Project GILJM
Windfarm support vessel
Final presentation

Principles of Naval Architecture – MEC-1004

Crew

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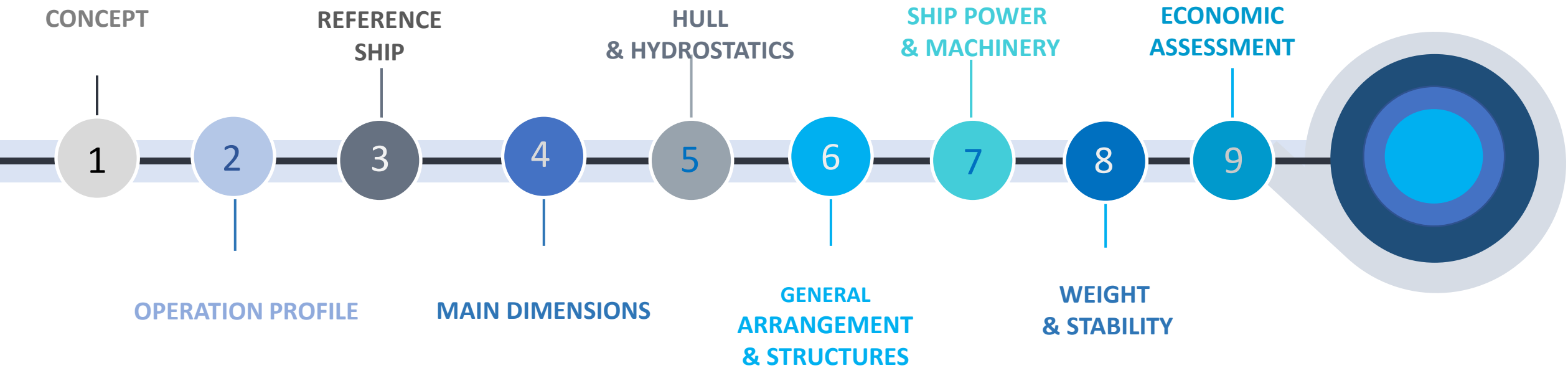
Lukas Schlichting

THE CONCEPT

Service Operation Vessel

- Offshore wind turbine maintenance
- Stability & positioning
- Personnel accommodation & comfort

Challenges

- Wind, waves, currents
- Alternative fuel
- Compact & efficient design
- Special equipment

Future-proof

- Offshore wind market is growing
- Core of the EU Green Deal
- Net zero emissions
- EEXI

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Wind of Change Borkum ©Augustin Vandenhove

OPERATIONAL PROFILE

Home ports:

- Emden (DE) or Esbjerg (DK)

North Sea wind farms, Denmark and Germany sector

- Walk to work distance ca 80 nm
- Cruising eco speed 10 kn
- Dynamic Positioning most of the operations
- Endurance min. 14 days

Accommodation of 40 technicians, 20 crew members in single cabins
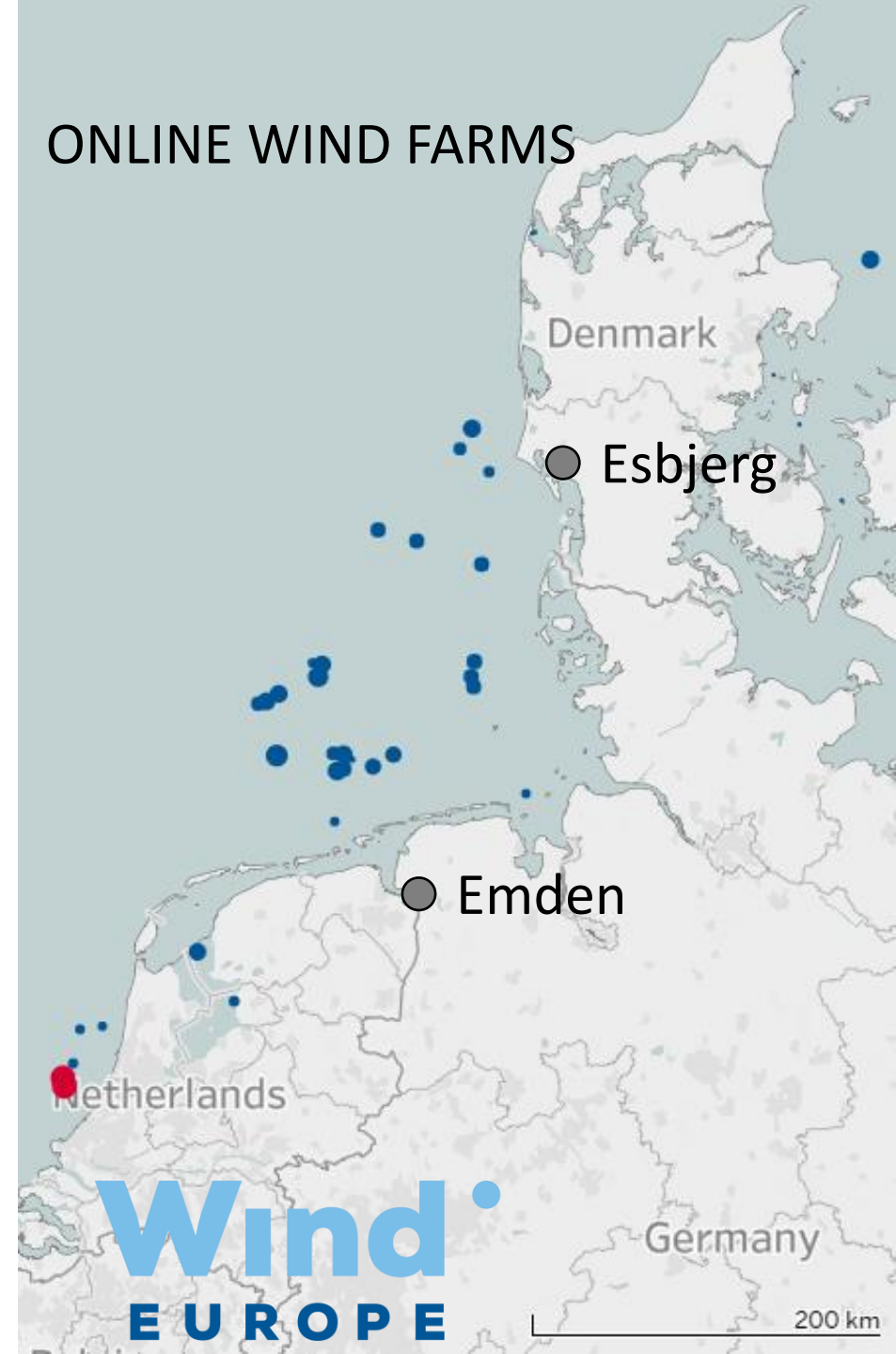
Depending on the season mean significant wave height varies 1.0-2.5 m

- Good Dynamic stability
- Advanced propulsion and positioning machinery
- Astern positioning

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ONLINE WIND FARMS

Denmark

○ Esbjerg

○ Emden

Netherlands

Wind
EUROPE

Germany

200 km

MAIN DIMENSIONS

Reference vessel:

- Wind of Change
- 2019 Cemre Shipyard, Turkey

Main dimensions:

- LOA = 76.5 m
- LPP = 68 m
- LWL = 72,1 m
- B = 17,7 m
- T = 5 m
- Displacement Volume: 4601 m^3
- Displacement weight: 4716 tons
- C_b = 0,721

HULL FORM

Hull form coefficients are in in accordance with or within the recommended value ranges.

Stability in waves and station keeping
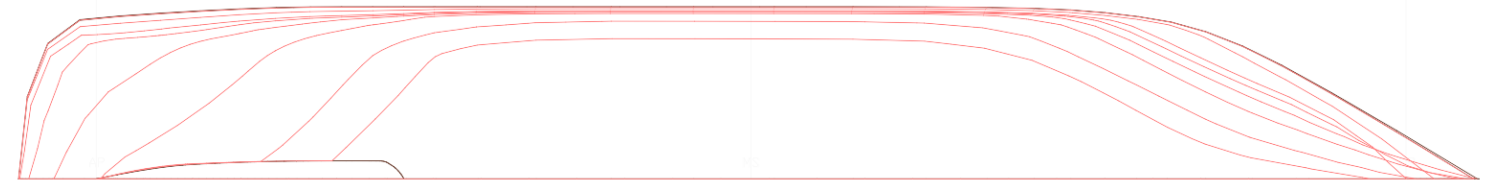
- $C_{WP} = 0.87$

