University of Zagreb
Faculty of Mechanical Engineering
and Naval Architecture

Decarbonization of marine operations - applications of technical and operative decarbonization measures to fishing vessels

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Europska unija

Operativni program
ZA POMORSTVO
I RIBARSTVO

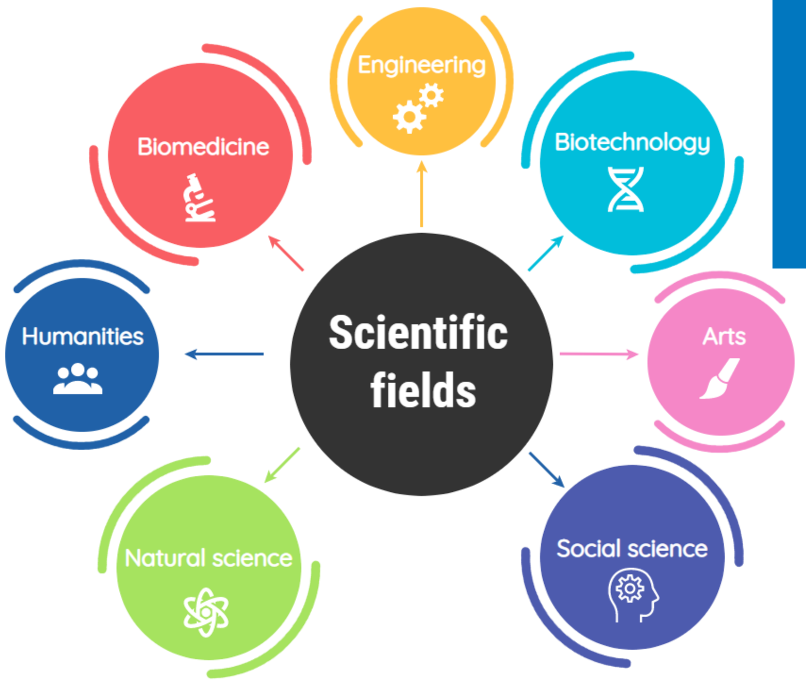
Sufinancirano sredstvima Europske unije iz Europskog fonda za pomorstvo i ribarstvo

GENERAL INFORMATION

General information

➢ University of Zagreb

- ✓ the oldest and biggest university in South-Eastern Europe (1669)
- ✓ strongly research-oriented institution, contributing with over 50% to the total research output of the country



29 Faculties
3 Art Academies

~ 72,500 students

Academic Ranking of World Universities 2020

Top 1000 | Methodology | Statistics

World Rank	Institution*	By location: Croatia	National/Regional Rank	Total Score	Score on Alumni
401-500	University of Zagreb		1		0

Faculties of the University of Zagreb

- Faculty of Agriculture
- Faculty of Architecture
- Catholic Faculty of Theology
- Faculty of Civil Engineering
- Faculty of Chemical Engineering and Technology
- Faculty of Croatian Studies
- Faculty of Economics and Business
- Faculty of Education and Rehabilitation Sciences
- Faculty of Electrical Engineering and Computing
- Faculty of Food Technology and Biotechnology
- Faculty of Forestry and Wood Technology
- Faculty of Geodesy
- Faculty of Geotechnical Engineering
- Faculty of Graphic Arts
- Faculty of Humanities and Social Science
- Faculty of Kinesiology
- Faculty of Law
- Faculty of Mechanical Engineering and Naval Architecture
- Faculty of Metallurgy
- Faculty of Mining, Geology and Petroleum Engineering
- Faculty of Organization and Informatics
- Faculty of Pharmacy and Biochemistry
- Faculty of Philosophy and Religious Studies
- Faculty of Political Science
- Faculty of Science
- School of Dental Medicine
- School of Medicine
- Faculty of Teacher Education
- Faculty of Textile Technology
- Faculty of Transport and Traffic Sciences
- Faculty of Veterinary Medicine

General information

➢ Faculty of Mechanical Engineering and Naval Architecture (UNIZAG FSB)

Organizational scheme of UNIZAG FSB

<u>Departments</u>

- Design
- Applied Mechanics
- Thermodynamics, Thermal & Process Engineering
- IC Engines & Transport System
- Energy, Power & Environmental Engineering
- Naval Architecture & Offshore Engineering
- Industrial Engineering
- Quality
- Robotics and Production System Automation
- Materials
- Welded Structures
- Technology
- Aeronautical Engineering
- Fluid Mechanics

Department of Naval Architecture and Offshore Engineering

Department consists of 5 organizational units and 6 laboratories:

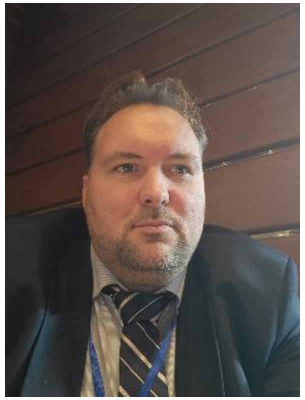
- ✓ ***Chair of Marine Engineering***
- ✓ *Chair of Ship Hydrodynamics*
- ✓ *Chair of Ship Structures*
- ✓ *Chair for Ship Design and Offshore Engineering*
- ✓ *Chair of Ship Production Engineering*

- ✓ *Laboratory for the Computer Application in Shipbuilding*
- ✓ *Laboratory of Ship Structures*
- ✓ ***Laboratory of Marine Engineering***
- ✓ *Laboratory for the Improvement of Shipbuilding Production*
- ✓ *Laboratory of Ship Hydrodynamics*
- ✓ *Laboratory of Sea Technology*

General information

- Research group – 6 members
- Number of projects focused on protection of marine environment
- Cooperation with the world's leading shipyards and ship owners

https://mareng.fsb.hr/



N. Vladimir

M. Perčić

M. Koričan

I. Jovanović

T. Bujas

M. Vukić

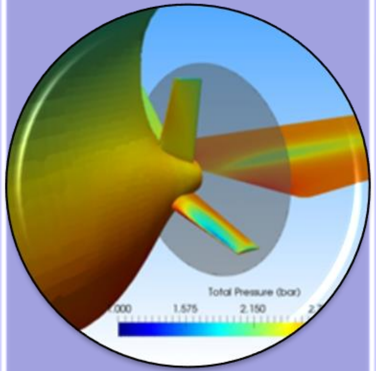
Selected research topics

Energy efficiency & Environmental Friendliness

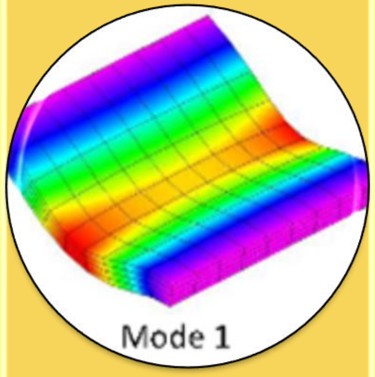
Protection of marine environment

Fisheries & Aquaculture

Advanced ship design procedures



Fluid-structure interaction (ship hydroelasticity)



Specific strength & vibration problems in marine structures

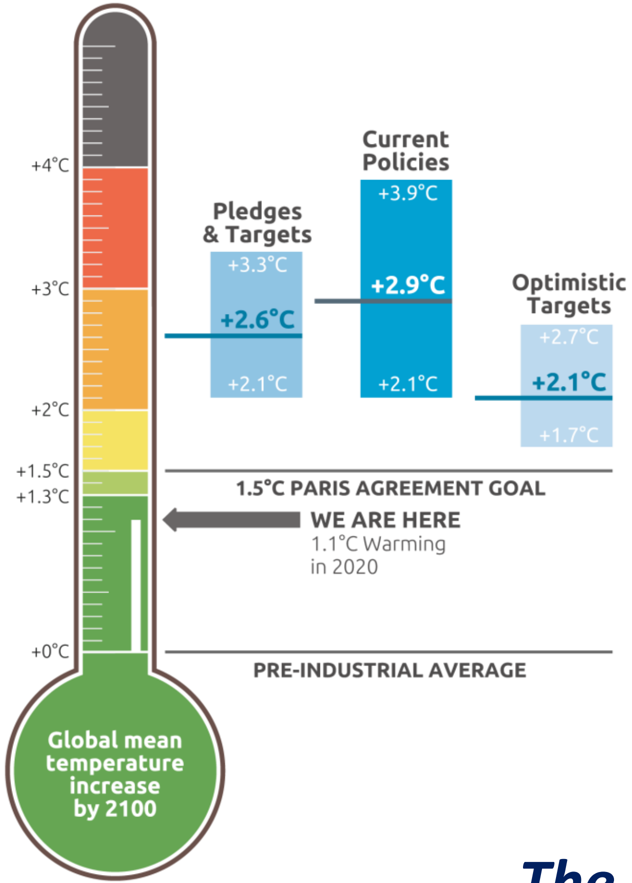
Research projects & Technical consultancy

Ongoing projects

- ✓ 11/2022 – 04/2026 - ***Hybrid Tandem catalytic conversion process towards higher oxygenate E-fuels* (E-TANDEM),** HORIZON Europe Framework Programme.
- ✓ 08/2022 – 12/2023 – ***Hybrid ENergy System for fishing vessels (HENSUS),*** Research Project funded by the Croatian Ministry of Agriculture.
- ✓ 01/2022 – 12/2023 – ***Research center for INTELligent, innovative, environmentally friendly, and sustainable MARICulture (INTEL MARIC),*** Research Project funded by the Croatian Ministry of Agriculture.
- ✓ 12/2020 – 12/2023 - ***Improvement of High-Efficiency Welding Technology (ImproWE)***, granted by the European Regional Development Fund (ERDF), Operational programme Competitiveness and Cohesion 2014-2020, Priority axis: Strengthening the Economy through Research and Innovation.
- ✓ 09/2020 – 09/2023 - ***Development of LNG System for the Ships Powered by Dual Fuel Engines (FO/LNG)***, granted by the European Regional Development Fund, Operational programme Competitiveness and Cohesion 2014-2020, Priority axis: Strengthening the Economy through Research and Innovation.
- ✓ 04/2020 – 03/2023 - ***Sector Adaptive Virtual Early Warning System for Marine Pollution (SEAVIEWS)***, INTERREG ADRION.
- ✓ 01/2020 – 12/2022 – ***Autonomous Auxiliary Fishing Vessel (APROPO)***, Research Project funded by the Croatian Ministry of Agriculture.
- ✓ 01/2020 – 12/2023 - ***Energy Efficient and Environmentally Friendly Power System Options for Inland Green Ships***, Croatian-Chinese Bilateral Project with Wuhan University of Technology, funded by Ministry of Science and Education of Croatia.
- ✓ 06/2020 – 12/2023 – ***Network of fishermen and Scientists to Improve Energy Efficiency of Croatian Fishing Fleet (MORZ)***, Research Project funded by the Croatian Ministry of Agriculture.
- ✓ 03/2018 – 07/2023 - ***Green Modular Passenger Vessel for Mediterranean (GRiMM)***, Croatian Science Foundation.

ENVIRONMENTAL PROBLEMS

GLOBAL EMISSIONS



- *Marine industry consumes cca. 330 million metric tons of marine fuel per year and 77% of it is Heavy Fuel Oil (HFO)*
  - 33% of all emissions resulting from the burning of fossil fuels in trades
  - emissions are projected to rise with a 270% increase by 2050, compared to 2007
  - NOx emissions produced by marine vehicles are in range from 14 to 31%
  - SOx emissions are in range from 4% to 9%

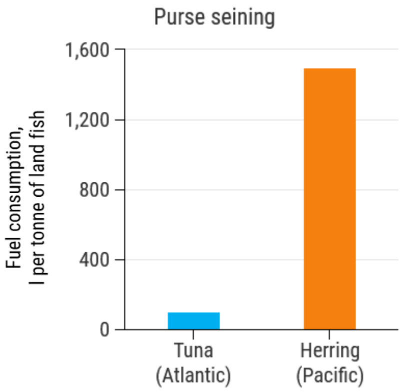
- *Paris Agreement (2016)*
  - aims to limit the increase in the global average temperature to well below 2°C, above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C
  - implementation entails economic, social and technical transformations in every sector, including maritime

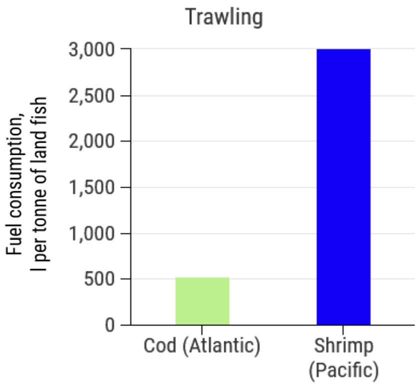
- *Glasgow Climate Act (2021)*
  - reducing the gap between existing emission reduction plans and what is required to reduce emissions, so that the rise in the global average temperature can be limited to 1.5°C

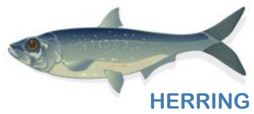
The fishing sector accounts for approx. 179 million tonnes of $CO_{2\text{-equivalent}}$ GHGs.

