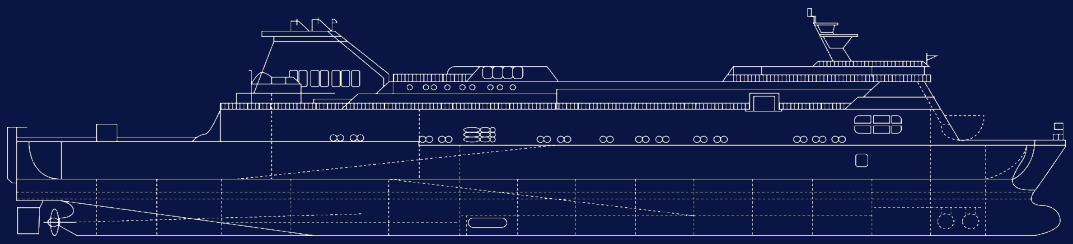


Decarbonizer Premium Report

A guide on upcoming rules and regulations on maritime sustainability

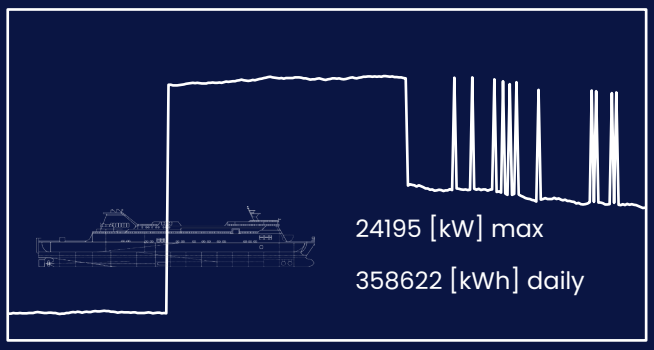
+ measures to reduce carbon emissions for Lady Ice Cold

Client Name	**Fire Ferries**
Date	**2023-06-25**
Source	**Sustainable Ships**

EXECUTIVE SUMMARY

The purpose of this document is to provide Fire Ferries with guidance and insights on maritime sustainability of Lady Ice Cold. This report elaborates on your operational profile, applicable rules and regulations and finally on carbon reduction measures and costs.

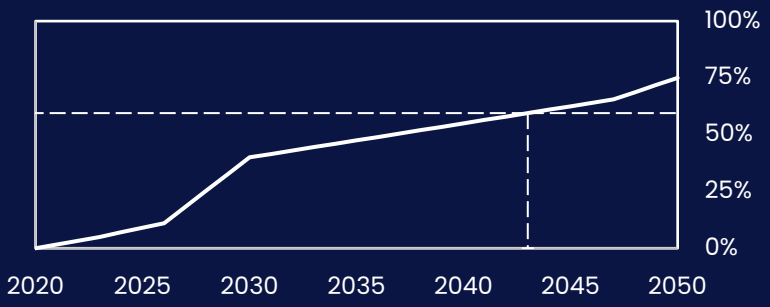
Operational Profile

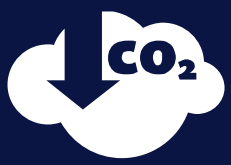


day/year

Fuel	55,118	[l/day]
CO2	169,920	[kg/day]
ETS	€ 14,443	[€/day]
OPEX	€ 48,290	[€/day]
CII	D / D / D / D	
EEXI	28.8 / 28.7	

Rules and Regulations





2043
Target Date

60%
Reduction

Decarbonization Measures	CO_2	CAPEX	Δ-OPEX [daily]	Payback [days]
-				
Hull_Coating	-7%	€ 492,165	-€ 2,988	**165**
-				

	CO_2	CAPEX	OPEX [daily]	Payback [days]
Current situation	0%	€ 0	€ 48,290	-
Future Lady Ice Cold	**-7%**	**€ 492,165**	**€ 45,302**	**165**

A negative Δ-OPEX means you will pay less than your current OPEX

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About Report

Legislation is uncertain

Legislation, rules and regulations or politics in general are vague by nature. In contrast to the engineer's worldview, there is and will always remain uncertainty over upcoming rules and regulations due to 'the political process'. Additionally, the engineering performed for retrofitting is uncertain as well, as it is subject to significantly varying parameters and assumptions.

Our solution to this conundrum is twofold. First, we provide you with a free to use helpdesk, that can help you clarify and answer questions even after this report has been delivered. You can ask any question related to maritime sustainability by clicking on the 'contact helpdesk' button on the top of the page.

Secondly, we provide you with a model, not a solution. Our tools are fully customizable to your vessel and provide you with the option to easily change input parameters when new information is provided. In other words, you can use the Decarbonizer tool as a sensitivity analysis for your vessel, in which you can easily determine what works for you and what does not.

Class is exempt

Class rules and regulations from either DNV, Lloyds or other classification bureaus are excluded in the upcoming rules and regulations section because these are technical of nature. They are included in the cost breakdowns as lump-sum estimates that you can easily customize.

Liability Disclaimer

Sustainable Ships will not be held responsible for any damages that could arise from using the information provided in this report or on its platform. View all terms and conditions here.

