MOSES

Innovative feeder vessel design

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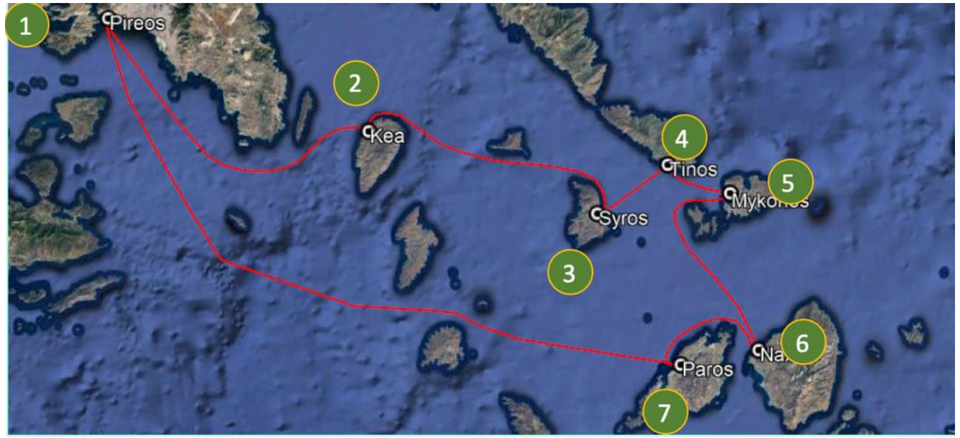
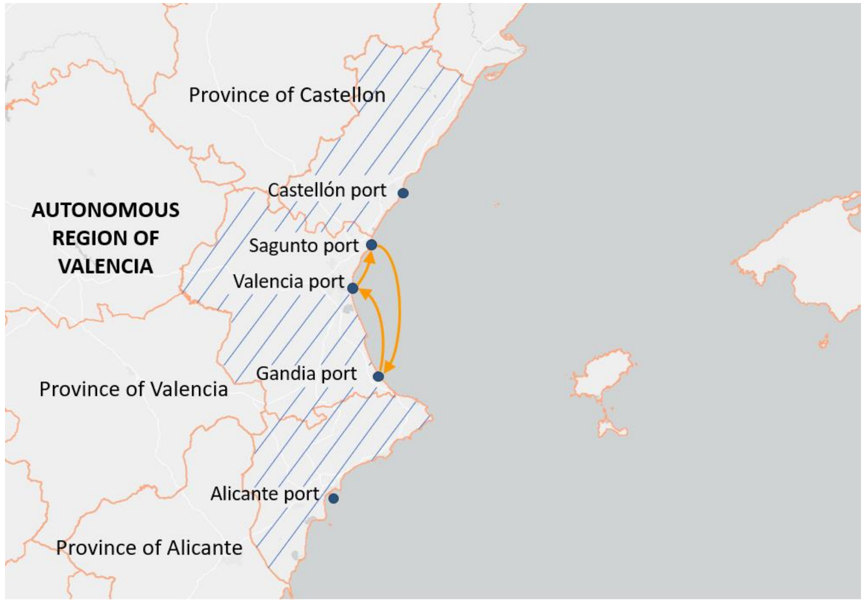
MOSES Objectives for vessel design

- **To conceptually design one RoCoPax and two SSS small feeder vessels.**
- **To provide the configurations for sustainable propulsion for both the RoCoPax and the SSS Feeder designs at a conceptual level.**

Greek case



Spanish case



Concept designs for one RoCoPax and two SSS small feeder vessels

- **Design methodology**
- **Concept of operation and requirements**
- **Trip simulations**
- **Energy and power**
- **Vessel design concepts**
- **Hazard identification and risk assessment**
- **Operational cost**
- **Conclusions and recommendations**

Specifications and requirements

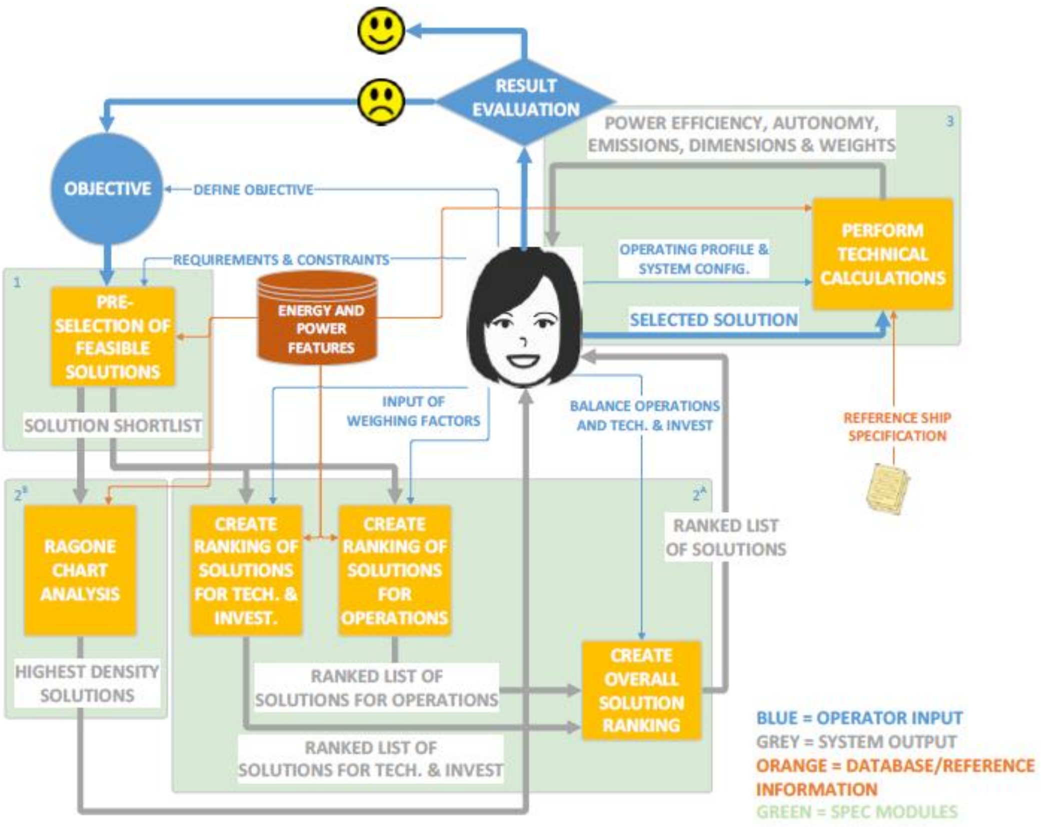
- Market study was done for the automated vessel
- Description of the current status of the market and opportunities for SSS
- Business cases for two feeder vessels, one for Pireaus and one for Valencia
- Requirement description and derived specifications for the various vessel and navigation functions (cargo capacity, emission, speed, route planning, manoeuvring)
- Operational scenario's
- KPI's

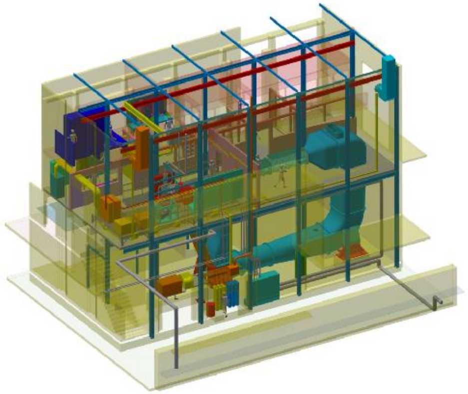
Innovative Feeder Vessel Design

Question: What is the emmision level that is expected to design for in the year 2030?

EU targets in the Green Deal

- *At least 40% cuts in **greenhouse gas emissions***
- *At least 32% share for **renewable energy***
- *At least 32.5% improvement in **energy efficiency***

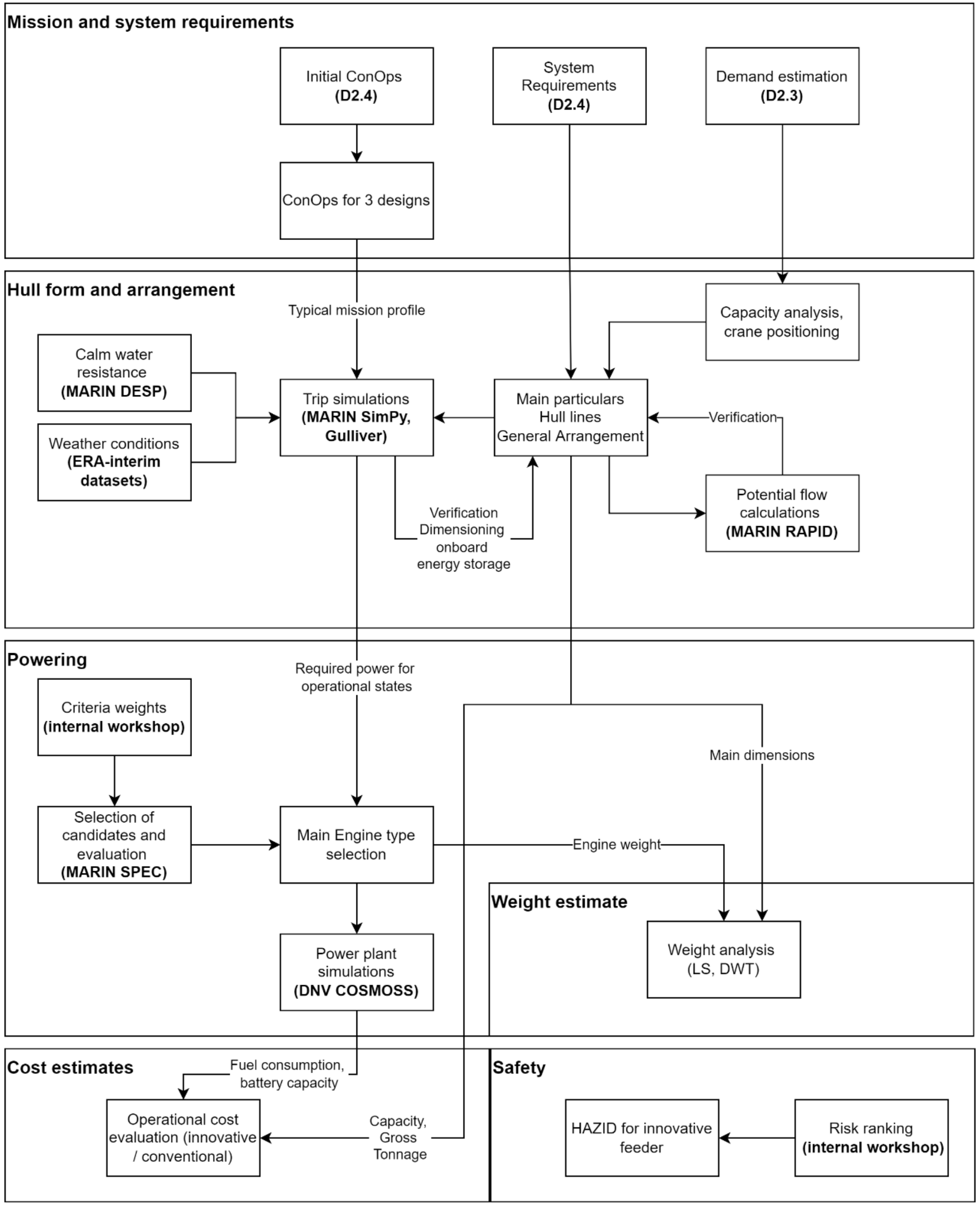




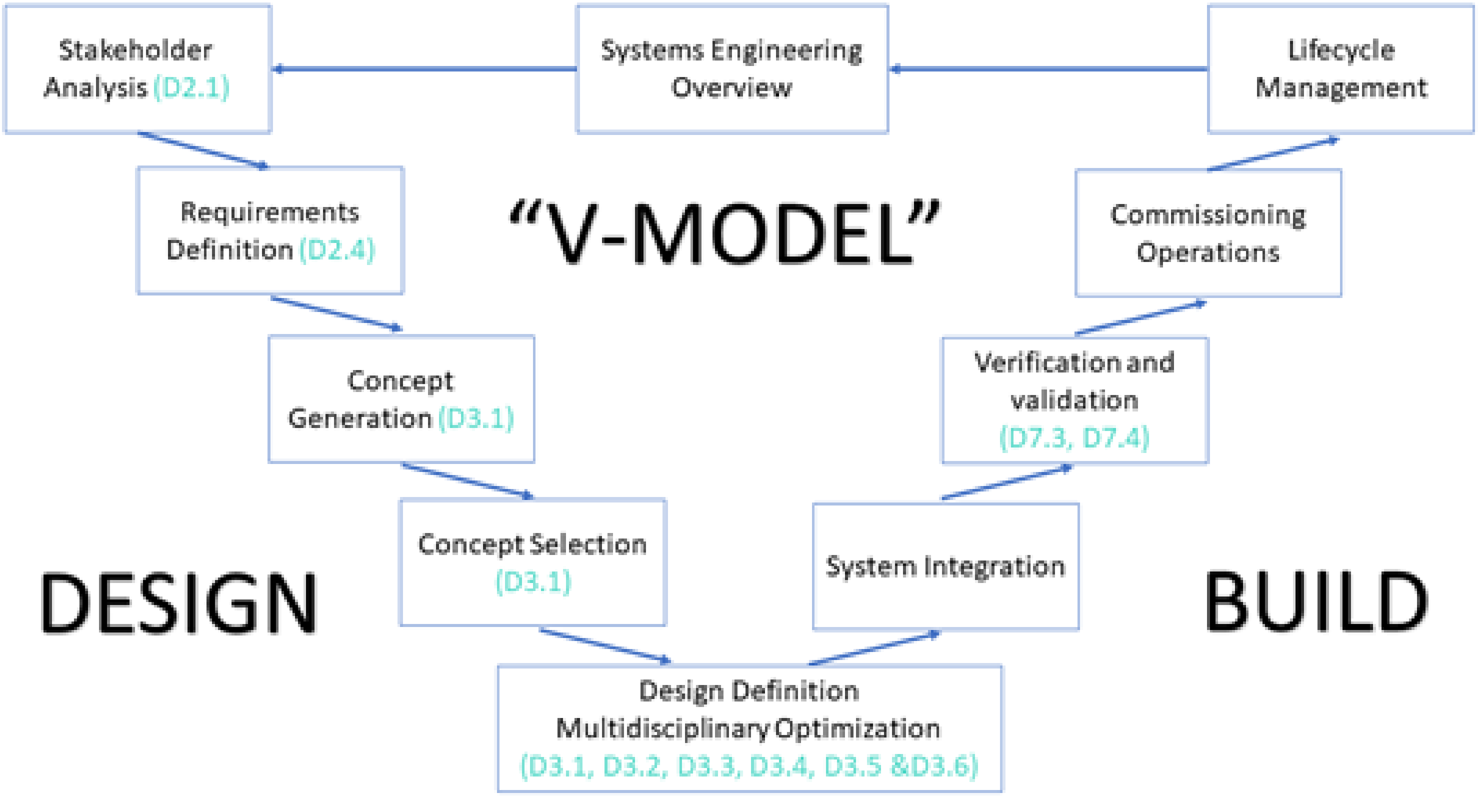
Zero-emission investigation, including wind assisted propulsion

Design methodology

1. Model based system engineering
2. Design process
3. Risk identification



V-model


Stakeholder Analysis (D2.1)
Systems Engineering Overview
Lifecycle Management
Requirements Definition (D2.4)
"V-MODEL"
Commissioning Operations
Concept Generation (D3.1)
Verification and validation (D7.3, D7.4)
Concept Selection (D3.1)
System Integration
DESIGN
BUILD
Design Definition Multidisciplinary Optimization (D3.1, D3.2, D3.3, D3.4, D3.5 &D3.6)