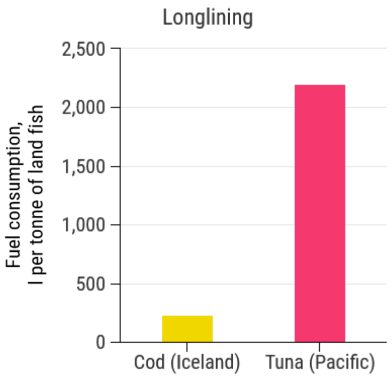
FISHERIES

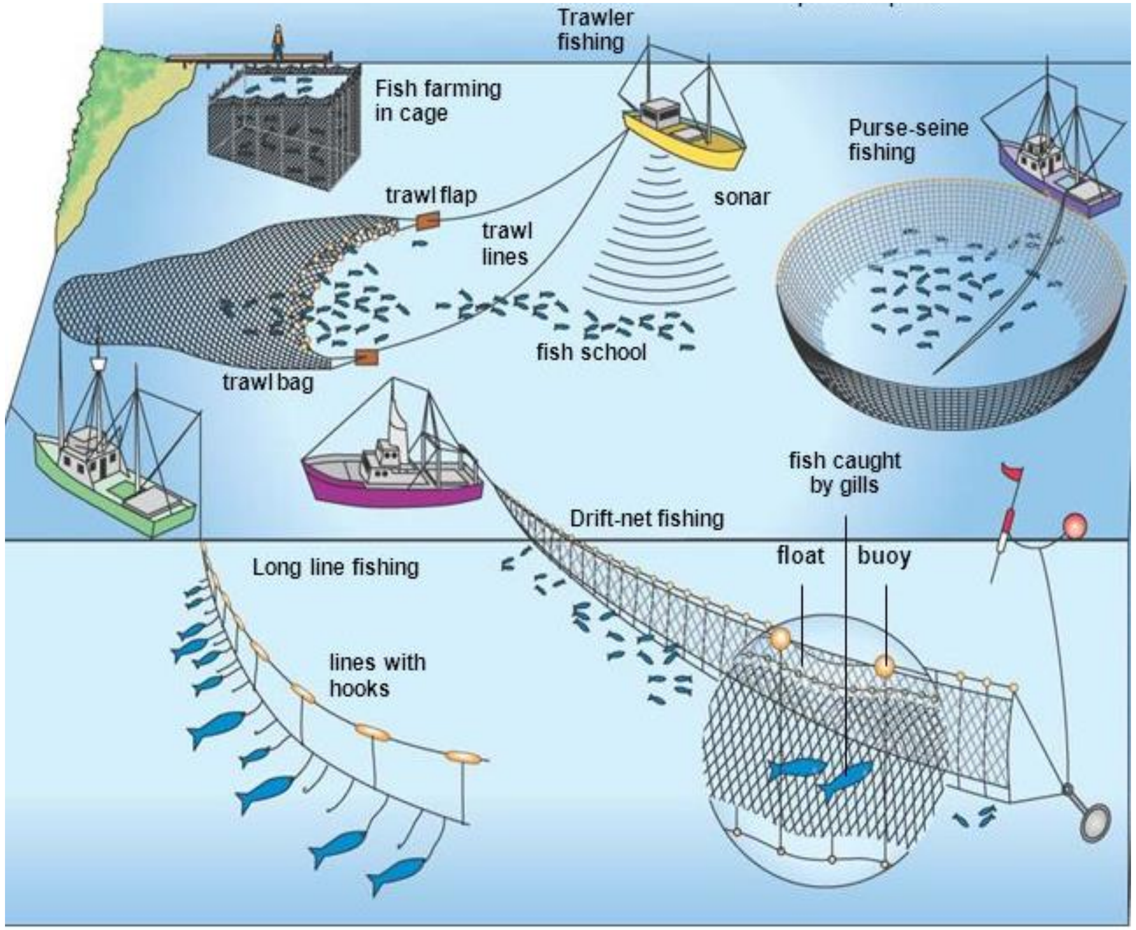
- emissions are directly related to the energy consumption, which depends on the type of fishing vessel, type of fishing activity and fishing route
- significant factor in fuel consumption is also the type of caught fish



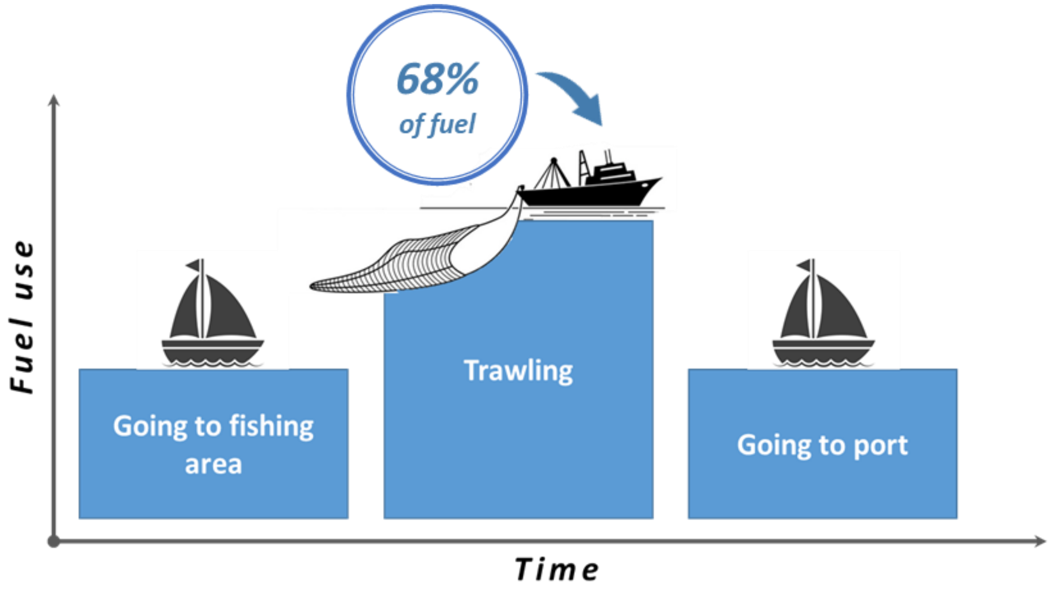


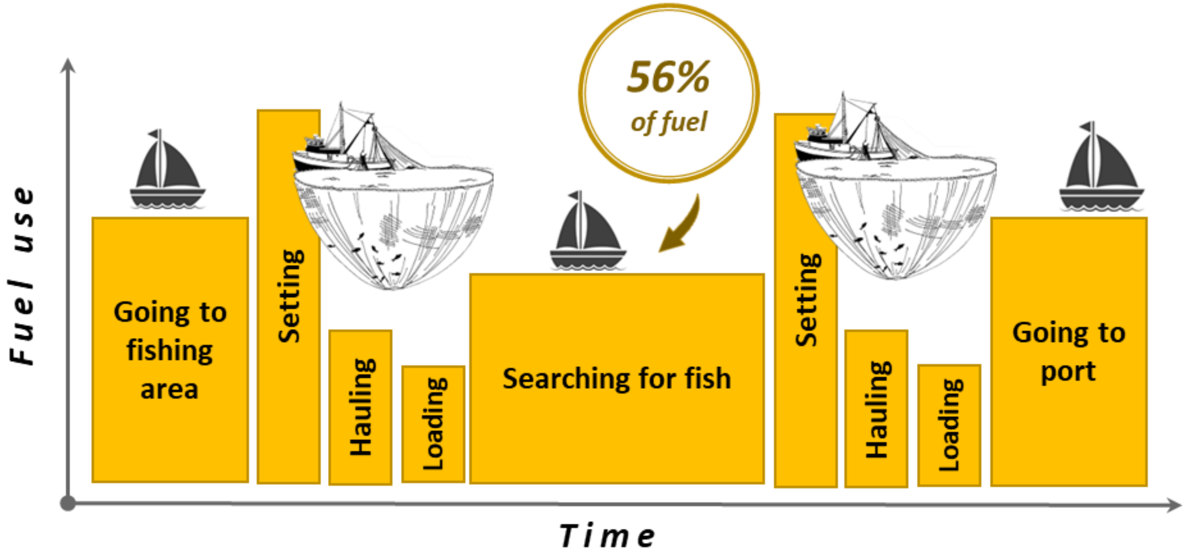






FISHING VESSELS





TRAWLERS	PURSE SEINERS
• the most fuel-demanding fishing vessels • typical fishing actions inherent to trawlers are sailing to the required location and fishing, i.e. net dragging	• dedicates more than half of total fuel consumption to cruising • a lower average fuel usage than trawlers • mainly used for catching small pelagic species

EMISSION CONTROL

➢ IMO prescribes number of technical and operative measures to reduce environmental effect of shipping

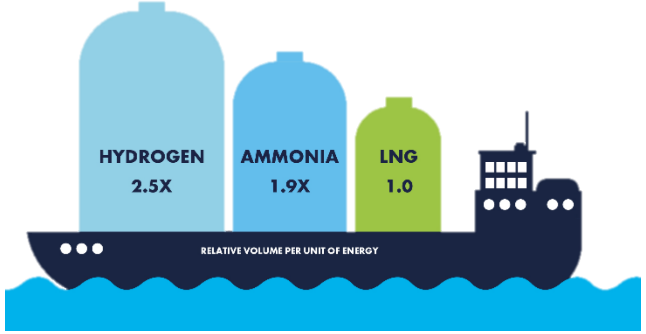
Data on real-time monitoring of fuel consumption!

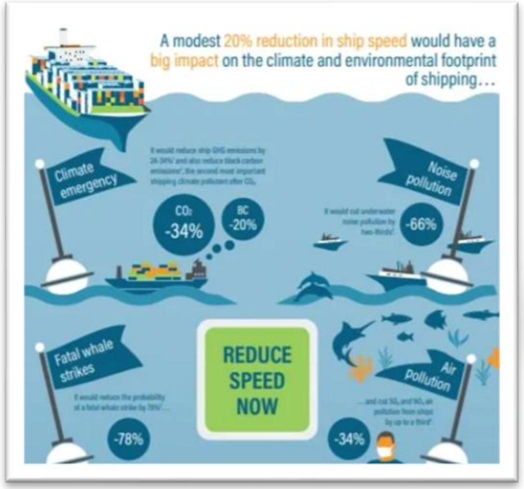
Technical measures

- ✓ measures related to the propulsion system
- ✓ vessel design and equipment
- ✓ exhaust after treatment
- ✓ engine internal measures
- ✓ use of alternative fuels

easures

- ated to speed reduction
- ing
- ✓ on-board information system
- ✓ optimal maintenance





RESEARCH BACKGROUND

REGULATORY FRAMEWORK

MARPOL Annex VI - chapter IV

applies to all ships of 400 gross tonnage and above

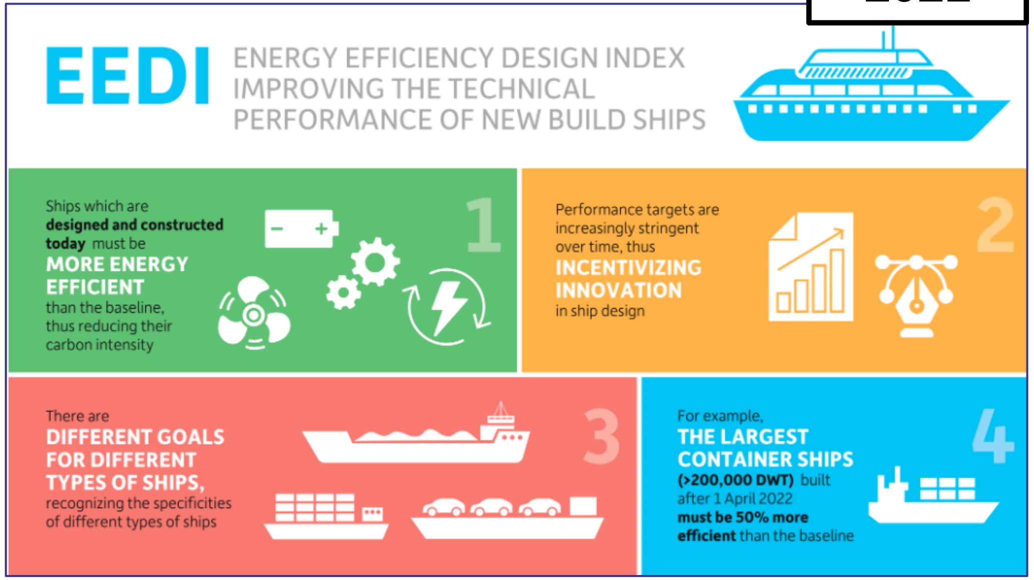
pres … gn and

Fishing Vessels Represent An EXCEPTION Both On The Basis Of Size & Operation In Coastal Waters

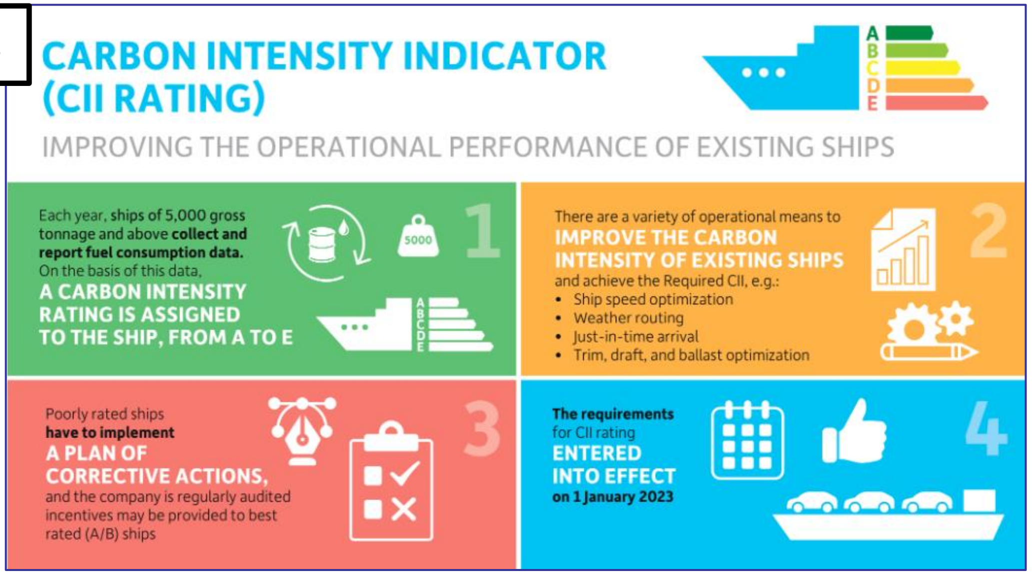
➢ … pted … duce

➢ The measures are regularly discussed and improved to ensure better implementation.