Space onboard

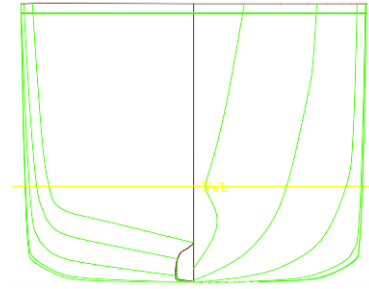- $C_B = 0.7$, B = 17.6 m, D = 14 m

Hydrodynamic & propulsive efficiency

- Fn = 0.23, $C_P = 0.74$, $C_M = 0.95$

Building cost

- Compact design
- Simpler geometry

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HYDROSTATICS
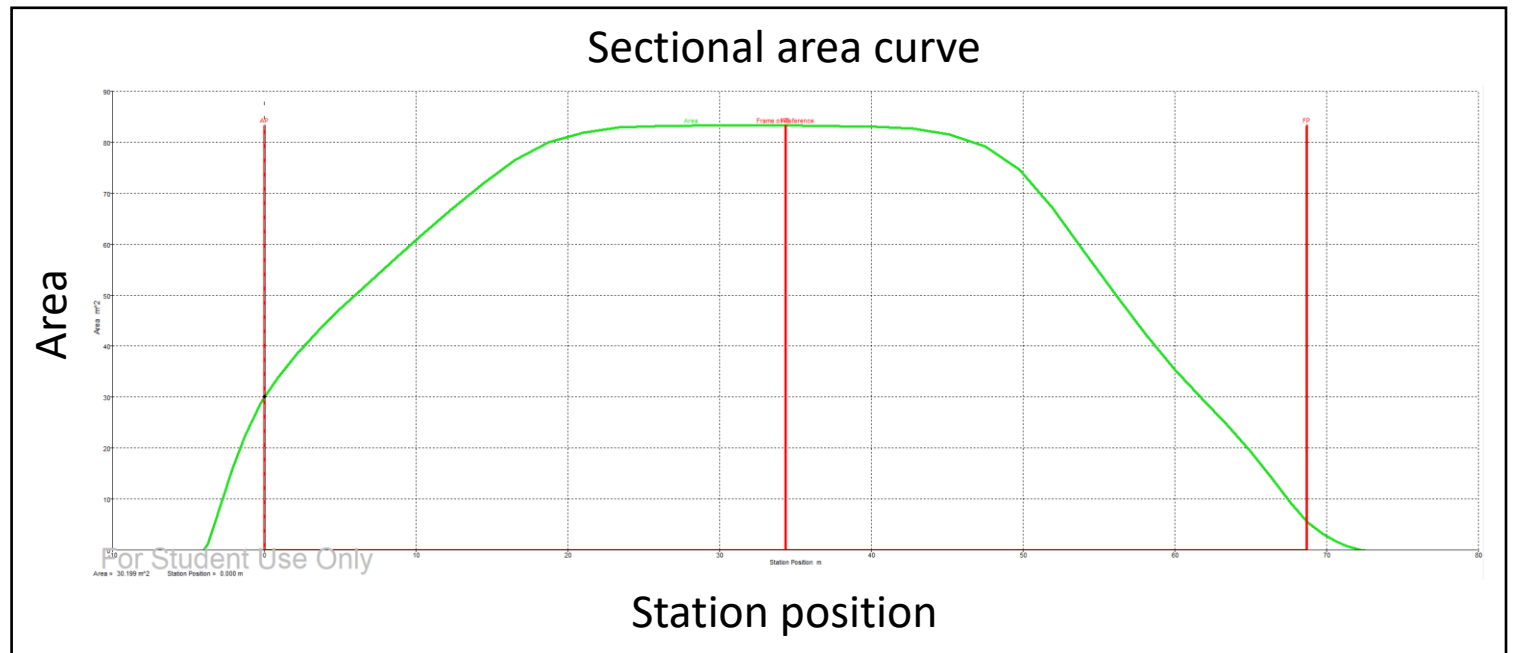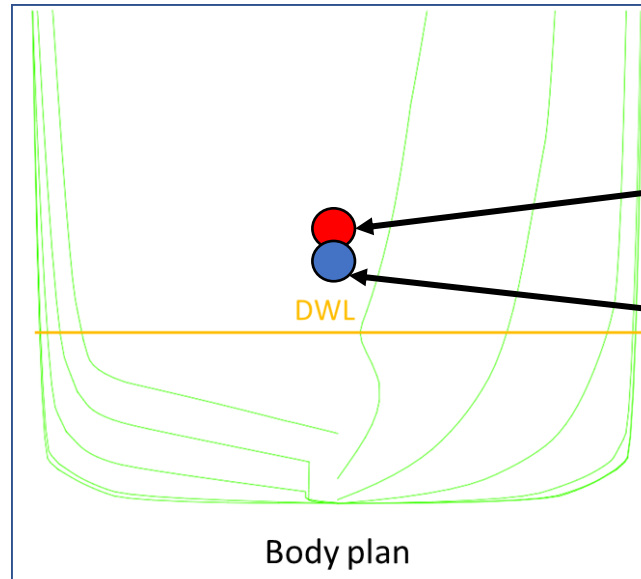
Intact stability

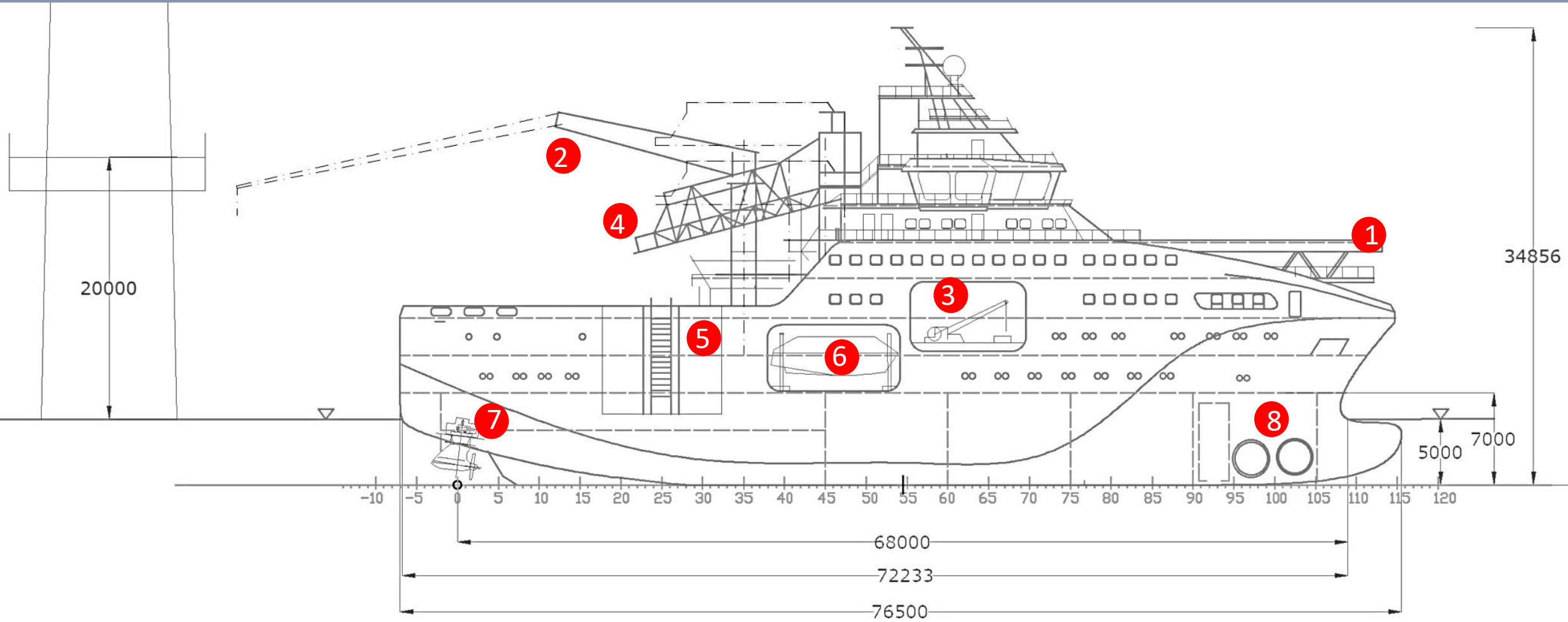- Find metacenter,
- Transversal stability – roll

Sectional area curve

- LCB -2%, shifted to aft

Hydrostatic curves

- Draft change effect on
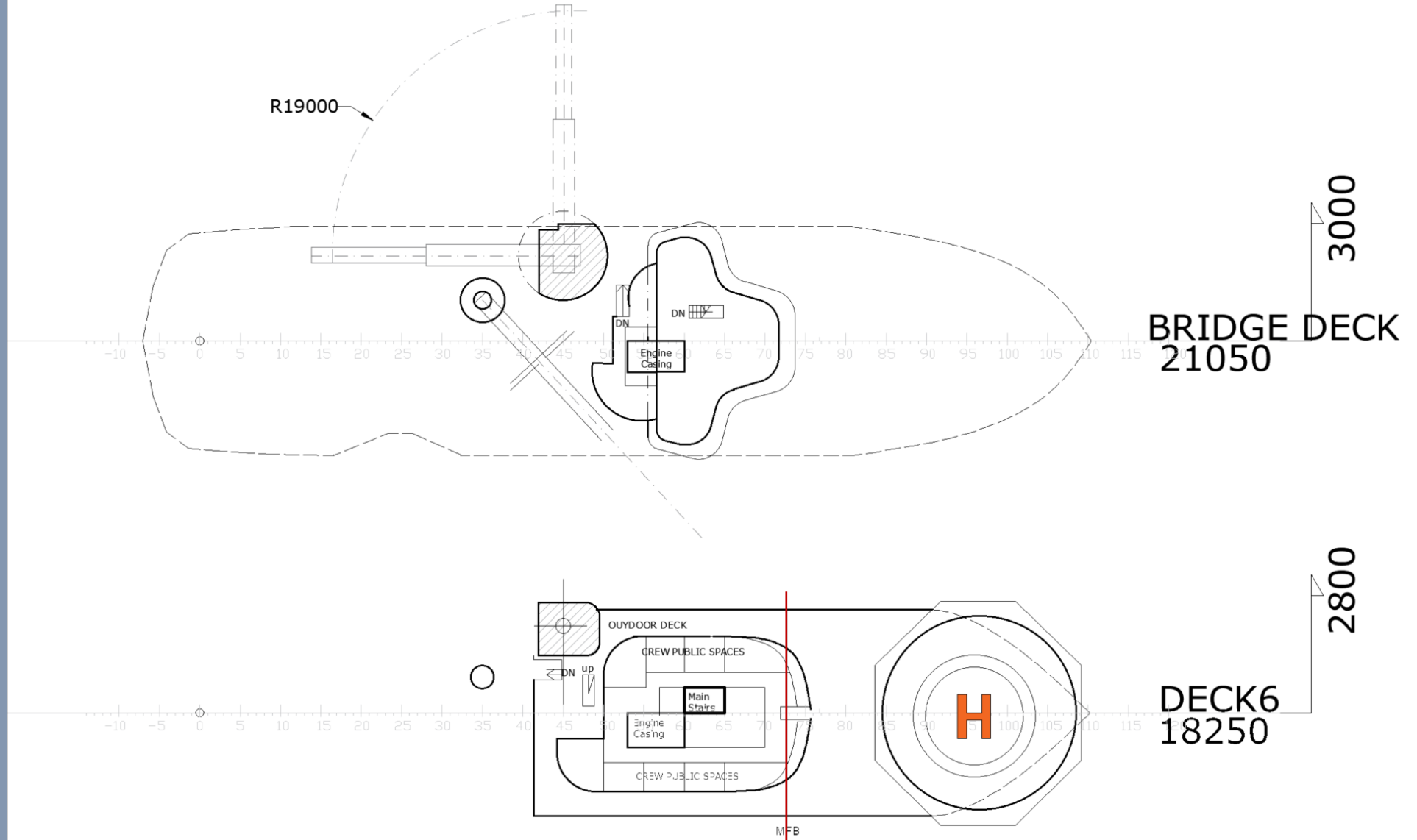 - Displacement
  - Stability
  - Floating position