Overview of various tasks

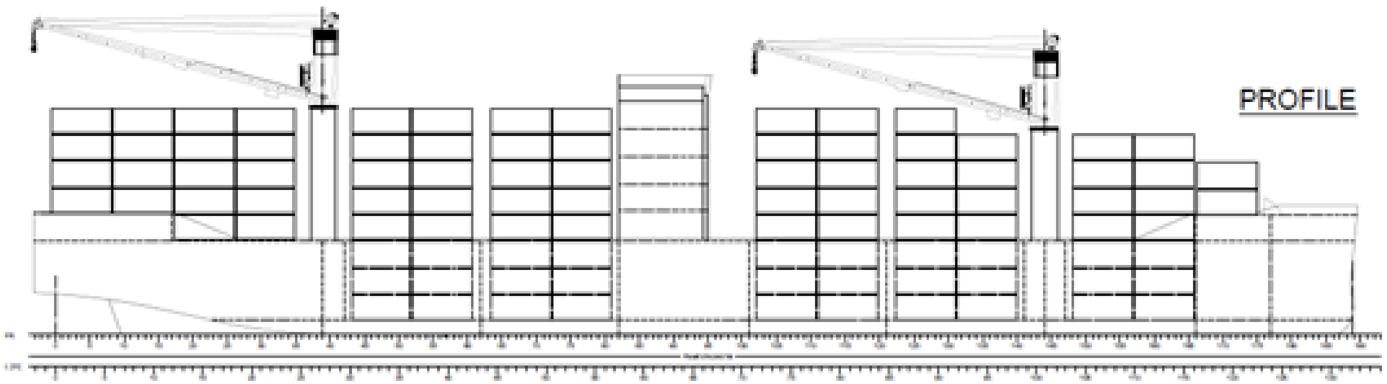
1. Mission and system requirements
   - Initial ConOps,
   - System Requirements
   - Demand estimation
2. Hull form and arrangement
   - Typical mission profile
   - Trip simulations
   - Calm water performance
   - Main particulars, hull lines, General Arrangement
   - Capacity analysis
3. Powering
   - Criteria weights
   - Selection powering candidates
   - Main engine type
   - Powering plant simulations
4. Weight analysis
5. Cost estimate
6. Safety

Risk identification

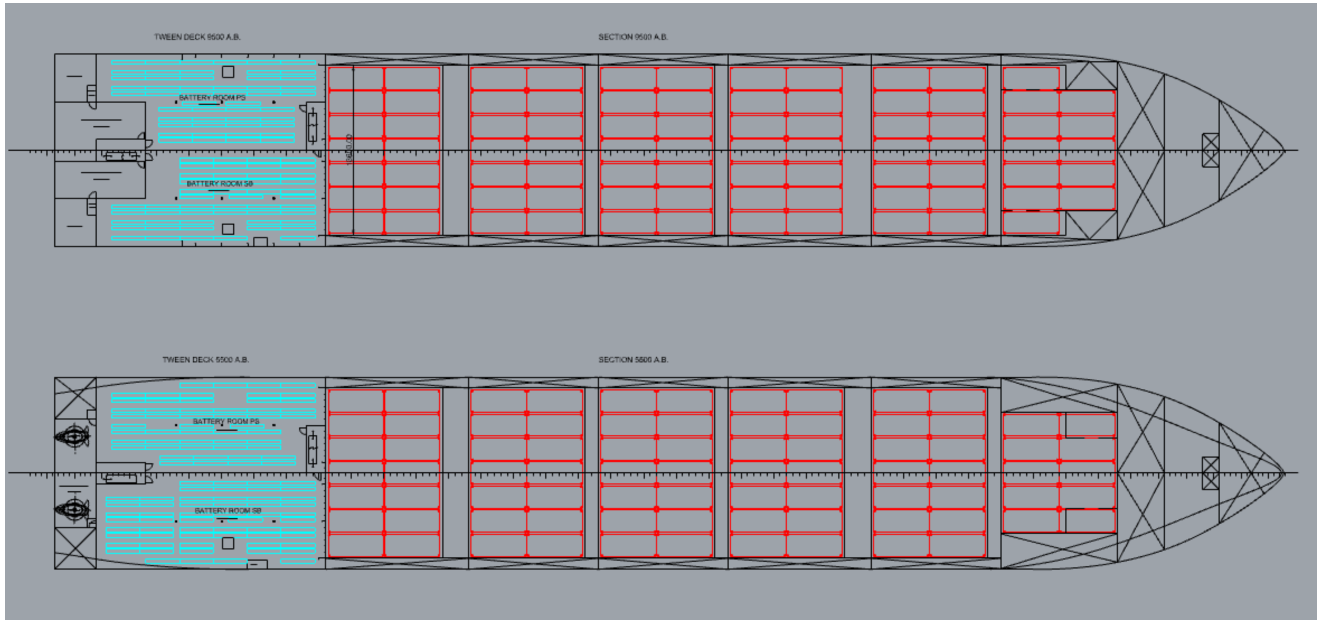
1. Main particulars
2. Hull design
3. General arrangement
4. Battery
5. Power redundancy
6. Engine
7. Fuel
8. Actuators

General arrangement	
Operation at lower speeds compared to the selected design speed range	Higher fuel consumption and lower cargo capacity than possible for low speeds.
Omit high sea states in the design phase.	Poor operation in harsh weather, as expected for the Greek case.
Underestimation of propulsion power demand at prevailing sea states for the cases of interest.	Failure to meet demand in actual conditions.
Capacity underestimation	Failure to meet market demand.
Capacity overestimation	Failure to assess actual system performance
Crane's position hinders visibility	Failure to observe objects / smaller crafts (e.g. touristic crafts) at the vicinity of the vessel. Risk of collision
Superstructure's position hinders visibility	Failure to observe objects / smaller crafts (e.g. touristic crafts) at the vicinity of the vessel. Risk of collision
Battery room space underestimation	Failure to assess actual vessel capacity. Potential overestimation of capacity
Underestimation of space required for designated zones and safe passage, leading to possible overestimation of cargo space and therefore vessel capacity	Failure to assess actual vessel capacity. Potential overestimation of capacity

What is in the concept design for the Spanish case?



1	Main particulars
2	Propulsion concept
3	General arrangement
4	Weight calculation



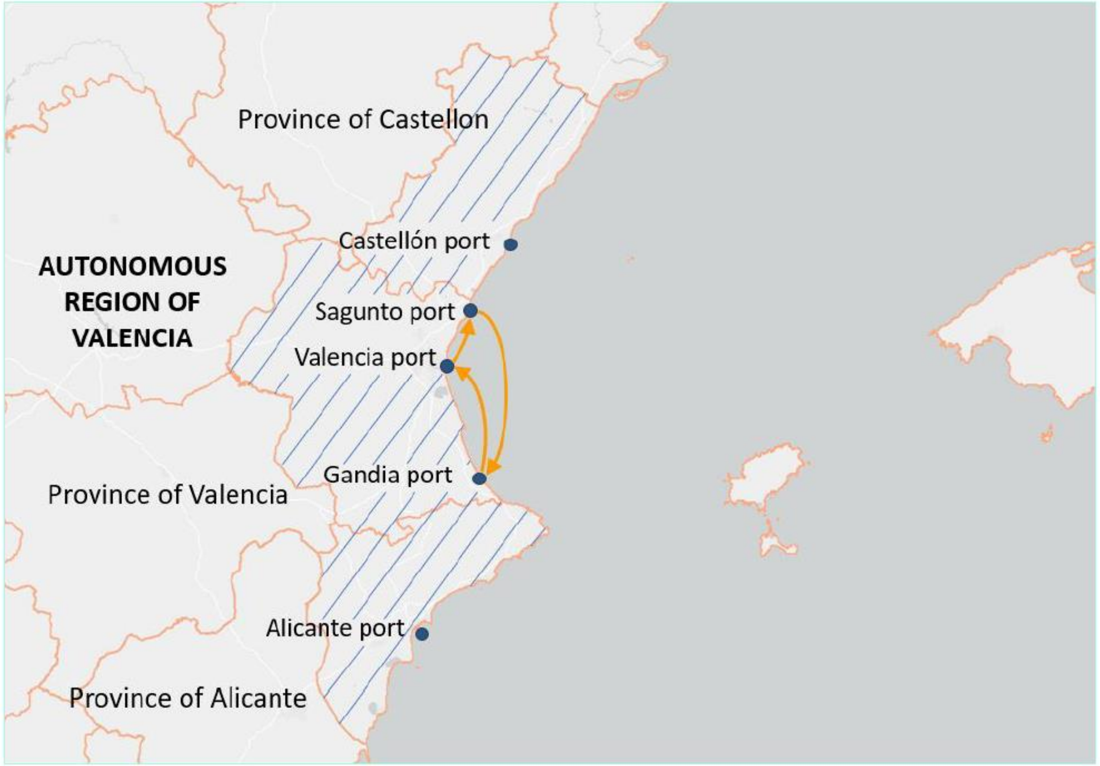
Spanish case

Designation	Symbol	Magnitude	Unit
Length between perpendiculars	Lpp	132	m
Length on waterline	Lwl	134.2	m
Length overall submerged	Los		m
Breadth moulded on WL	B	21	m
Draught moulded on FP	Tf	7.25	m
Draught moulded on AP	Ta	7.25	m
Displacement volume moulded	DISV	16761	m3
Displacement mass in seawater	DISM	17197	t
Wetted surface area hull	S	4153.25	m2
LCB position fwd of 1/2FP	FB	-2.6	%
Block coefficient	Cb	0.834	-
Midship section coefficient	Cm	0.99	-
Prismatic coefficient	Cp	0.838	-
Length-Breadth ratio	Lpp/B	6.29	-
Breadth-Draught ratio	B/T	2.90	-

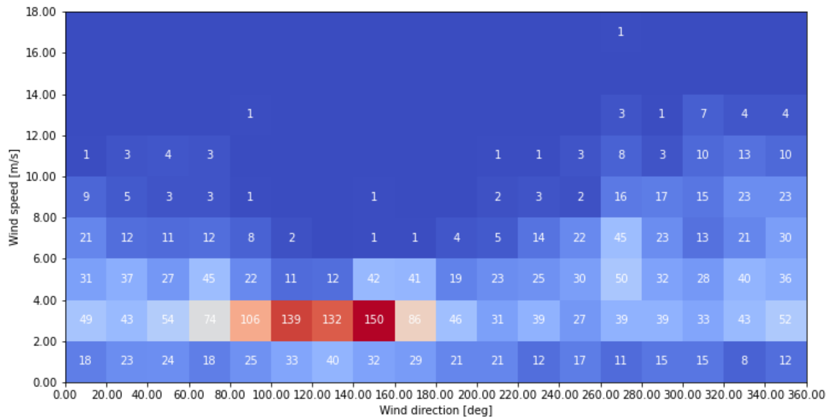
V	Ps
Knots	kW
1.00	2
2.00	15
3.00	52
4.00	123
5.00	240
6.00	410
7.00	640
8.00	982
9.00	1343
10.00	1763