1.0 OPERATIONAL PROFILE LADY ICE COLD

1.1 Vessel and operational properties

Parameter	Value	Unit
Ship name	Lady Ice Cold	
Ship type	Ro-ro passenger	
Fuel type	HFO	
Main Engines	MaK 8M43	
Installed Power	33600	[kW]
Engine Type	2-Stroke	150 [g/kWh]
Engine Speed	Medium	
Aux Engines	MaK / 8M20C	
Aux Power	6080	[kW]
Aux. Engine Type	4-Stroke	
Aux. Engine Speed	High	[kW]
Year built	2018	[years]
Ship age	5	[years]
Lifetime from today	25	[years]
Target Date	2043	
Gross Tonnage	51,388	[-]
Deadweight	7,445	[mT]
Cargo capacity	5,956	[m3]
Area	Europe	
Propulsion Type	Direct Drive	
Cruising speed	19	[knts]
Tank Capacity	1,226	[m3]
Length overall	187	[m]
Extreme Beam	31.6	[m]
Hull Roughness	Smooth	

Parameter		
Idle / Moored	25%	91 days per year
Sailing	38%	137 days per year
Working	38%	137 days per year

1.2 Current OPEX Lady Ice Cold

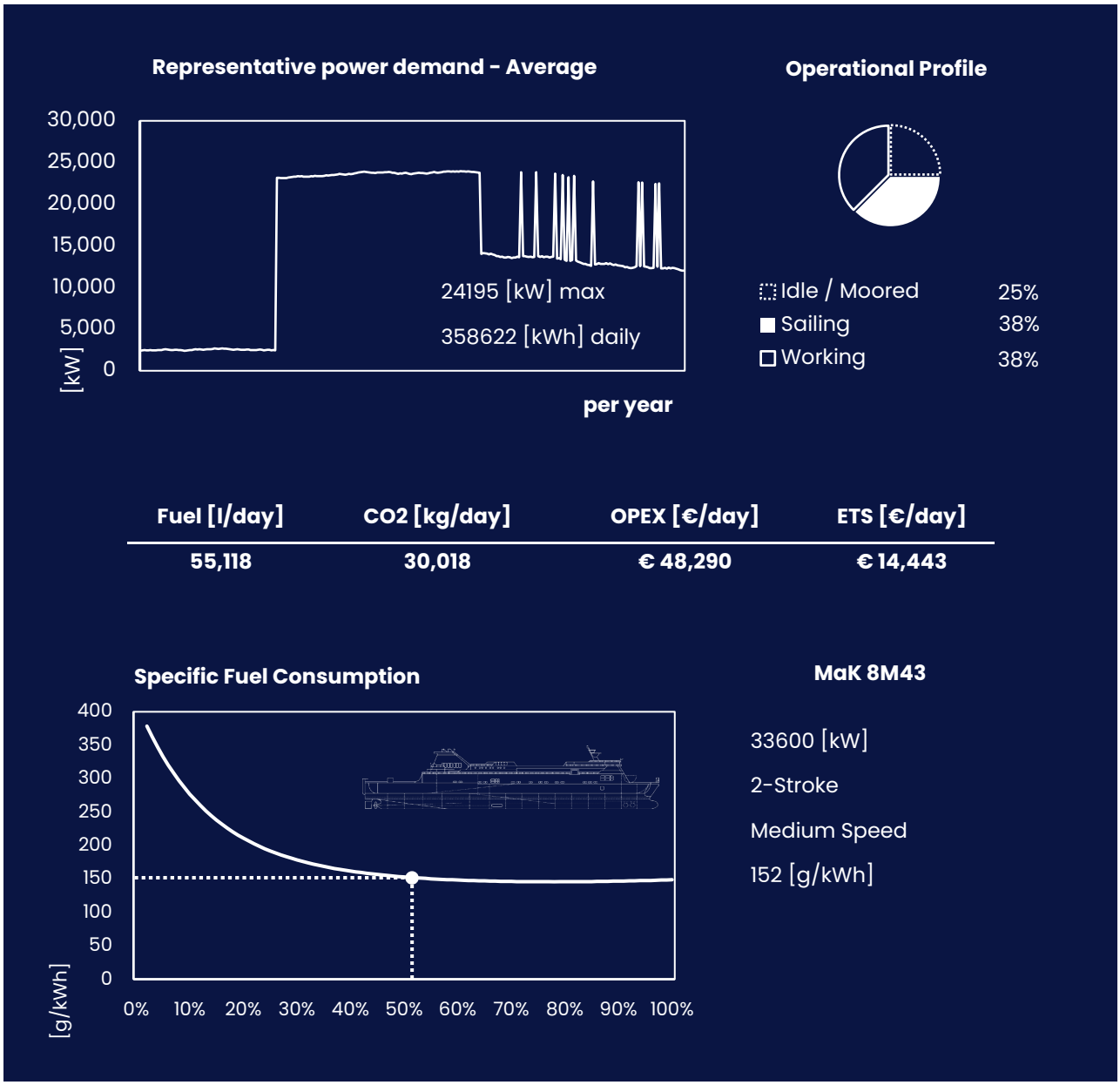
		Idle / Moored 91 [days/year]	Sailing 137 [days/year]	Working 136.875 [days/year]	Average per [day]
Max Power	[kW]	2,685	23,968	24,195	24,195
Average Power	[kW]	2,491	23,634	14,552	14,943
Energy Required	[kWh]	59,780	567,222	349,250	358,622
Fuel Consumption	[liter]	9,737	83,789	56,700	55,118
Engine Hours	[hrs]	24	24	24	24