Body plan

Metacenter$_t$ 8.35 m from keel

Lightweight CG 7.59 m from keel

Metacentric height GM = 0.76 m

Sectional area curve

GA / Profile

CRANE

GANGWAY

BATTERY ROOM

BRIDGE

CREW PUBLIC

CREW CABIN

CREW CABIN

CREW PUBLIC

HELIDECK

OUTDOOR DECK

CREW PUBLIC

CASING

MAIN STAIRS

CREW PUBLIC

CREW PUBLIC

CREW PUBLIC

MOORING DECK

CREW PUBLIC

CREW PUBLIC

CREW PUBLIC

CREW PUBLIC

CREW PUBLIC

ESCAPE

CREW CABIN

CREW CABIN

CREW CABIN

CREW CABIN

BOSUN STORE

ESCAPE

CREW PUBLIC

CREW CABIN

CREW CABIN

CREW CABIN

ESCAPE

CREW CABIN

CREW CABIN

CREW PUBLIC

ESCAPE LAUNDRY

ESCAPE

TECHNICAL SPACES

TECHNICAL SPACES

TECHNICAL SPACES

TECHNICAL SPACES

THRUSTER ROOM

ENGINE ROOM

SWITCHBOARD ROOM

20000

34856

26650
2600 TOP DECK 24050
3000 BRIDGE 21050
2800 DECK 6 18250
2800 DECK 5 15450
2800 DECK 4 12650
2800 DECK 3 9850
2800 DECK 2 7050
2900 DECK 1 4150
3300 TANKTOP 850
850

7000
5000

−10 −5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120

MFB

MFB

68000

72233

76500

Crew Public Area   Crew Accommodation Area   Technical Spaces   Escape   Engine Casing

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GA

Bridge Deck

- Bridge

DECK 6

- Helideck
- Crew public areas
- Gangway entrance platform
- Outdoor crew deck

![Aalto University School of Engineering logo]

R19000

BRIDGE DECK
21050

3000

DN

DN

Engine
Casing

DECK6
18250

2800

OUYDOOR DECK

CREW PUBLIC SPACES

DN   up

Main
Stairs

Engine
Cas'ng

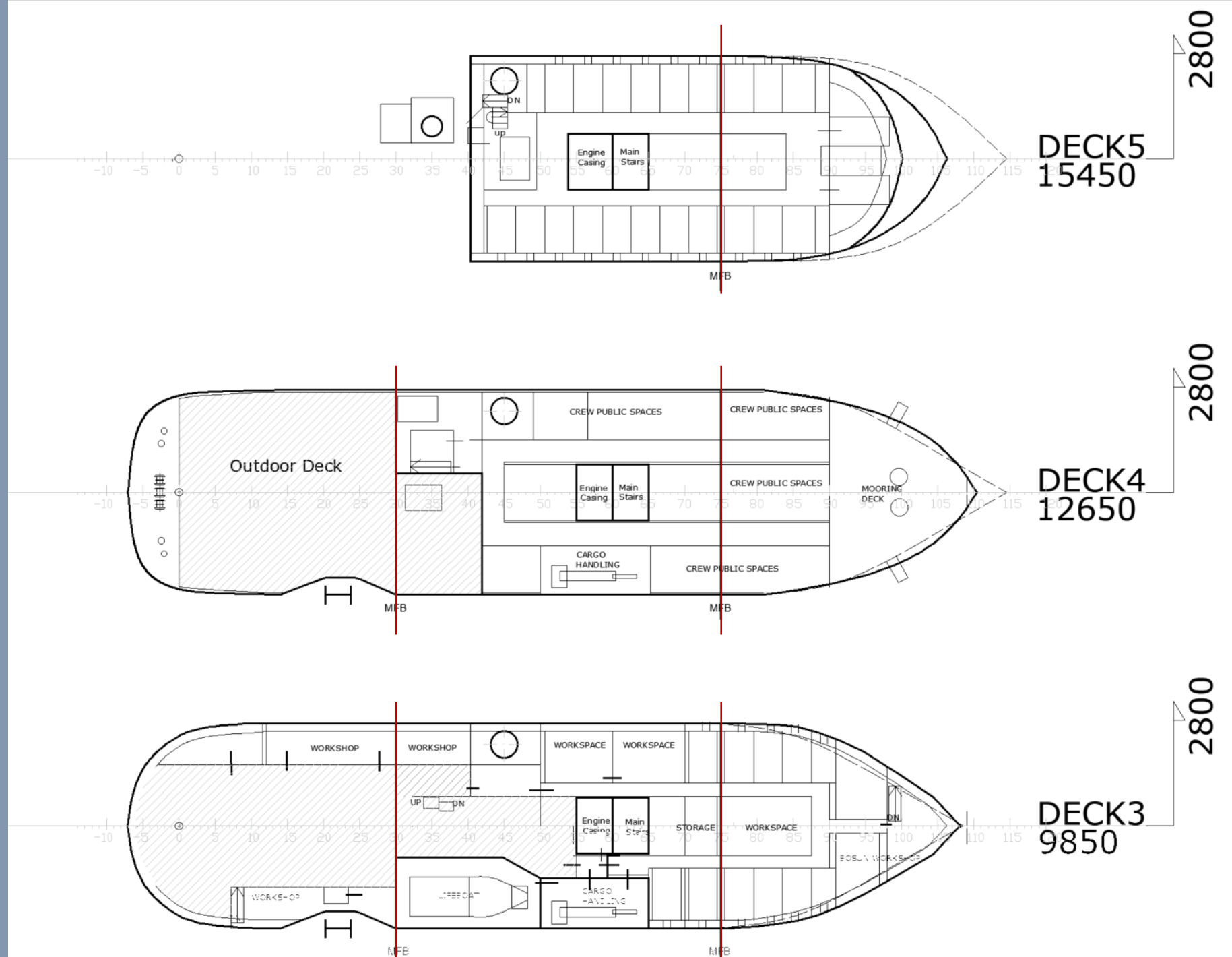CREW PUBLIC SPACES

H

MFB

GA

DECK 5

- Crew Cabins (20)
- Technical Space
- Storage

DECK 4

- Mooring deck
- Crew public areas
- Storages / Provisions
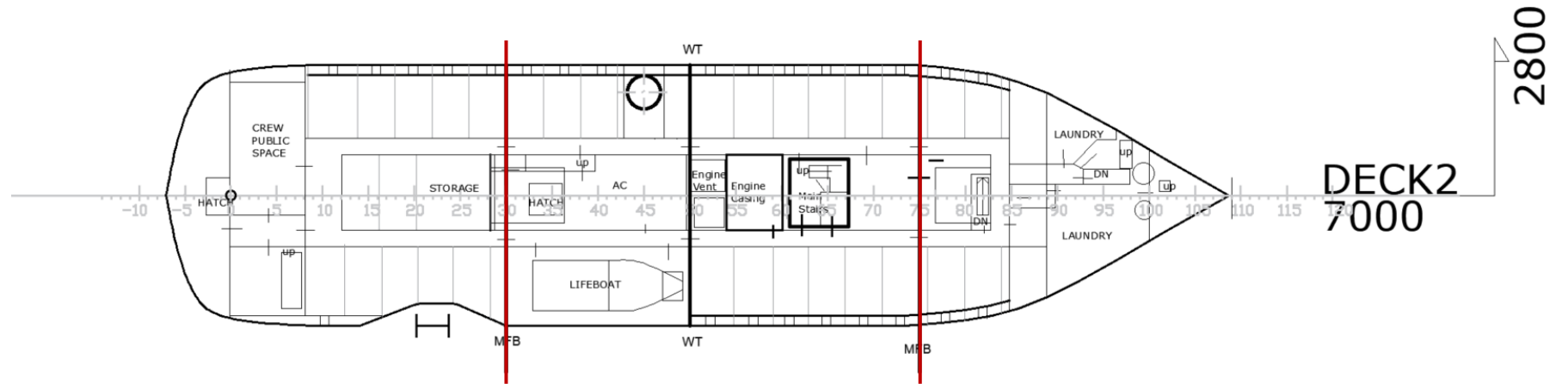- Main outdoor loading deck
- Cargo handling crane

DECK 3

- Crew Public Spaces
- Crew Cabin (10)
- Storages / Provisions
- Main Indoor Working Deck & Workshops
- Life-saving Appliances