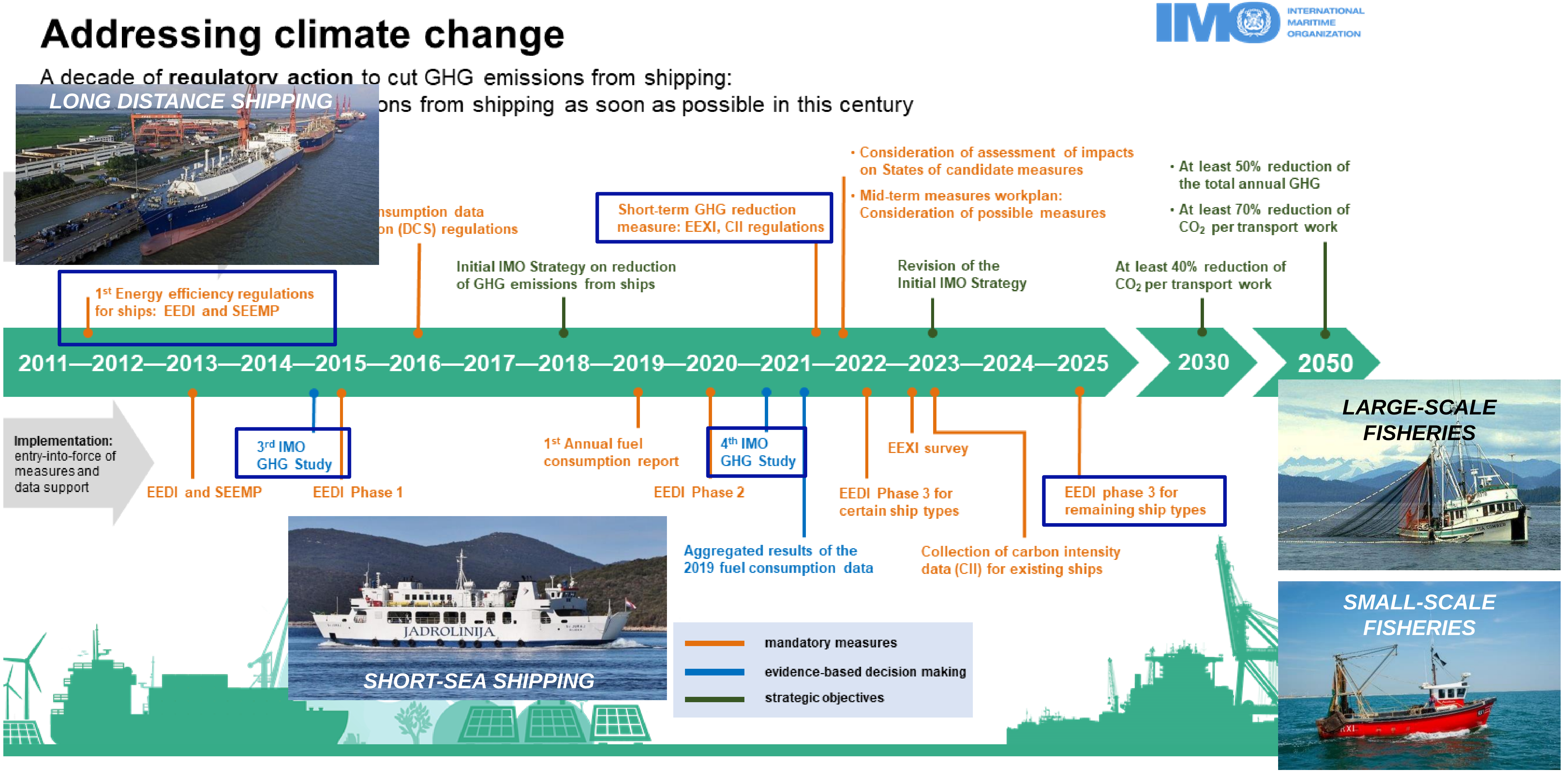
2021



Jan 2023



REGULATORY FRAMEWORK



LONG-DISTANCE SHIPPING

Maersk Montana – 4,544 TEU

Antwerp - Norfolk

Rigoletto – 9,415 TEU

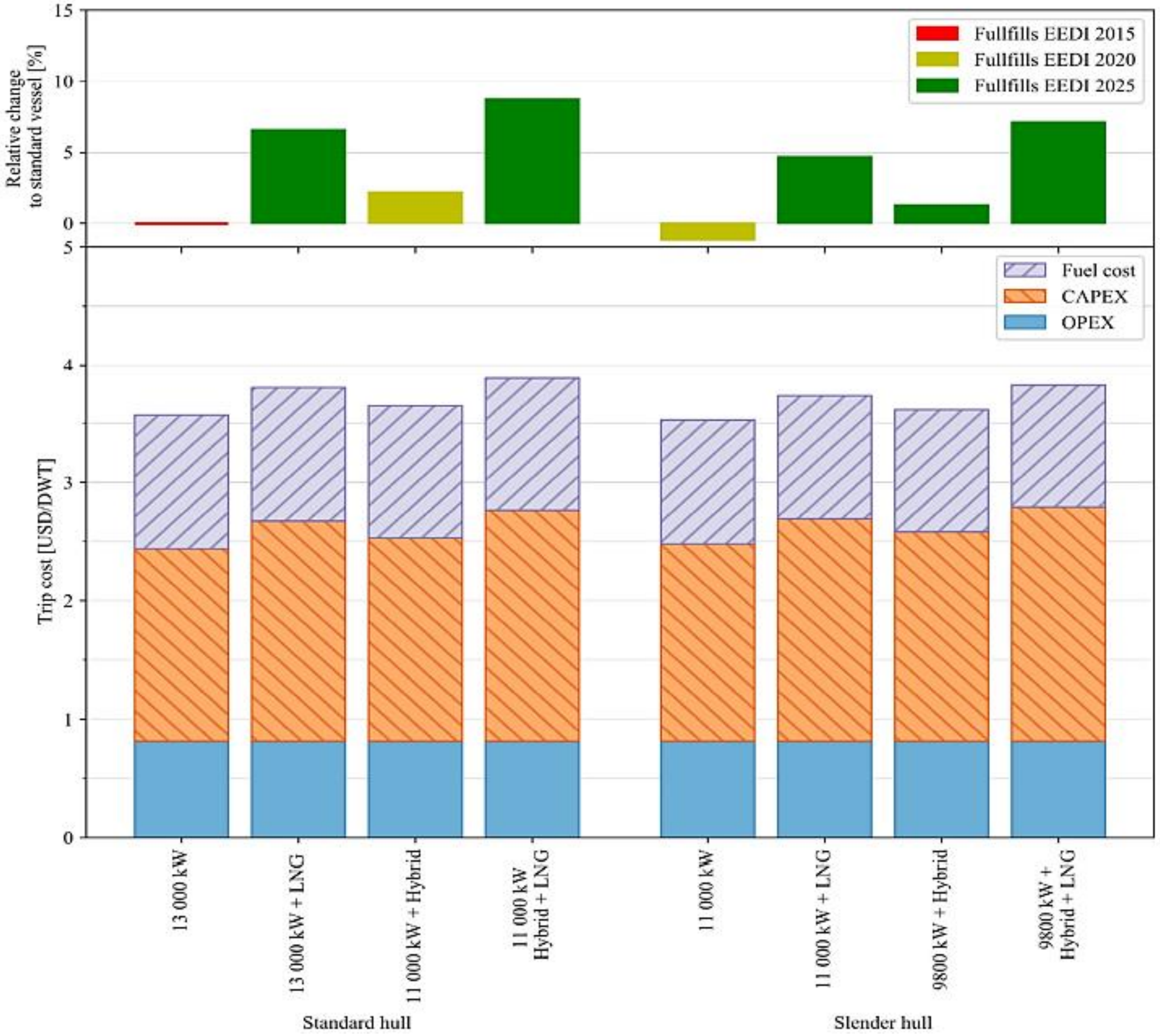
Caucedo - Singapore

One Mackinac – 13,900 TEU

Rotterdam - Busan

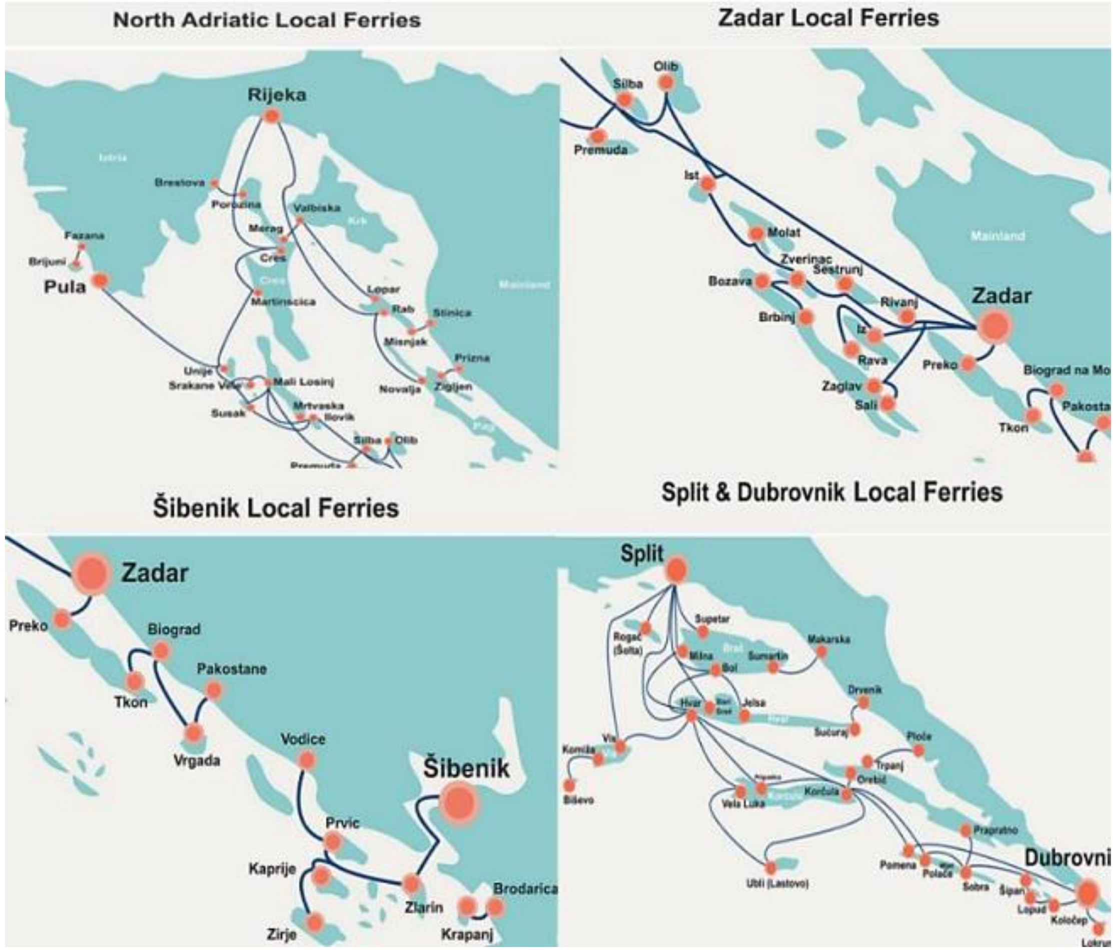
Marit Maersk – 18,270 TEU

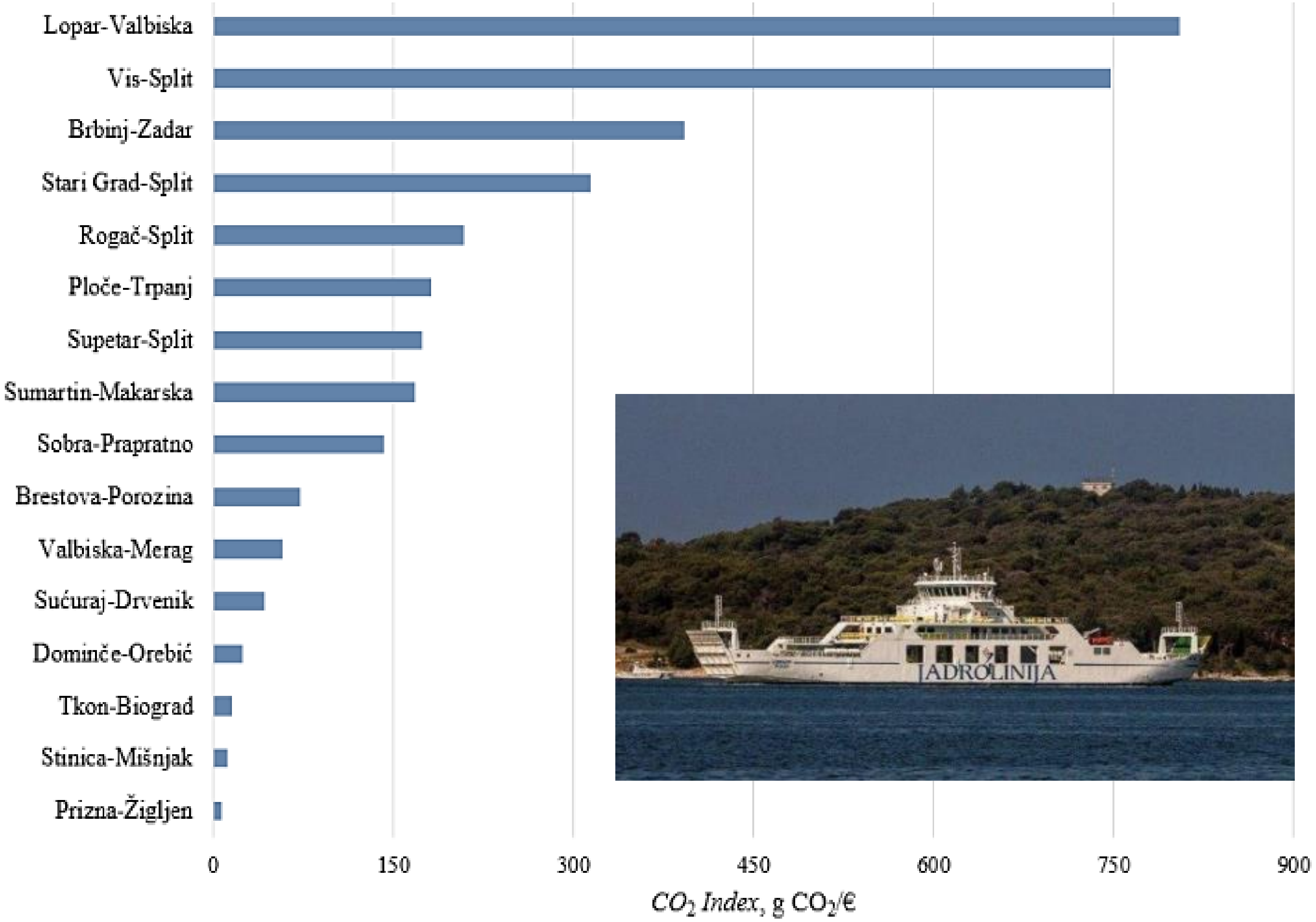
Hamburg - Shanghai



Elizabeth Lindstad, Torstein Ingebrigtsen Bø: Potential power setups, fuels and hull designs capable of satisfying future EEDI requirements, Transportation Research Part D: Transport and Environment, Volume 63, 2018, https://doi.org/10.1016/j.trd.2018.06.001.