CO2 Emissions	[kg]	30,018	258,309	174,800	169,920
NOx Emissions	[kg]	745	6,409	4,337	4,216
SOx Emissions	[kg]	460	3,959	2,679	2,604
PM Emissions	[kg]	70	601	407	396
CH4 Emissions	[kg]	0	4	3	3

Fuel	[€]	€ 5,842	€ 50,273	€ 34,020	€ 33,071
Lease / Rental	[€]	€ -	€ -	€ -	€ -
Engine Maintenance	[€]	€ 480	€ 480	€ 480	€ 480
Spares / Consumables	[€]	€ 48	€ 48	€ 48	€ 48
ETS Costs	[€]	€ 2,552	€ 21,956	€ 14,858	€ 14,443
Coating	[€]	€ 248	€ 248	€ 248	€ 248

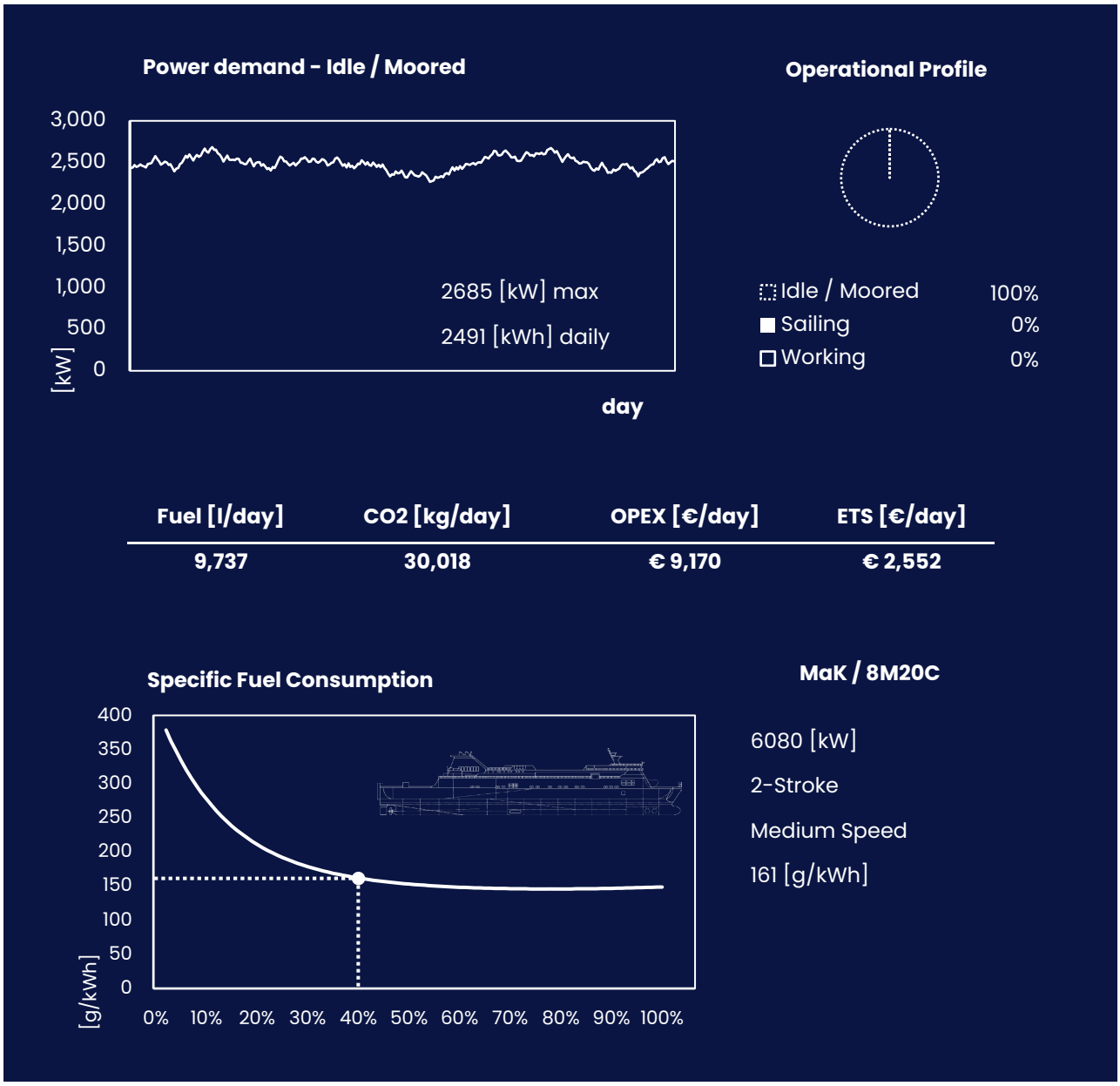
OPEX	**daily**	**€ 9,170**	**€ 73,006**	**€ 49,654**	**€ 48,290**
	yearly	**€ 3,346,985**	**€ 26,647,035**	**€ 18,123,812**	**€ 17,625,814**