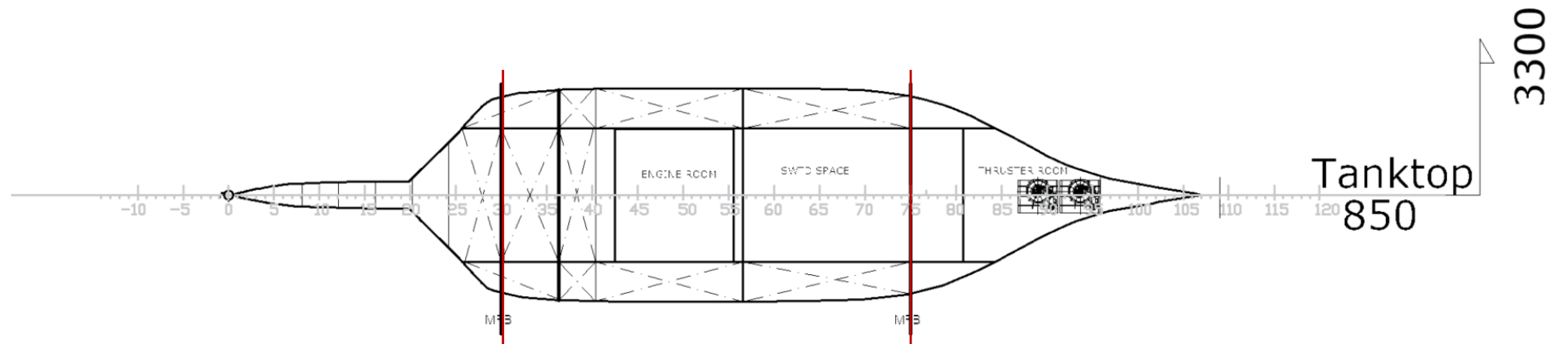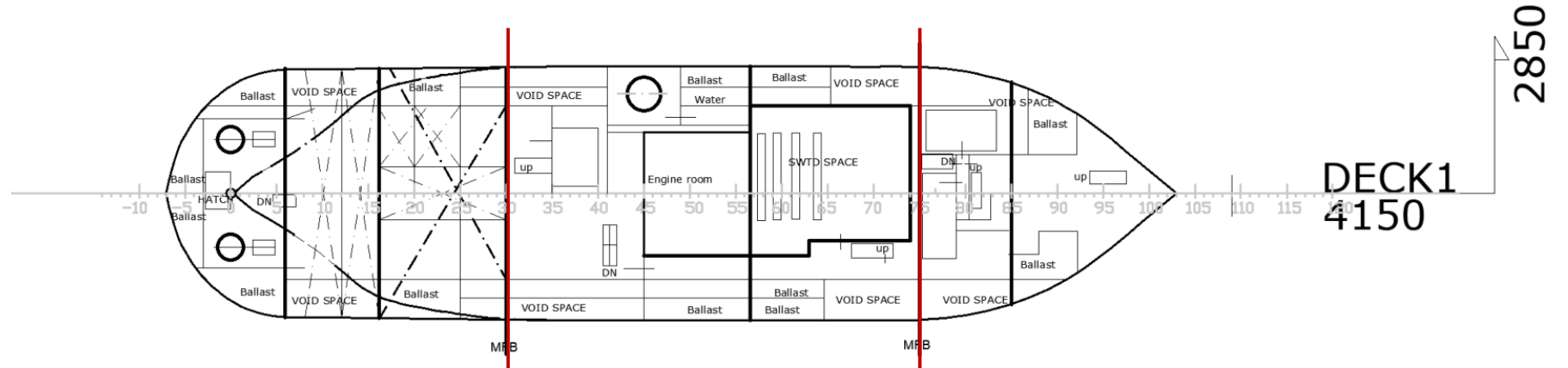**Aalto University
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GA

DECK 2

- Crew Cabins (30)
- Crew Public Areas
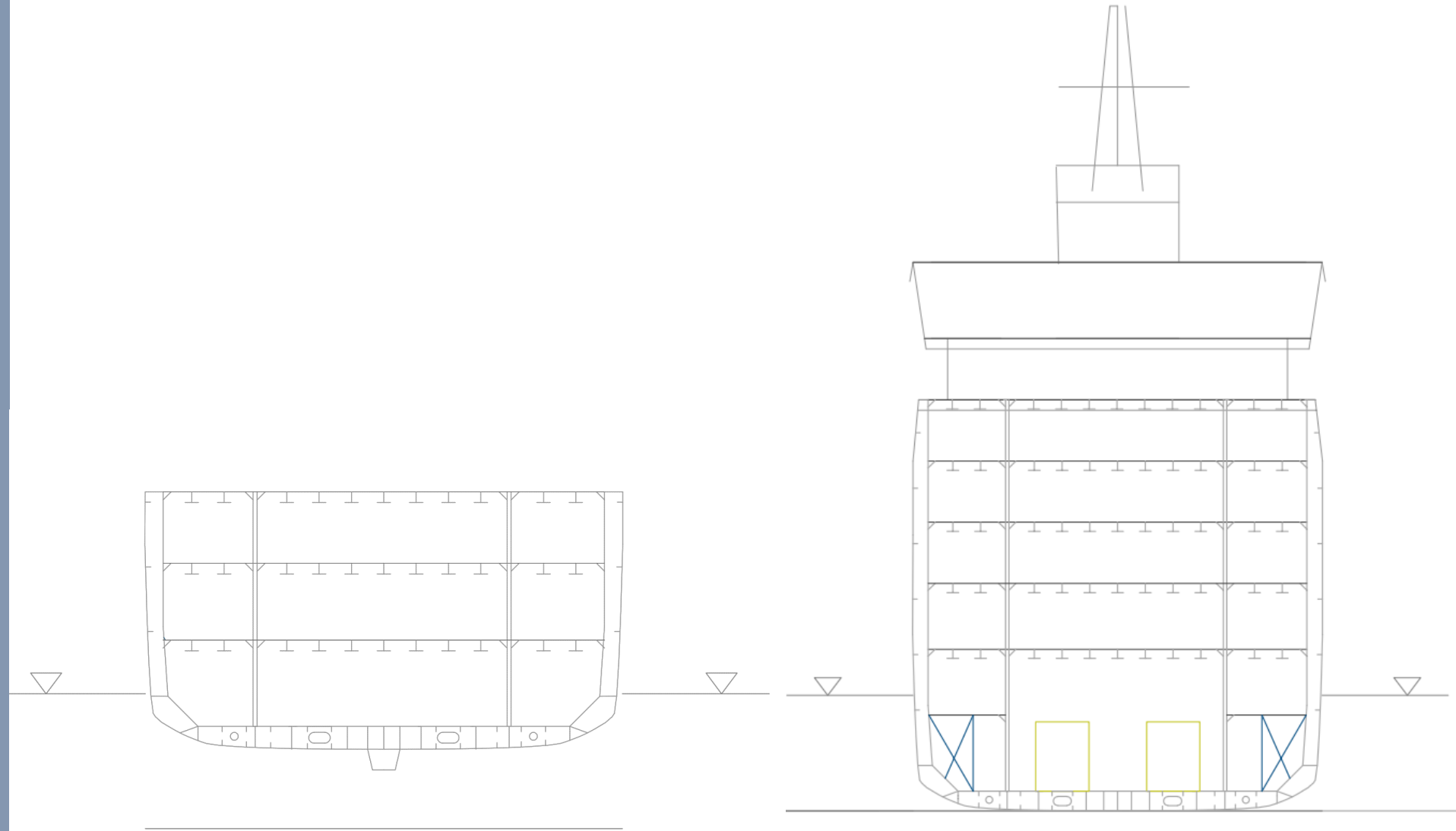- Storages / provisions
- Laundry
- Lifeboat

DECK 1 & Tanktop

- Engine Room
- Switchboard Room
- Boilers & technical spaces
- Thruster room
- Ballast , fuel tanks, and other tanks

STRUCTURE

- Longitudinal and transverse stiffening
- Increased aft deck platting
- Structural continuity considered.
- Wide open spaces near the centerline.

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SHIP POWER & MACHINERY

- Generators: 4x 1600 kW + 300 kW Auxiliary
  - Fuel: methanol / Diesel

- Batteries: 2x 200 kWh

- Dynamic positioning DP-2 → 2x 1850 kW Voith propellers + 2x 700 kW bow thruster

14 Day Operating Profile
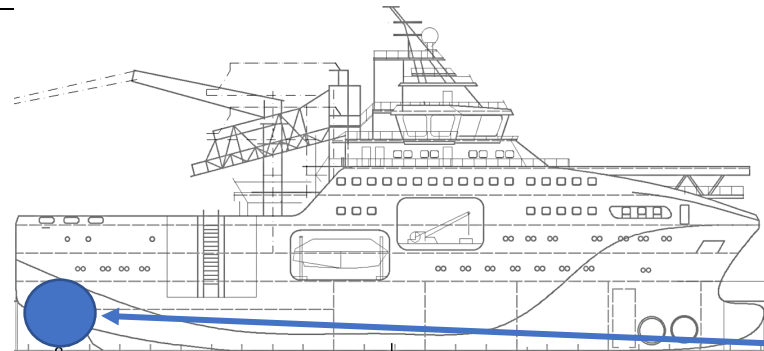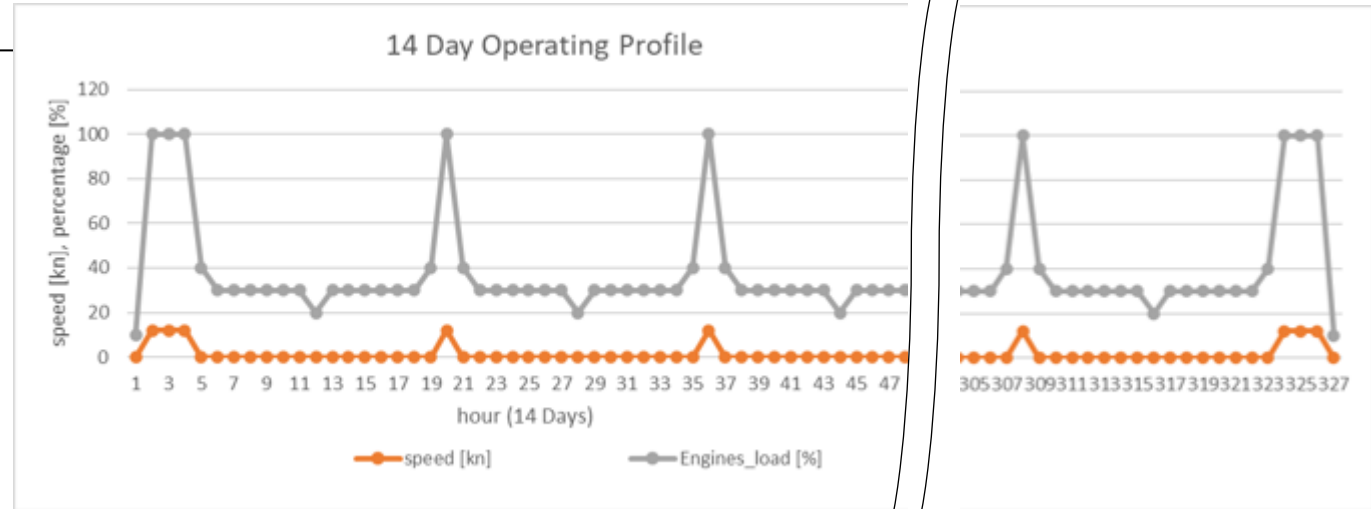
SPECIFIC EQUIPMENT