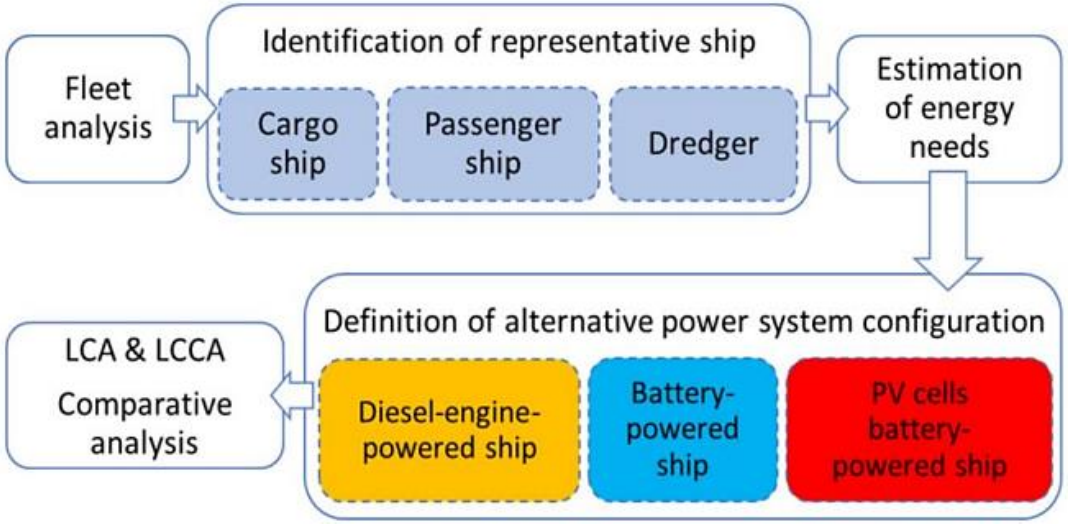
SHORT-SEA SHIPPING



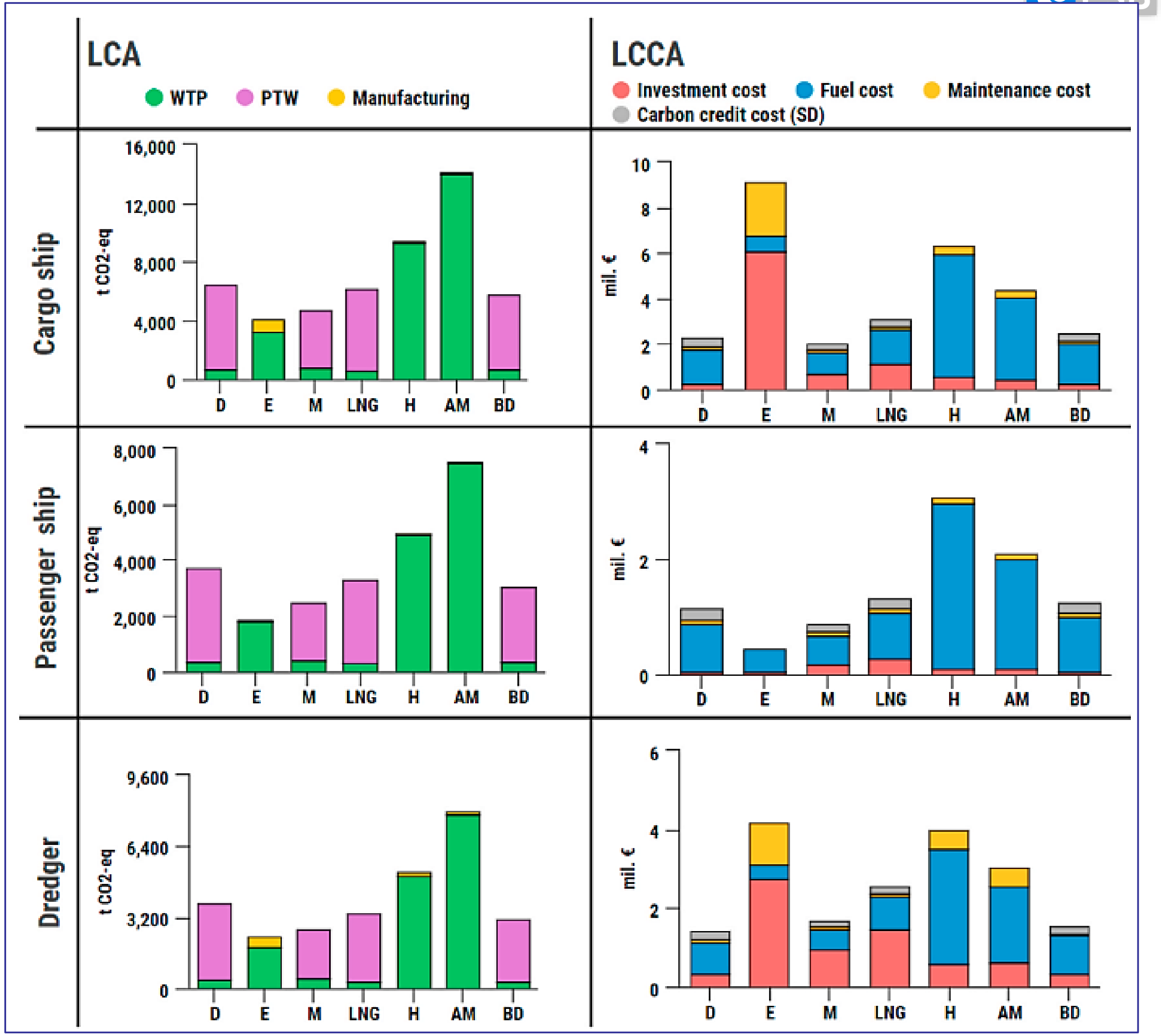


Same methods can be used to determine the energy efficiency and environmental footprint of fisheries.

INLAND WATERWAY SHIPS



	Cargo ship	Passenger ship	Dredger
Length overall (m)	75.9	13.2	68.94
Breadth (m)	9.0	4.12	9.30
Deadweight (t)	967	15.72	484.6
Main engine(s) maximum continuous rating (kW)	855	236	804
Auxiliary engine(s) maximum continuous rating (kW)	100	-	476
Total power installed (kW)	955	236	1,280



INLAND WATERWAY SHIPS

- increase of ship energy efficiency
- reduction of fossil fuel consumption = reduction of ship CF
- achieved with a set of measures:
  - ✓ slow steaming
  - ✓ consumption of alternative fuel (hydrogen, lng, methanol, biofuels, etc.)
  - ✓ alternative power system configuration (hybrid power system, full electrification, fuel cells)
  - ✓ implementation of renewable energy resources for power generation on board (solar energy, wind energy)

CARGO SHIP „OPATOVAC”

DREDGER „PAPUK”

PASSENGER SHIP „TROŠENJ”

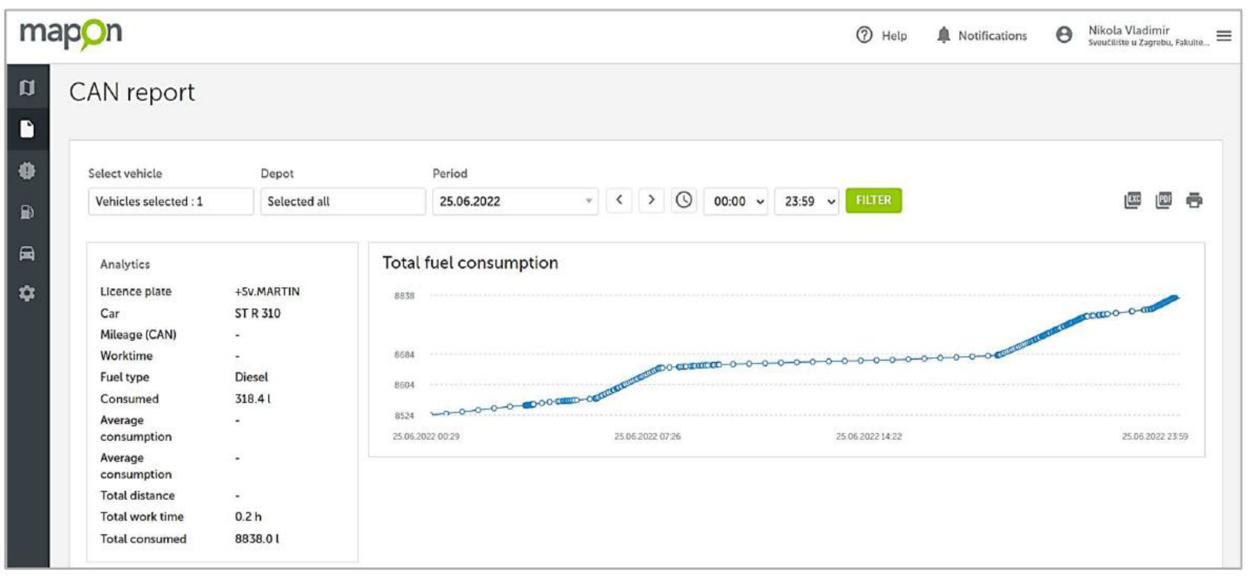
DATASET

MEASUREMENT DATA

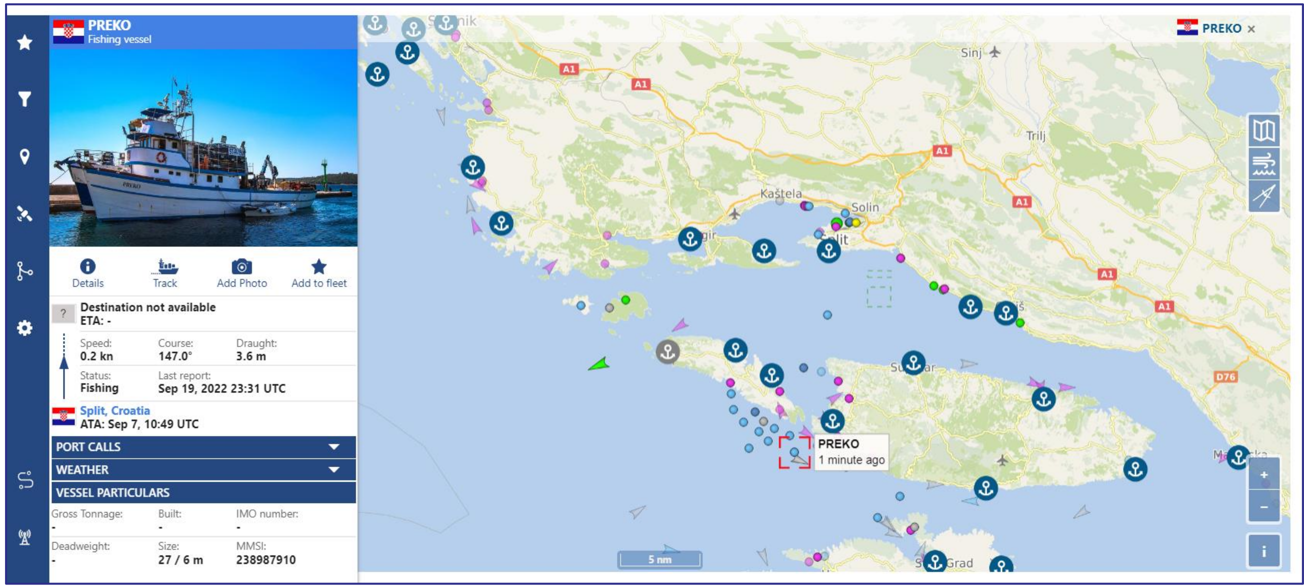
- ✓ Comparative base – annual fuel consumption for the last 5 years (obtained from the Ministry of Agriculture, Directory of Fisheries, Croatia)

- ✓ Measurements
  - fuel consumption, average speed, GPS location, route history, workgraphs…
  - influencing factors – weather conditions, route details, quality of catch…

MAPON Software



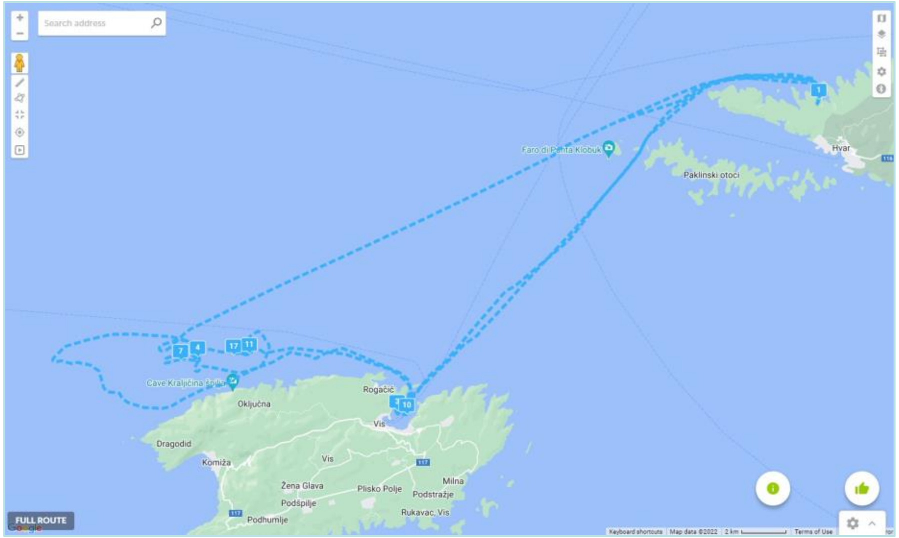
AIS Applications

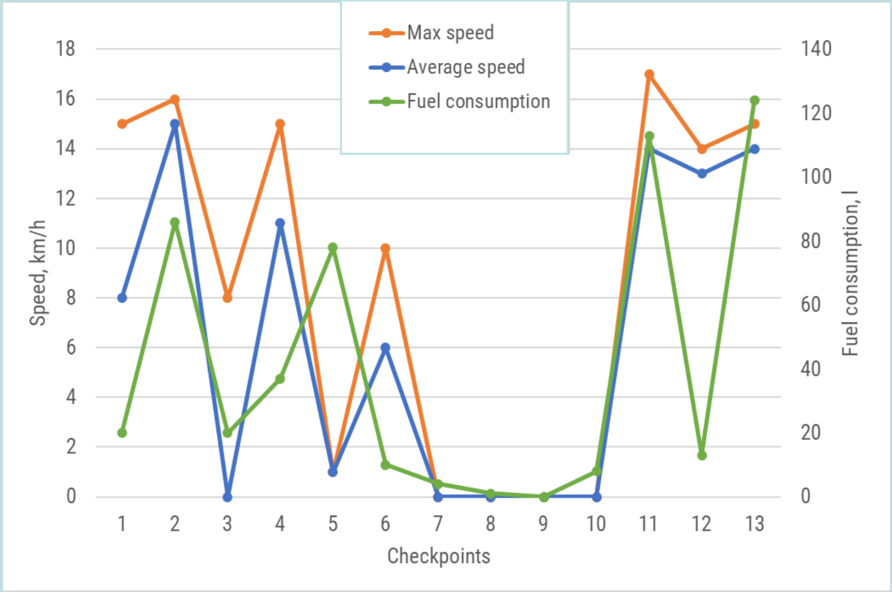


MEASUREMENT DATA

MAPON Software

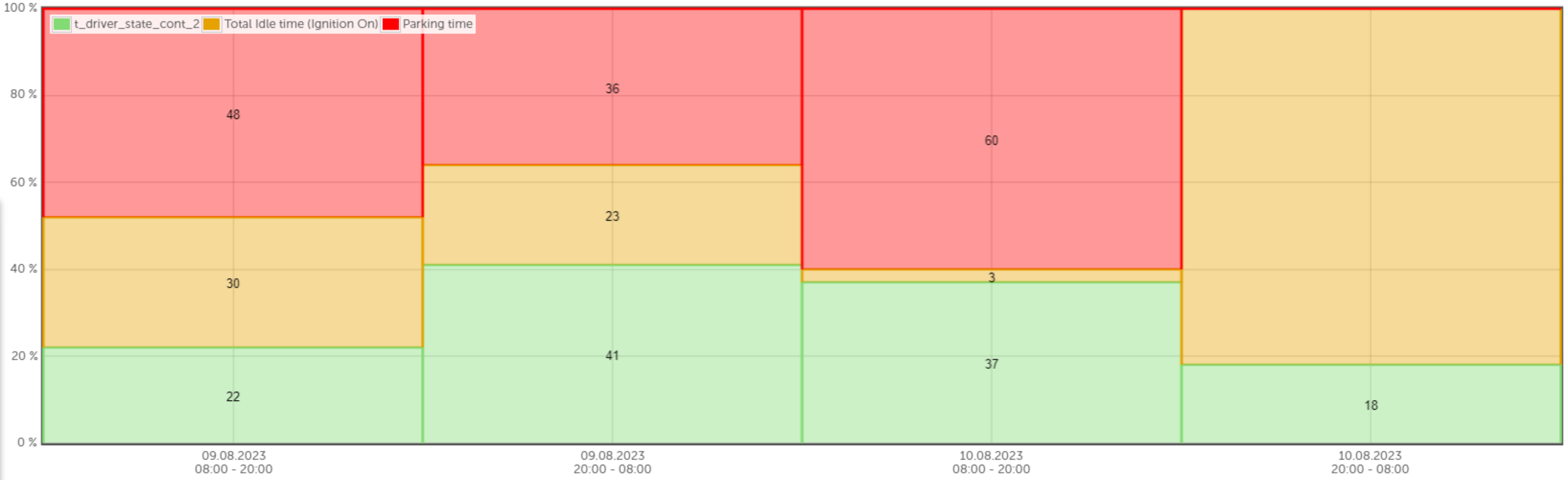
PERIOD:			04.09.2022. – 05.09.2022.		
Checkpoint	**Distance, km**	**Time travelling, h**	**Max speed, km/h**	**Average speed, km/h**	**Fuel consumption, l**
1	2.8	00:21	15	8	20
2	20.7	01:24	16	15	86
3	0.045	00:00	8	-	20
4	10.6	00:55	15	11	37
5	0.258	00:06	1	1	78
6	2.2	00:21	10	6	10
7	0.082	00:02	-	-	4
8	0.135	00:01	-	-	1
9	0.040	00:01	-	-	-
10	0.032	00:03	-	-	8
11	30.1	02:06	17	14	113
12	2.5	00:11	14	13	13
13	33.9	02:22	15	14	124
TOTAL:	**103.4**	**07:58:55**	**-**	**-**	**514**