1.3 Combination – Yearly

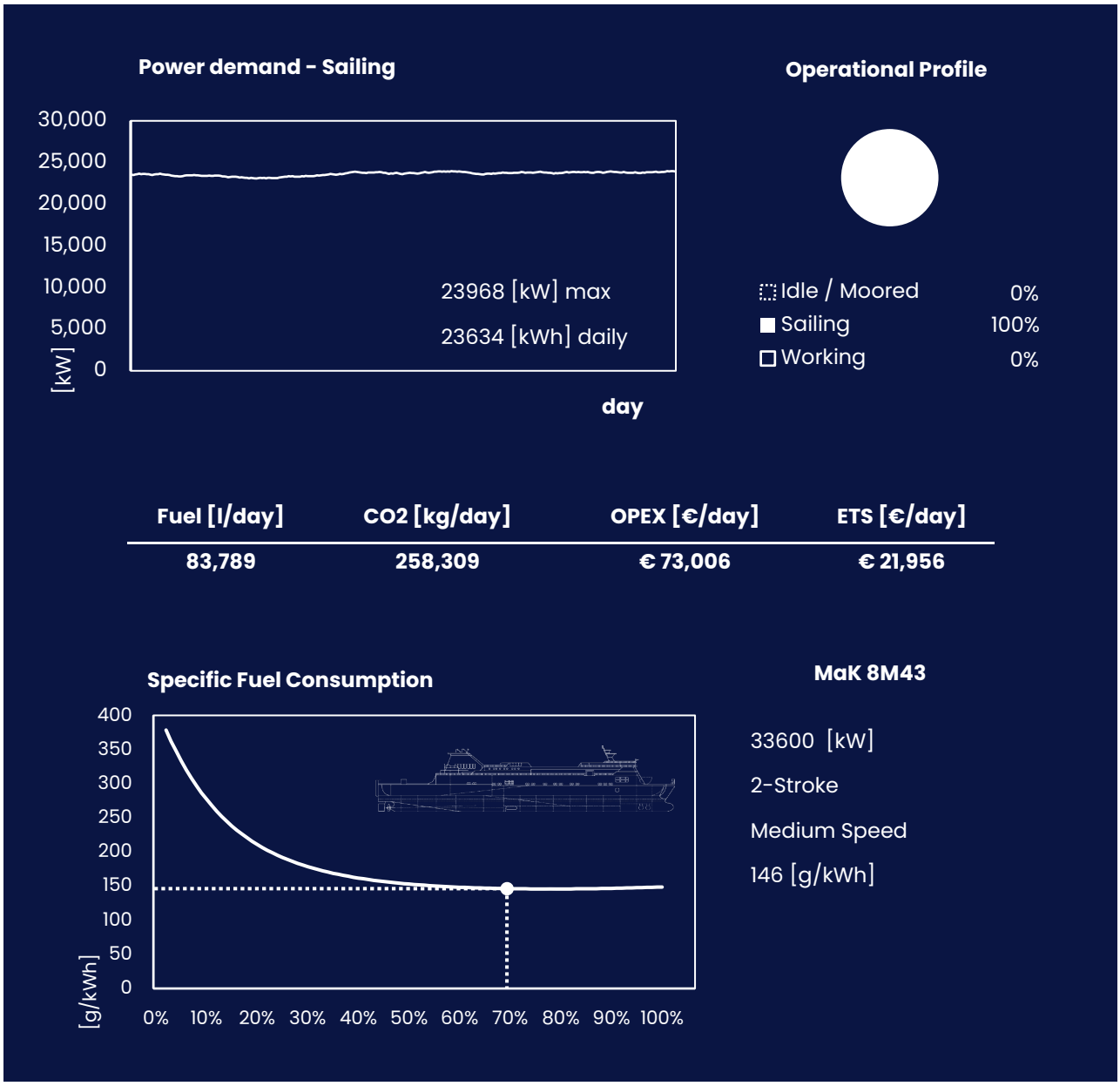


The estimated operational profile of Lady Ice Coldwhen operational modes are combined (i.e. idle/moored, sailing and working). For example, a vessel can be moored for 25% of the year and sailing for 75% of the year, which results in a combined power demand representing vessel operations. This can be viewed as 'yearly combined profile".