- Deck Cranes:
    - 1 x motion compensated offshore crane. ⟶ 60 m·t
    - 1 x HEILA offshore crane ⟶ 20 m·t
    - 1 x HEILA offshore crane ⟶ 2 m·t

- Motion compensated Gangway:
    - Ship – Wind turbine distance ~ 16 m
    - For waves up to 2.5 m

Methanol

Selected energy densities
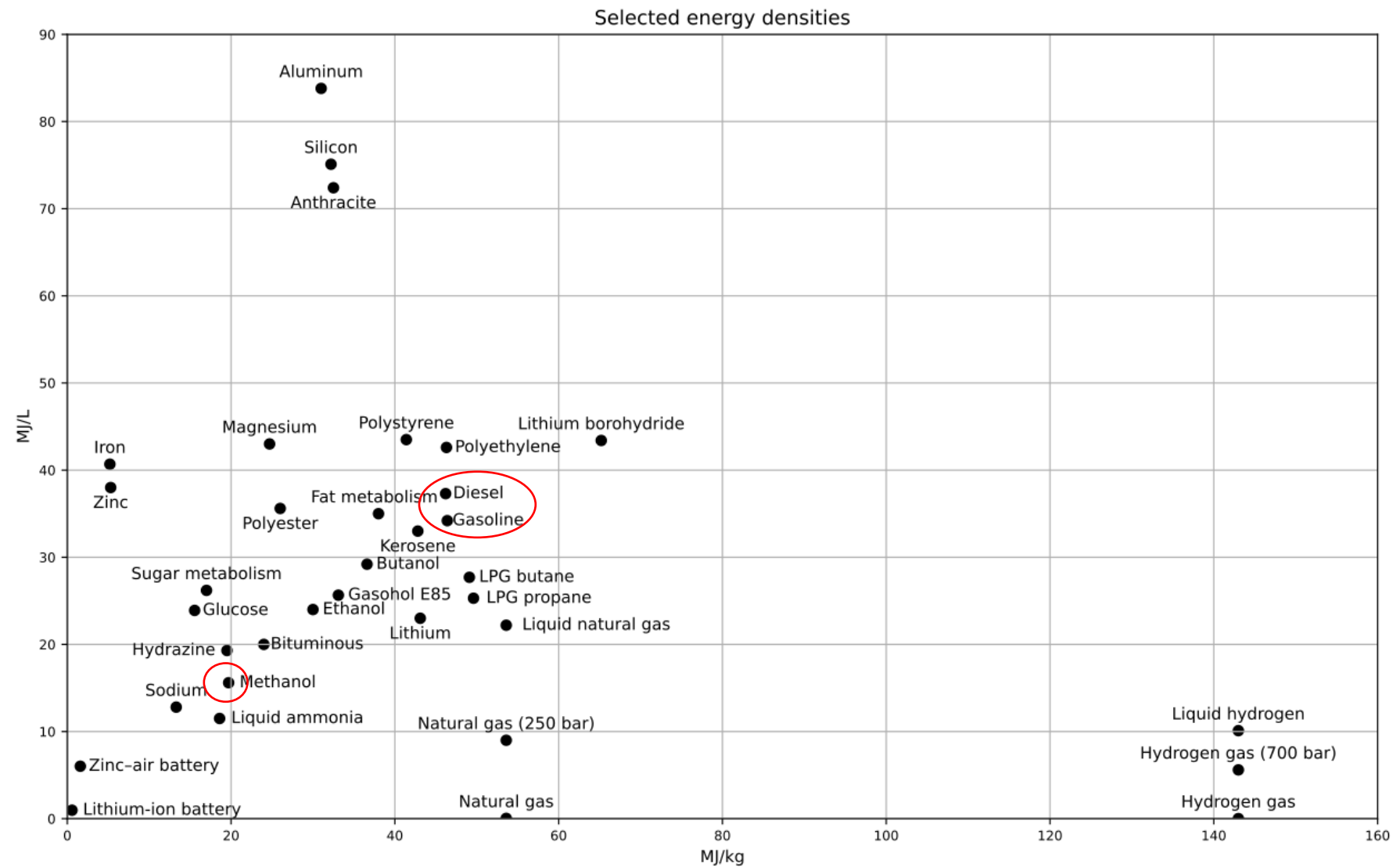
Energy density: 11 − 17.4 kWh/l

$E_{tot} = E_p + E_{aux} \approx \mathbf{221\ MWh}$

$V_{methanol} = \mathbf{42\ m^3}$

Weight & Stability

DWT

DWT		1650 ton
W_{Fuel}	$42\ m^3 * 792\ \dfrac{kg}{m^3}$	34 ton
$W_{Freshwater}$	$\dfrac{0.17t}{person *\ day} * 60\ \text{person} * 14\ \text{day}$	142.8 ton
$W_{Crew\&Effects}$	$\dfrac{0.17\ t}{person} * 60\ \text{person}$	10.2 ton
$W_{Provisions}$	$\dfrac{0.01\ t}{person\ *\ day} * 60\ \text{person} * 14\ \text{day}$	84 ton
W_{Cargo}		1379 ton

Weight & Stability

Lightweight
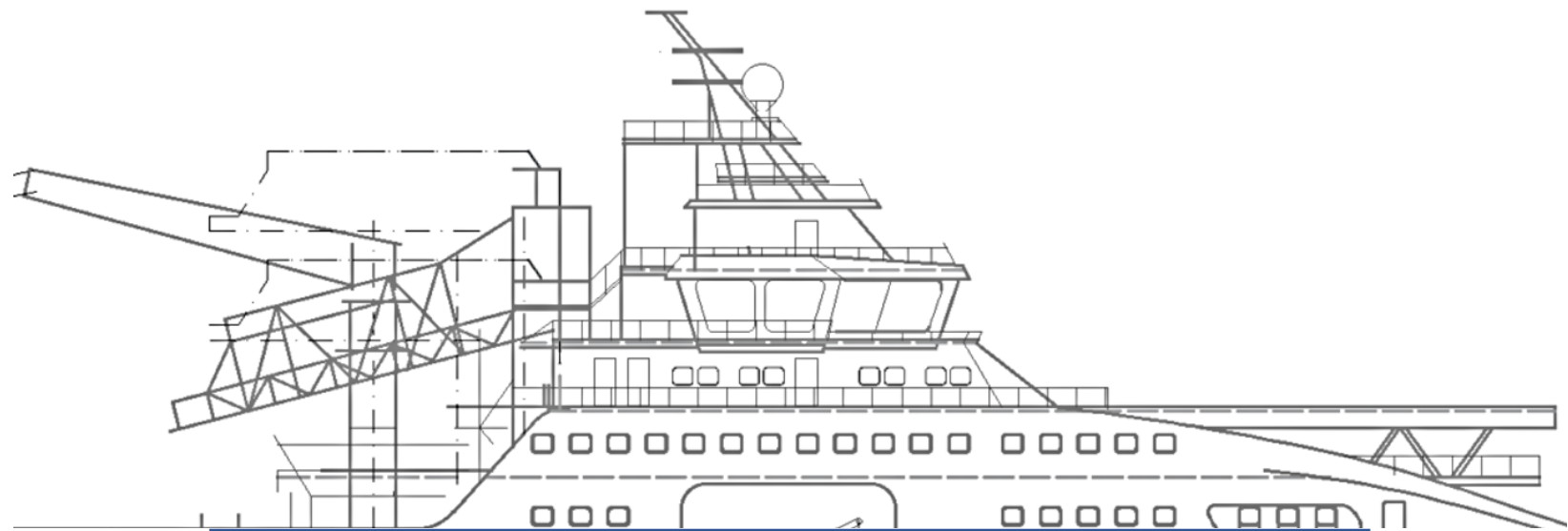
Structural weight	
Length of superstructure (m)	52.621
Height of superstructure (m)	7.21
Length of deckhouse (m)	15.32
Height of deckhouse (m)	12.942
WS (tonne)	**2121**

Machinery weight		Outfitting weight	
No of engines	4	W_o **(tonne)**	**844**
Height of double bottom (m)	0.9		
Height of engine room (m)	6.146		
W_M **(tonne)**	**474**		

Lightship Weight	
3439	

ECONOMICAL ASSESSTMENT

ESTIMATED SHIP COST: 50.000.000 eur

Return of investment: 12 years

NET PRESENT VALUE:

ANNUAL REVENUE: 17.822.500 eur

NPV: 8.429.723 eur

ANNUAL COSTS: 10.000.000 eur

Worldwide Installed Offshore Turbines

(# of turbines)

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
7,233	8,257	9,663	11,029	12,861	15,075	17,258	19,527	22,057	24,412	26,901
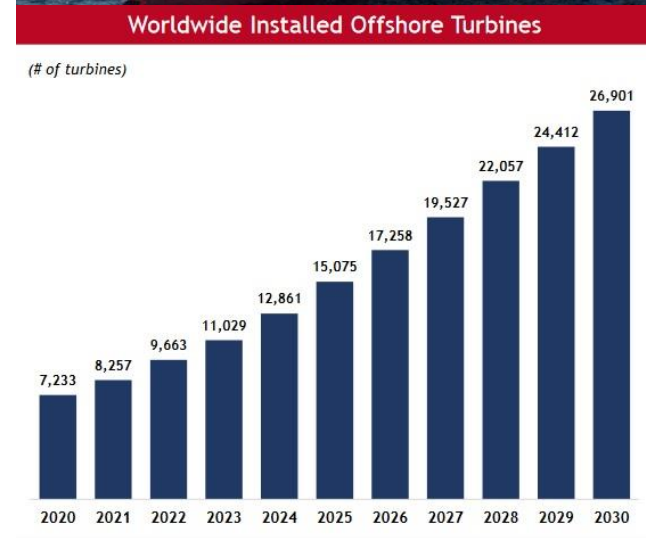
Offshore wind turbine installations are projected to increase by 270%.