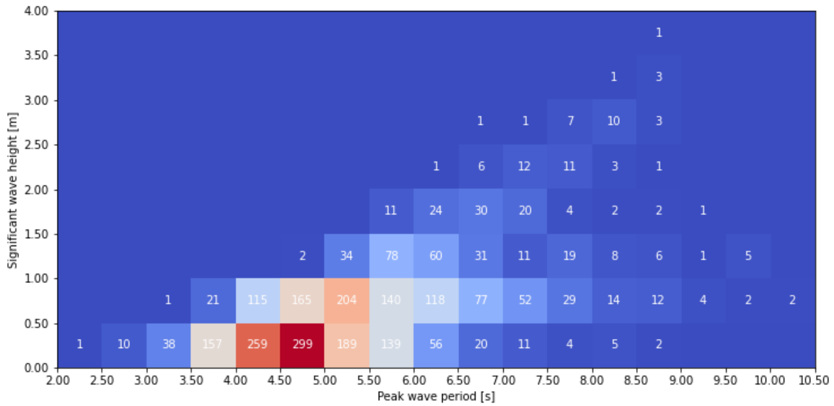
Trip voyage evaluation

Route of the Spanish case



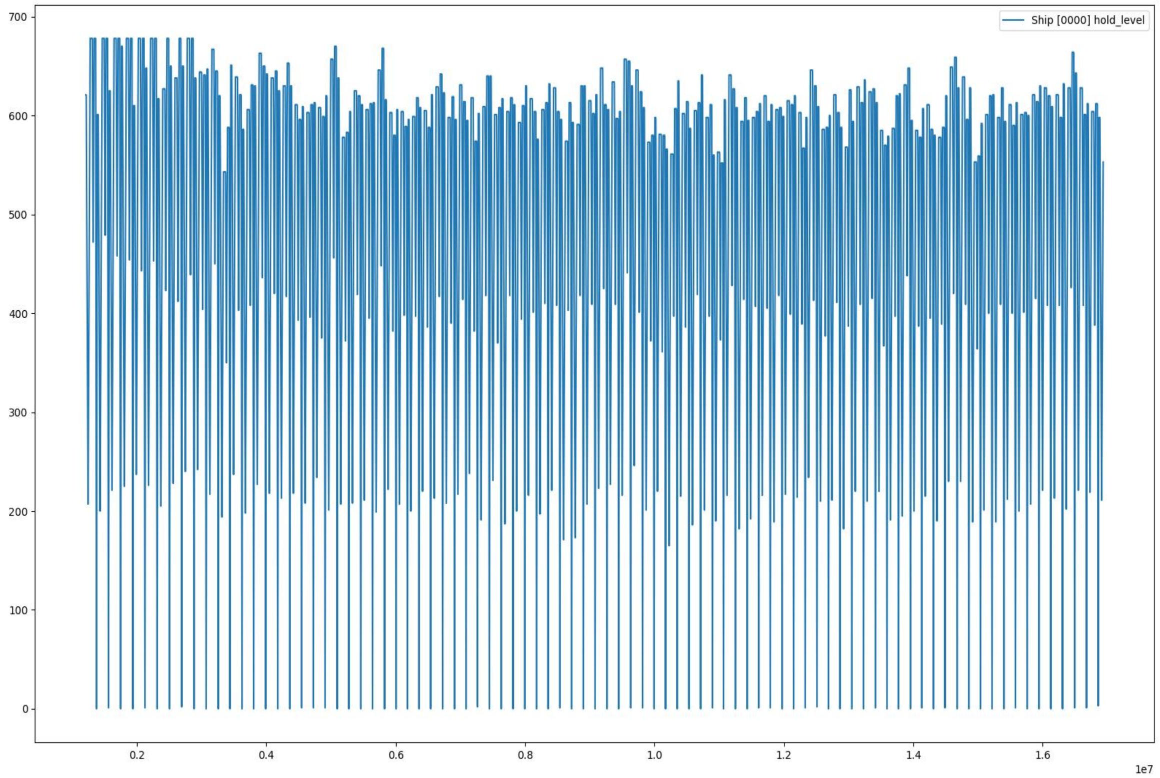
Hindcast weather database



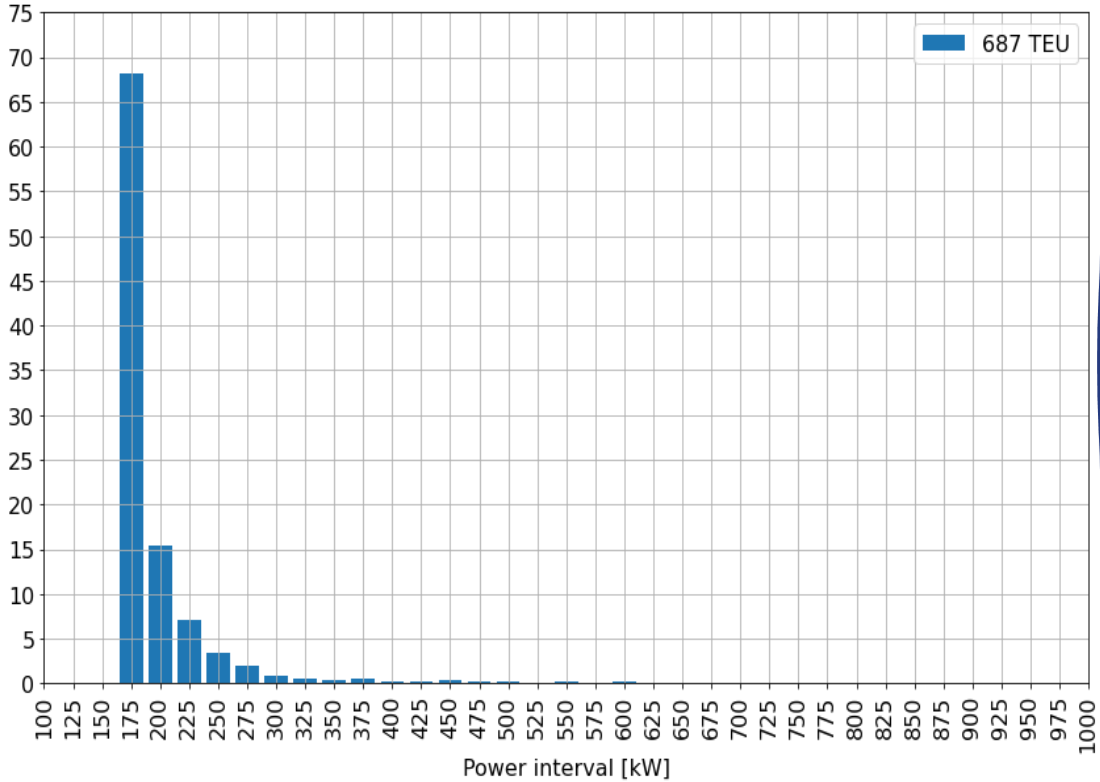


Wind (above) and wave (below) scatter diagram near Valencia

Result of trip simulations, 2-year period

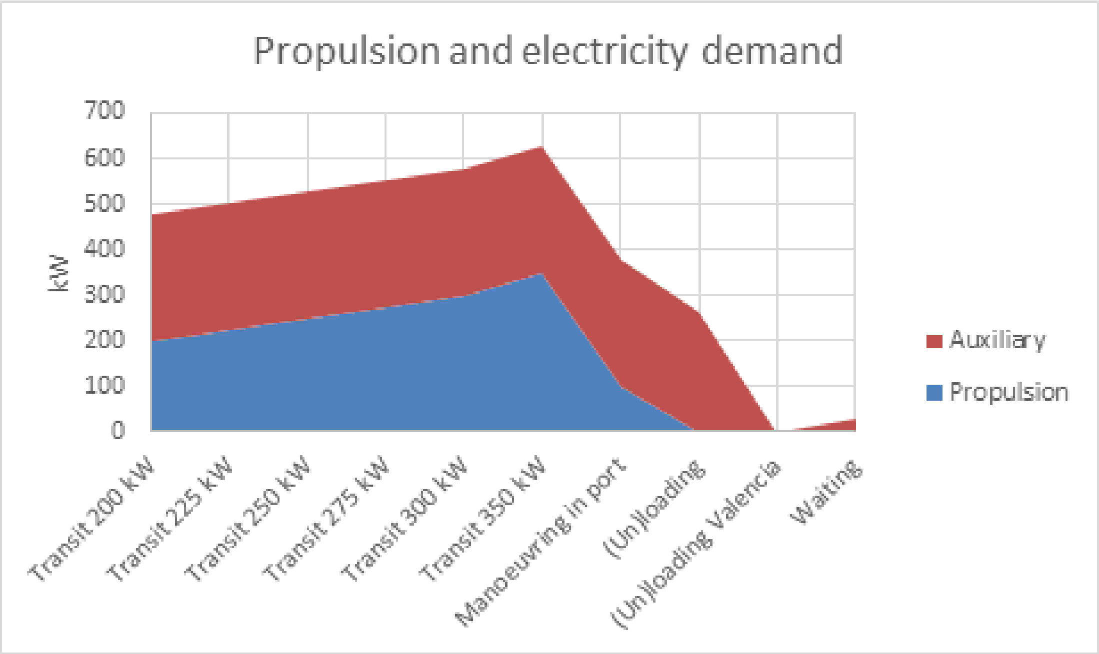


Number of containers on board

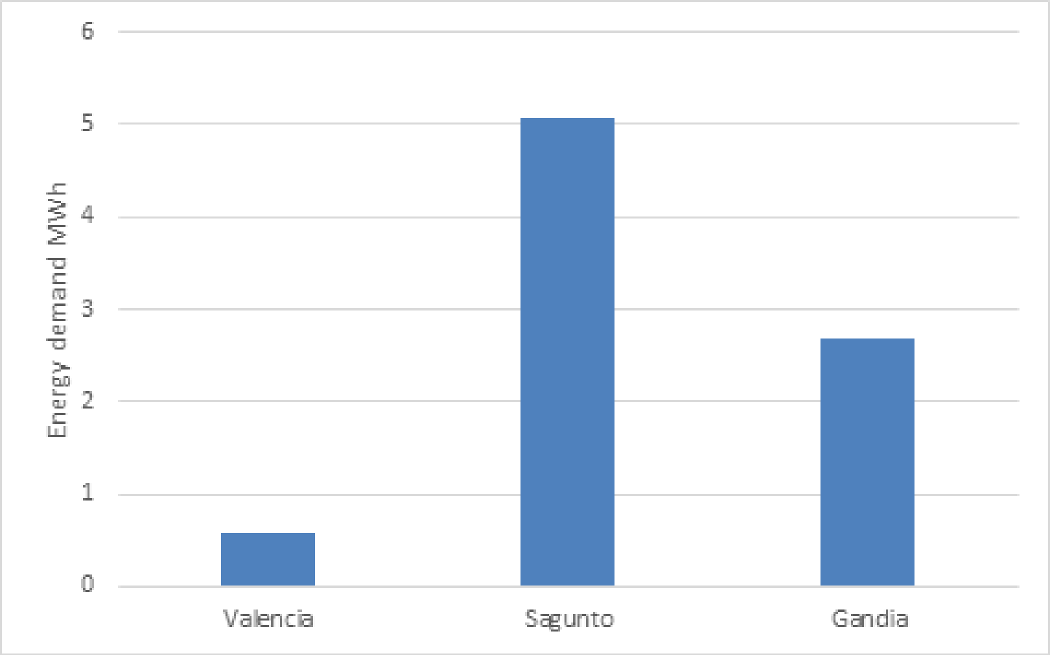


Power requirement interval and occurrence

Power evaluation from trip simulations

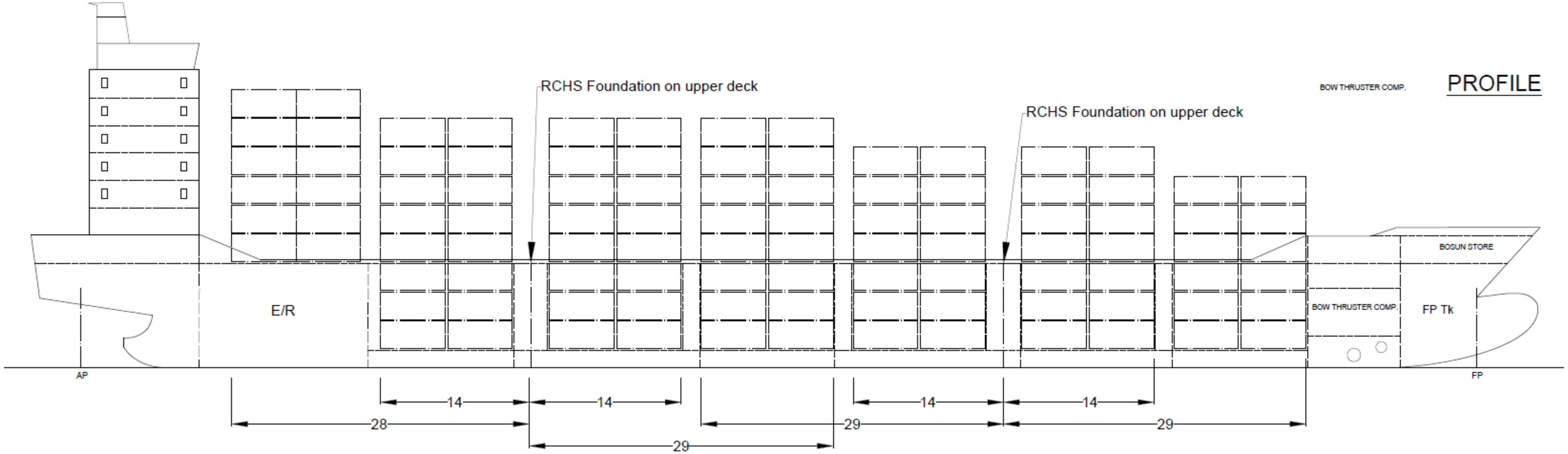


Propulsion and electricity demand per operating mode

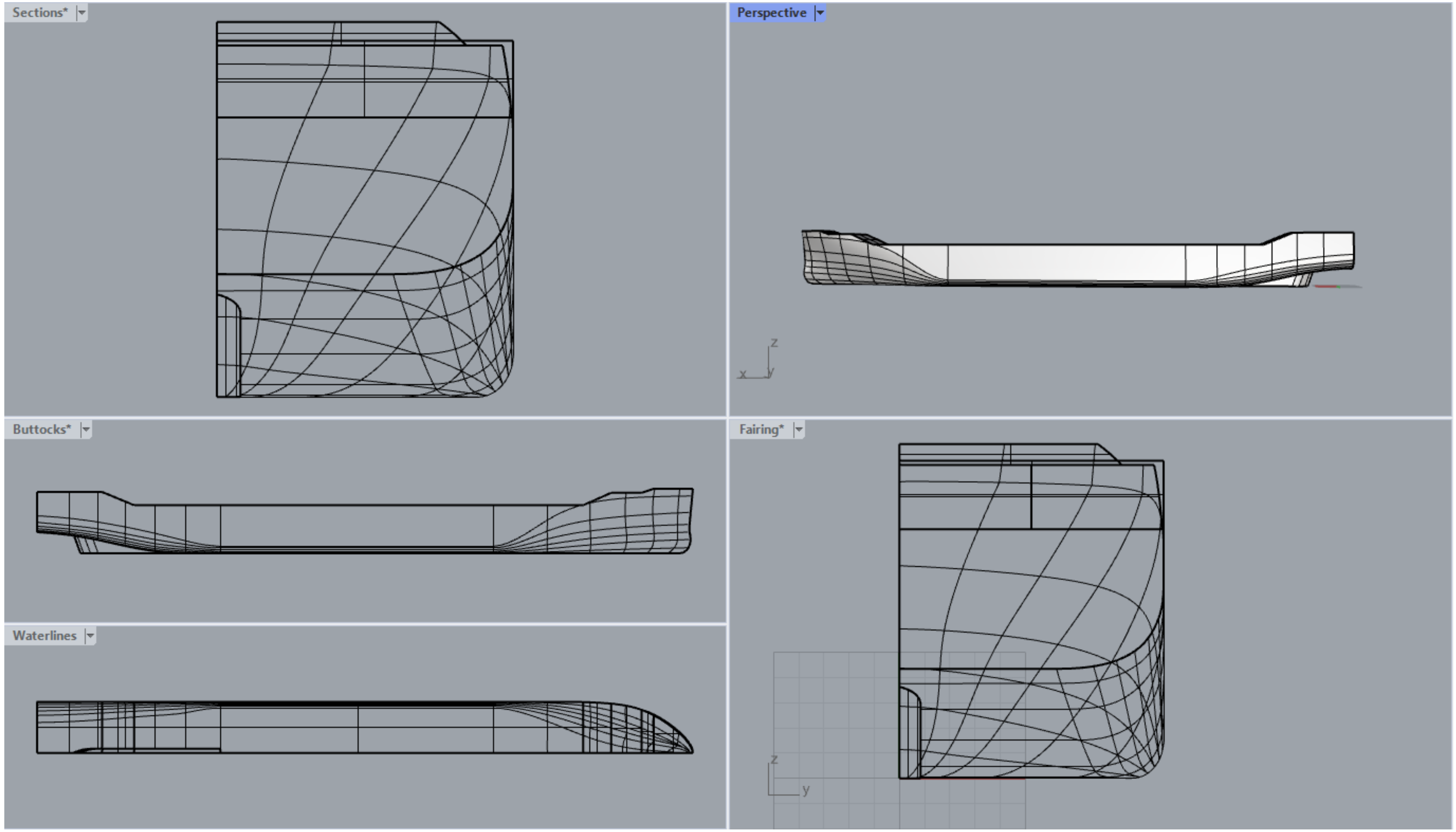


Energy demand at port operations

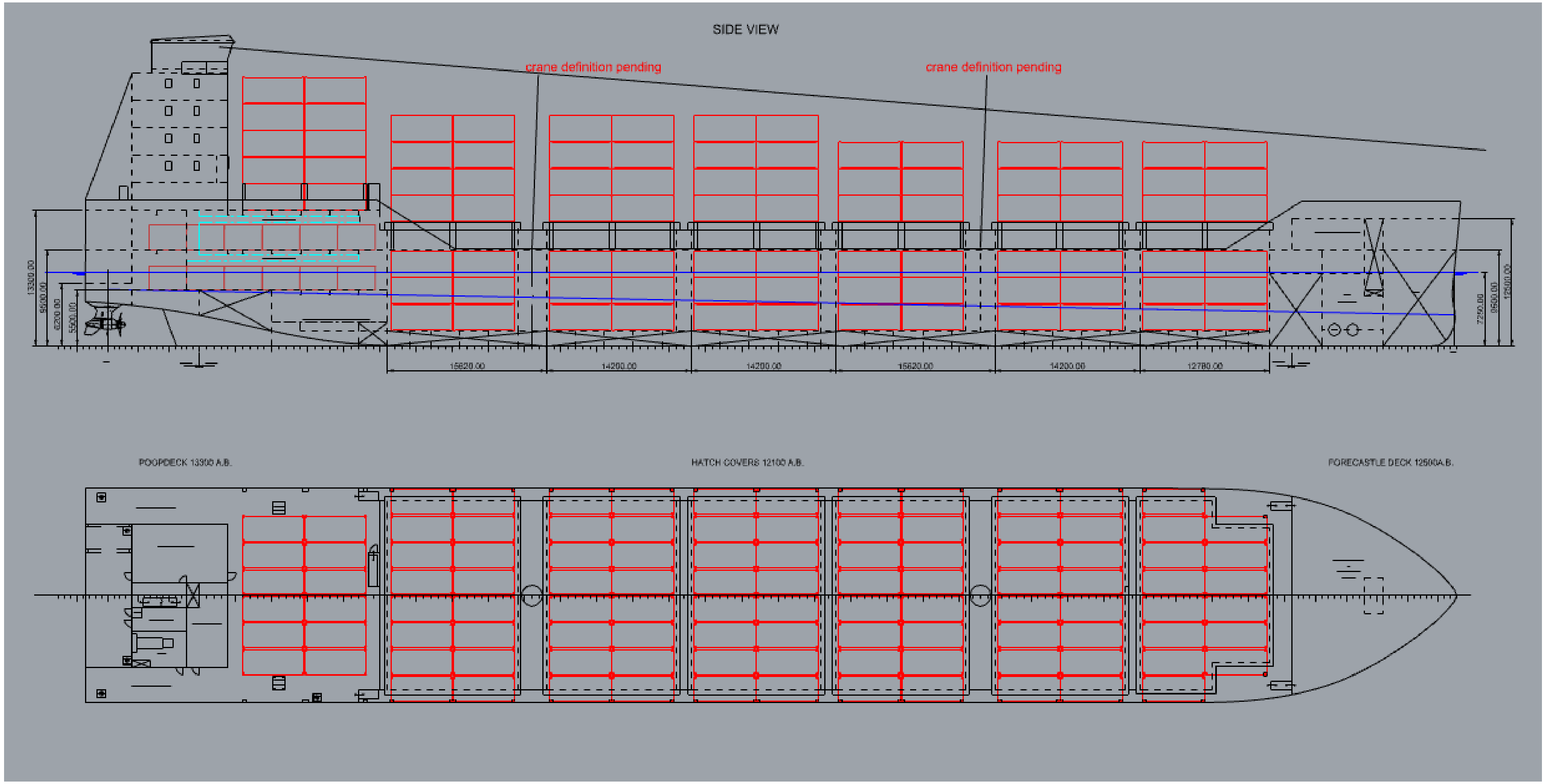
Spanish case, one of the first versions of the General Arrangement



