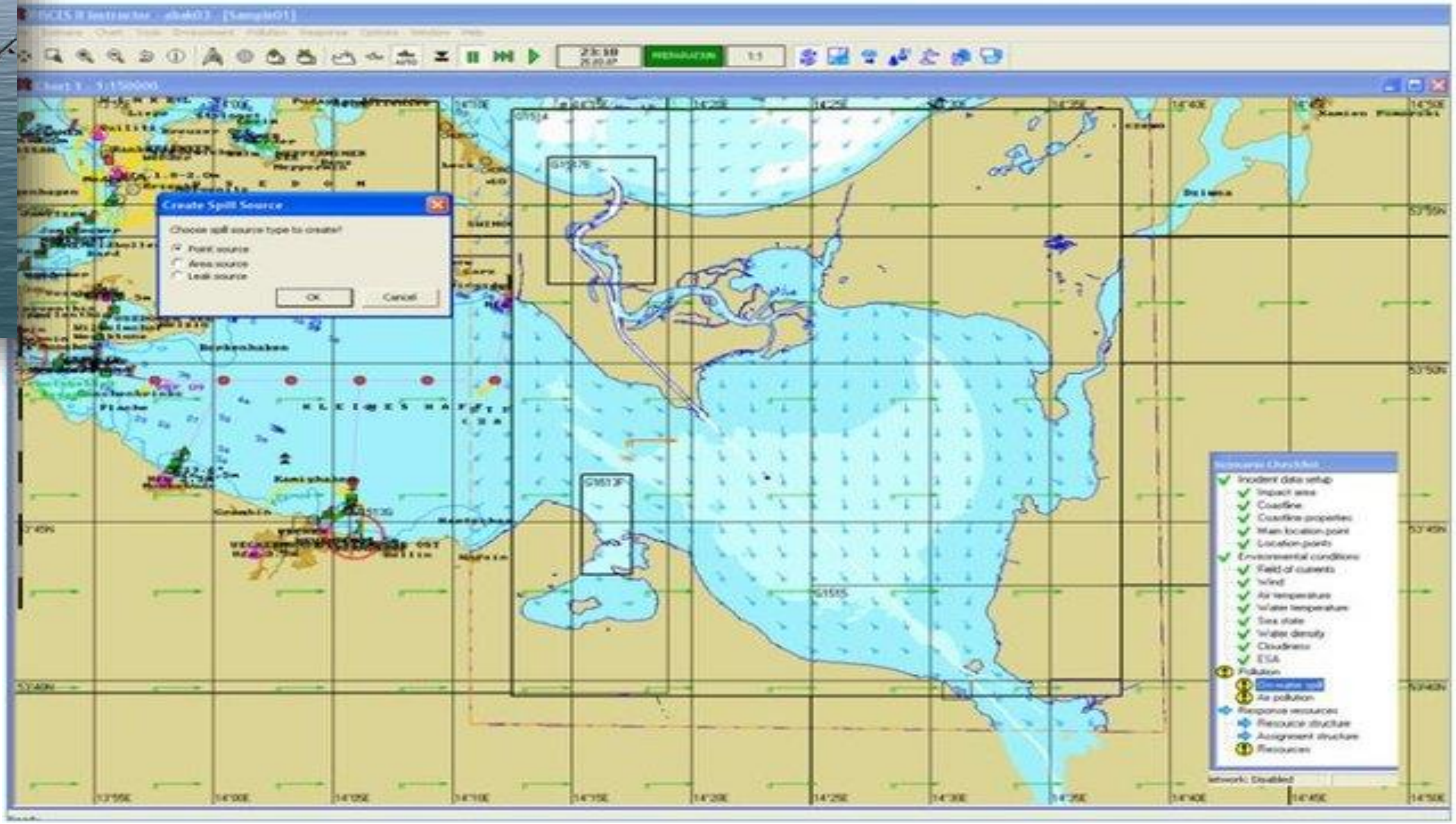
Horiba U-50 series Multi-parameter water quality checker

Underwater acoustic recorder & Hydrophone



SMART BAY LAB – Simulations of oil spills

Wärtsilä Oil Spill Response Simulator



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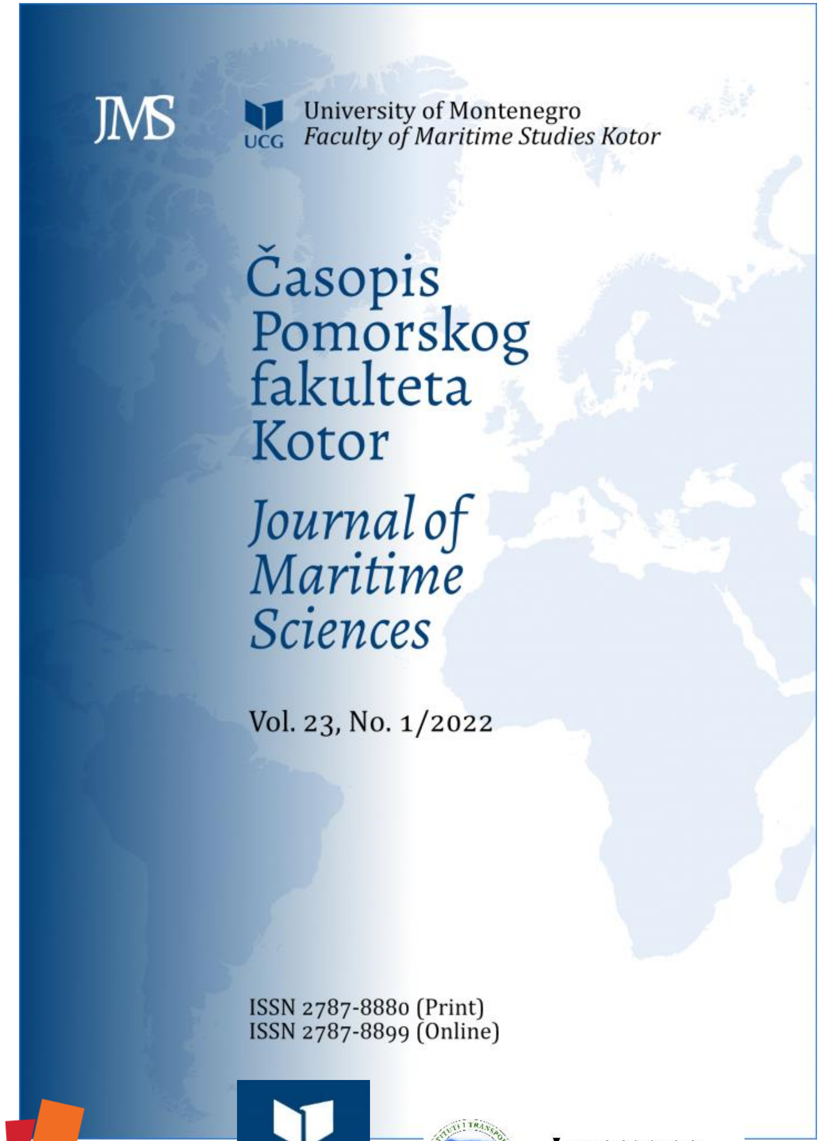

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