COMPARISON OF CONVENTIONAL AND AZIMUTH PROPULSION SYSTEMS FOR MERCHANT VESSELS

OSER | SPAIN | APR 2024

CONCEPT COMPARISON

Concept Comparison – 1x CPP vs. 2x Azimuth

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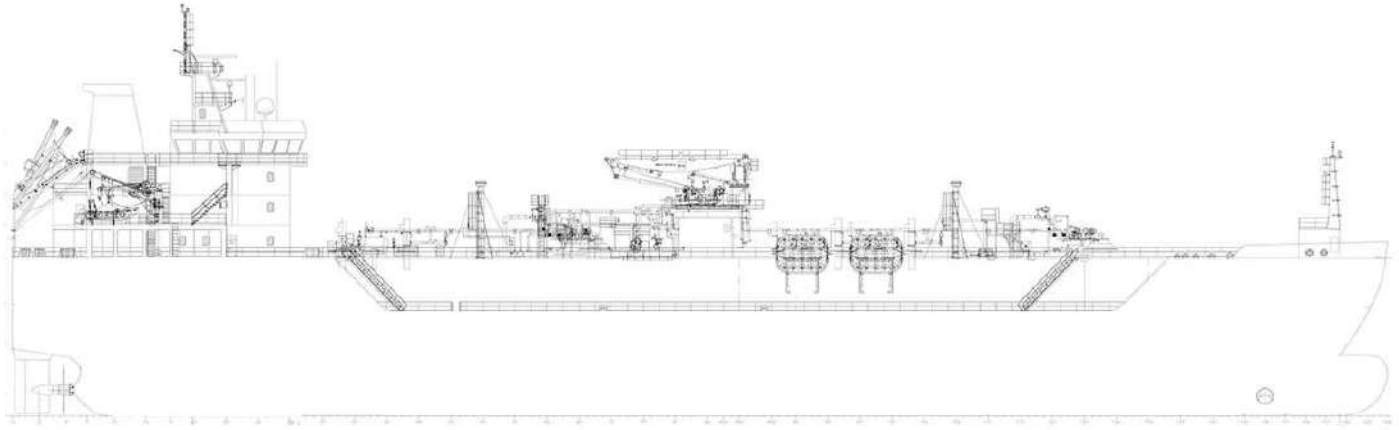
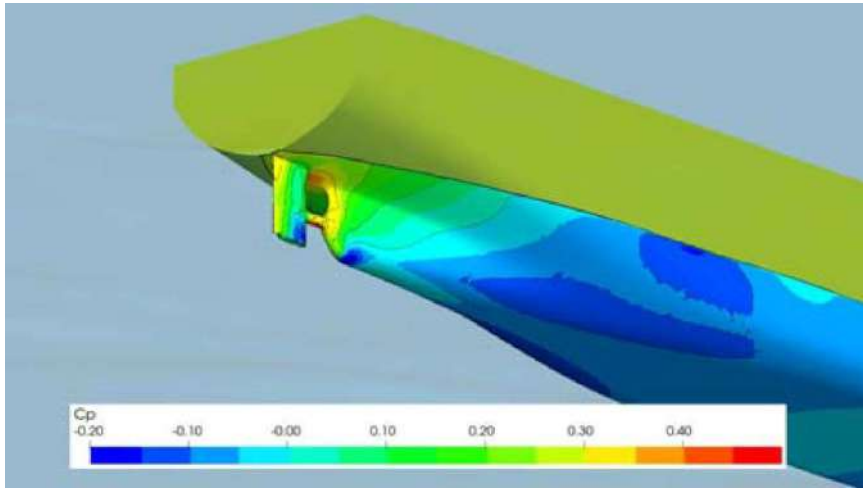
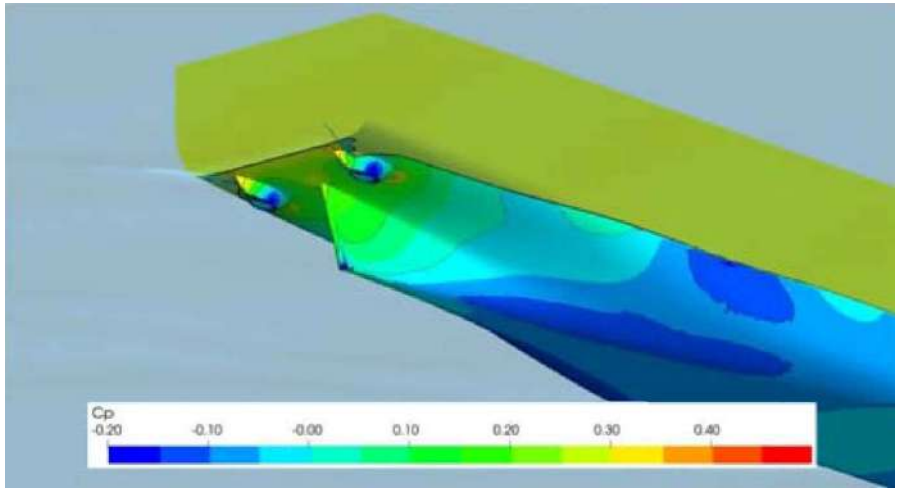
Investigation of the possibility to switch from a 1x CPP solution to a 2x SRE solution.