MEASUREMENT DATA

BRILJANT ST R 269



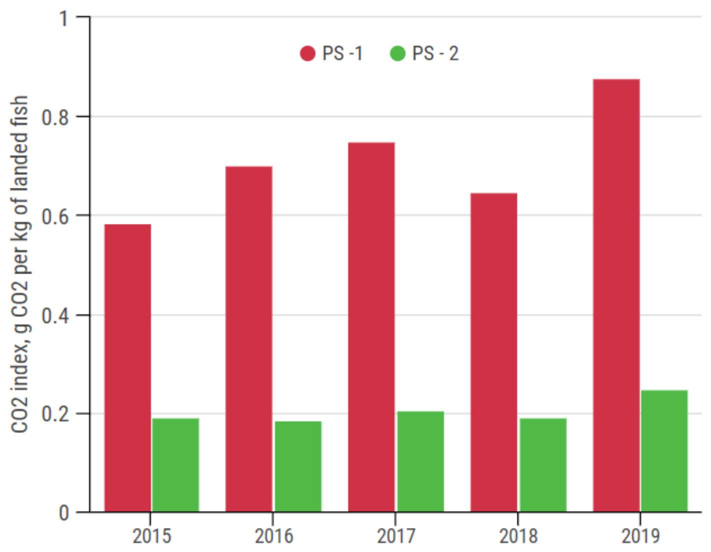
	Starting time	From	End time	To	e compens	Distance	Time	Max speed	Average sp	Fuel consumption	CO2 emissions (l
+BRILJANT (ST R 269)											
09.08.2023											
	17:20	D416 1, 20230, Broce, Croatia	19:58	MP67+7W Korita, Croatia	38,7	38,7	2:38:17	19 km/h	14 km/h	196.54 l	525280
	20:24	MP58+9G Korita, Croatia	20:27	MP58+9G Korita, Croatia	0,287	0,287	0:02:15	-	-	17.99 l	45560
	21:55	MP58+3C Korita, Croatia	21:57	MP58+3C Korita, Croatia	0,089	0,089	0:02:02	-	-	11.92 l	29480
	22:56	MP48+XG Korita, Croatia	22:58	MP48+XG Korita, Croatia	0,039	0,039	0:01:18	-	-	8.05 l	21440
	23:37	MP58+3C Korita, Croatia	23:38	MP58+3C Korita, Croatia	0,039	0,039	0:01:16	-	-	3.91 l	8040
	23:56	MP58+5M Korita, Croatia	00:00	MP58+5M Korita, Croatia	0,029	0,029	0:03:02	-	-	1.57 l	2680
10.08.2023											
	00:00	MP58+5M Korita, Croatia	00:05	MP58+9G Korita, Croatia	0,023	0,023	0:05:37	-	-	8.27 l	21440
	00:40	MP58+5M Korita, Croatia	00:42	MP58+5M Korita, Croatia	0,042	0,042	0:02:32	-	-	14.44 l	37520
	01:55	MP48+QV Korita, Croatia	02:21	MP48+78 Korita, Croatia	0,312	0,312	0:25:23	-	-	7.98 l	18760
	02:32	MP48+78 Korita, Croatia	02:38	MP48+83 Korita, Croatia	0,060	0,060	0:06:53	-	-	2.83 l	5360
	02:46	MP48+83 Korita, Croatia	02:47	MP48+83 Korita, Croatia	0,022	0,022	0:01:16	-	-	3.84 l	8040
	03:06	MP48+83 Korita, Croatia	03:07	MP48+83 Korita, Croatia	0,027	0,027	0:01:15	-	-	0.96 l	
	03:08	MP48+83 Korita, Croatia	03:11	MP48+83 Korita, Croatia	0,030	0,030	0:02:15	-	-	2.2 l	5360
	03:19	MP48+83 Korita, Croatia	03:21	MP48+78 Korita, Croatia	0,051	0,051	0:01:11	-	-	5.25 l	13400
	04:02	MP57+MC Korita, Croatia	11:38	QR3C+J3 Uble, Croatia	115,4	115,4	7:35:47	19 km/h	15 km/h	373.9 l	999640
					155,2	**155,2**	**11:10:19**			**659.65 l**	1742000
					155,2	**155,2**	**11:10:19**			**659.65 l**	1742000

EMISSION INDEX

SIMPLIFIED CO2 INDEX

The specificity of the operational regime, the diversity of the fleet, influenced by the location of work, weather conditions, type of catch and the fact that it is a very traditional sector, measures that would be appropriate for the fishing part of the marine sector have not yet been adopted.

- **CO_2 index** - calculated to analyse the socio-economic impact of the fishing operations
- represents a ratio of CO_2 emission per ton of cargo transported, in this case, land fish



$$CO_2 index = \frac{P_{eng} \cdot C_F \cdot SFC \cdot t}{Landed\ fish}$$

P_{eng} – engine power, kW
C_F – conversion factor between FC and CO_2 emissions
SFC – specific fuel consumption, kg of fuel per kWh

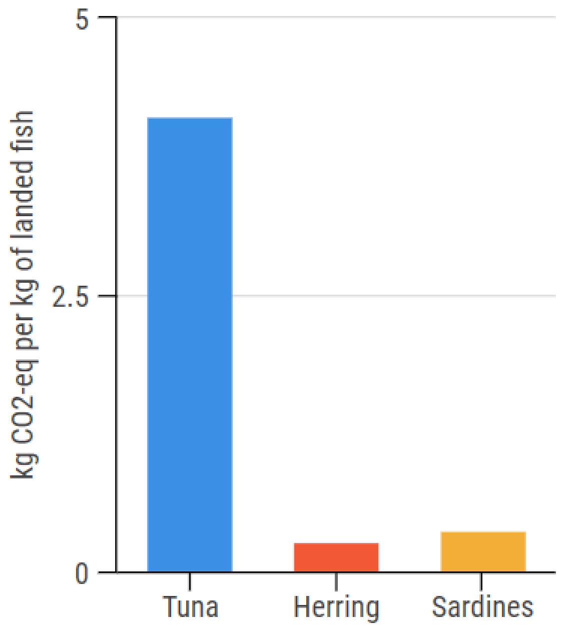
PS - 1				
Engine power, kW		526		
Gross Tonnage (GT)		96		
Fuel consumption FC, kg per year				
2015	2016	2017	2018	2019
57,351.0	57,423.7	47,315.8	69,638.9	56,119.8
Average, kg per year		57,569.8		
Landed fish, kg per year				
2015	2016	2017	2018	2019
601,828.0	502,544.0	469,221.0	543,702.0	400,861.0
Average, kg per year		503,631.2		

PS – 2				
Engine power, kW		221		
Gross Tonnage (GT)		141		
Fuel consumption FC, kg per year				
2015	2016	2017	2018	2019
57,520.6	37,518.1	37,118.3	40,266.8	37,964.2
Average, kg per year		42.077.6		
Landed fish, kg per year				
2015	2016	2017	2018	201977
777,678	800,158.5	718,973.0	773,238.0	594,320.0
Average, kg per year		732.873.5		

- the engine power has a significant impact on the end result
- **high fuel consumption does not necessarily mean greater catch**
- the reduction of engine power would have a significant impact on the environmental impact of the ship → **fish species?**

SIMPLIFIED CO2 INDEX

- measures like EEDI and SEEMP adapted to different branches of fisheries
- herring and sardines - type of small pelagic fish - the emission of harmful gases is approximately the same
- purse seining tuna results in much greater fuel consumption compared to purse seining small pelagic species → a great impact on the environment



- impact of NO_X and SO_X emissions should also be calculated in the index
- creating a better picture of the impact on the environment
- calculating the obtained income – may show that tuna fishing is an economically and ecologically more acceptable option than the fishing of small pelagic species

Further research - the impact categories, which include global warming, acidification, eutrophication, etc.

EXTENDED EMISSION INDEX (EEI)

Emission index

- assessment of the energy efficiency of fishing vessels
- EEI gives an insight into the environmental impact in accordance with the benefit for society
- it takes into account the global warming potential (GWP), acidification potential (AP) and eutrophication potential (EP)
- benefit for society (BS) – the estimated value on catch

$$EEI = \frac{\alpha \cdot GWP + \beta \cdot AP + \gamma \cdot EP}{BS}$$

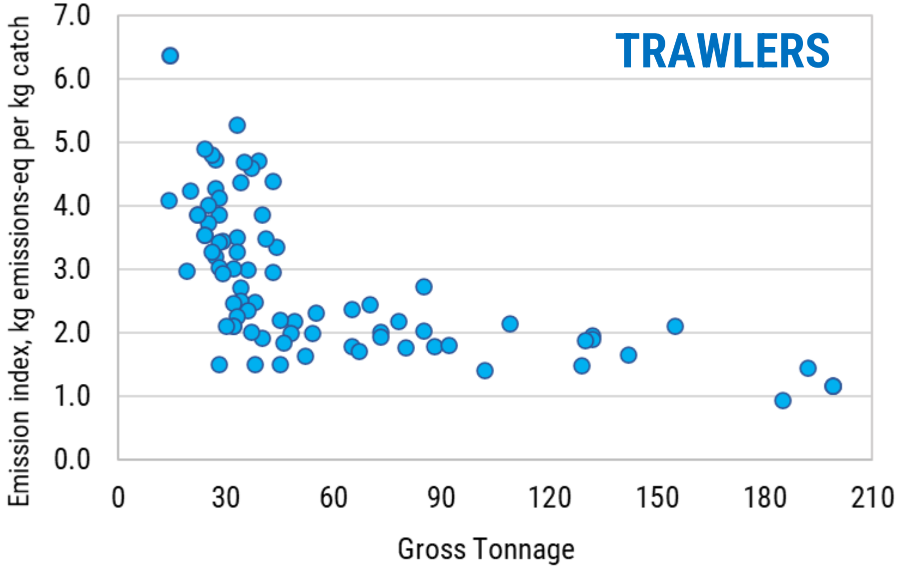
Different emissions:

$$GWP = 1 \cdot E_{CO2} + 36 \cdot E_{CH4} + 298 \cdot E_{N20},$$
$$AP = 1 \cdot E_{SOx} + 0.7 \cdot E_{NOx},$$
$$EP = 0.13 \cdot E_{NOx}.$$

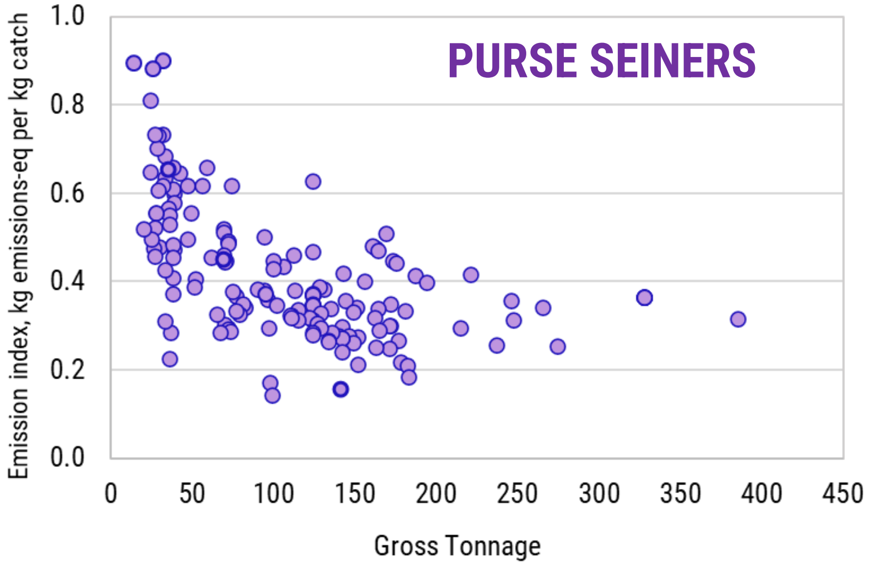
- tailpipe emissions *Ei* depend on the type of the power system (diesel, LNG, RES, hydrogen…)

EXTENDED EMISSION INDEX (EEI)

- evaluation of environmental friendliness of fishing vessels – Croatian fishing fleet
- 7,808 vessels (Ministry of Agriculture of the Republic of Croatia)
- „General Fisheries Commission for the Mediterranean” database – 163 purse seiners and 82 single-boat bottom otter trawlers



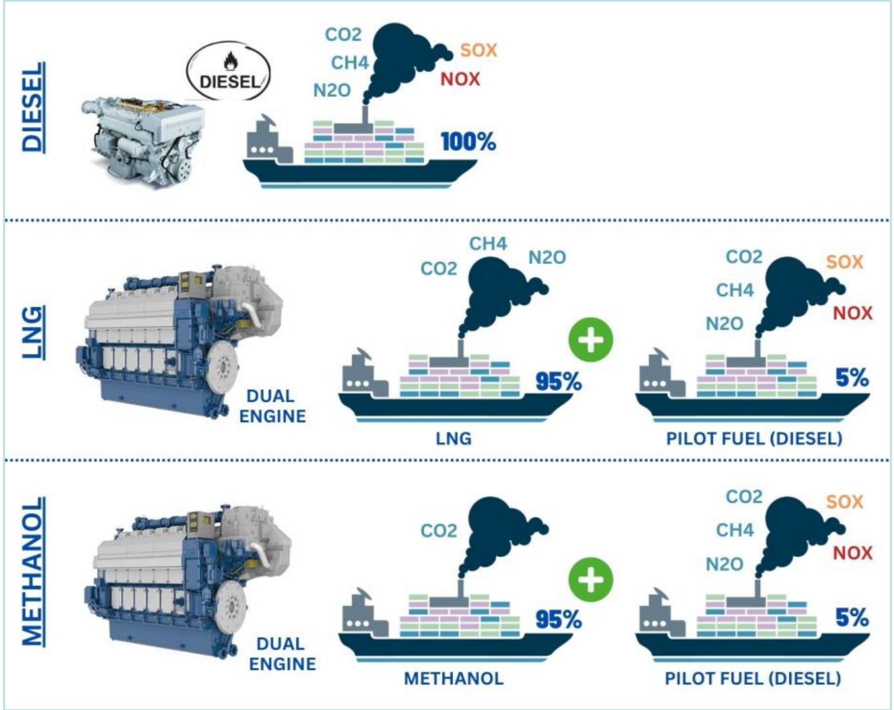
- ✓ higher emission index values than purse seiners
- ✓ average power of the trawl engine is lower than that of purse seiners