Spanish case, hull lines

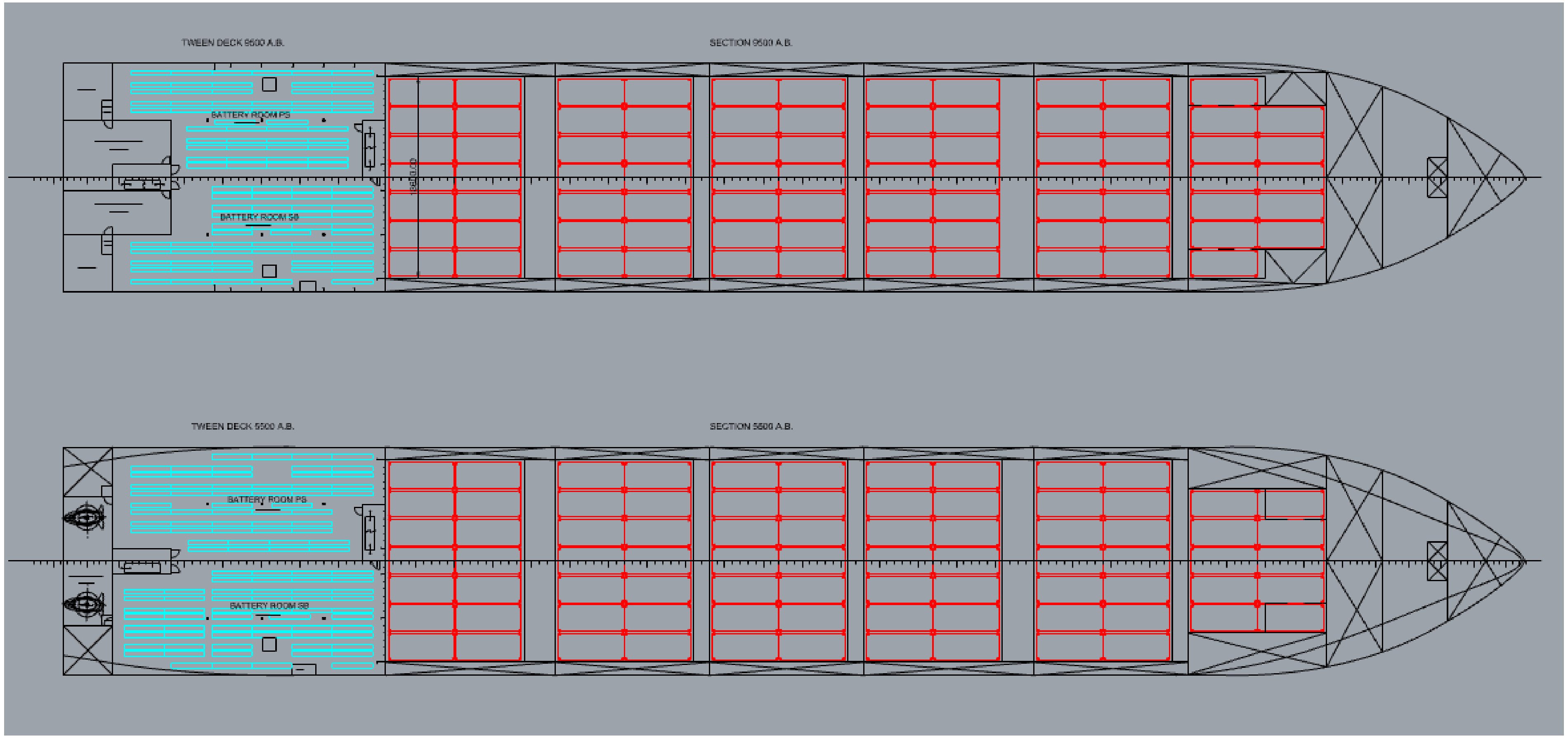


Spanish case, initial general arrangement



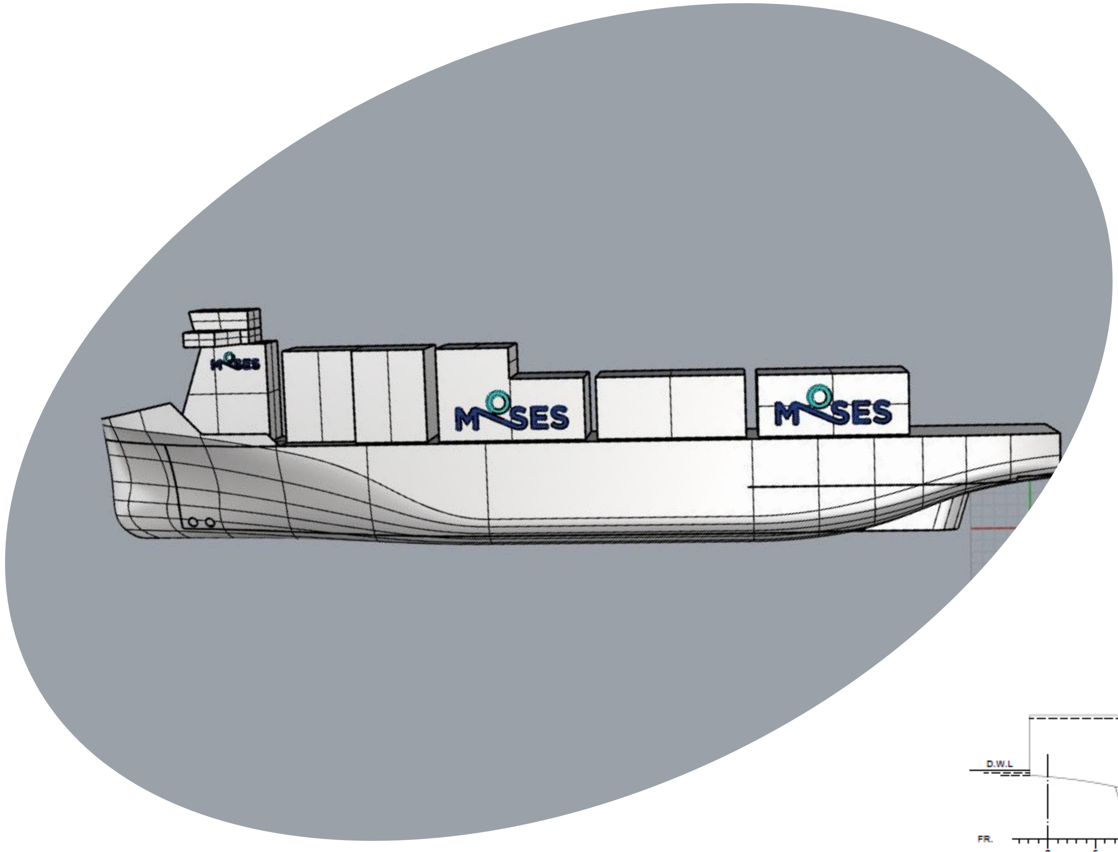
Full battery design, work in progress version