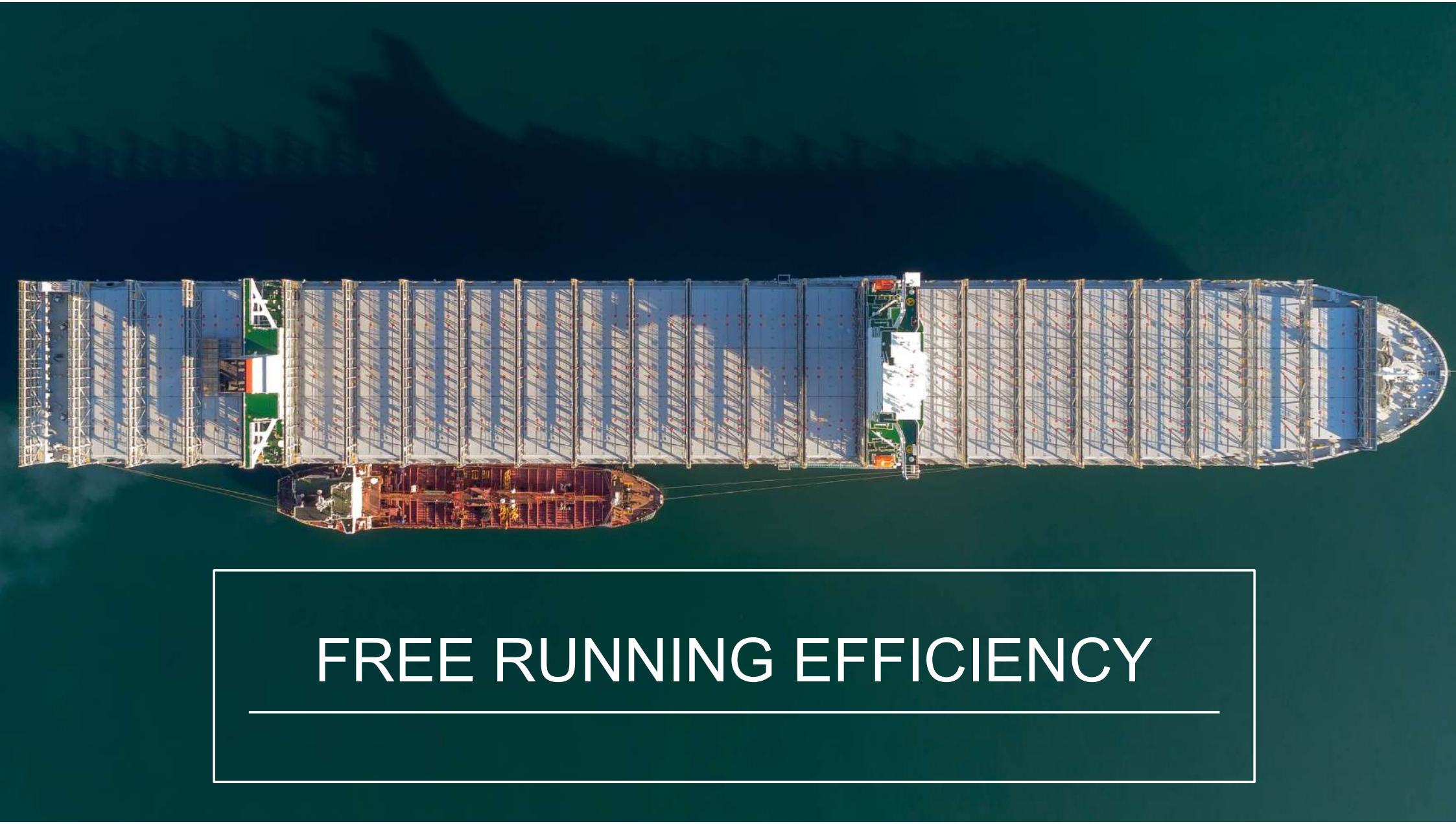






Propulsion Concept Data

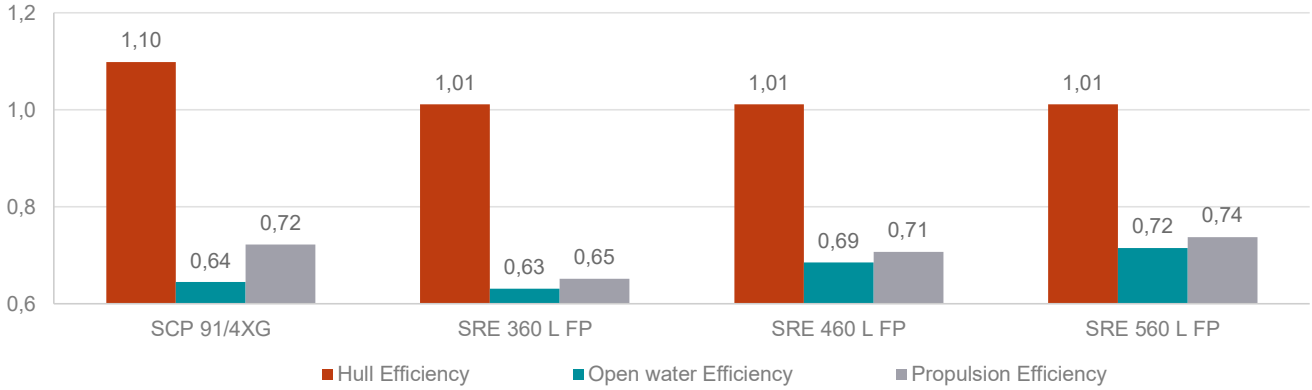
Propulsion system			SINGLE screw CPP	TWIN screw pull azimuth thruster		
Type			SCP 91/4XG	2 x SRE 360 L FP	2 x SRE 460 L FP	2 x SRE 560 L FP
Propeller diameter	D_{Prop}	[mm]	4,3	2,3	2,7	3,1
Gear ratio	i_{ges}	[-]	7,849	3,533	3,538	3,615
Input rpm	n_{Input}	[rpm]	1040,1	970	703	568
Input Power	P_{Input}	[kW]	1 x 2400	2 x 1200	2 x 1200	2 x 1200
Mechanical losses	$\eta_{mec.}$	[-]	0,97	0,97	0,97	0,97
Input Torque	M_{input}	[kNm]	22,95	12,30	16,96	21,01
Service Factor	SF	[-]	-	0,76	0,60	0,53
Propeller speed	$n_{Propeller}$	[rpm]	132,5	274,6	198,9	157,2