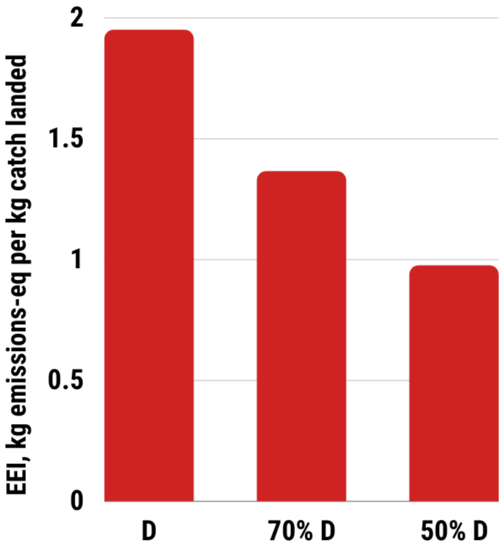


- ✓ higher values belong to vessels with a lower GT

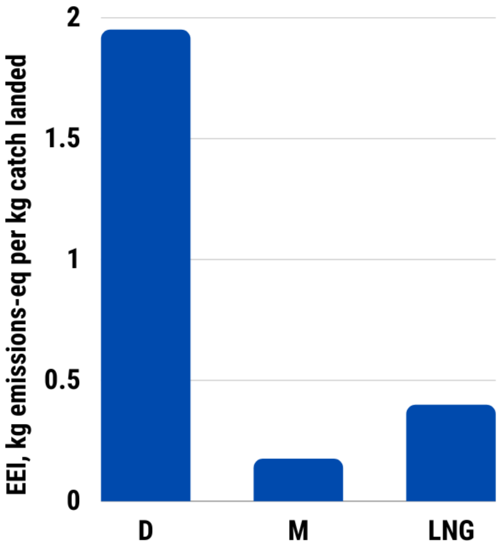
EXTENDED EMISSION INDEX (EEI)

- calculation was performed for one purse seiner operating in the Adriatic Sea
- data on operational characteristics were obtained by direct monitoring of the selected purse seiner





Comparison of EEI for different diesel systems



Comparison of EEI for different power systems

GOAL --->

- replacing traditional diesel with LNG or methanol significantly reduced the EEI values due to lower SOx and NOx emissions

DECARBONIZATION

LIFE-CYCLE ASSESSMENTS (LCA)

- LCA investigates the environmental aspects and potential impacts throughout a product's life
- focused on the emission released throughout its life-cycle

I. WTP (Well-to-Pump) phase

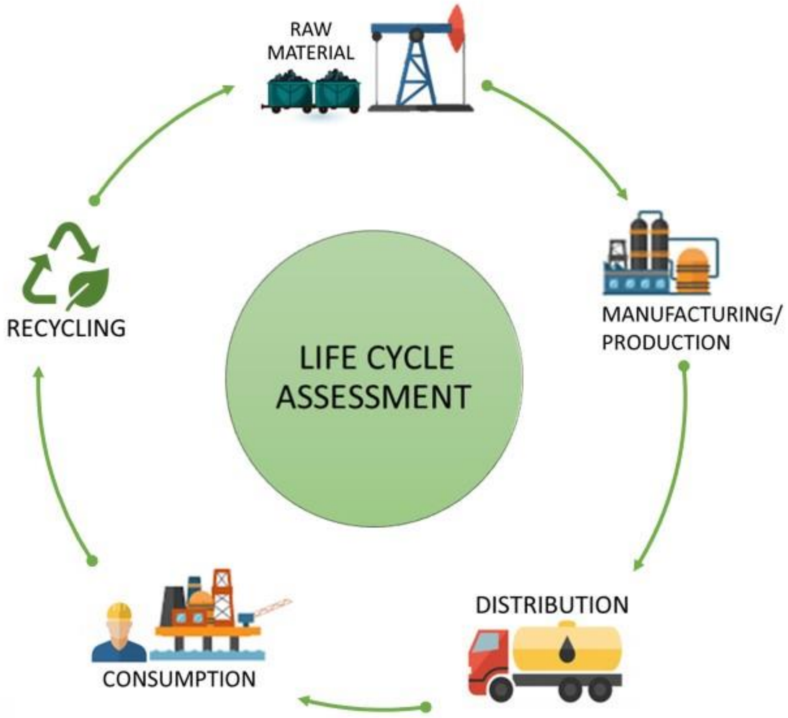
analyses the fuel cycle – from the extraction of raw material, production of fuel and transport to the refuelling station

II. PTW (Pump-to-Wake) phase

analyses the fuel usage in a power system that causes tailpipe emissions (TE)

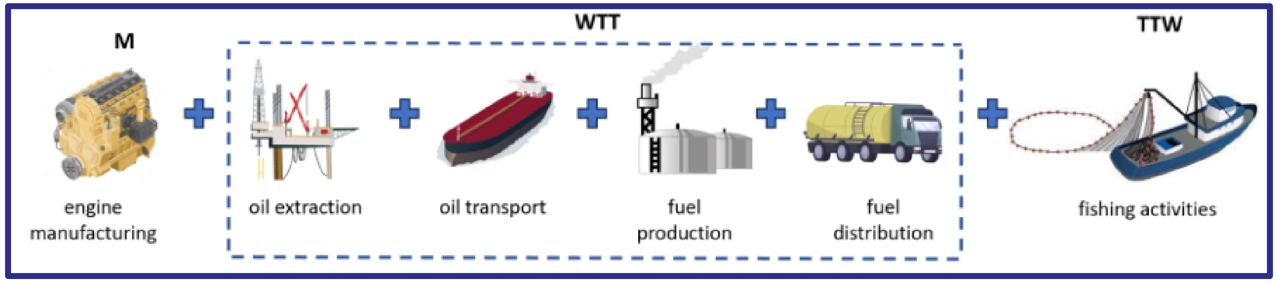
III. Manufacturing phase

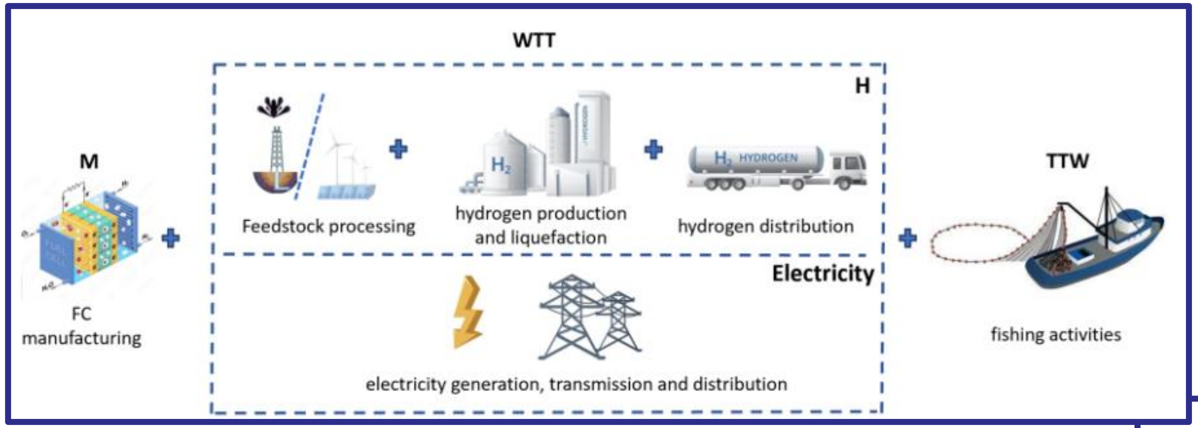
analyses the manufacturing process of the main elements in a power system

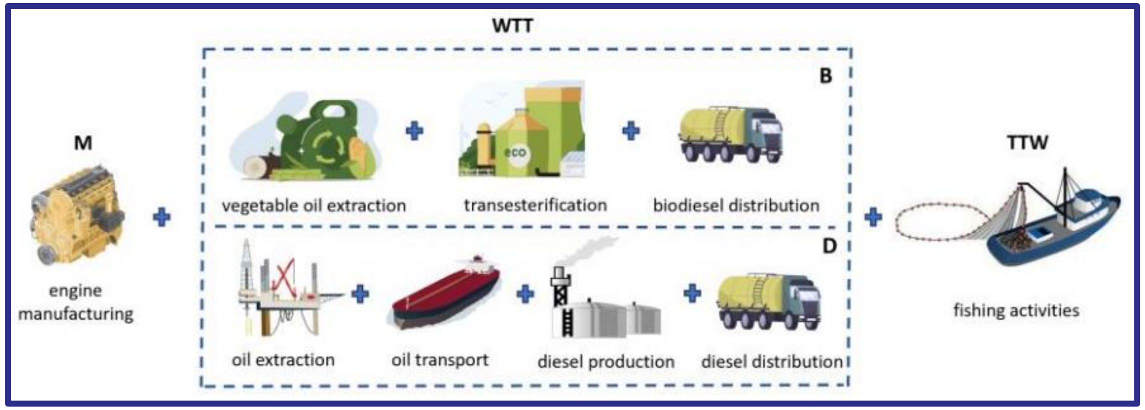


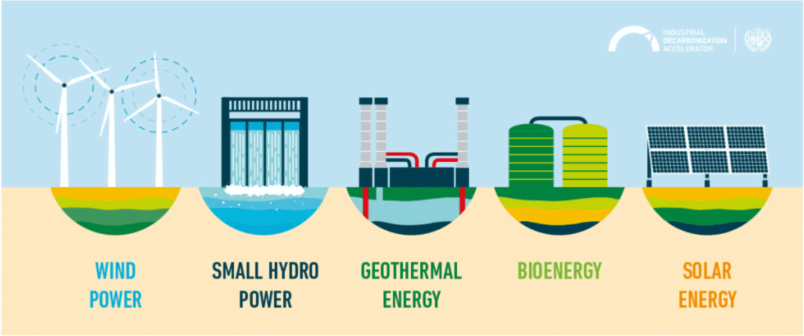
Argonne GREET LIFE-CYCLE MODEL

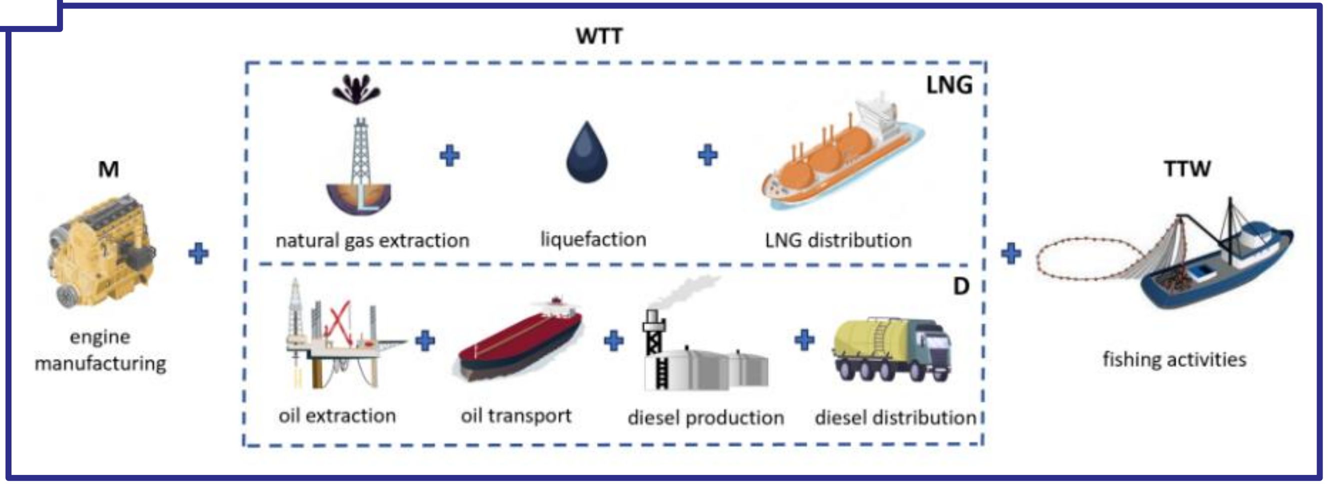
LIFE-CYCLE ASSESSMENTS (LCA)



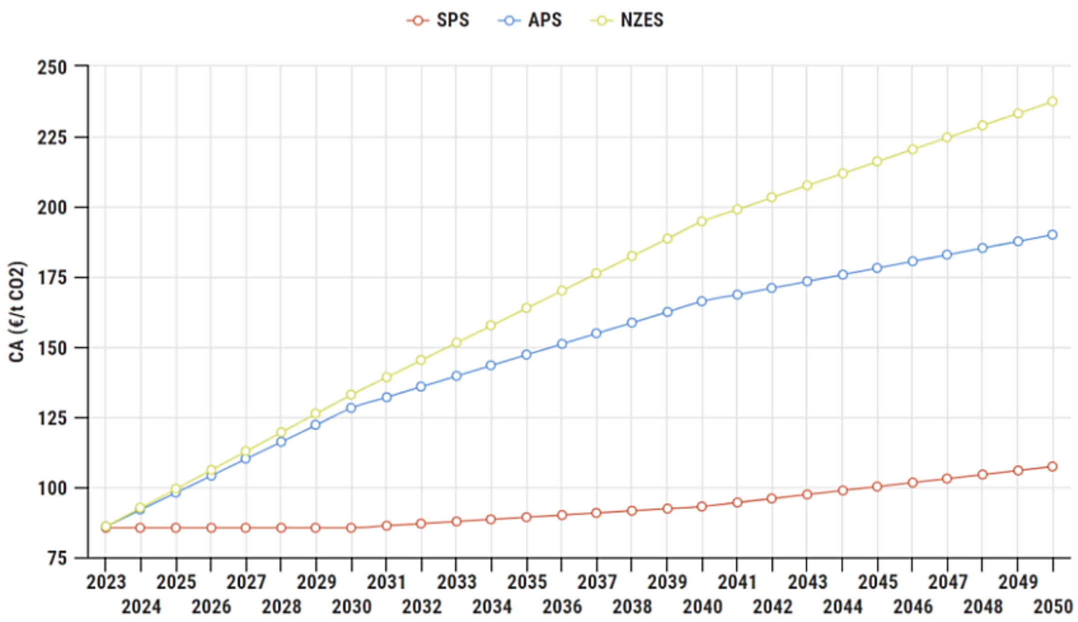








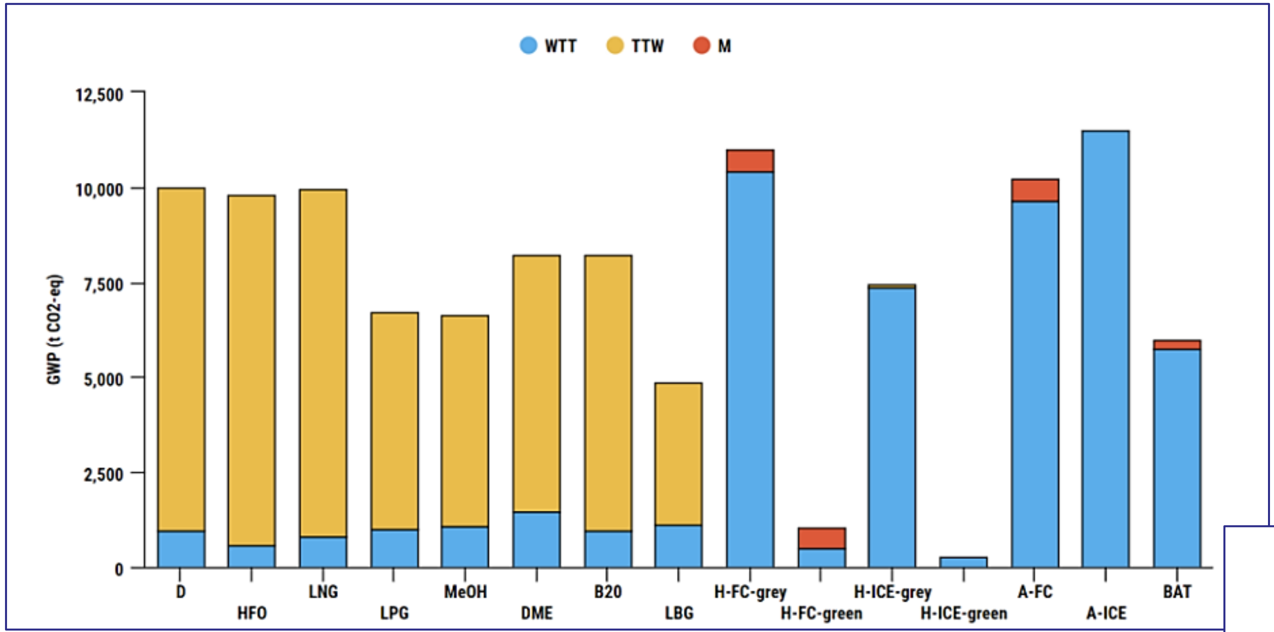
LIFE-CYCLE COST ASSESSMENTS (LCCA)