1.4 Idle/Moored – Daily

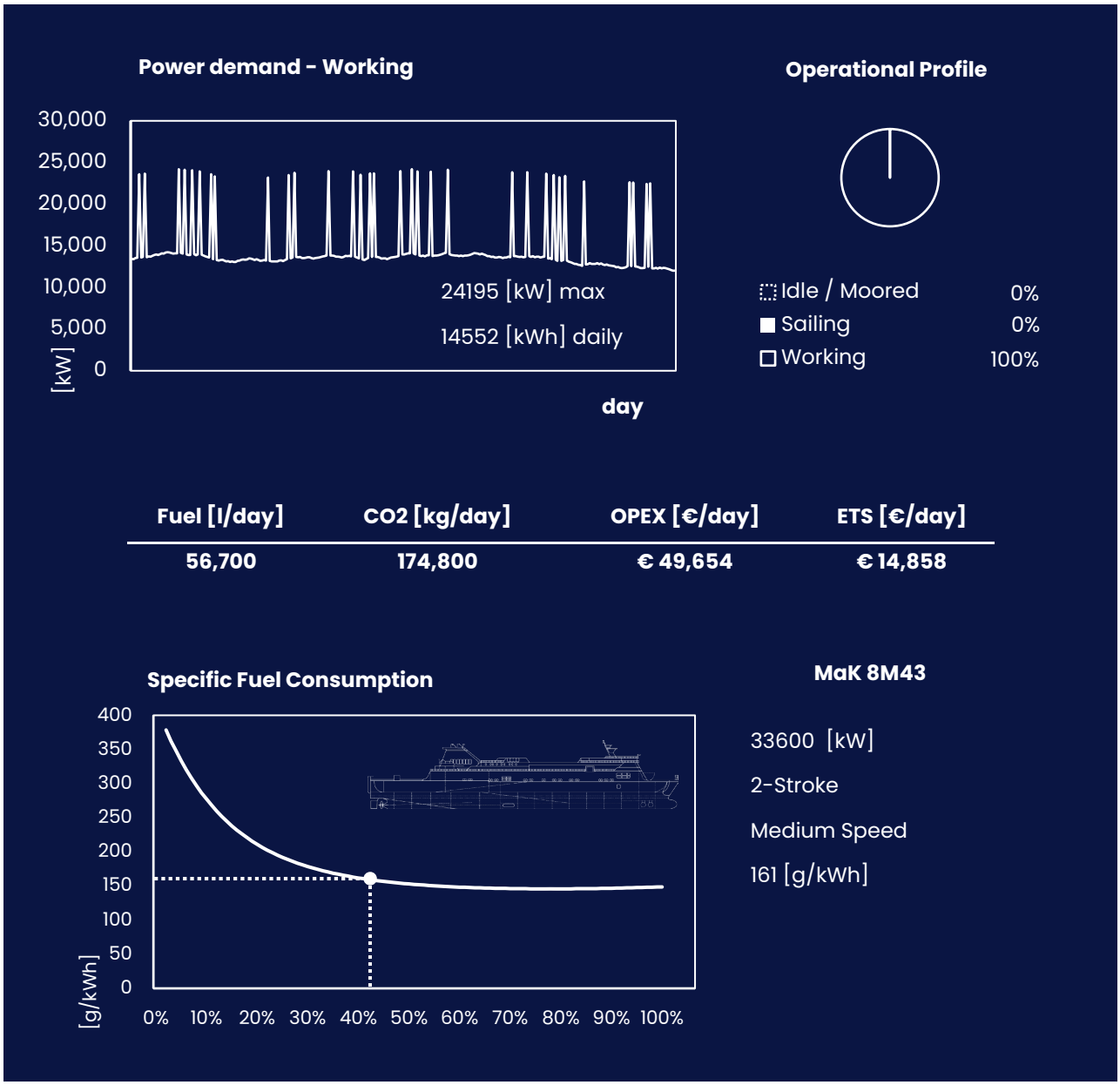


1.5 Sailing – Daily



Fuel [l/day]	CO2 [kg/day]	OPEX [€/day]	ETS [€/day]
83,789	258,309	€ 73,006	€ 21,956

1.6 Working – Daily



Fuel [l/day]	CO2 [kg/day]	OPEX [€/day]	ETS [€/day]
56,700	174,800	€ 49,654	€ 14,858

MaK 8M43

33600 [kW]

2-Stroke

Medium Speed

161 [g/kWh]

'Working' is defined as an operational mode in which the vessel operates on its main engines and experiences peaks in power demand. This can be the case for offshore working vessels when on DP or operating cranes.