Spanish case

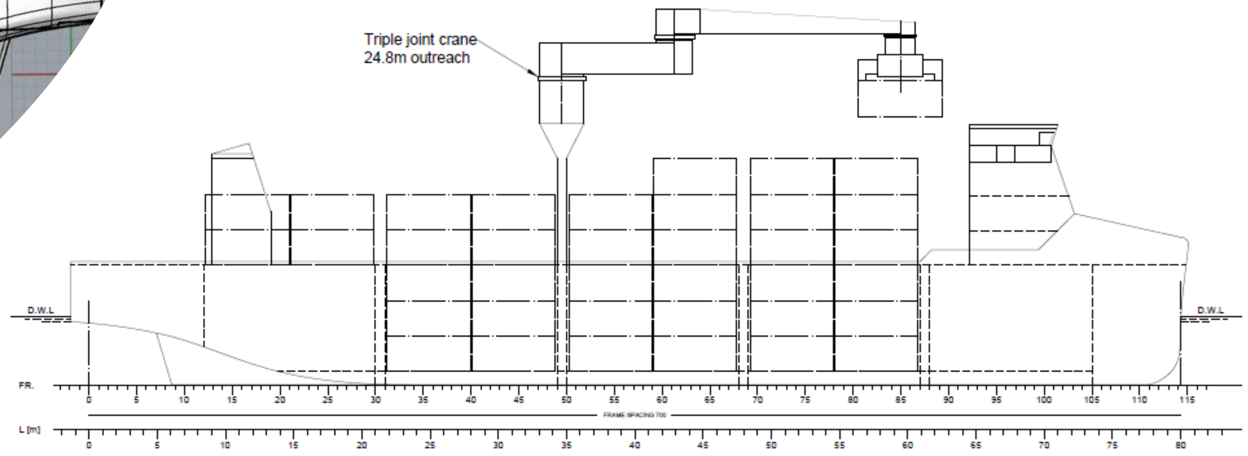


Full battery design, work in progress version

The Greek case

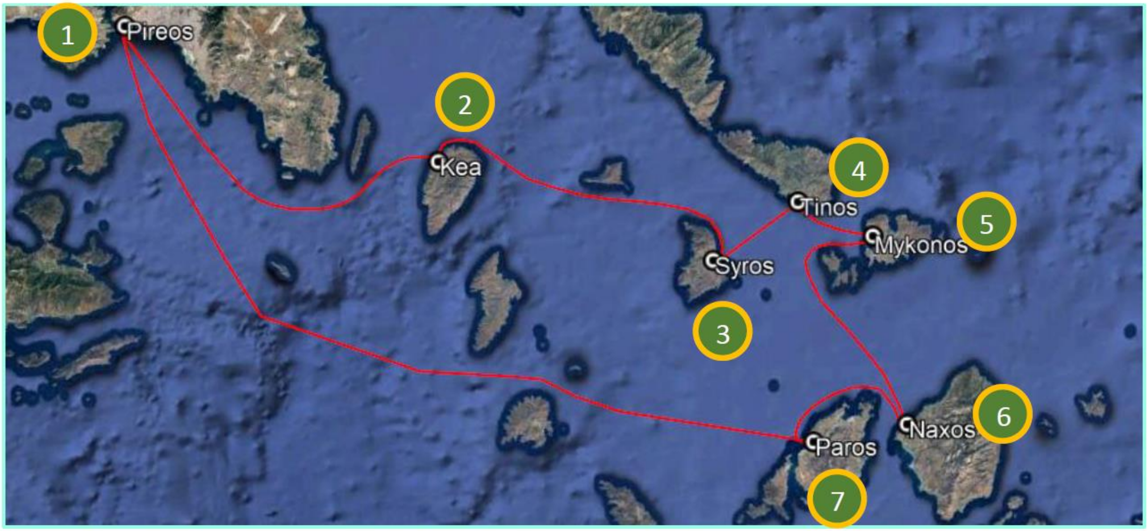


- Autonomous operation of ship and crane
- Reduced / zero emission operations

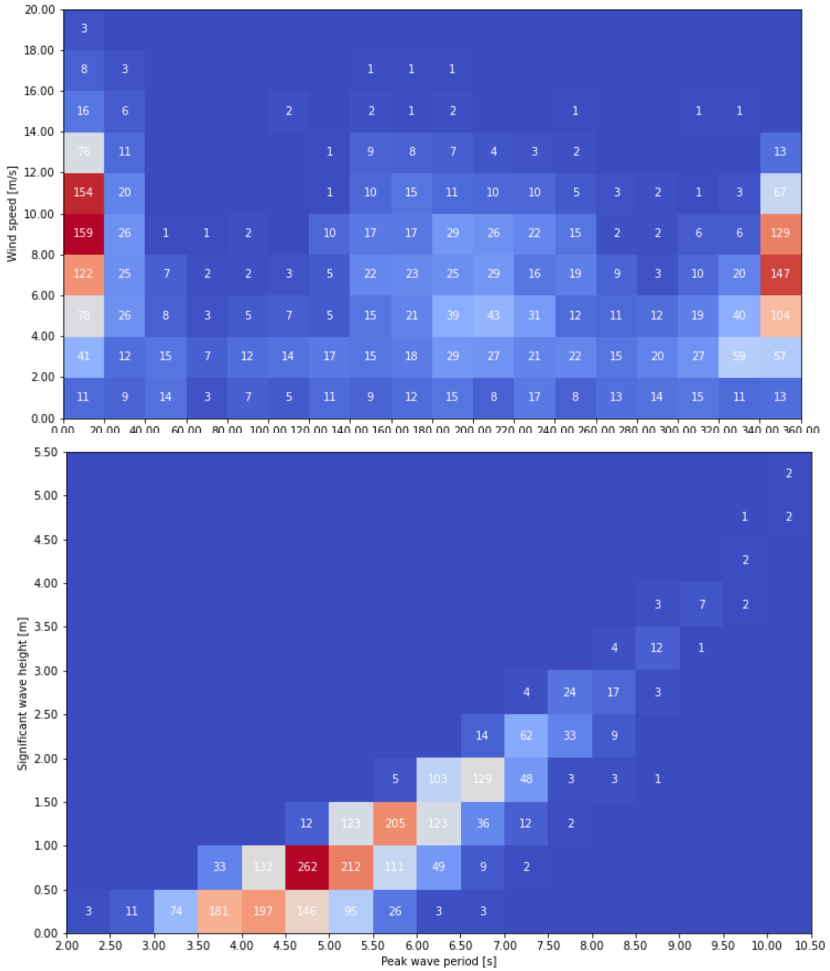


Trip voyage evaluation

Route of the Greek case

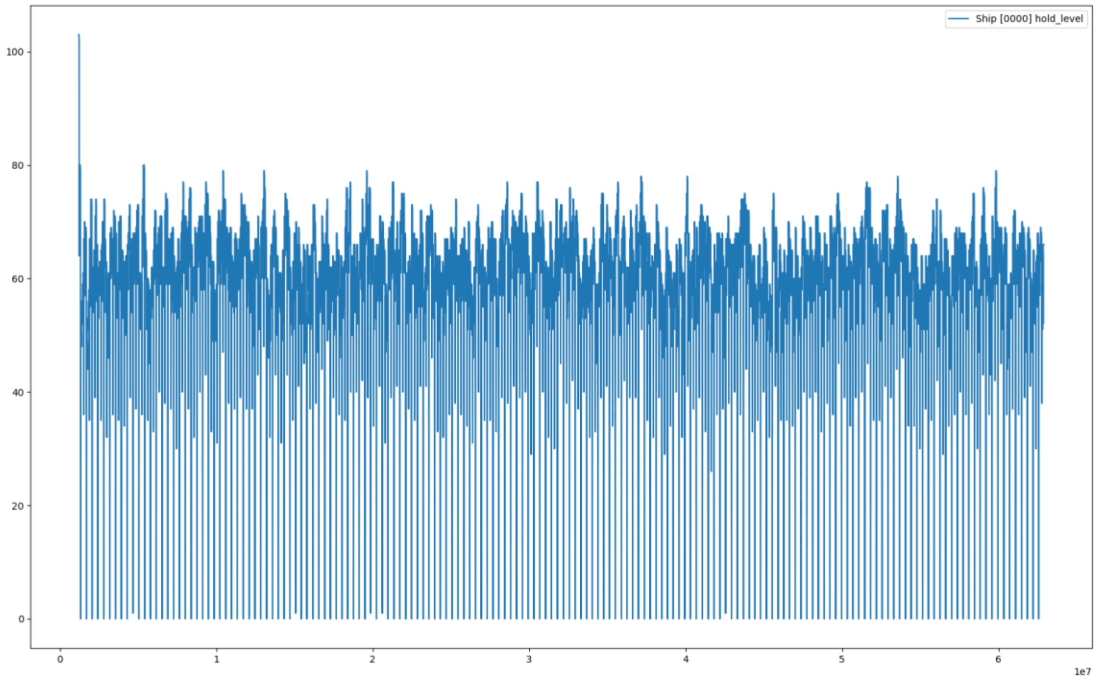


Hindcast weather database

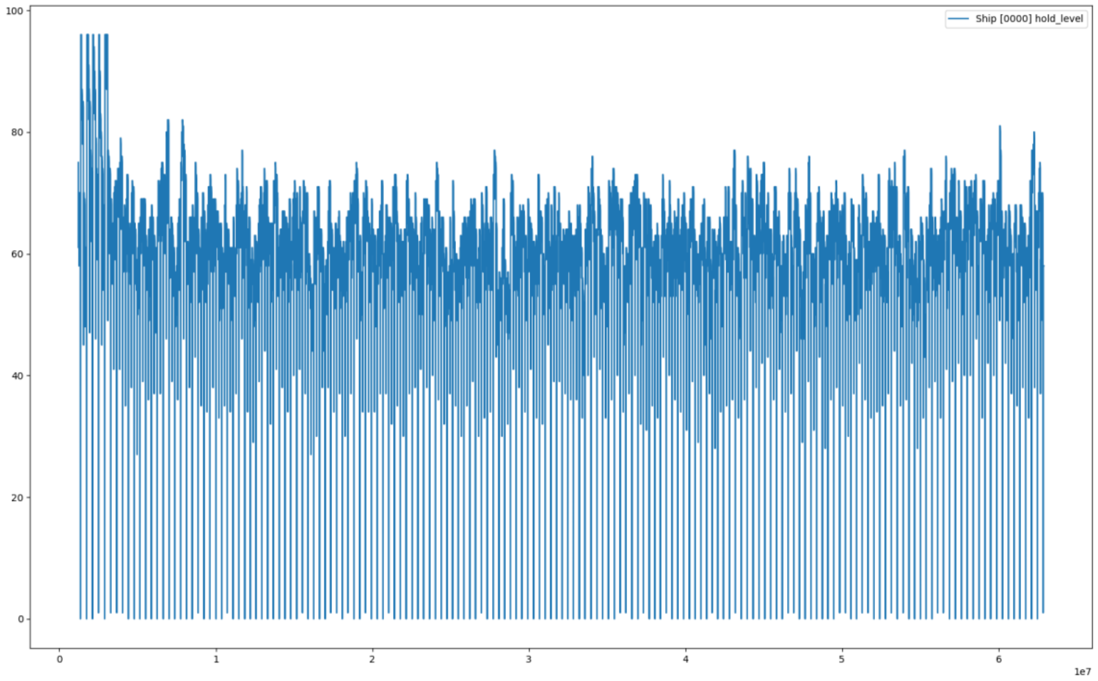


Wind (above) and wave (below) scatter diagram near Mykonos

Two Greek cases



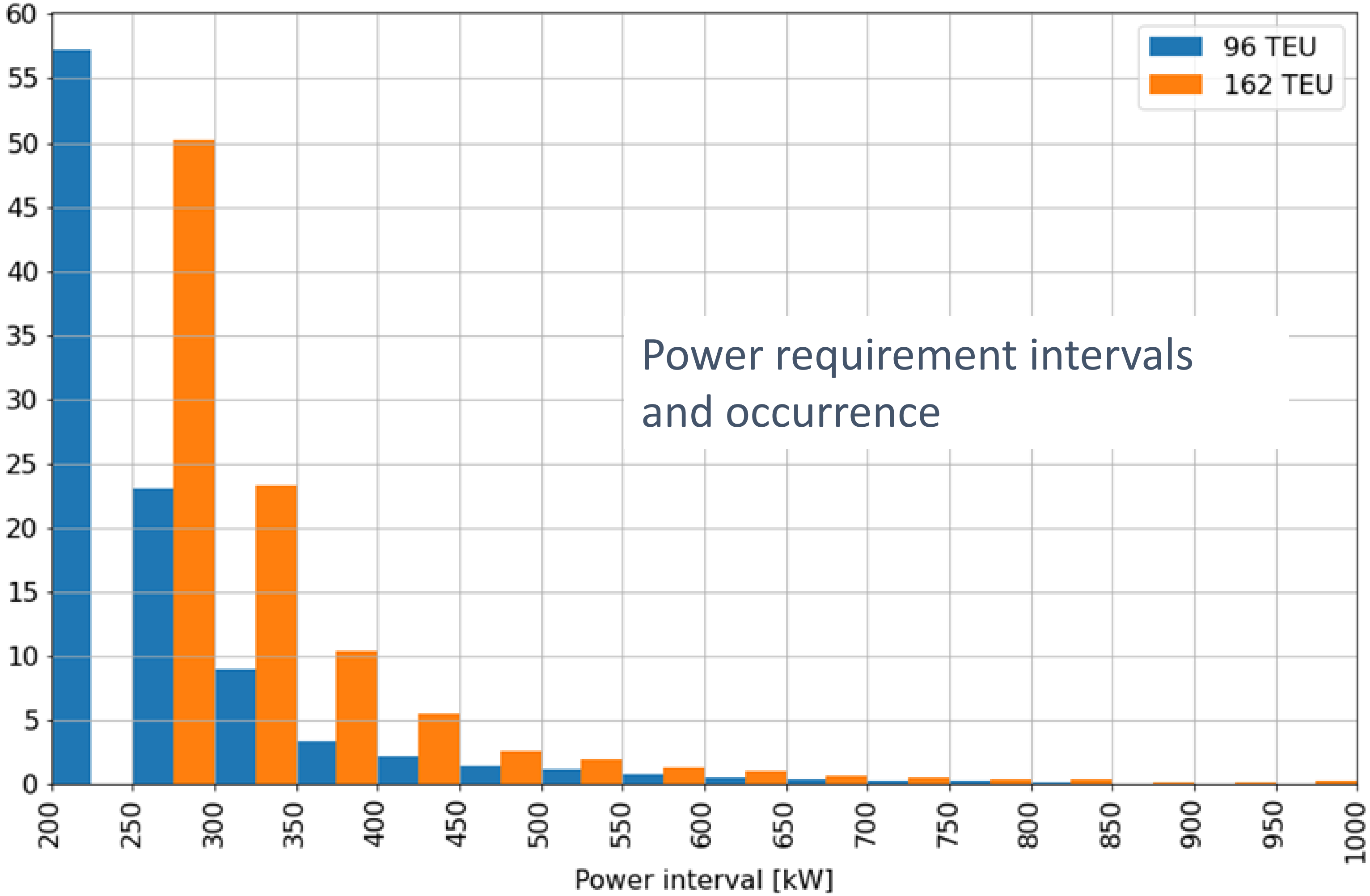
Number of containers in hold 162 TEU vessel



Number of containers in hold 96 TEU vessel

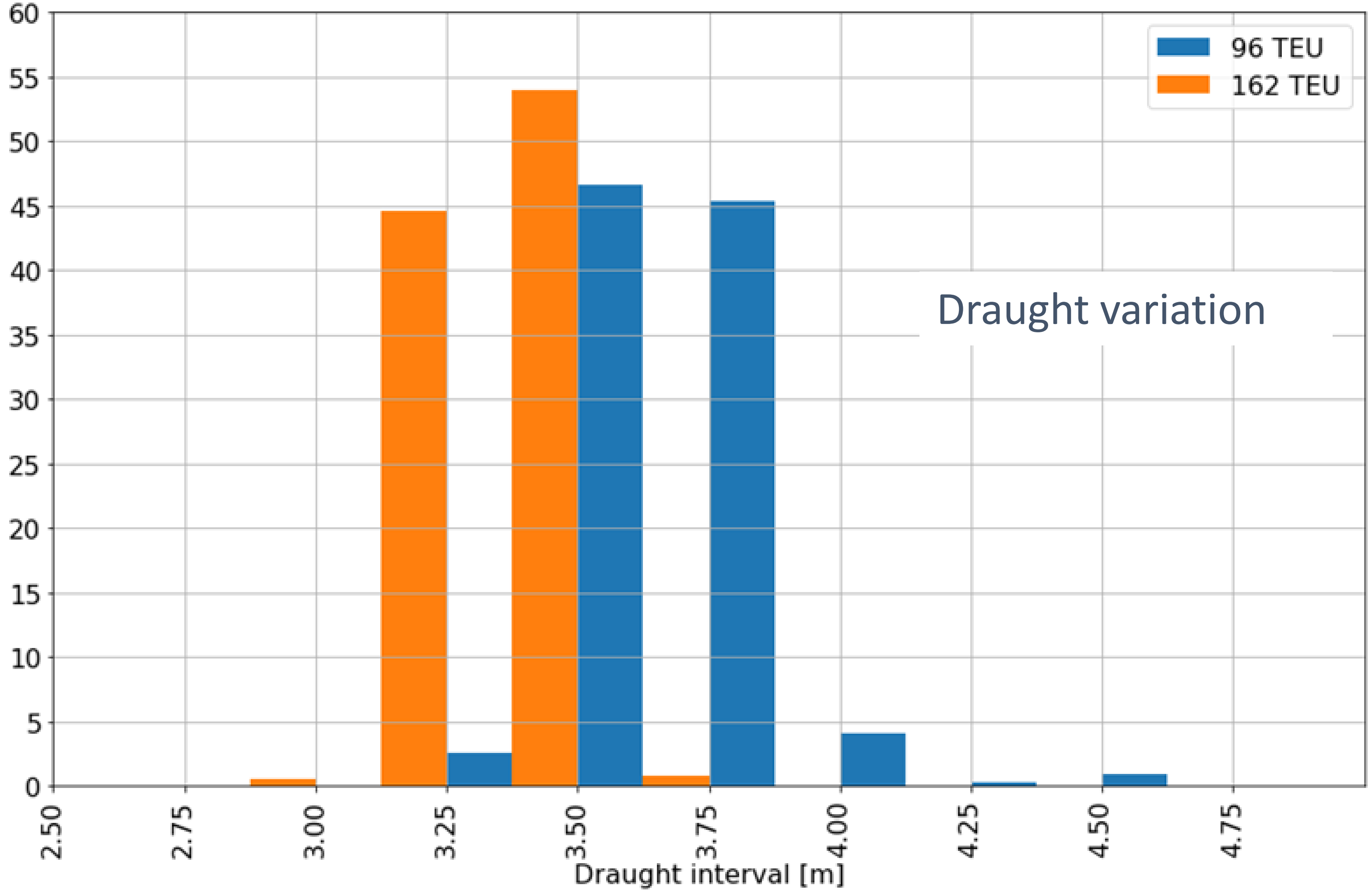
On average the 162 TEU vessel is only 50% loaded

Greek case I&II, power interval



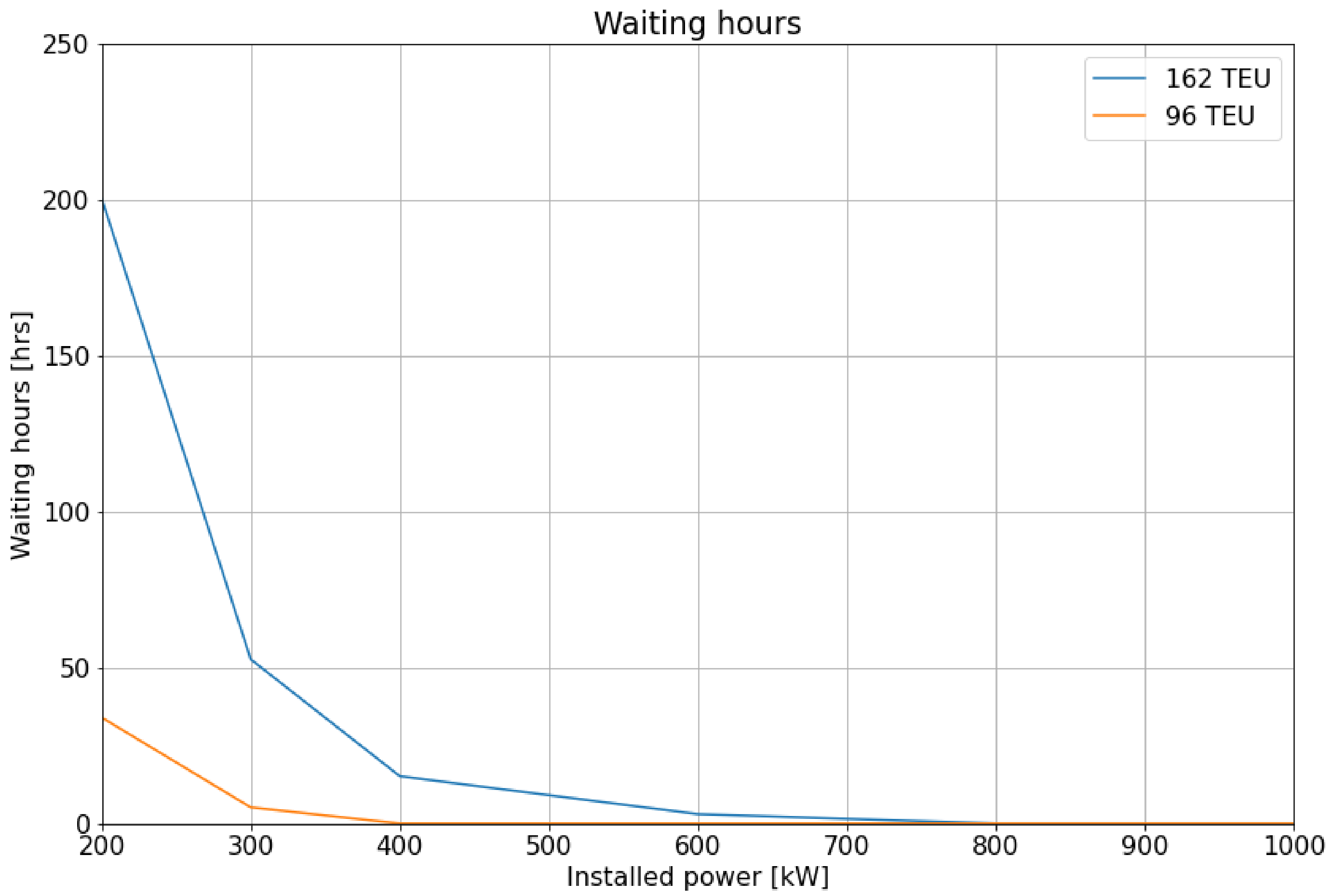
Power requirement intervals and occurrence

Greek case I&II, draught variation



Draught variation

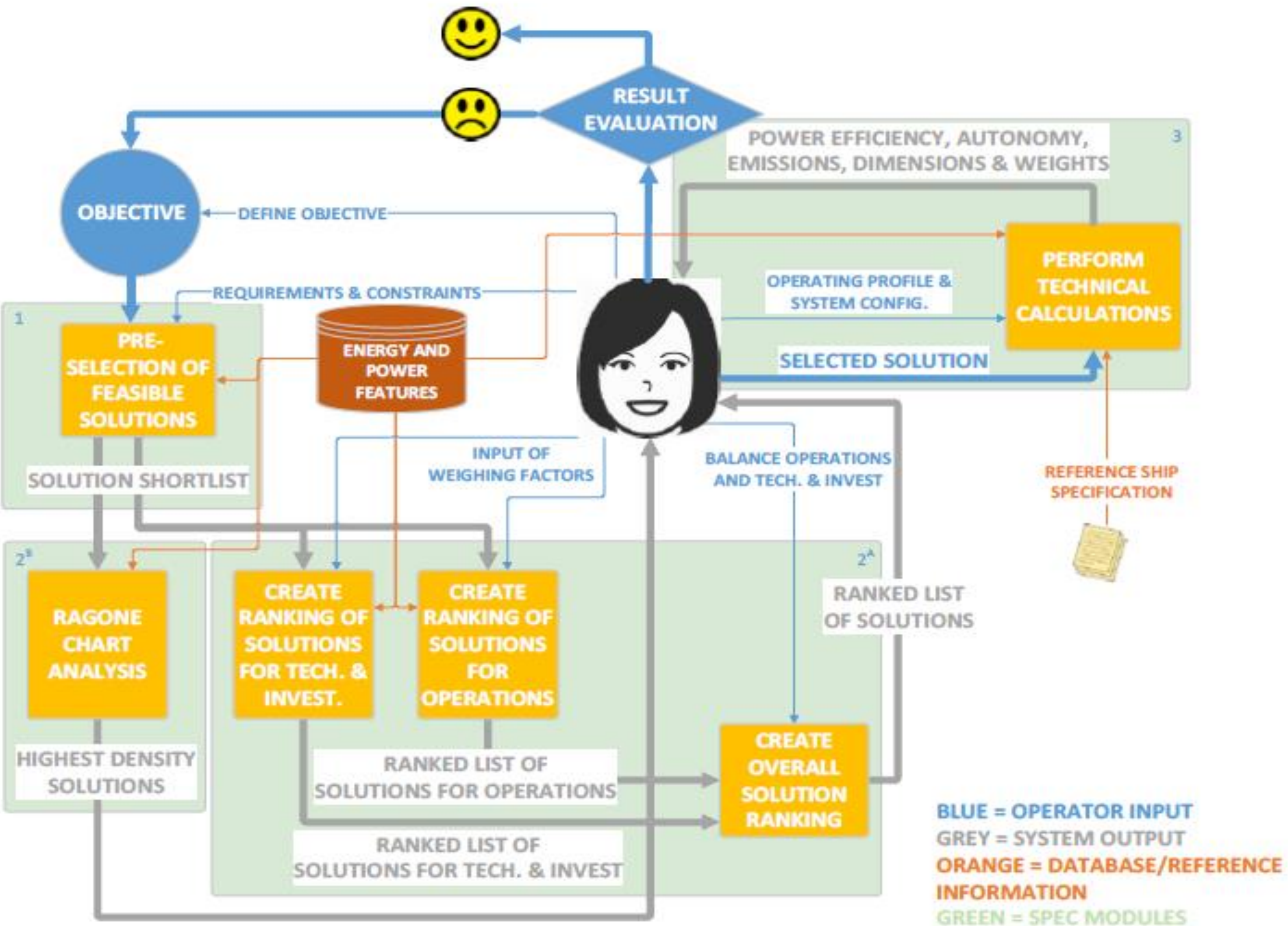
Greek cases I&II, the waiting hours



Waiting hours for two cases

Selection process of energy and power

- SPEC methodology
  - Requirements
  - Compliant solutions



Many options to choose from, 29 evaluated

- Diesel
- Methane gas (LNG)
- Propane
- Ethanol
- Ammonia
- Methanol
- DiMethylEther
- Hydrogen
- Batteries
- Liquid Organic Hydrogen Carrier (LOHC)
- Sodium borohydride ($NaBH_4$)
- Iron powder
- Formic acid
- Uranium