Thank you

Project Schedule

		W36	W37	W38	W39	W40	W41	W42	W43	W44	W45	W46	W47	W48	W49	W50
1	Ship concept	■	■													
2	Reference ship data		■													
3	Main dimensions		■	■												
4	Hull form			■	■											
5	Hydrostatics				■	■										
6	General Arrangement						■	■	■							
7	Ship Structures								■	■						
8	Ship Power & Machinery									■	■					
9	Weight & Stability										■	■				
10	Economic Assesment											■	■			
11	Final presentation												■	■		
12	Final report														■	■

SFI / Main components system of ship

1. General
(Details and costs that cannot be charged to any specific function on board)

1.1 Specification
1.2 General arrangement
    1.2.1 Cabin arrangement
        1.2.1.1 Crew cabin
    …
    1.1.2 Public Area
        1.1.2.3 Crew public area
    …
1.5 Quality assurance
1.6 Launching,
1.7 Dry-docking
1.8 Guarantee work

2. Hull Systems
(Hull, superstructure and material protection of the vessel)

2.1 Keel
    2.1.1 Material
    2.1.2 Main stiffeners
2.3 Double bottom
    2.3.1 Transverse stiffener
2.4 Structural bulkhead
2.5 Transverse stiffener
…
2.8 Light aluminum-alloy structures

3.Cargo Equipment
(Cargo equipment & machinery)

3.1 Loading/discharging systems
    3.1.1 Deck cranes
3.2 Cargo winches and hatches
    3.2.1 Cargo winches
    3.2.2 Hatches

4.Ship Equipment
(Ship specific equipment- and machinery.)

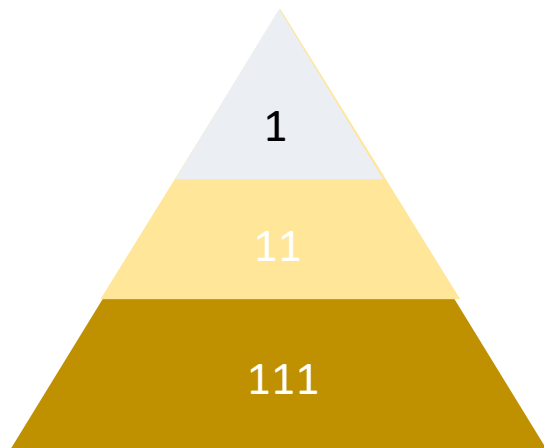**4.1** Navigational equipment
4.2 Maneuvering machinery
4.3 Anchoring equipment
4.4 Communication equipment
…
4.8 Special Equipment
    4.8.1 Gangway

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1 — General / **Primary Group / 1st digit**

11 — General Arrangement **/ Secondary Group / 2nd digit**

111 — Cabin Arrangement / **Tertiary Group / 3rd digit**

SFI provides a common plan of **technical account/codes** in the handling of:

- Specifications
- Estimates
- Drawings
- Purchase
- Material Administration
- Maintenance and Repair Planning
- Instruction Material
- Budgets and Cost Control
- Files

Code	Name	Hours	Materials
73	Compressed air systems		
731	Starting air systems	200	
731.001	Starting air compressor		$150,000
731.003	Starting air emergency compressor		$98,000
731.005	Starting air water/oil separator		$17,000
731.010	Starting air tanks		$33,000
731.012	Starting air bottles		$9,500
731.014	Starting air coolers		$12,000
731.016	Starting air compressor silencers		$5,000

Main components of ship according to SFI

G5:
Live saving boat
Live saving equipment
Crew cabin furniture
Common rooms
furniture
Sanitary systems
Kitchen equipment
Maintenance
equipment

G6:
4 generators
2 batteries
2 main engines
2 main propellers
2 bow thrusters
1 retractable bow thruster
Frequency converters
Energy distribution systems
boilers

G7:
Fuel
Lubrication oil
Wear parts (e.g. lubrication
filters)
Electrical wiring
Exhaust system for
generators
Control system
Generator starter system
Ventilation system
machinery room

G8:
- Water ballast system
- Water pumps for firefighting
  system
- Electrical distribution system
- Water system for crew
- Ventilation system for decks
- Mooring system
- Anchoring system
- Waterproof doors and
  hatches
- Evacuation system

Ship's lightweight estimation

Ship lightweight is divided in:

Structural weight			Machinery weight			Outfitting weight	
Length of superstructure (m)	52.621		MCR (KW)	1600		Co	0.62
Height of superstructure (m)	7.21		N (rpm)	750		W_o (tonne)	**843.9006**
Length of deckhouse (m)	15.32		type of plant	other		KG_o (m)	13.75
Height of deckhouse (m)	12.942		No of engines	4			
E	2707.059		cm	0.83			
K	0.045		W_M (tonne)	**473.890**			
WS (tonne)	**2121.24**		Height of engine room (m)	6.146			
KG_{hull} (m)	5.664		Height of double bottom (m)	0.9			
LCG_{hull} (m)	32.412		KG_M (m)	2.7361			

Ship's lightweight estimation

Ship's main characteristics	
L(m)	76,9
B(m)	17,7
T(m)	5
D(m)	12,5
CB	0,724
LCB(m) @AP (m)	32,562
Lightship weight	
3439,03	
KG_{Light}	
7,245	

Deadweight

Cargo

- **1731 ton**

Fuel

- $M_{methanol} = 40\ m^3 * 792\ \dfrac{kg}{m^3} = \approx \textbf{32 } \textit{\textbf{ton}}$

Fresh Water

- $W_{FW} = \dfrac{0.17\text{t}}{\text{person} \times \text{day}} * 60 \text{ person} * 14 \text{ day} = \textbf{142.8 ton}$

Crew and their effects

- $W_{C\&E} = \dfrac{0.17\ \text{t}}{\text{person}} * 60 \text{ person} = \textbf{10.2 } \textit{\textbf{ton}}$

Provisions

- $W_{PR} = \dfrac{0.01\ \text{t}}{\text{person} \times \text{day}} * 60 \text{ person} * 14 \text{ day} = \textbf{84 ton}$

- **TOTAL: 2000 ton**

Uncertainty estimation

- **Displacement: Lightweight** $+ Deadweight = 3439 + 2000 = 5439\ ton$

  - Hull shape displacement: 4716 ton $\longrightarrow$ Deadweight: 1277 ton

Uncertainty Margin:

$Lightweight + 5\% = 3611\ ton$ $\longrightarrow$ Deadweight for hull displacement: 1105 ton

Vertical center of gravity

Hull

$$VCG_H(L \leq 120 \text{ m})$$

$$= 0.01D \left(46.6 + 0.135(0.81 - C_B) \left(\frac{L}{D} \right)^2 \right) + 0.008D \left(\frac{L}{B} - 6.5 \right)$$

Machinery

$$VCG_M = h_{db} + 0.35(D' - h_{db})$$

Outfitting

$$VCG_O(L \leq 125 \text{ m}) = D + 1.25$$

Lightship

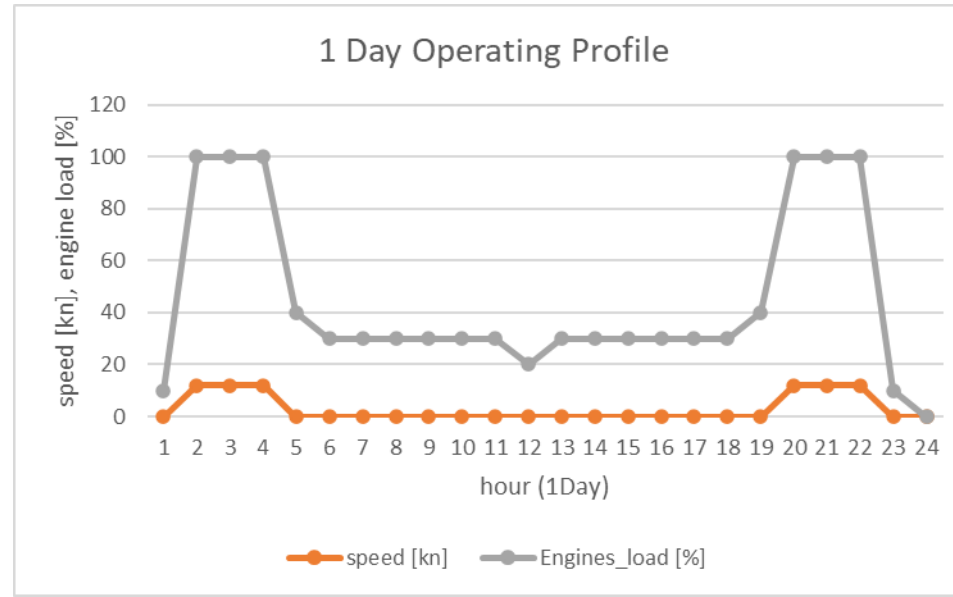$$VCG_{light} = \frac{W_S \cdot VCG_S + W_M \cdot VCG_M + W_O \cdot VCG_O}{W_{light}}$$

| Center of Gravity	
LCG$_{hull}$ (m)	32.412
KG$_{hull}$ (m)	5.664
KG$_M$ (m)	2.7361
KG$_o$ (m)	13.75
KG$_{light}$ (m)	**7.593**