2.0 KEY UPCOMING RULES AND REGULATIONS FOR LADY ICE COLD

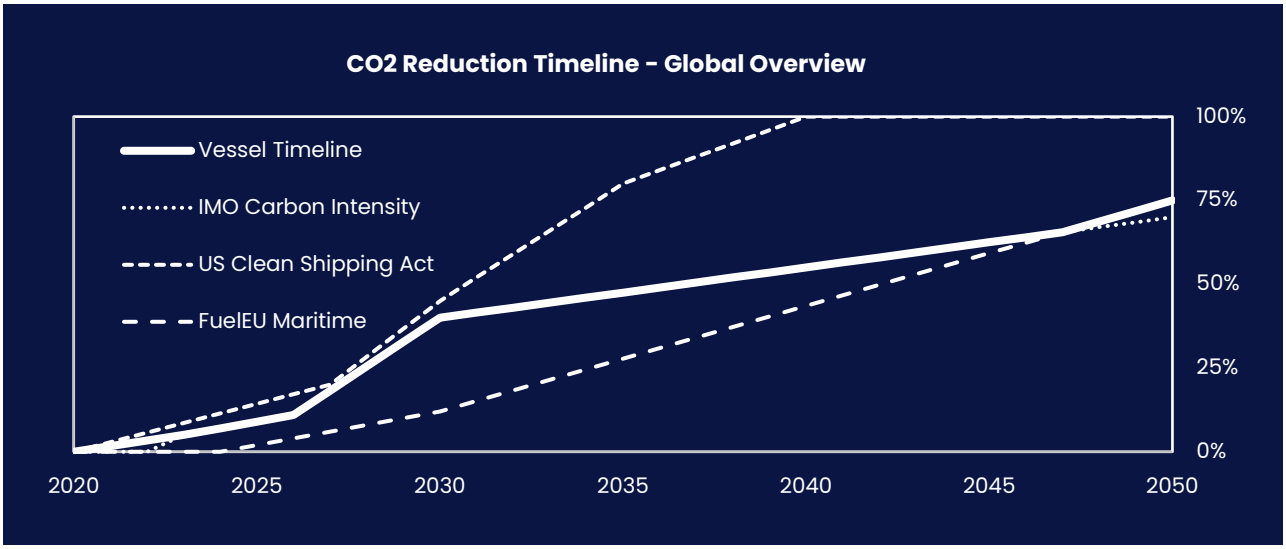


Figure 5. CO2 reduction timelines for key organizations around the world.

Key takeaways	
For 2043 a CO2 reduction of 60% is required	Key regulatory frameworks for maritime sustainability include IMO and EU, of which IMO is more stringent at the moment and EU probably after 2030. In addition, the US Clean Shipping Act requires all vessels to be fully zero emission by 2040. Client requirements have not yet been incorporated.
Electrification is excluded	Electric vessels 'pass' all rules and regulations that have been identified. It is therefore highly recommended to pursue a course of electrification of your vessel where possible to ensure smooth sailing in the future.
Shore power is mandatory	Shore power will become fully mandatory in EU and US by 2030, as per FuelEU and US clean shipping act and this trend in expected to be tightened while at berth. Shore power in the Netherlands is more attractive for operators due to HBE.
Carbon tax & fossil is expensive	Shipping industry will be incorporated into EU ETS from 2025 onwards. With the current price of €85 per mT CO2, that would equate to a surtax of roughly €255 per mT of fuel.

Key rules and regulations for Lady Ice Cold				
Rule/Reg	**Organization**	**In Effect**	**Area**	**Impact / Restraint**
PAS	Netherlands	2021	Europe	-80% NOx
HBE	Netherlands	2022	Europe	Get € 0.04-0.20 kWh
CII	IMO	2023	Global	Your CII rating is non-compliant (D)
EU ETS	EU	2024	Europe	€ 5271779 per year
FuelEU Maritime	EU	2025	Europe	Unknown
ECA Norway	IMO	2019	Europe	0.1% SOx max
Global Sulphur Limit	IMO	2020	Global	0.5% SOx max
ECA North Sea	IMO	2021	Europe	0.1% SOx max
EEXI	IMO	2023	Global	Required EEXI = 28.71
ECA Mediterranean	IMO	2025	Europe	0.1% SOx max
IMO Carbon Price	IMO	2026	Global	Unknown

CII / EEXI / EU ETS		
CII	**EEXI**	**EU ETS [year]**
D / D / D / D	28.83	€ 5,271,779

Purchase the **premium Rules and Regulations report** for an overview on all rules and regulations on sustainability. This includes regulations imposed by energy majors, shipping companies and ports around the world that might affect your operations, as well as a one-hour consult. Click below fore more information.

Learn more

3.0 CARBON REDUCTION MEASURES & COSTS

3.1 All carbon reduction measures

Below is an overview of several key carbon reduction measures. Δ-OPEX represent the difference between current OPEX and OPEX when measures is implement. OPEX of carbon reduction measures include fuel, ETS and maintenance costs. All costs are indicative. No rights or claims can be made based on this analysis.

Measure	CO_2	CAPEX	Δ-OPEX [daily]	Payback [days]
Shore_Power	-4%	€ 671,400	€ 2,260	-
Shore_Battery	-4%	€ 23,019,177	€ 2,260	-
Solar_PV	-1%	€ 441,605	-€ 166	2,666
Wind_Power	n.a.	-	-	-
Hull_Coating	**-7%**	**€ 492,165**	**-€ 2,988**	**165**
Battery_Hybrid	n.a.	-	-	-
Biofuels	-56%	€ 676,800	-€ 1,398	484
Ammonia	-93%	€ 24,101,820	€ 55,658	-
Methanol	-85%	€ 15,384,794	€ 50,239	-
Hydrogen	-93%	€ 155,837,418	€ 204,587	-
Full_Electric	-93%	€ 247,290,188	-€ 4,155	59,512
Carbon_Capture	n.a.	-	-	-

Current situation	**0%**	**€ 0**	**€ 48,290**	**-**
After measures	**-7%**	**€ 492,165**	**€ 45,302**	**165**

Target reduction **-60%** Estimate based on vessel end-of-life

3.2 Selected measures for Lady Ice Cold

The below carbon reduction measures have been applied to Lady Ice Cold Click on the buttons below the figures to learn more, or contact the helpdesk to clarify any questions.