FREE RUNNING EFFICIENCY

Results – Maximum ship-speed

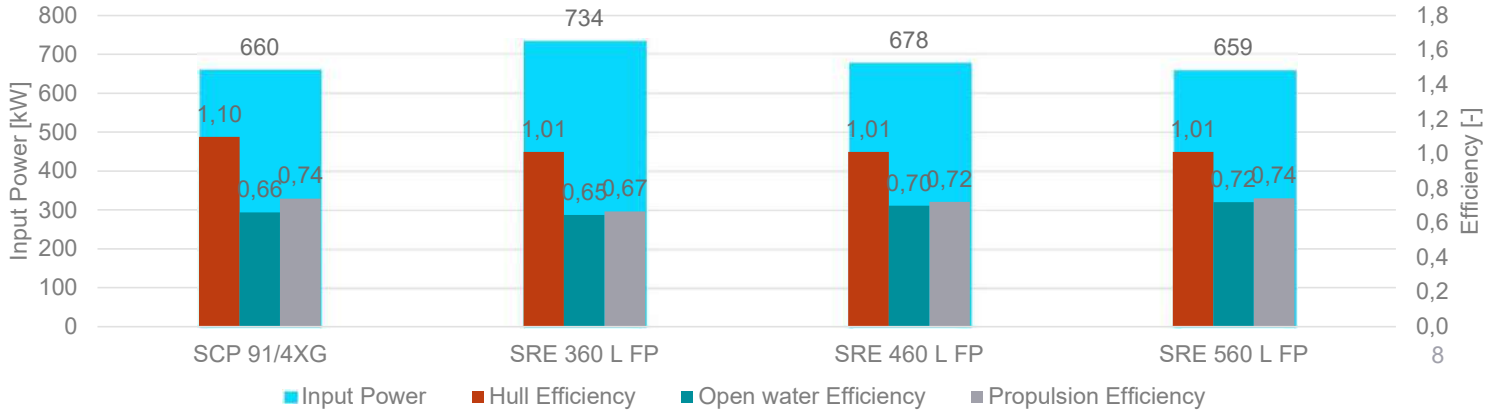
Propulsion system			SINGLE screw CPP	TWIN screw pull azimuth thruster		
Typ			SCP 91/4XG	2 x SRE 360 L FP	2 x SRE 460 L FP	2 x SRE 560 L FP
Ship speed	V_{ship}	[kn]	14,6	14,2	14,5	14,7
Input Power	P_{Input}	[kW]	2400	2400	2400	2400
Wake fraction	w	[-]	0,29	0,11	0,11	0,11
Thrust deduction	t	[-]	0,22	0,10	0,10	0,10
Rotative Efficiency	η_{Rot}	[-]	1,02	1,02	1,02	1,02
Hull Efficiency	η_H	[-]	1,10	1,01	1,01	1,01
Open water Efficiency	η_O	[-]	0,64	0,63	0,69	0,72
Propulsion Efficiency	η_D	[-]	0,72	0,65	0,71	0,74



Results – Transit ship-speed

Propulsion system			SINGLE screw CPP	TWIN screw pull azimuth thruster		
Type			SCP 91/4XG	2 x SRE 360 L FP	2 x SRE 460 L FP	2 x SRE 560 L FP
Ship speed	V_{ship}	[kn]	10	10	10	10
Input Power	P_{Input}	[kW]	660	734	678	659
Wake fraction	w	[-]	0,29	0,11	0,11	0,11
Thrust deduction	t	[-]	0,22	0,10	0,10	0,10
Rotative Efficiency	η_{Rot}	[-]	1,02	1,02	1,02	1,02
Hull Efficiency	η_H	[-]	1,10	1,01	1,01	1,01
Open water Efficiency	η_O	[-]	0,66	0,65	0,70	0,72
Propulsion Efficiency	η_D	[-]	0,74	0,67	0,72	0,74

Diesel-direct driven vessel:
Diesel motor at ~ 27 % load is most likely not in a good SFOC efficiency area (shell diagram).
→ Advantage for DE vessels where generator size can be planned to operate in an optimal load range