Ship Operating Profile

1 Day of Operating

- Port Emden -> Gode Wind Farm: ~33 nm @ 12 kn ~ 3h
- 15 hours operating time
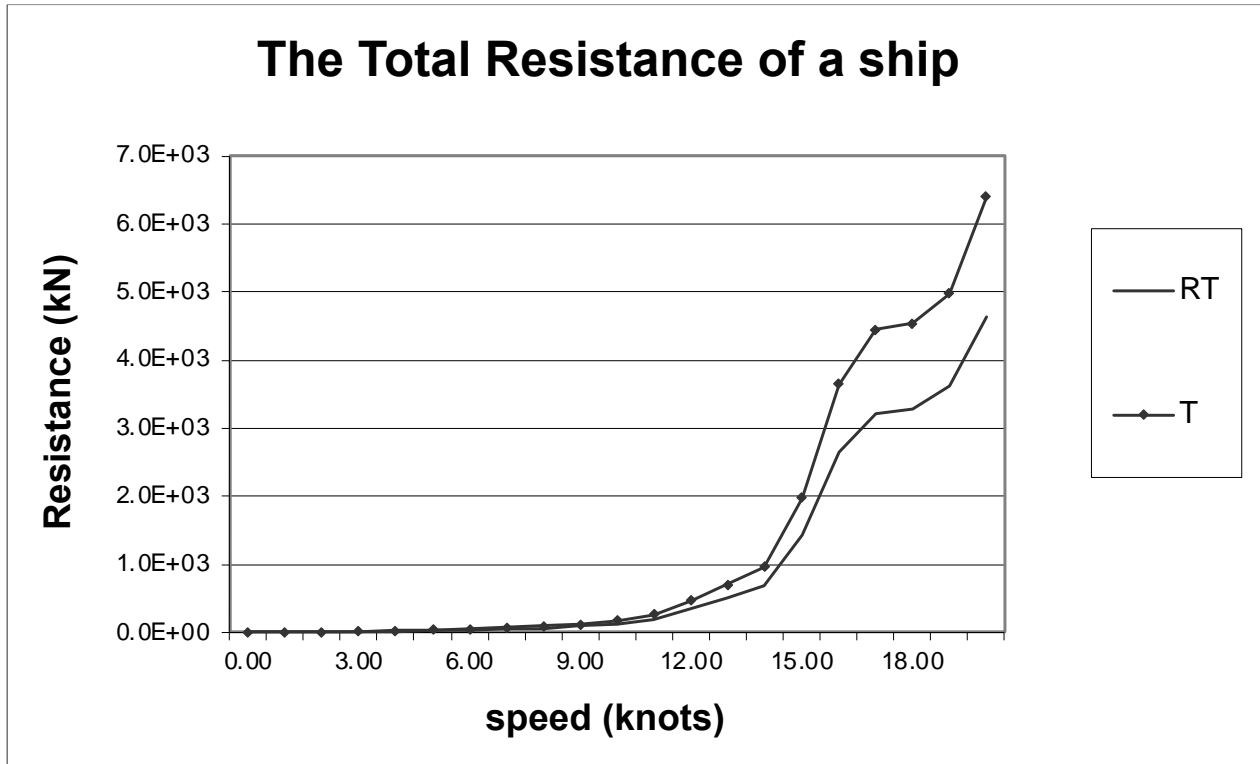- Gode Wind Farm -> Port Emden: ~ 3h

14 Days of Operating

- Port Emden -> Gode Wind Farm:
- Repeat:
  - 15 hours operating time
  - 1 hour travel time
  - 15 hours operating time
  - 1 hour travel time
  - ....
- Gode Wind Farm -> Port Emden
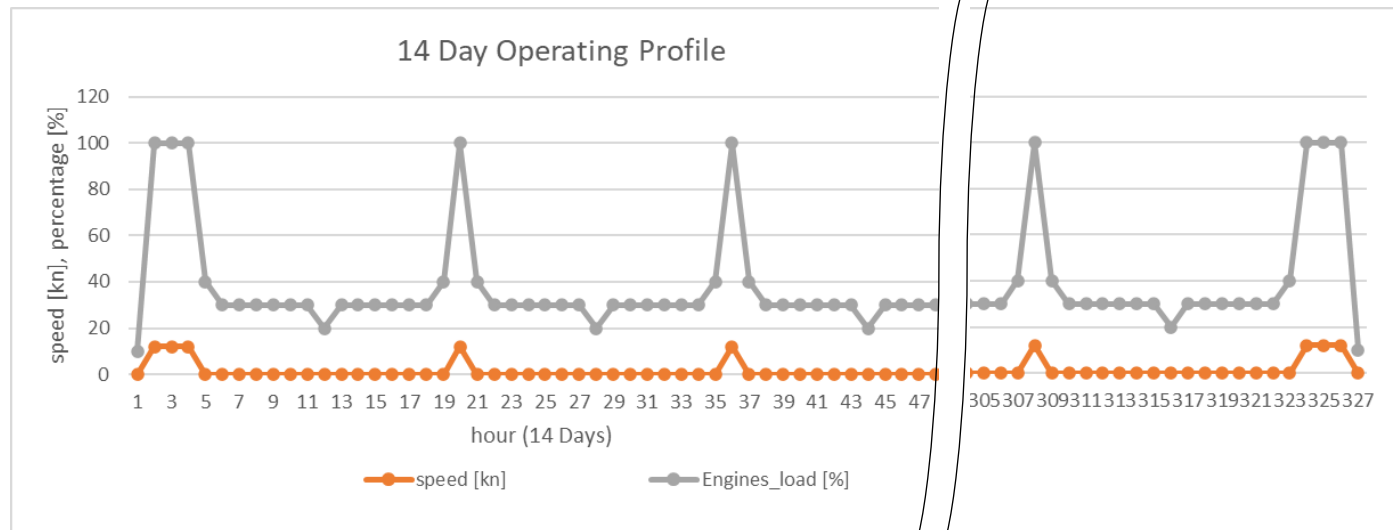
Resistance & Power Calculation

The Total Resistance of a ship

- Total Resistance @ 12 kn: 337 kN
- Shaft Power Demand @ 12 kn: 2460 kW

- If increase by 2 kn to 14 kn:
- Total Resistance @ 14 kn: 695 kN
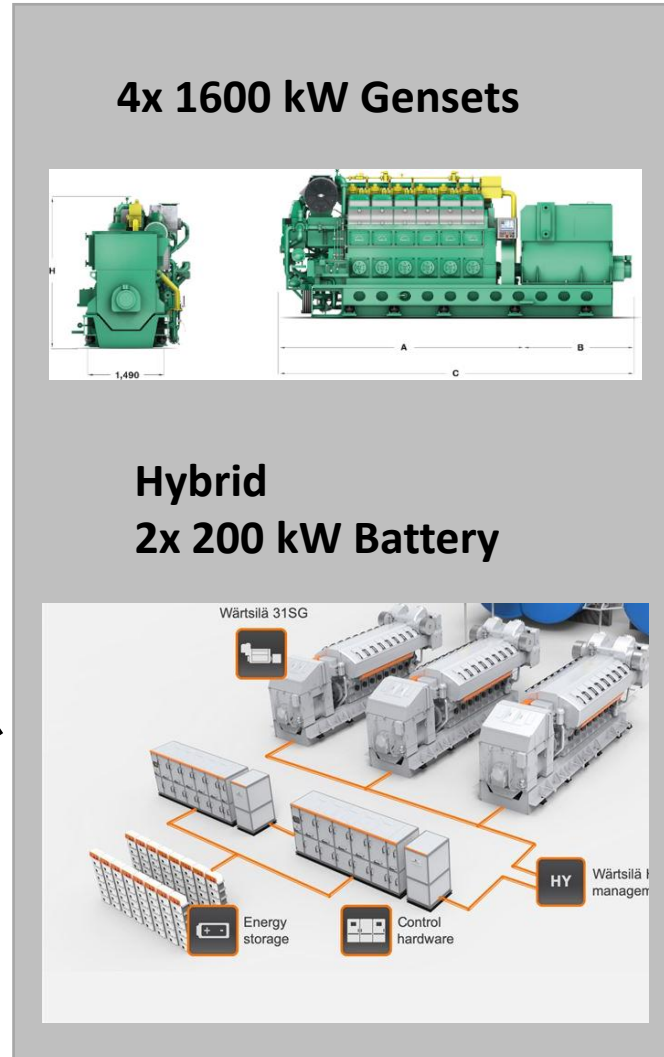- Shaft Power Demand @ 14 kn: 7000 kW

Reference Ship: Wind of Change:
- 4 x 1600 kW main propulsion -> ~ our power demand
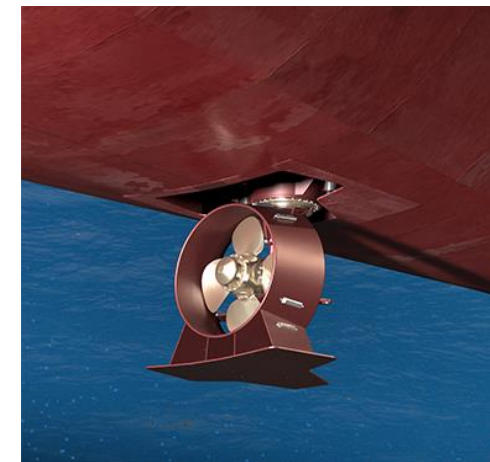
Power Demand & Supply