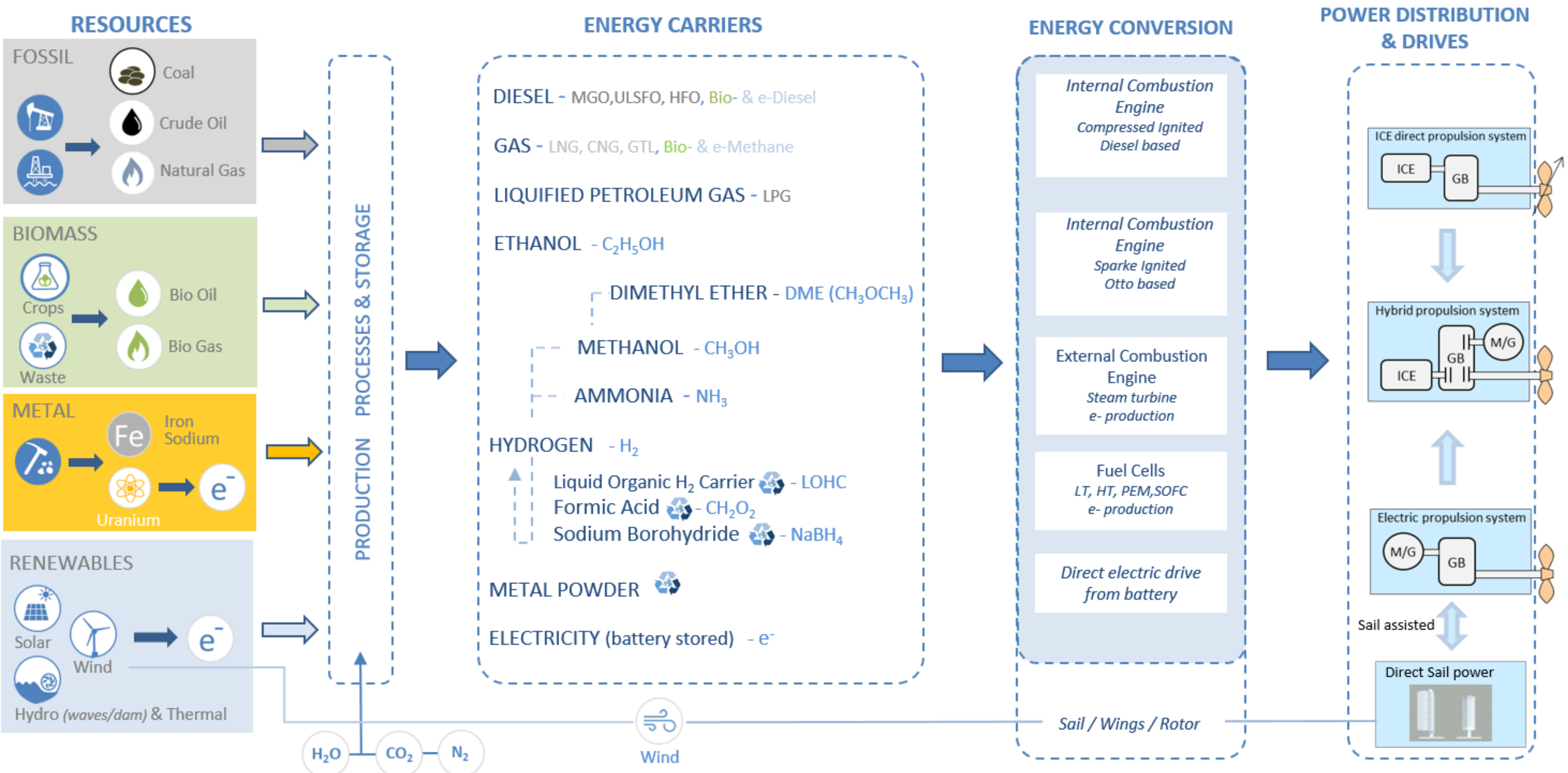
There's more even – but this is about the envelope currently considered in both academic studies and practical demonstrations!

Multi-criteria analysis on solutions

The following criteria are considered:

- Greenhouse gas emissions
- Pollutants
- Total system weight
- Total system volume
- Toxicity to aquaculture
- Toxicity of vapours
- Intrinsic fire safety of energy carrier
- Energy carrier lifetime on board
- TRL of shore infrastructure in deep sea
- Cost of vessel system
- Cost per trip
- Maintenance and reliability
- TRL of vessel systems

Evaluation from well to wake



https://sustainablepower.application.marin.nl/

European Sustainable Shipping Forum

Sustainable Alternative Power for Shipping

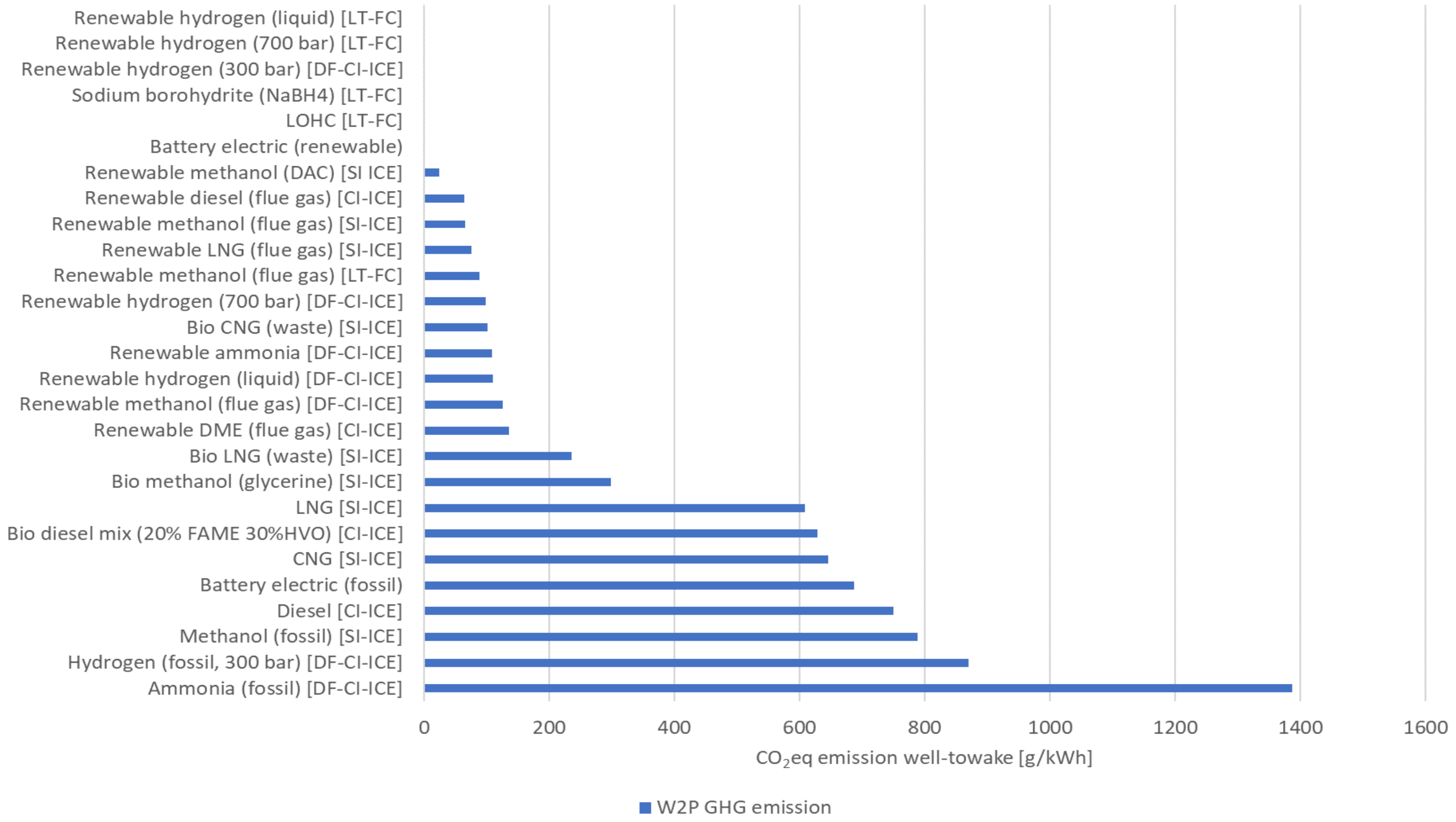
Multi criteria analysis: the weighing

Criteria	GWP20 emissions	Pollutants	Total system weight	Total system volume	Toxicity to aquaculture	Toxity of vapours	Intrinsic fire safety of energy carrier	Energy carrier lifetime on-board	TRL of shore infrastructure in deep sea port	Cost of ship system	Cost per trip	Maintenance and reliability	TRL of ship systems	Total
Weighing NTUA [%]	95	90	35	20	90	30	30	10	60	20	60	30	40	
Weighing DNV[%]	100	100	50	50	90	90	90	10	10	10	10	10	10	
Weighing MARIN [%]	100	100	20	20	0	0	0	0	0	20	80	20	0	
Weighing derived from D2.1 [%]	93	93	0	0	0	0	0	0	0	63	63	0	0	
Weighing [%]	97.00	95.75	26.25	22.50	45.00	30.00	30.00	5.00	17.50	28.25	53.25	15.00	12.50	478.00

Results, per power alternative

Criteria	GWP20 emissions	Pollutants	Total system weight	Total system volume	Toxicity to aquaculture	Toxity of vapours	Intrinsic fire safety of energy carrier	Energy carrier lifetime on-board	TRL of shore infrastructure in deep sea port	Cost of ship system	Cost per trip	Maintenance and reliability	TRL of ship systems	Total
Weighing [%]	97.00	95.75	26.25	22.50	45.00	30.00	30.00	5.00	17.50	28.25	53.25	15.00	12.50	478.00
	[% reference]	[0-9]	[% reference]	[% reference]	[0-9]	[0-9]	[0-9]	[0-9]	[0-9]	[% reference]	[% reference]	[0-9]	[0-9]	Sum of factors
Solutions	Lower is better	Higher is better	Lower is better	Lower is better	Lower is better	Lower is better	Higher is better	Higher is better	Higher is better	Lower is better	Lower is better	Higher is better	Higher is better	Higher is better
Ammonia (fossil) [DF-CI-ICE]	184	5	130	149	7	9	6	4	6	124	625	4	4	116
CNG [SI-ICE]	147	6	317	147	7	7	2	9	6	132	142	4	6	195
LNG [SI-ICE]	140	6	103	120	8	7	3	3	9	95	93	4	8	213
Hydrogen (fossil, 300 bar) [DF-CI-ICE]	106	5	479	673	2	0	2	9	5	397	124	3	7	252
Bio LNG (waste) [SI-ICE]	84	6	103	120	8	7	3	3	9	95	255	4	6	253
Methanol (fossil) [SI-ICE]	119	6	178	126	3	7	6	9	6	151	140	5	7	259
Battery electric (fossil)	79	9	1990	1928	2	6	3	9	7	3415	67	9	9	273
Diesel [CI-ICE]	100	5	100	100	9	2	7	9	9	100	100	6	9	274
Renewable LNG (flue gas) [SI-ICE]	45	6	103	120	8	7	3	3	9	95	419	4	7	280
Bio CNG (waste) [SI-ICE]	49	6	317	147	7	7	2	9	6	132	260	4	6	281
Bio diesel mix (20% FAME 30%HVO) [CI-ICE]	69	5	101	100	9	2	7	5	9	102	225	6	8	291
Renewable hydrogen (300 bar) [DF-CI-ICE]	24	5	482	679	2	0	2	9	5	398	543	3	7	300
Renewable hydrogen (liquid) [DF-CI-ICE]	23	5	220	365	2	0	3	1	5	325	533	4	6	311
Renewable methanol (DAC) [DF-CI-ICE]	12	5	178	126	3	7	6	9	6	151	625	5	7	316
Renewable methanol (flue gas) [DF-CI-ICE]	17	5	178	126	3	7	6	9	6	151	536	5	7	318
Renewable ammonia [DF-CI-ICE]	12	5	130	149	7	9	6	4	6	124	125	4	4	321
Bio methanol (glycerine) [SI-ICE]	48	6	99	101	3	7	6	9	6	102	275	5	7	322
Sodium borohydrite (NaBH4) [LT-FC]	0	9	317	649	4	2	8	6	2	773	4697	1	5	323
Renewable diesel (flue gas) [CI-ICE]	8	5	100	100	9	2	7	9	9	100	525	6	5	326
Renewable DME (flue gas) [CI-ICE]	18	6	157	128	3	7	6	9	3	159	435	5	5	327
Renewable hydrogen (700 bar) [DF-CI-ICE]	24	5	224	241	2	0	1	9	5	181	348	3	6	328
LOHC [LT-FC]	0	9	496	672	5	2	8	9	2	587	4940	3	5	328
Renewable methanol (DAC) [LT-FC]	3	9	295	359	3	7	6	9	6	505	777	4	5	332
Renewable methanol (DAC) [SI-ICE]	4	6	178	126	3	7	6	9	6	151	625	5	7	335
Renewable methanol (from DAC) [HT-FC]	4	8	294	359	3	7	4	9	6	504	281	5	5	354
Battery electric (renewable)	0	9	2011	843	2	6	3	9	7	3472	107	9	9	360
Renewable methanol (flue gas) [SI-ICE]	11	6	178	126	3	7	6	9	6	151	210	5	7	360
Renewable hydrogen (700 bar) [LT-FC]	0	9	298	401	2	0	1	9	5	395	370	5	6	383
Renewable hydrogen (liquid) [LT-FC]	0	9	220	366	2	0	3	1	5	325	291	5	6	396