Selected carbon reduction measures		
Shore Power	Prevent Measure	Change Measure
None Chosen		None Chosen
-	Hull_Coating	-

3.3 CII / EEXI / EU ETS

Below is an overview of CII, EEXI and EU ETS before and after implementation of carbon reduction measures. Elaboration on the calculation of CII, EEXI and EU ETS are provided in Appendix I.

CII / EEXI / EU ETS			
	CII	**EEXI**	**EU ETS**
Current	D / D / D / D	28.83	€ 5,271,779
After	C / C / D / D	26.87	€ 4,915,096

3.4 Technical Details Shore Power n.a.

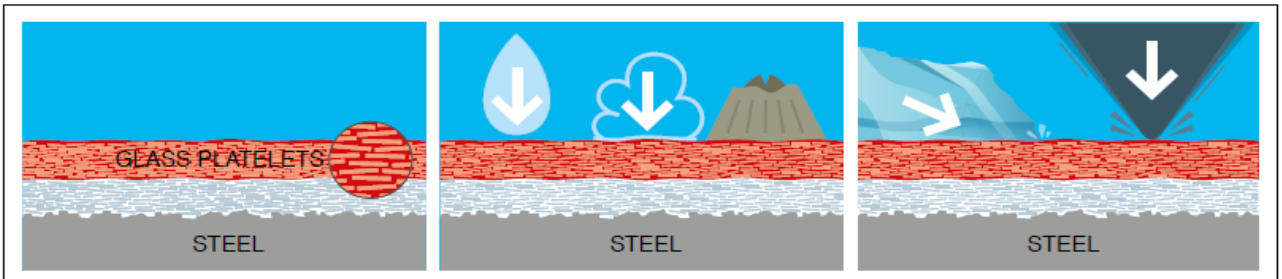
None chosen

3.5 Technical Details Prevent Measure Hull Coating

Hull coating is the practice of applying coating to reduce vessel drag, thereby reducing the energy required to propel the vessel through water. In this case, Ecospeed is used as benchmark. Ecospeed is a hard, non-toxic coating system which provides long-lasting protection and optimal hydrodynamic performance for all ship hulls. Instead of using chemicals to try to kill and repel marine fouling organisms, Ecospeed uses a hard coating along with mechanical removal of fouling at an early stage. With pro-active cleaning, the system results in major fuel savings and a reduction in carbon dioxide emissions compared to conventional coating systems. The average fuel consumption reduction for your vessel over a 10-year period is estimated at 7%.

Other	Value	Unit
Sailing Time	38	[%]
Estimated Ship Hull Area	7072	[m2]
Ecospeed Paint Costs	40	[€/m2]
Conventional Coating Costs	30	[€/m2]
Application and Grid Blasting Costs	25	[€/m2]
Conventional Coating R&M Costs	18	[€/m2]
Cleaning	6	[/year]
Cleaning Costs	3	[€/m2]
Hull roughness	Smooth	-
Ship Age	5	[years]
Fuel reduction 10-yr average - sailing only	13	[%]
Max. fuel reduction 10-yr average - sailing only	23	[%]
Current hull coating costs	248	[€/day]
Ecospeed hull coating costs	475	[€/day]
Fuel reduction with Ecospeed	2238	[€/day]
Percentage cleaning costs	73	[%]
Conventional coating grid blasting?	TRUE	

Learn more about Hull_Coating



Two identical layers applied on the prepared surface make an impermeable barrier.

Water, chemicals and marine growth cannot penetrate through the coating.

Recognized as abrasion resistant ice coating withstanding mechanical impact.

"After 10 years of trading on the same routes, m/v Patriot's Ecospeed coating is still going strong. We know that after an underwater clean the fuel consumption goes down to what it was when the paint was new."
Michael Tensing, Interscan Schiffahrt

"Ecospeed with regular hull cleaning was a solution that worked for this cruise ship owner. The improved performance led to lowered fuel costs and CO_2 emissions."
Philip Gennotte, Project Manager Meyer Werft

"The biggest thing was the surprise at seeing the areas where you'd expect it to have taken a lot of damage. I then jokingly asked the question, 'Are you sure you've taken this ship to the ice?"
Stephen Lee, Senior Marine Engineer
British Antarctic Survey (BAS)

"The Ecospeed solution was the most effective coating system for reducing drag. With a hard coating we are also permitted to clean the hull underwater in the ports where we operate without damaging its waters and sediments."
Ismo Saaros, Director, Project Management,
VG-Shipping

SUBSEA INDUSTRIES

Haven 29, 2030 Antwerp - Belgium | Phone: +32 3 213 53 18 | info@subind.net | www.subind.net