FUEL COST EXAMPLE

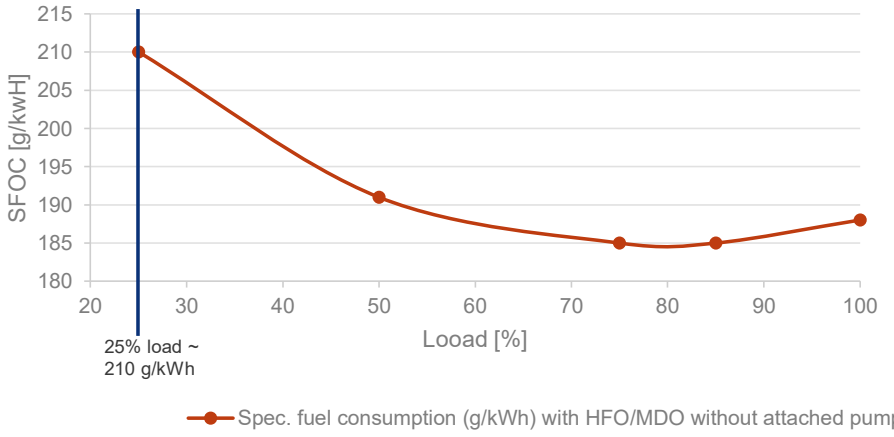
Fuel cost calculation

Specific fuel oil consumption of propulsion engine and generator

Diesel direct system

- One main engine with 2400 kW

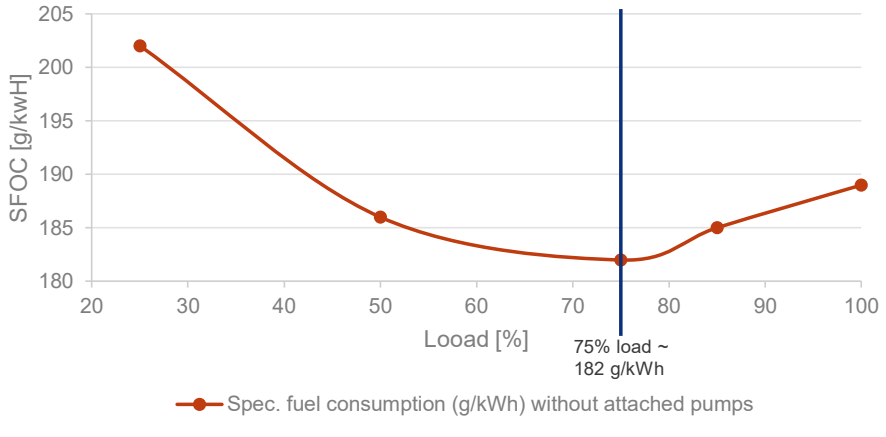
Propulsion: 6-9L27/38: 340 kW/cyl. @ 800 rpm, Controllable-Pitch Propeller (CPP)



Diesel electric system

- Several smaller gensets with in total 2400 kW
- One genset to be sized 900 kW (75 % MCR is 660 kW for 10 kn transit speed)

Genset: L21/31 at 900 rpm (Part Load Optimized): 5L21/31: 200 kW/cyl.



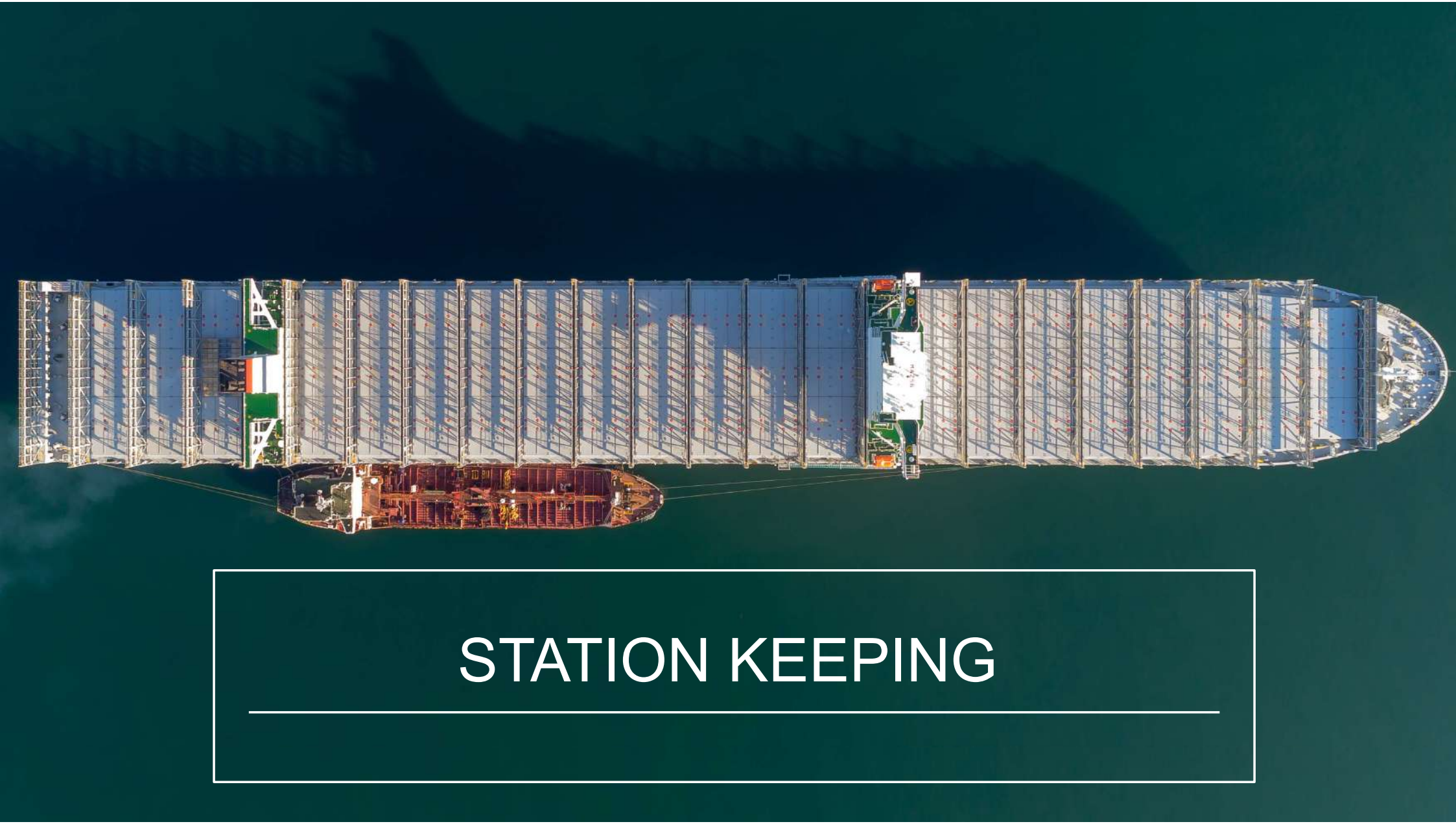
Fuel cost calculation

Example calculation

Assumptions:

- Transit operation: 4500 hours per year
- Transit ship-speed: 10 kn
- Fuel costs: 850 USD /mt
- Medium speed combustion engines

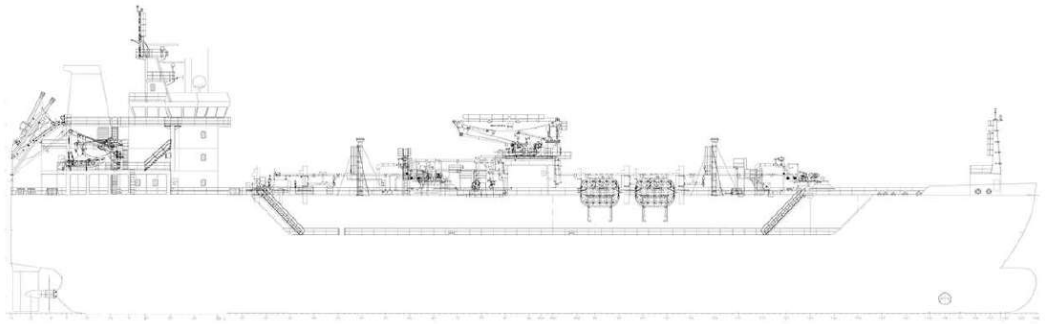
Propulsion	Power consumption at 10 kn [kW]	Losses motor + VFD + alternator	SFOC [kg/kWh]	Transit / year [h]	Fuel consumption [kg/a]	MGO price [EUR/mt]	Fuel costs [EUR/a]
2x SRE	659	10%	0,182	4500	593.693	790 €	469.018 €
1x SCP	660	0%	0,210	4500	623.700	790 €	492.723 €



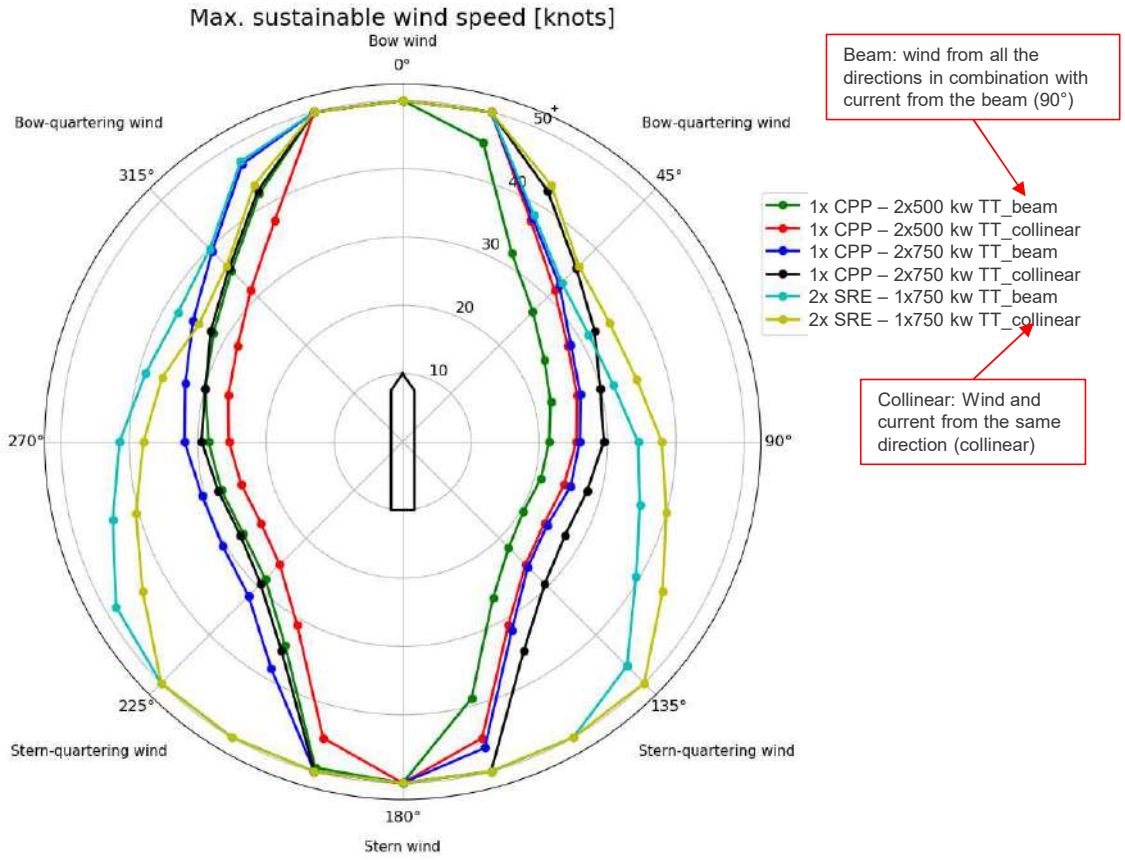
STATION KEEPING

Results – Station keeping

- Higher station keeping capability for azimuth driven vessel (especially when wind hits stern section)
- Higher efficiency and less power consumption for azimuth driven vessel (especially when wind hits stern section)
- Rule of thumb: double power consumption of 1x CPP compared to 2x SRE