Zero emission design Greek case

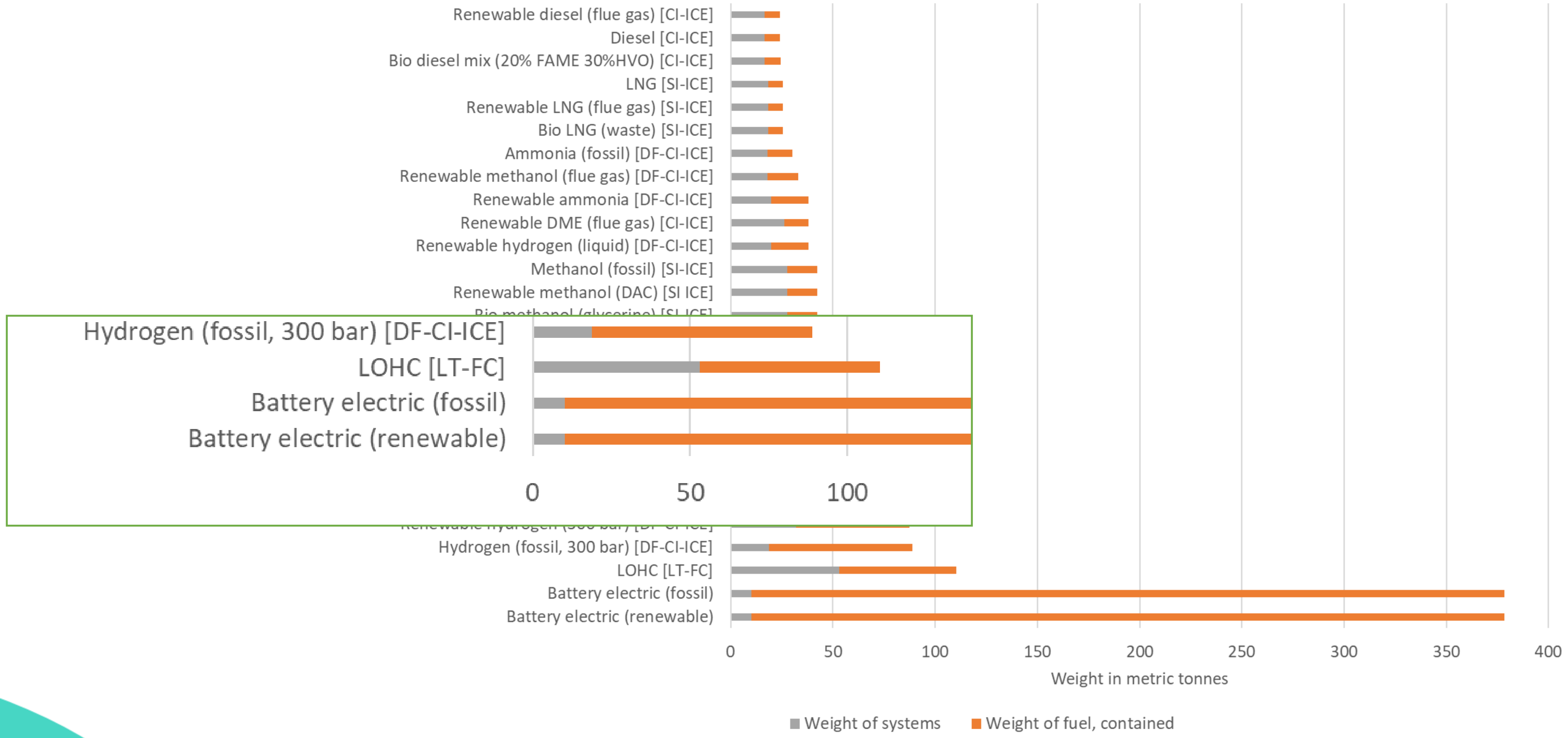


SPEC results for greenhouse gas emissions

Results, which were selected for further design

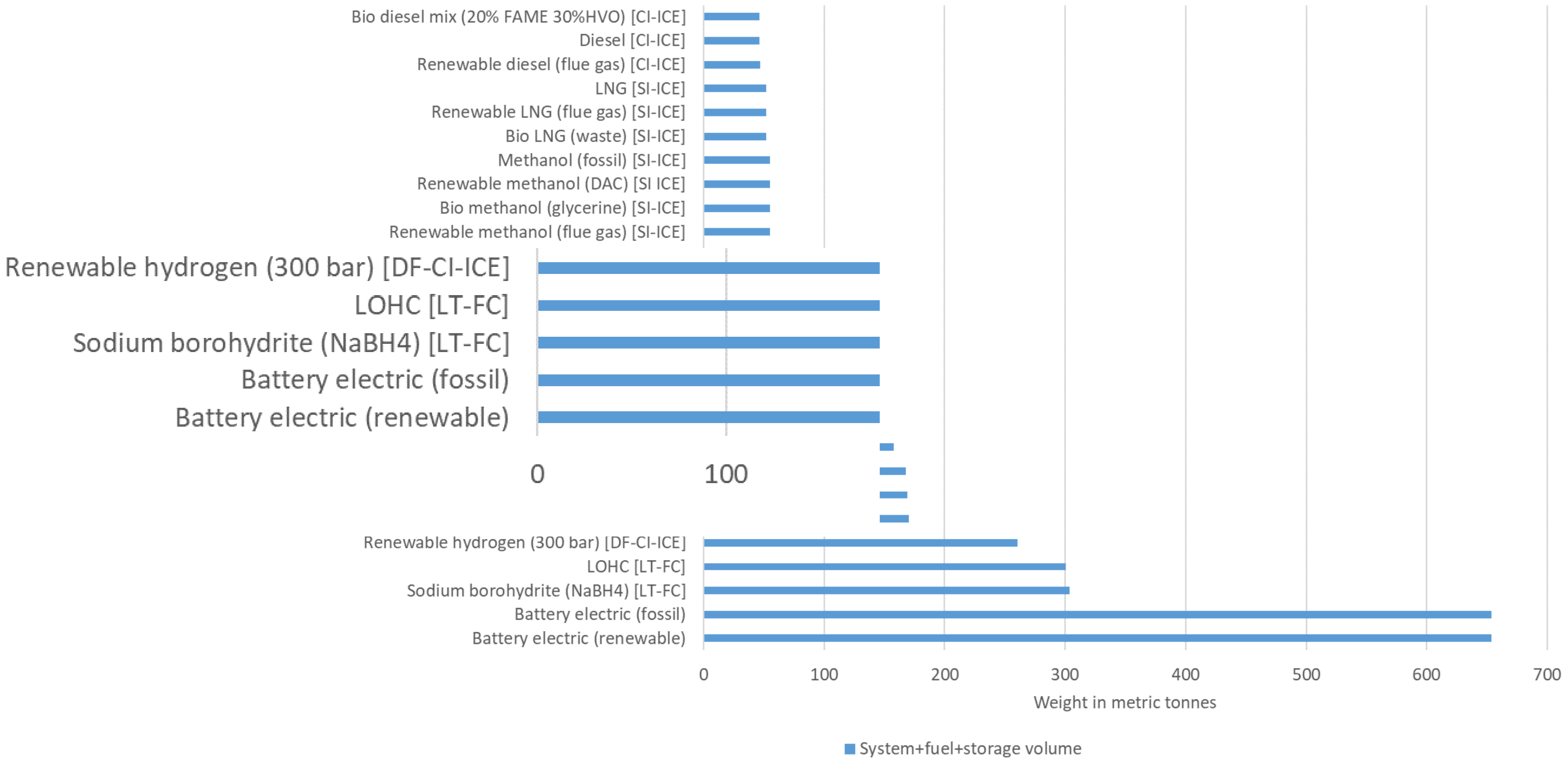
1. Renewable hydrogen (700 bar) with LTPEM fuel cell / Renewable hydrogen (liquid) with LTPEM fuel cell;
2. Renewable methanol (flue gas) with SI-ICE (spark ignited combustion engine);
3. Battery-electric (renewable).

Which challenges remain for full electric for the Greek case?



1. SPEC results for weight

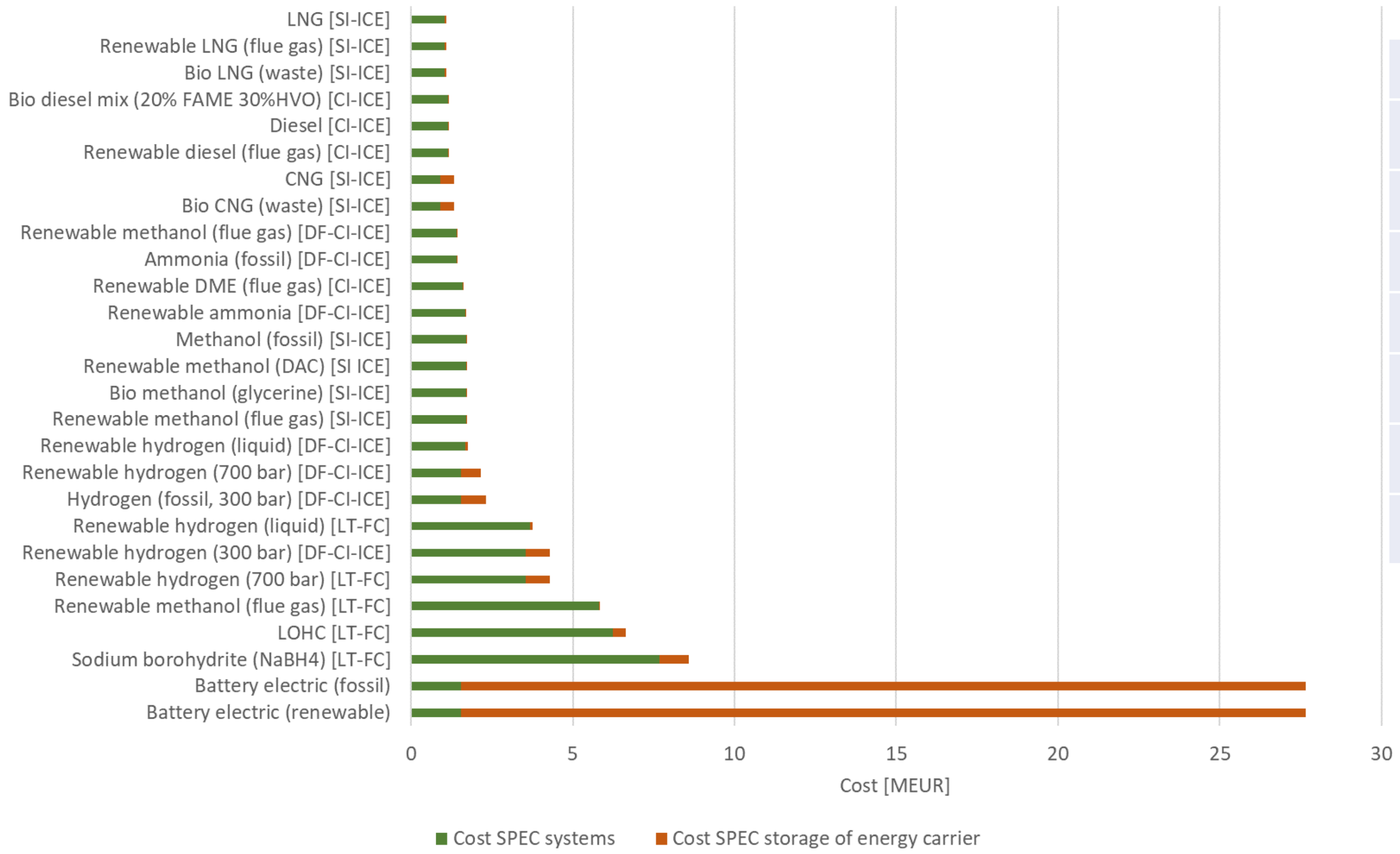
Which challenges remain for full electric for the Greek case?



2. SPEC results for volume (system+fuel+storage)

Which challenges remain for full electric for the Greek case?

MARIN

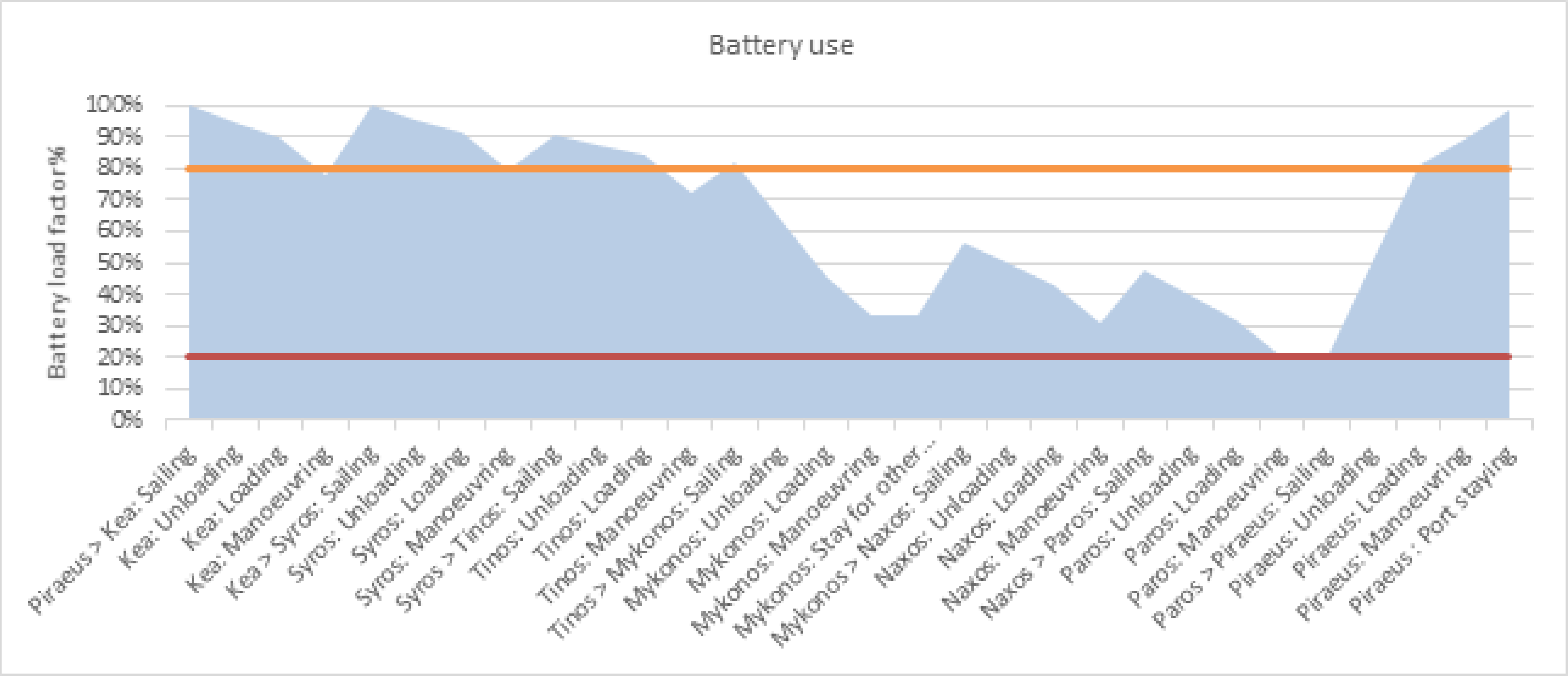


1	LNG
2	Renewable LNG (flue gas)
3	Bio LNG
…	
…	
25	Sodium borohydrite
26	Battery electric (fossil)
27	Battery electric (renewable)

3. SPEC results system costs

MOSES

Zero emission operation



Battery use per leg and mode of operation, hybrid case, from DNV’s COSMOSS simulations

Preliminary hazard identification and risk assessment

Design elements considered

- Engine and propulsion machinery configuration (redundancy for autonomous operation)
- Design speed (low service speed Spanish case)
- Superstructure longitudinal position (midship bridge)
- Open top hull (hatch coverless)
- Cargo handling (in DP mode, without mooring lines)

Preliminary hazard identification and risk assessment

12 identified hazards, 9 “Remote“ or “Reasonably probable”.

2 hazardous events are expected to occur more frequently during the ship’s lifetime:

1. Position of the container crane on board impedes operation of port cranes: The feeder vessel is expected to be (un)loaded using the port cranes once or twice a week.
2. Water accumulates in cargo hold in harsh weather conditions due to open top design: The innovative feeder and particularly the designs for the Greek case are expected to be exposed to extreme weather (i.e. high waves and wind) during the summer and winter months.