CARBON TAXES

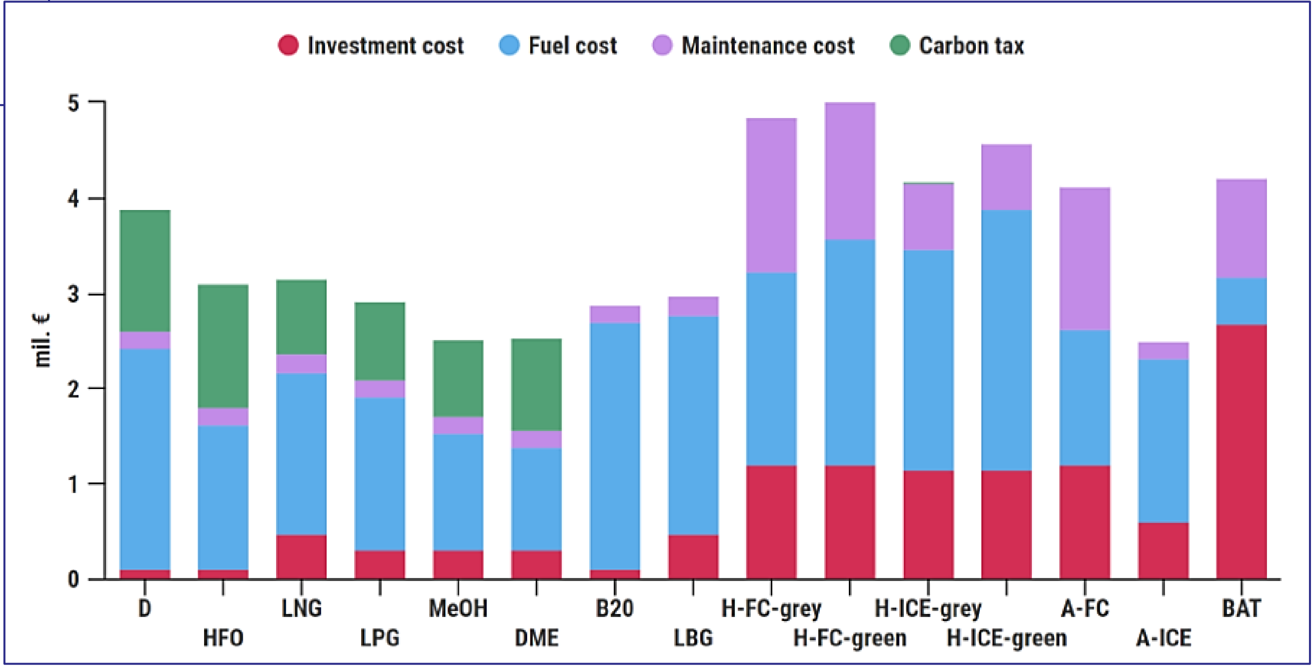
- SPS: current policies and today's policy intentions and targets for the EU
- APS: advanced economies with net zero emissions pledges
- NZES: advanced economies with net zero emissions pledges

LIFE-CYCLE ASSESSMENTS (LCA)



LIFECYCLE ASSESSMENT

LIFECYCLE COST ASSESSMENT



ELECTRIFICATION & RES

DEMAND

FUEL DEMAND OF THE FIS
- Arrival and departure patte
- Occupancy of the berth at
- Power demand of the sele
- Operation profiles througho
- **Fuel demand of the fishi**

ELECTRICITY DEMAND OF
- Arrival and departure patte
- Occupancy of the berth at (number of fishing vessels
- The electricity demand of t
- Operation profiles througho
- **Hourly electricity deman**

DEMAND

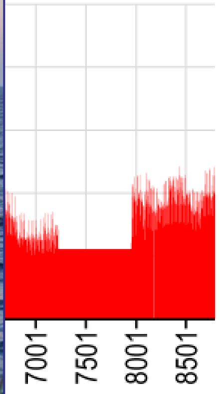
ELECTRICITY DEMAND O
- Substation measurements
- **Hourly electricity demar**

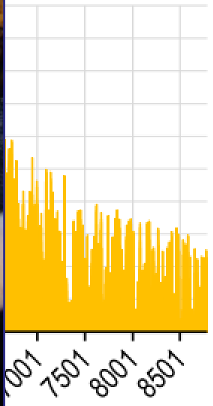
SUPPLY

VARIABLE RENEWABLE E
- **Photovoltaic (PV) powe**
  - Hourly solar irradiation me
  - Predicted future PV powe
- Hourly PV production dist

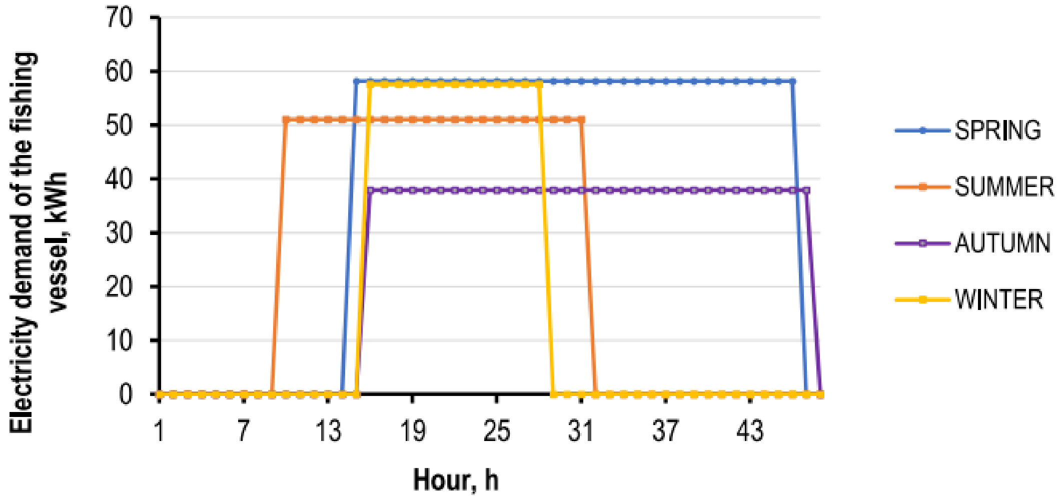
TECHNOLOGY COST
- Variable Operation
- Fixed Operation
- Investment
- Interest Rate

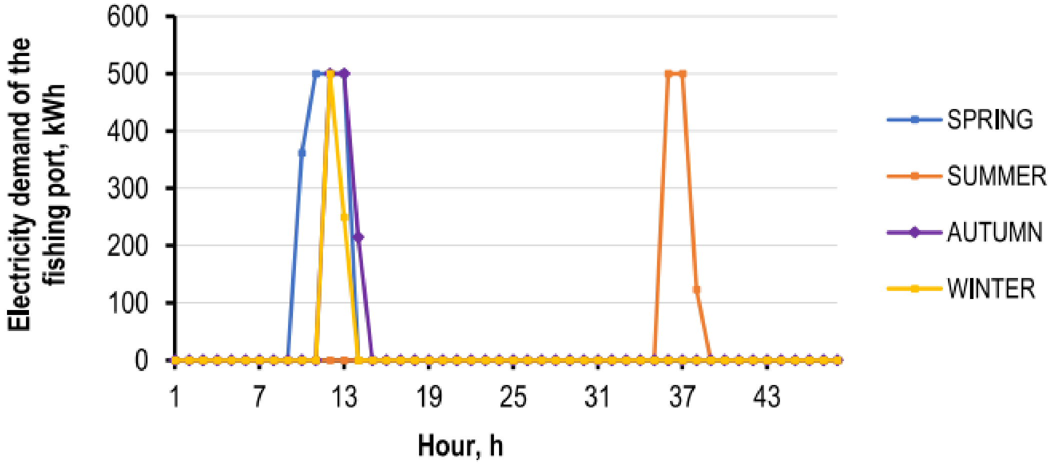
ND OF CRES





ELECTRIFICATION

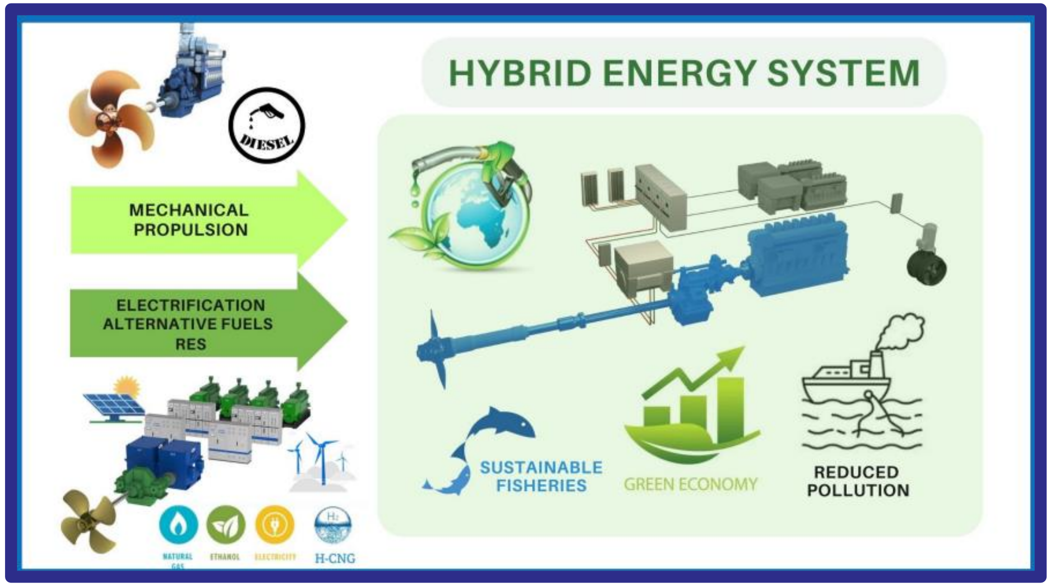




- Electricity consumption of the fishing vessel and electricity demand of the fishing port for each operation profile

Scenario no.	Scenario name	Electricity demand of the island, GWh/year	Fuel demand of the fishing vessels, GWh/ year	Electricity demand of the electric fishing vessels, GWh/year	Installed capacity of the PV unit, MW
S1	Business as usual (10 ships)	17.01	2.90	0	21
S2	Electrification (10 ships)	17.01	0	1.65	21
S3	Business as usual (20 ships)	17.01	5.79	0	21
S4	Electrification (20 ships)	17.01	0	3.31	21
S5	Business as usual (30 ship)	17.01	8.69	0	21
S6	Electrification (30 ships)	17.01	0	4.96	21

HYBRID ENERGY SYSTEM FOR FISHING VESSELS



Types of Alternative Fuels	CO_2 Emissions Reductions
LNG	0–20%
Ammonia	0–100%
Biofuels	25–100%
Hydrogen	0–100%
Fuel cells	2–20%
Wind	1–32%
Solar	0–12%
Nuclear	0–100%
Electricity	0–100%

– MAIN OBJECTIVE –

Develop a computer application for initial design of hybrid power systems for fishing vessels to achieve higher energy efficiency, environmental friendliness, lower fuel consumption, and reduced life cycle costs compared to existing diesel engine solutions.

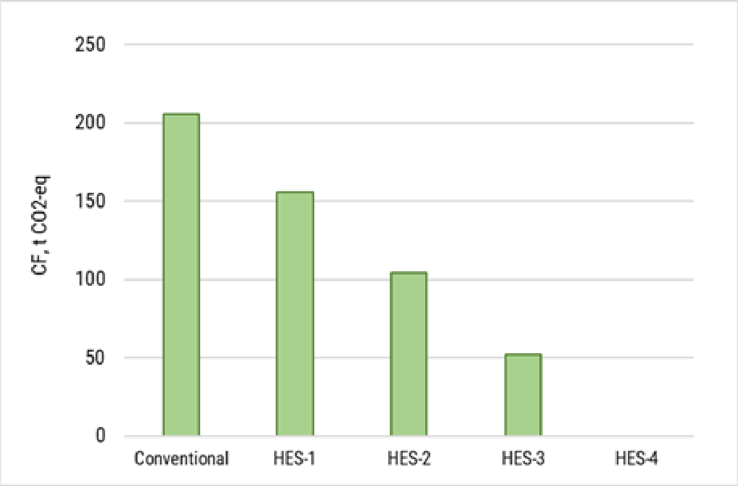
CHALLENGES

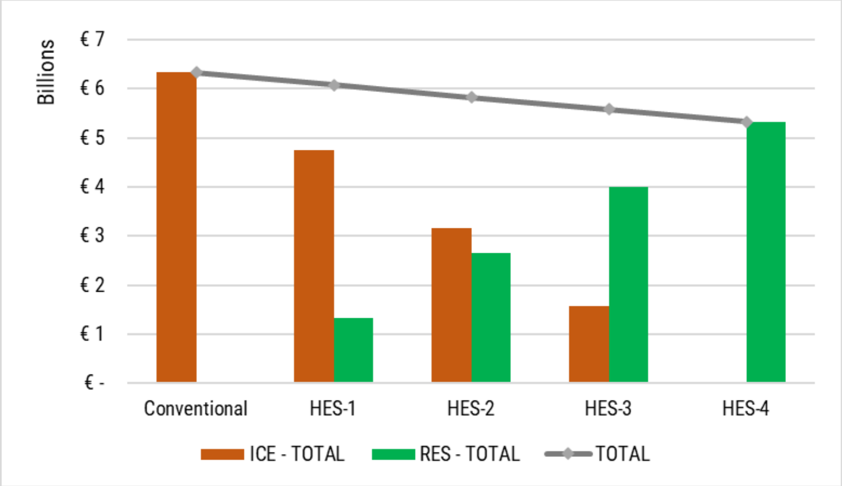
- ‼ Complicated design process due to multiple technical, operative, and market-based measures.
- ‼ Environmentally friendly options are often expensive, especially in the context of the fishing fleet with old and low-efficient engines.