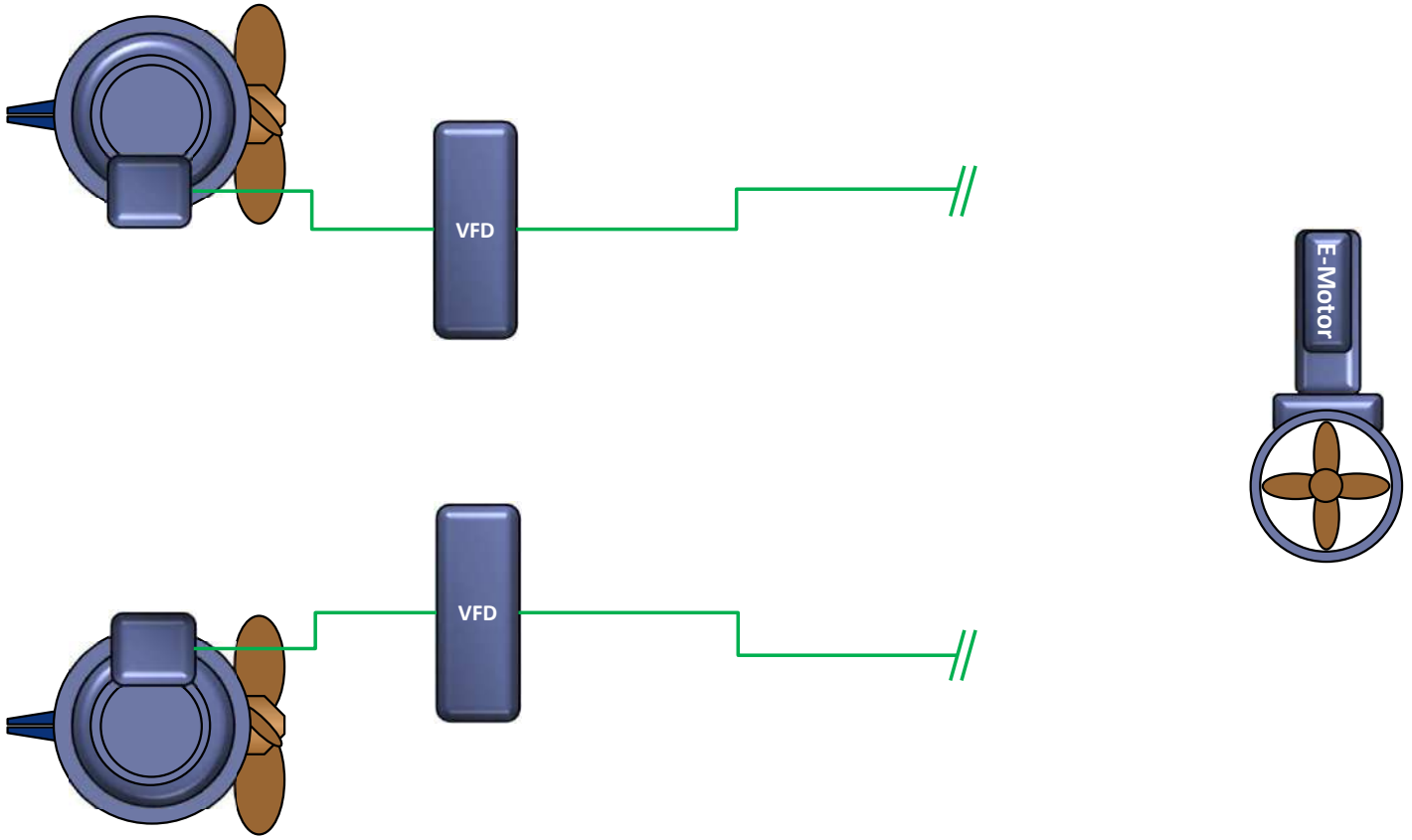


Current from beam

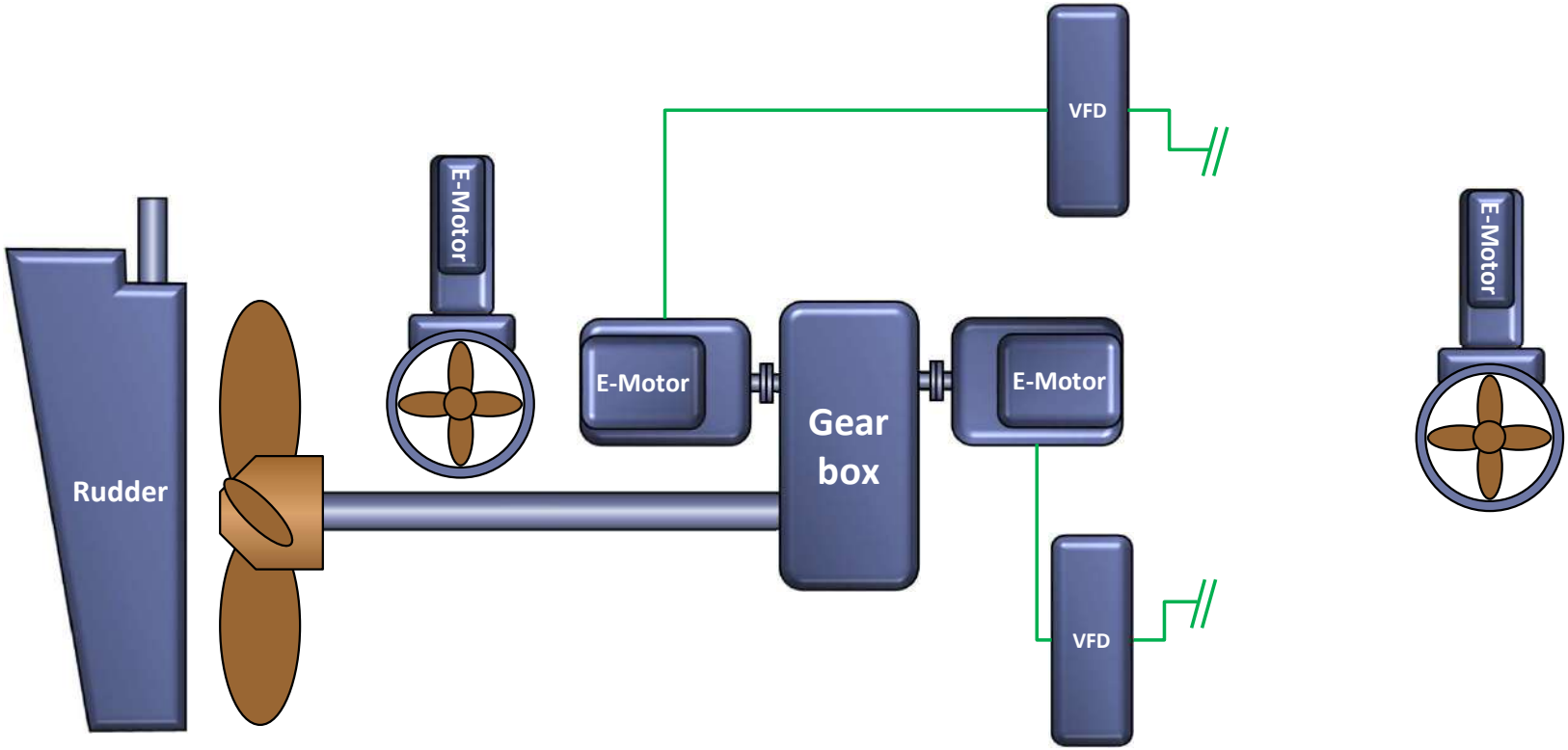


INVESTMENT COSTS

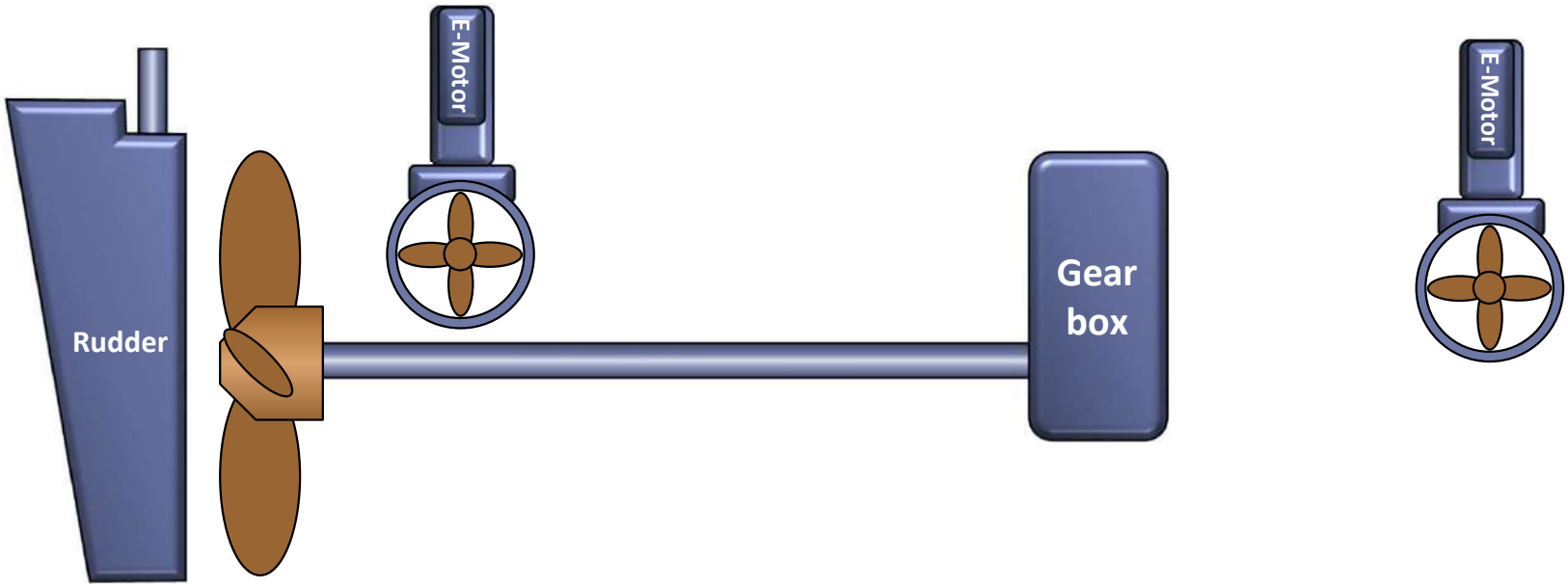
Diesel-Electric Concept



Diesel-Electric Concept



Diesel-Direct Concept



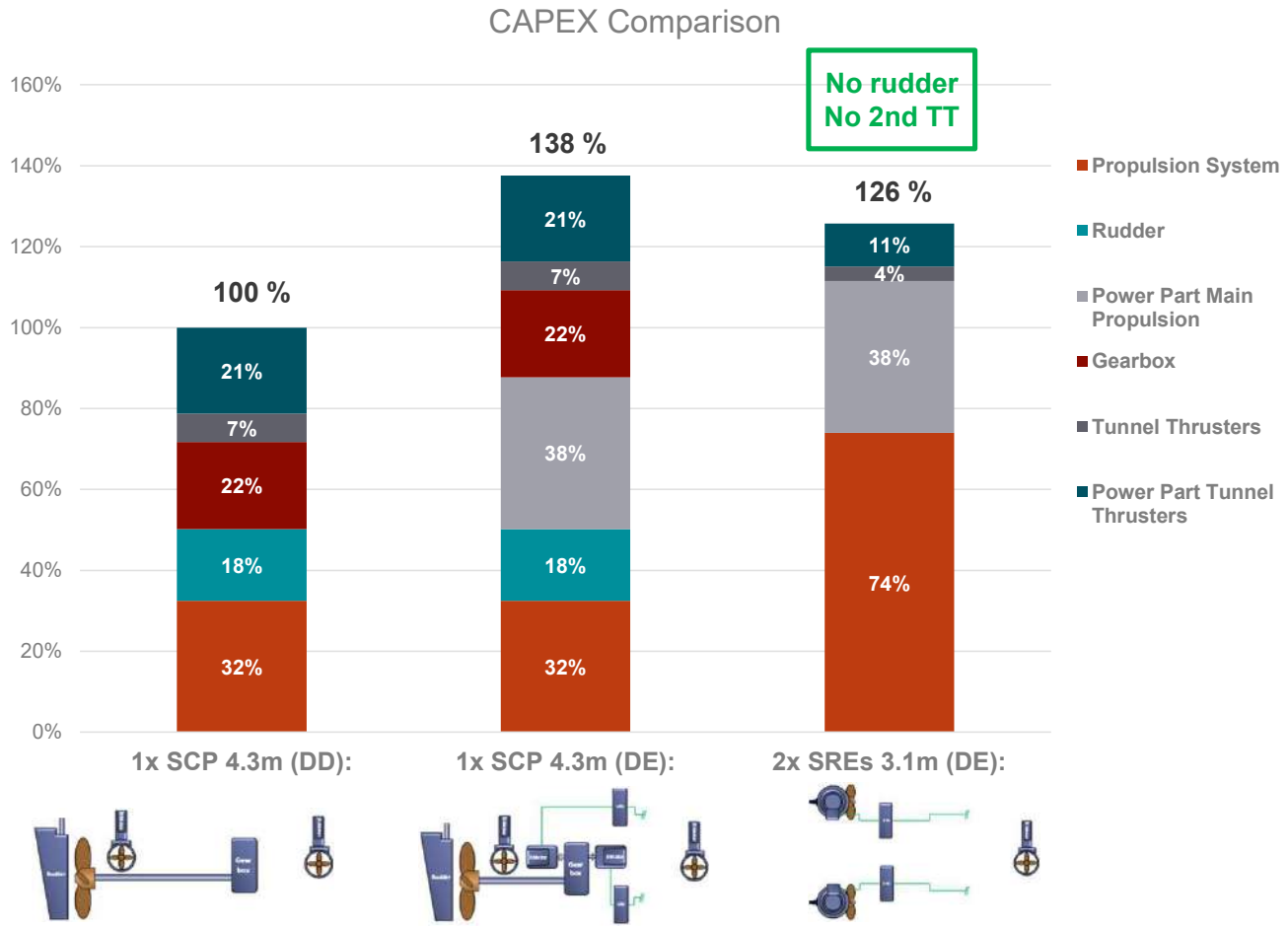
CAPEX Comparison and Conclusion

- Diesel direct concept with CPP builds the 100 % base costs
- Diesel electric concept with 2x SRE thrusters has 26 % higher CAPEX
- Diesel electric concept with CPP unit reflects the highest CAPEX

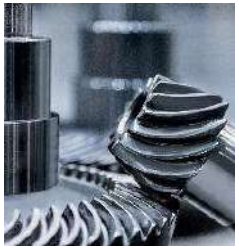
Conclusion:

DE azimuth concept:

- High flexibility in terms of generator setup and high load utilization