Frequency	F (per year)
Frequent	1
Reasonably probable	0,1
Remote	0,01
Extremely remote	< 0,01

Cost calculation

- Ship related costs
  - Port taxes
  - Vessel pilotage
  - Port tugboats
  - Mooring/unmooring
  - Vessel generated waste collection service tariff
- Container related cost
  - Stevedoring in the Pireaus port (outbound/return trip)
- Maritime link costs
  - Time charter vessel cost
  - Bunker consumption cost
- Land link costs
  - Local haulage in the destination islands

Innovative Feeder Vessel Design

- Cost calculation
  - Greek case, more expensive, but with carbon tax likely cheaper in the future*

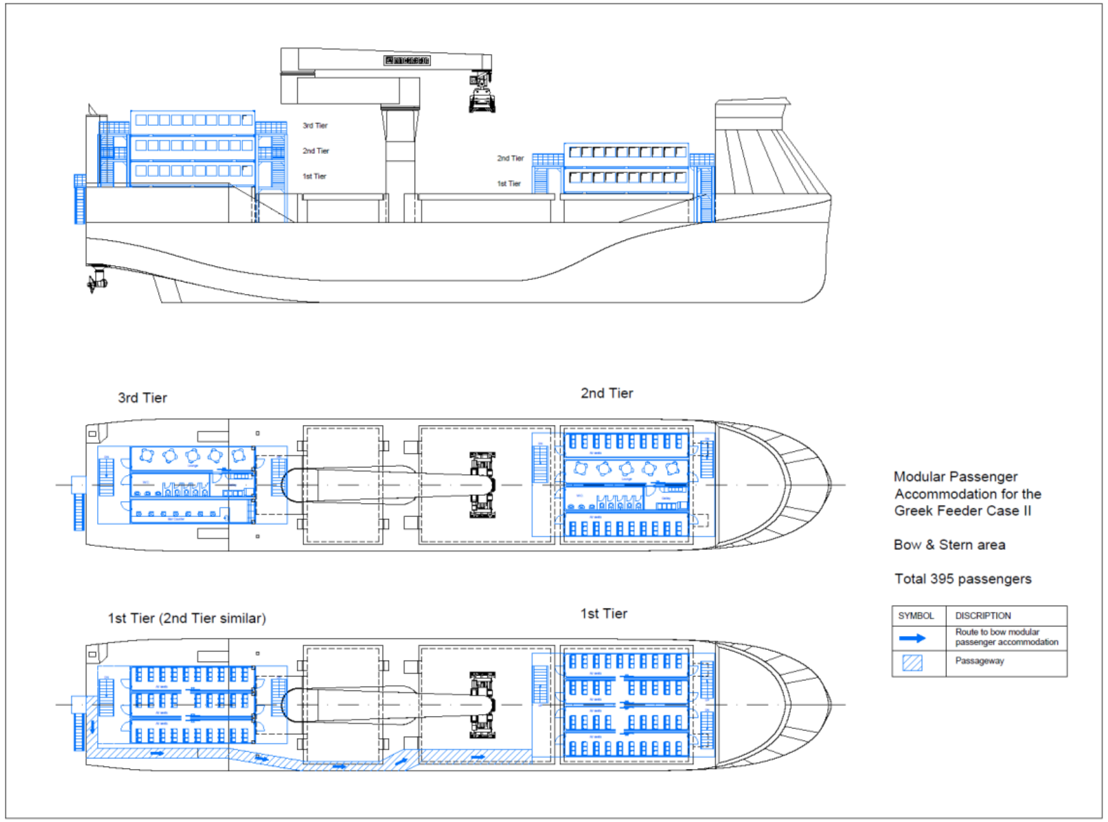
Item	Conventional vessel (€/TEU)	Innovative vessel (€/TEU)
	Case II	Case II
Bunker consumption cost	23.31	58.65
TOTAL	**269.6**	**304.94**

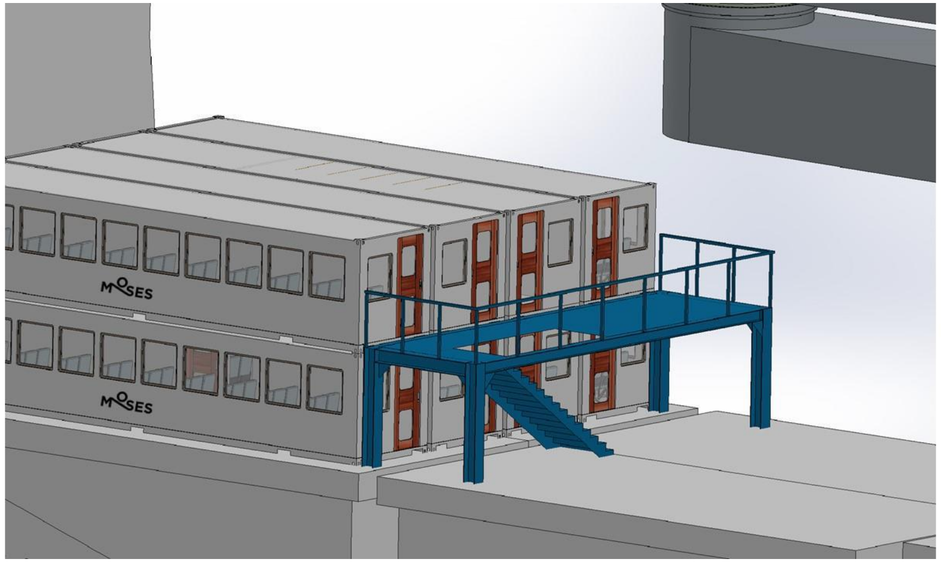
  - Spanish case, cheaper, due to autonomous operation, there are no cost for pilotage and the use of tugboats

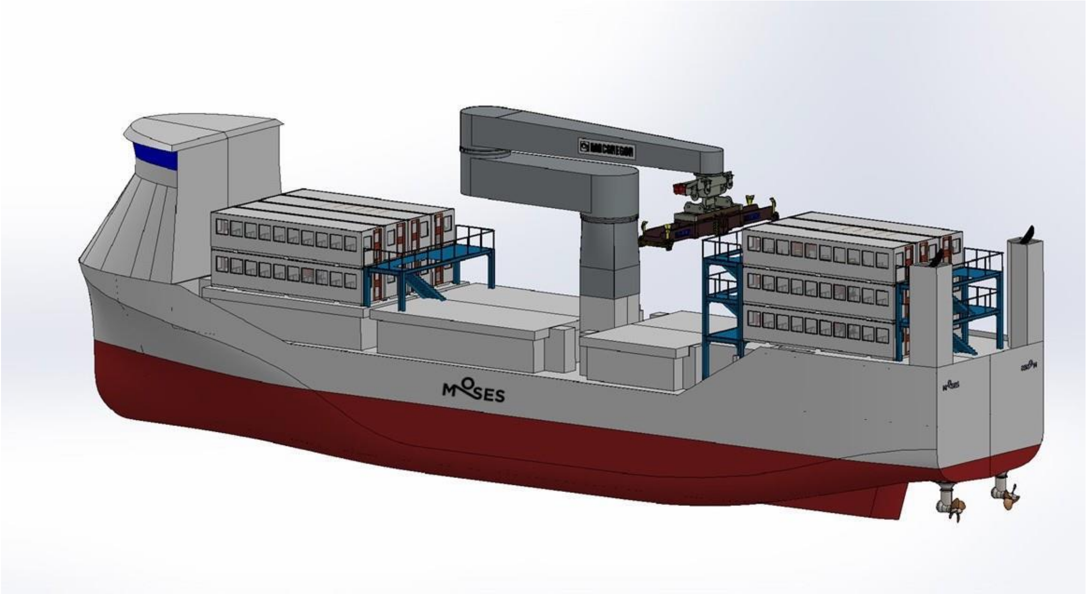
Item	Conventional vessel (€/TEU)	Innovative vessel (€/TEU)
Port tugboats	7.49	0
Bunker consumption cost	1.63	4.71
TOTAL	**192.12**	**171.36**

*conclusion in 2021

Passenger vessel



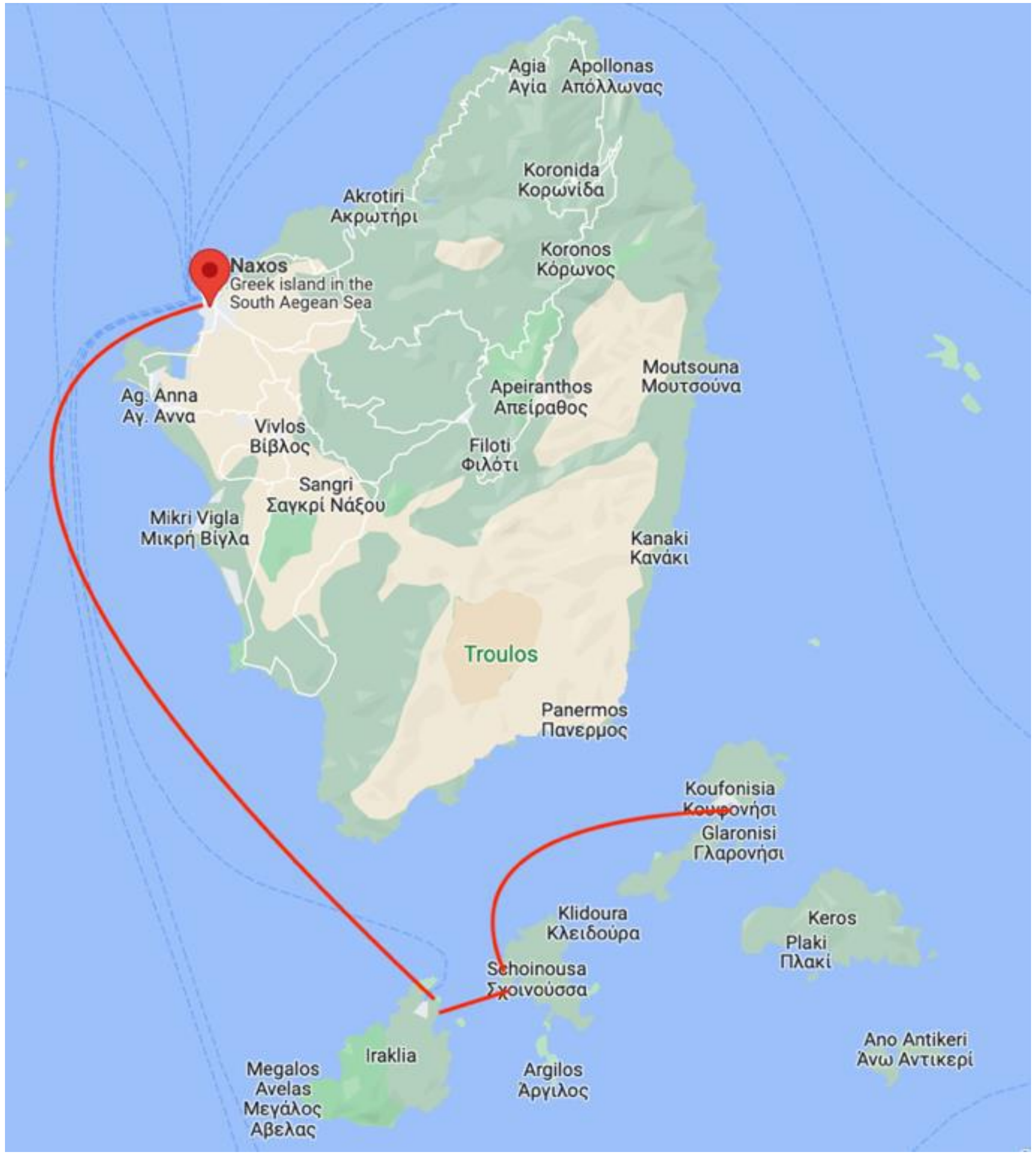




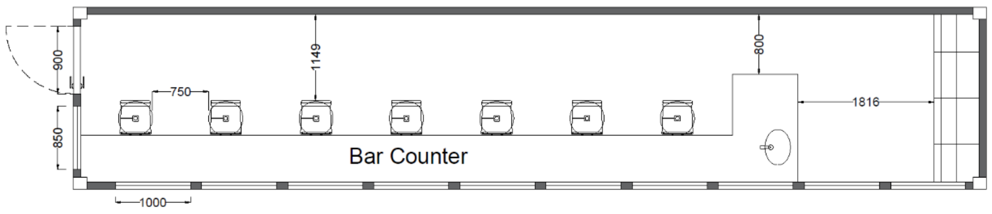
Modular concept

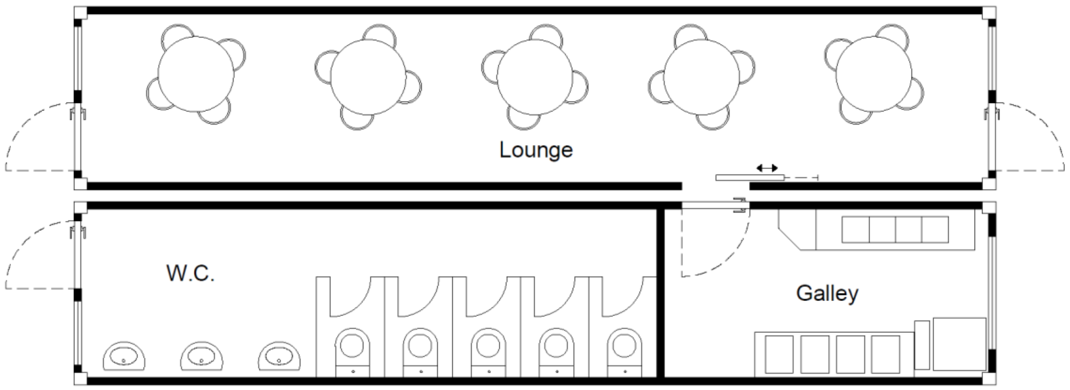
The route

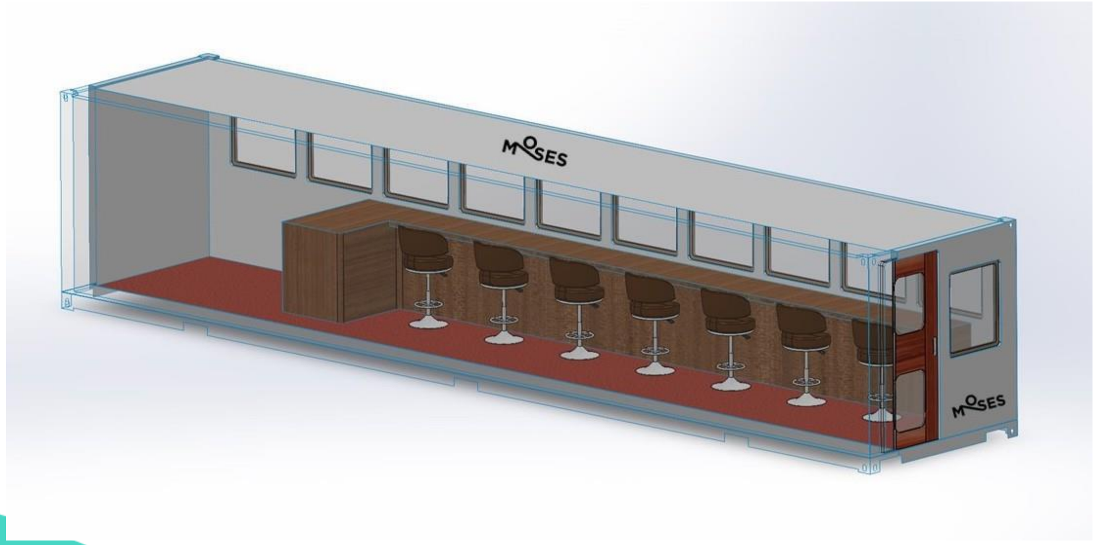
- Case study
  - Nasxos – Irakleia - Schinoussa - Koufonosia

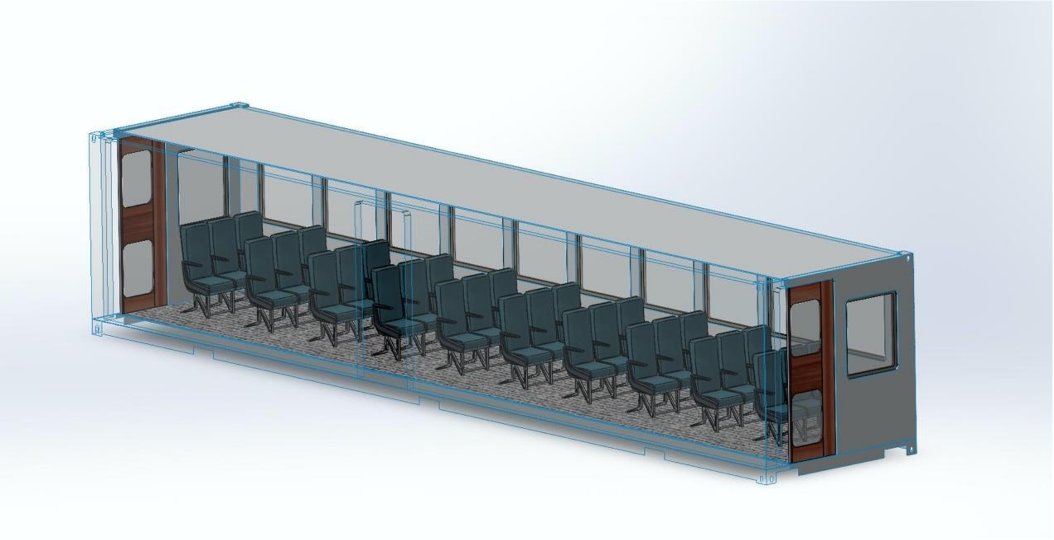


Inside view


900
850
750
1149
800
1816
1000
Bar Counter


Lounge
W.C.
Galley


MOSES
MOSES



Questions?

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Thank you for your attention!

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