FULL ELECTRIFICATION?

HYBRID ENERGY SYSTEM FOR FISHING VESSELS

	Conventional	HES-1	HES-2	HES-3	HES-4
Share of ICE	100%	75%	50%	25%	0%
Share of RES	0%	25%	50%	75%	100%
Battery storage	NO	YES	YES	YES	YES





BATTERY

- ✓ depending on the energy mix of country
- ✓ CO_2 emissions reduced, lower NO_x emissions
- ✓ PTW emissions eliminated

- ✓ different technologies to increase holding capacities, freezing technology, improvements in locating devices…
- ✓ LED lights - advantages such as radiation spectrum, and correlated colour temperature, decreased fuel consumption


SOFTWARE „HENSUS”

SOFTWARE „HENSUS”

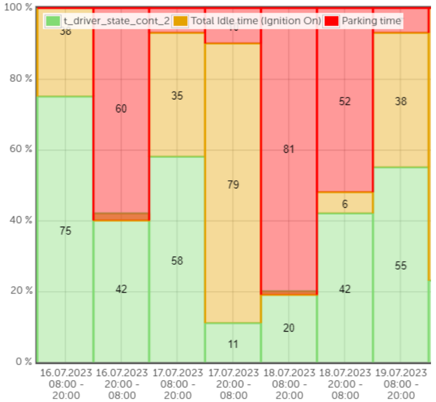
INPUT DATA

USER - FISHER

Licence plate	+BRILJANT
Car	ST R 269
Mileage (CAN)	-
Worktime	-
Fuel type	Diesel
Consumed	522.3 l
Average consumption	-
Average consumption	-
Total distance	-
Total work time	-
Total consumed	33709.3 l

Operative characteristics

- Fuel consumption, l/h
- Operative profile
- Carbon tax measure



Technical characteristics

- Ship name and CFR
- Engine power
- Auxiliary engines

PROGRAMMING

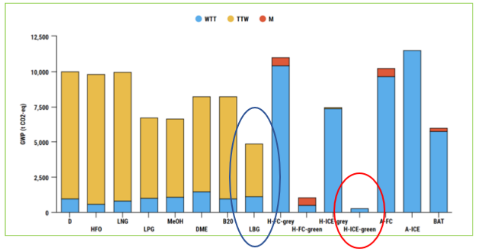
python™

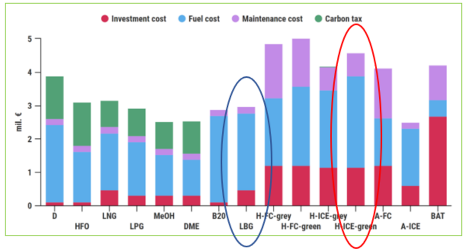
OUTPUT DATA

FSB
University of Zagreb
Faculty of Mechanical Engineering and Naval Architecture

„HENSUS” APPLICATION

Data analysis

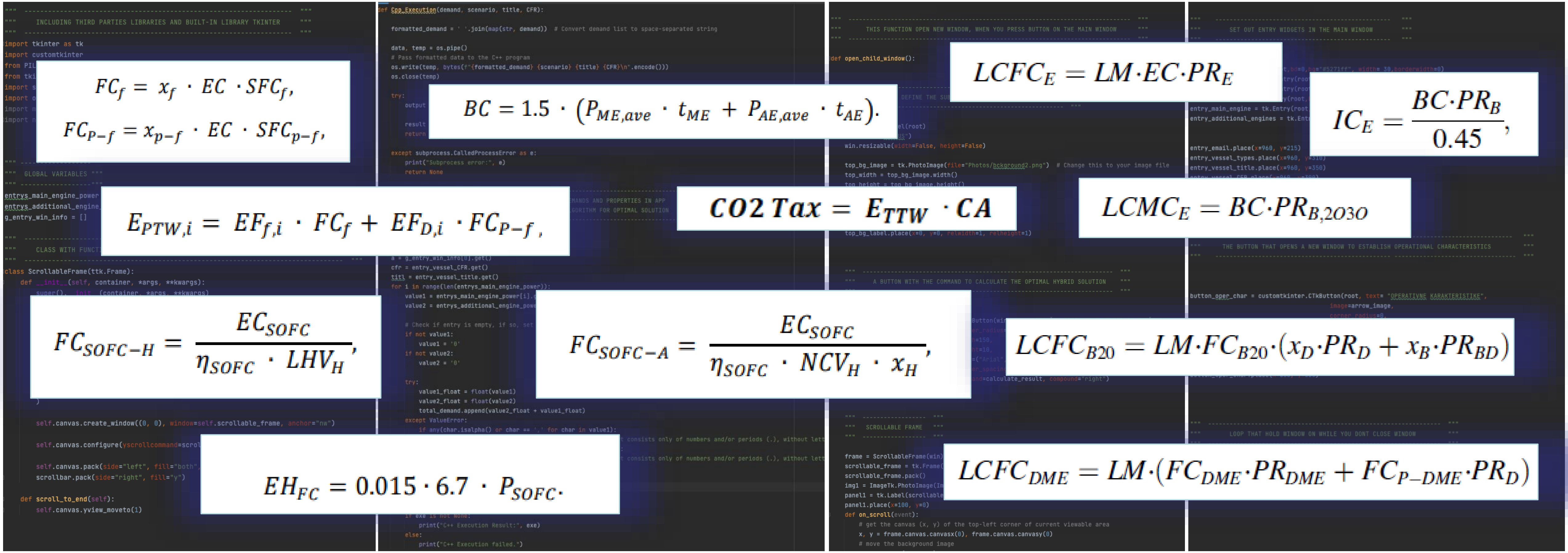




- OPTIMAL CONFIGURATION -

SOFTWARE „HENSUS”

- Includes all input data and equations needed to assess the released emissions of different power systems and cost of their implementation



$$FC_f = x_f \cdot EC \cdot SFC_f,$$

$$FC_{P-f} = x_{p-f} \cdot EC \cdot SFC_{p-f},$$

$$BC = 1.5 \cdot (P_{ME,ave} \cdot t_{ME} + P_{AE,ave} \cdot t_{AE}).$$

$$LCFC_E = LM \cdot EC \cdot PR_E$$

$$IC_E = \frac{BC \cdot PR_B}{0.45},$$

$$E_{PTW,i} = EF_{f,i} \cdot FC_f + EF_{D,i} \cdot FC_{P-f},$$

$$CO2\ Tax = E_{TTW} \cdot CA$$

$$LCMC_E = BC \cdot PR_{B,2030}$$

$$FC_{SOFC-H} = \frac{EC_{SOFC}}{\eta_{SOFC} \cdot LHV_H},$$

$$FC_{SOFC-A} = \frac{EC_{SOFC}}{\eta_{SOFC} \cdot NCV_H \cdot x_H},$$

$$LCFC_{B20} = LM \cdot FC_{B20} \cdot (x_D \cdot PR_D + x_B \cdot PR_{BD})$$

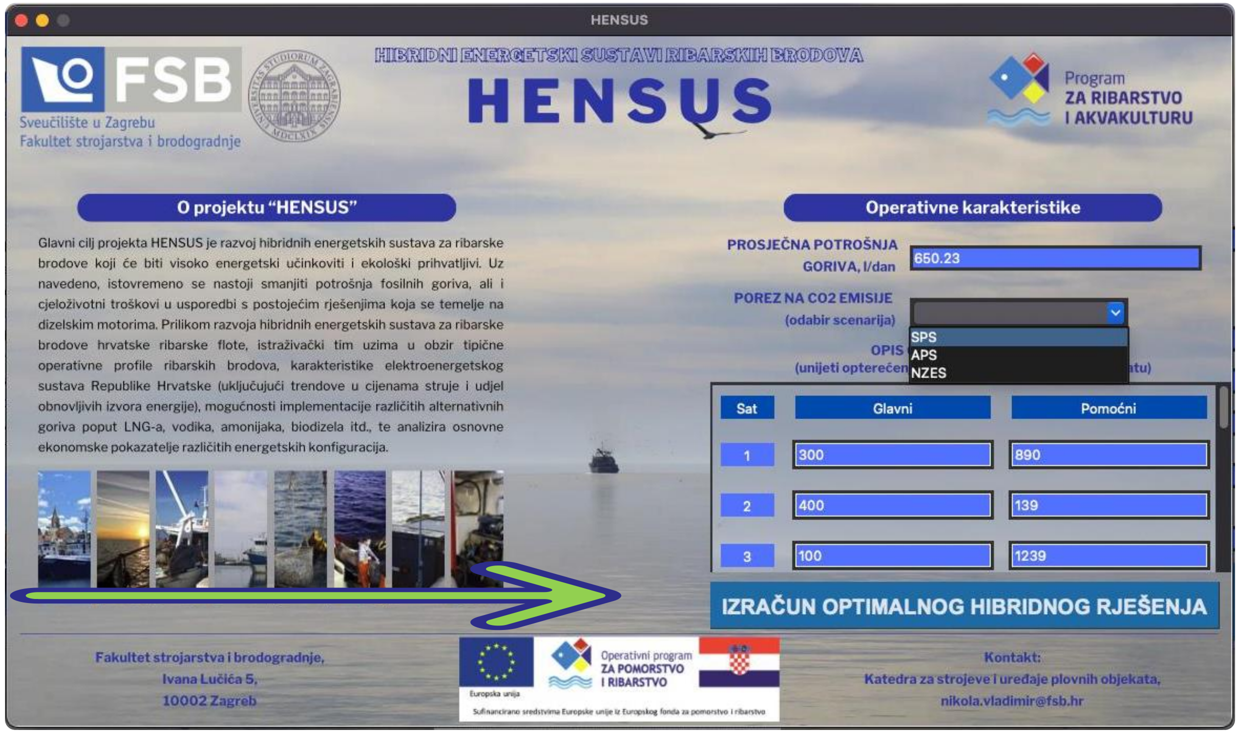
$$EH_{FC} = 0.015 \cdot 6.7 \cdot P_{SOFC}.$$

$$LCFC_{DME} = LM \cdot (FC_{DME} \cdot PR_{DME} + FC_{P-DME} \cdot PR_D)$$

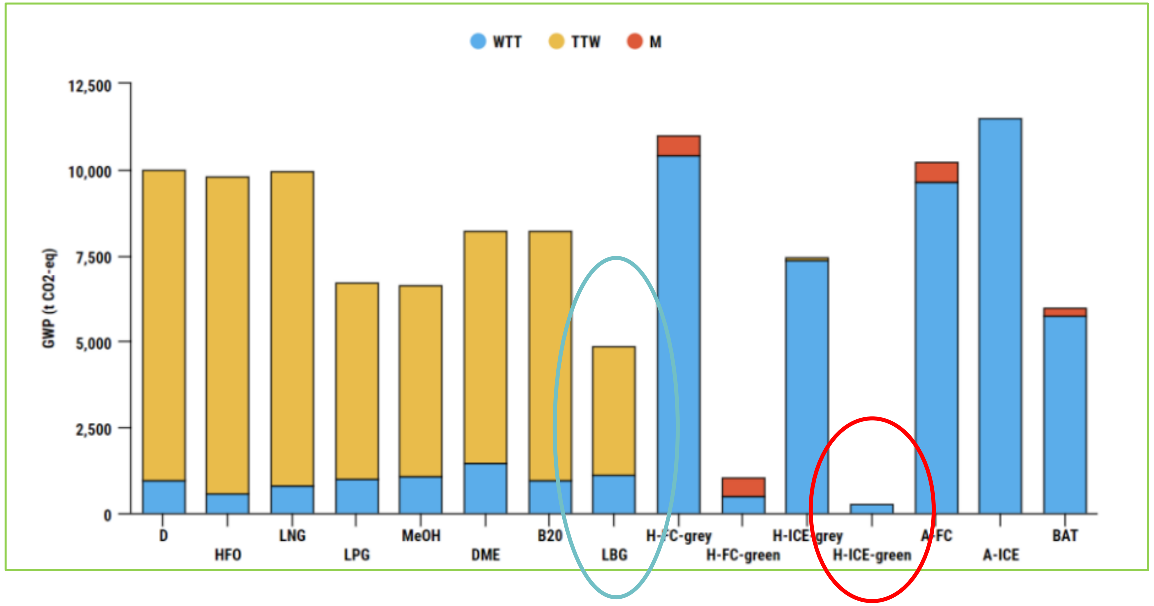
SOFTWARE „HENSUS”

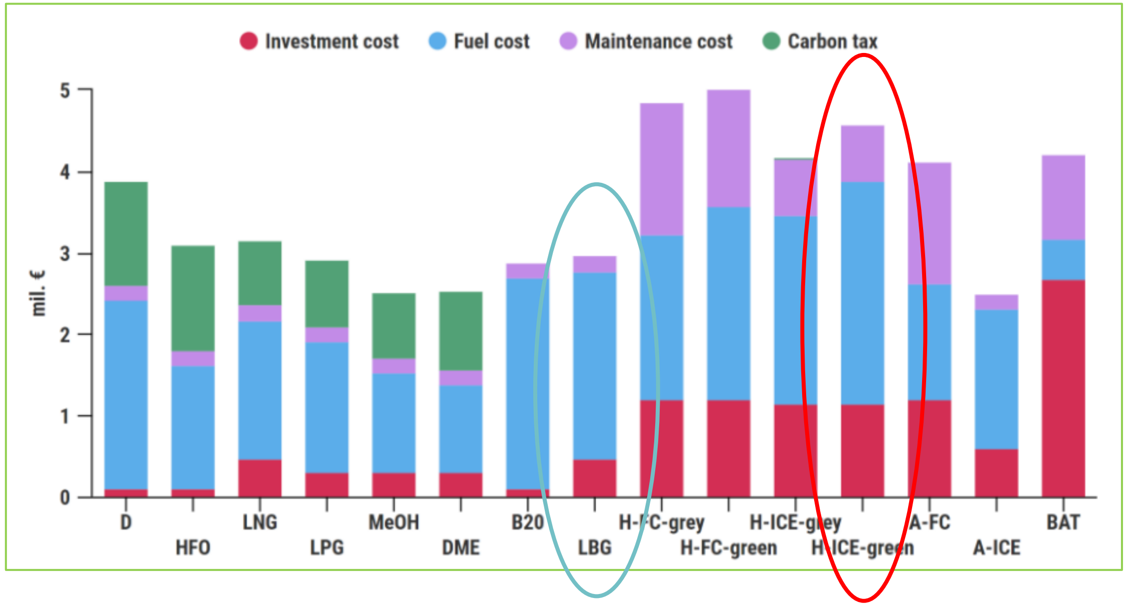
TECHNICAL CHARACTERISTICS

OPERATIVE CHARACTERISTICS



SOFTWARE „HENSUS”





OPTIMAL CONFIGURATION

Available for fishers in Croatia for free, upon request

CHAIR OF MARINE ENGINEERING
Laboratory of Marine Engineering

https://mareng.fsb.hr/

Thank You for Your Attention!

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Europska unija

Operativni program
ZA POMORSTVO
I RIBARSTVO

Sufinancirano sredstvima Europske unije iz Europskog fonda za pomorstvo i ribarstvo