- Moderate CAPEX increase
- Possible to exchange generators to different fuels later on



SCHOTTEL



Velocities

Ship's speed : V

Arriving water velocity to propeller (Speed of advance of propeller) : V_A

Effective wake velocity : $V_W = V - V_A$

Wake fraction coefficient : $w = \frac{V - V_A}{V}$

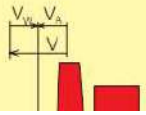
Forces

Towing resistance : R_T

Thrust force : T

Thrust deduction fraction : $F = T - R_T$

Thrust deduction coefficient : $t = \frac{T - R_T}{T}$



Power

Effective (Towing) power : $P_E = R_T \times V$

Thrust power delivered by the propeller to water : $P_T = P_E / \eta_H$

Power delivered to propeller : $P_D = P_T / \eta_B$

Brake power of main engine : $P_B = P_D / \eta_S$

Efficiencies

Hull efficiency : $\eta_H = \frac{1 - t}{1 - w}$

Relative rotative efficiency : η_R

Propeller efficiency - open water : η_O

Propeller efficiency - behind hull : $\eta_B = \eta_O \times \eta_R$

Propulsive efficiency : $\eta_D = \eta_H \times \eta_B$

Shaft efficiency : η_S

Total efficiency : η_T

$$\eta_T = \frac{P_E}{P_B} = \frac{P_E}{P_T} \times \frac{P_T}{P_D} \times \frac{P_D}{P_B} = \eta_H \times \eta_B \times \eta_S = \eta_H \times \eta_O \times \eta_R \times \eta_S$$