2 x ~1850 kW Voith Schneider Propeller

4x 1600 kW Gensets

**Hybrid
2x 200 kW Battery**

2 x bow thruster ~ 1400 kW

Dynamic Positioning System

1 x Retractable bow thruster ~900 kW

hotel load 500 kW

Machinery properties
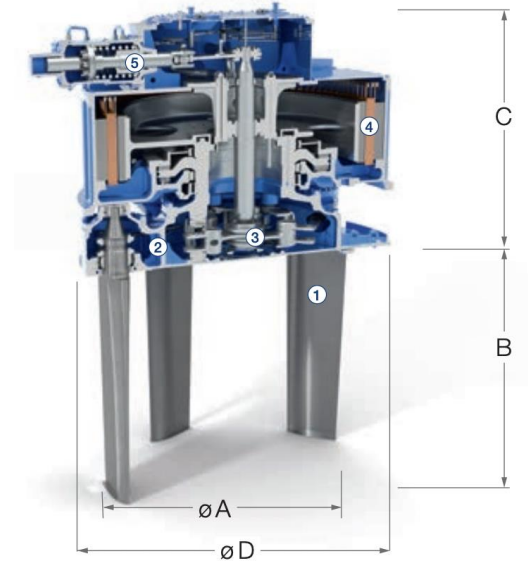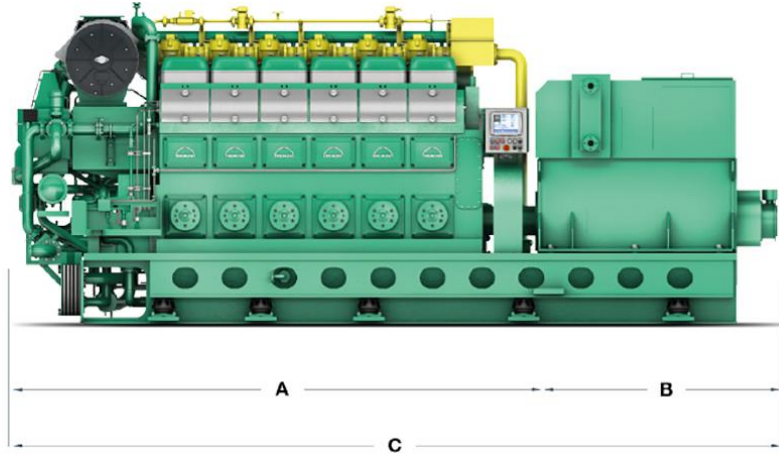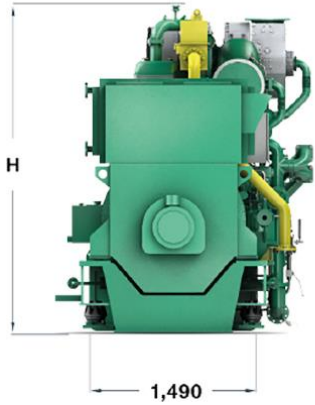
Dimensions — 1600 kW

Cyl. No.	B
	720/750
A	5,761
B	2,770
C	8,531
H	3,009
Dry mass	40,7

Housing diameter D [mm]	Weight without oil [abt. kg]	Oil filling [abt. l]	Electrical input power [kW]
*	*	*	200
*	*	*	375
*	*	*	700 / 800
3 100	26 000	1 750	1 050
3 300	39 000	3 200	1 850

Power Supply & Fuel

- 4 generators @ 1600 kW, Fuel Type: MGO, Methanol
- 2 x 200 kWh batteries for emergency supply
- Emergency generator 300 kW

Selected Energy Densities
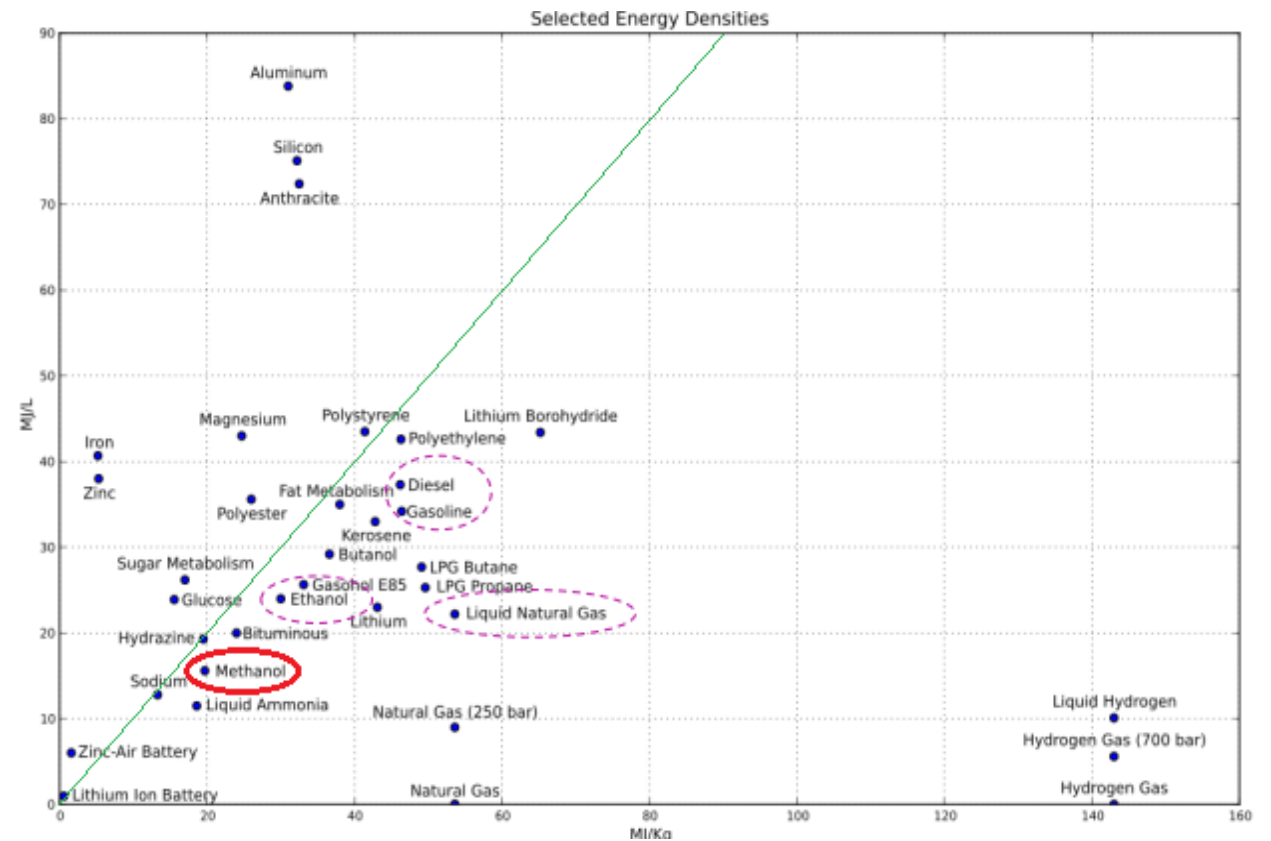
Equipment

Deck cranes

- 1 x motion compensated Offshore Cra[ne] for heavy weights
- Load: ~ 60 m*t

Vessel: *Siem Moxie*

- 1 x HEILA Offshore Crane for medium weights
- Load: ~ 20 m*t

- 1 x HEILA Offshore Crane for light weights
- Load: ~ 2 m*t

Equipment

Gangway

- for save entering of the wind turbine
- Distance ship – wind turbine: ~ 16m
- For wave heights up to 2.5 m

Equipment

Anchoring system

$$EN = \Delta^{\frac{2}{3}} + 2Bh_b + \left(\frac{A}{10}\right)$$

EN*	No.	Stockless bower anchors		Stud link chain cable for bower anchors		
					Min. diameter	
		Mass per anchor	Total length	Mild steel Gr. 1	Special quality Gr. 2	Extra special quality Gr. 3
		(kg)	(m)	(mm)	(mm)	(mm)
1	2	3	4	5	6	7
205-240	2	660	302.5	26	22	20.5
240-280	2	780	330	28	24	22
280-320	2	900	357.5	30	26	24
320-360	2	1020	357.5	32	28	24
360-400	2	1140	385	34	30	26
400-450	2	1290	385	36	32	28
450-500	2	1440	412.5	38	34	30
500-550	2	1590	412.5	40	34	30
550-600	2	1740	440	42	36	32
600-660	2	1920	440	44	38	34
660-720	2	2100	440	46	40	36
720-780	2	2280	467.5	48	42	36
780-840	2	2460	467.5	50	44	38
840-910	2	2640	467.5	52	46	40
910-980	2	2850	495	54	48	42
980-1060	2	3060	495	56	50	44
1060-1140	2	3300	495	58	50	46
1140-1220	2	3540	522.5	60	52	46
1220-1300	2	3780	522.5	62	54	48
1300-1390	2	4050	522.5	64	56	50
1390-1480	2	4320	550	66	58	50
1480-1570	2	4590	550	68	60	52
1570-1670	2	4890	550	70	62	54
1670-1790	2	5250	577.5	73	64	56
1790-1930	2	5610	577.5	76	66	58
1930-2080	2	6000	577.5	78	68	60
2080-2230	2	6450	605	81	70	62
2230-2380	2	6900	605	84	73	64
2380-2530	2	7350	605	87	76	66
2530-2700	2	7800	632.5	90	78	68

Qualifiers Anchor handling and Towing

Object	Documentation type	Additional description	Info
Anchor handling arrangement, towing winch arrangement	Z030 – Arrangement plan	Including: — towline paths showing extreme sectors and wrap on towing-equipment — towline points of attack — maximum expected BP — maximum design loads for each component — emergency release capabilities.	FI
	Z253 – Test procedure for quay and sea trial	Bollard pull	AP, L
	Z263 – Report from quay and sea trial	Winch and other equipment required by the class notation.	AP, L
Anchor handling winch, towing winch	C010 – Design criteria	Including: — RL and the expected maximum BP — hoisting capacity, rendering and braking force of the winch — release capabilities (response time and intended remaining holding force after release).	FI
	C020 – Assembly or arrangement drawing		FI
	C030 – Detailed drawing		AP
	C040 – Design analysis	Strength calculation of the drum with flanges, shafts with couplings, framework and brakes.	FI
	C050 – Non-destructive testing (NDT) plan		AP
Shark jaw, towing pins	C010 – Design criteria	Including: — maximum design load — emergency release capabilities in operational and dead ship condition.	FI
	C020 – Assembly or arrangement drawing		FI
	C030 – Detailed drawing	Components transmitting loads	AP
Object	*Documentation type*	*Additional description*	*Info*
	C040 – Design analysis		FI
	C050 –Non-destructive testing (NDT) plan		AP
Stern roller supporting structure, Shark jaw supporting structure, Towing pin supporting structure	H050 – Structural drawing	Including maximum applicable design loads.	AP
Anchor handling supporting structure, Towing winch supporting structure	H050 – Structural drawing	Including: — the maximum forces acting on the winches (see Sec.3 [2.1]) — foot print loads.	AP
Operation	Z220 - Vessel operation manual	Anchor handling operational and planning manual, refer the International Code on Intact Stability, 2008, Part B, paragraph 3.8.	FI

AP = for approval, FI = for information, ACO = as carried out, L = local handling, R = on request, TA = covered by type approval, VS = vessel specific

Equipment

Mooring system

stern line   breast line   spring line   breast line   bow line