3.6 Technical Details Change Measure n.a.

None chosen

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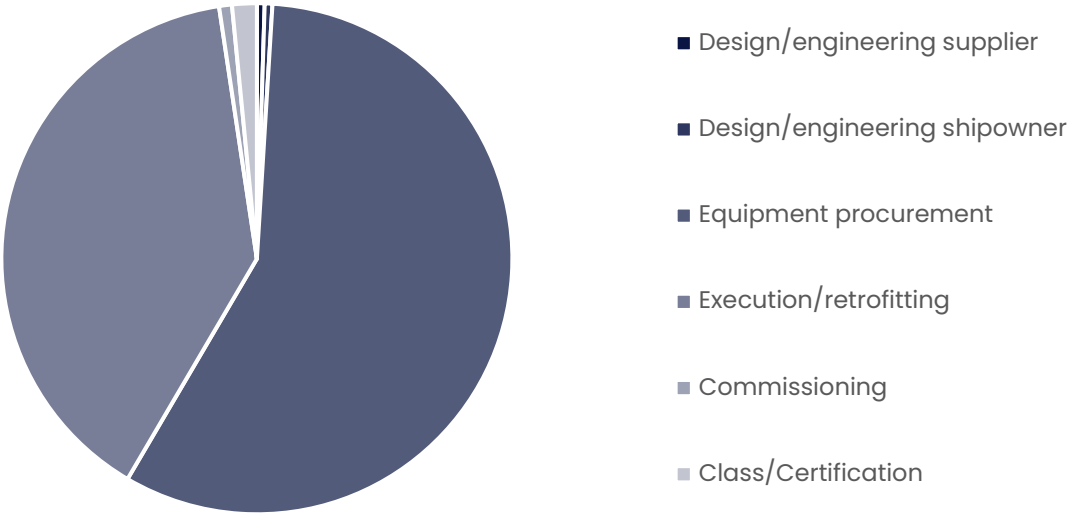
3.7 CAPEX Breakdown Shore Power n.a.

None chosen

None chosen

3.8 CAPEX Breakdown Prevent Measure Hull_Coating

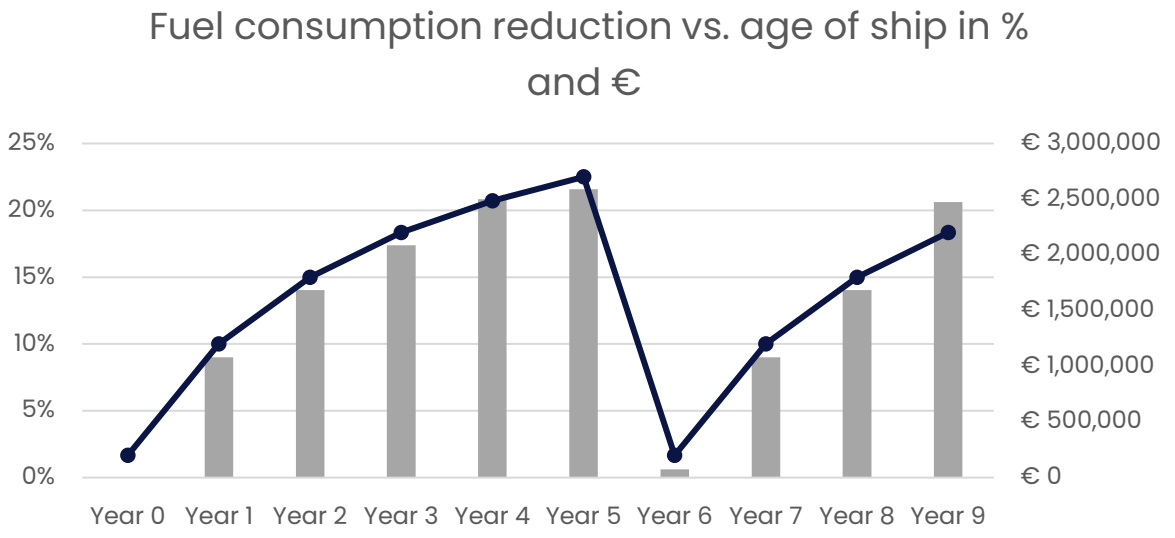
	Time [hours]	Costs
Design/engineering supplier	20	€ 2,400
Design/engineering shipowner	20	€ 2,400
Equipment procurement	-	€ 282,883
Execution/retrofitting	160	€ 192,802
Commissioning	40	€ 4,000
Class/Certification	40	€ 7,680
Total	**7 fte weeks**	**€ 492,165**



	Time [hrs]	Units	Parameter	Price per hour/unit	Total Cost
Design/engineering supplier	**20**				**€ 2,400**
General design and engineering supplier	20		EUR/hr	€ 120	€ 2,400
Design/engineering shipowner	**20**				**€ 2,400**
General design and engineering shipowner	20		EUR/hr	€ 120	€ 2,400
Equipment procurement	**0**				**€ 282,883**
Ecospeed Coating, price per m2		7072.08	EUR/m2	€ 40	€ 282,883
Execution/retrofitting	**160**				**€ 192,802**
Creating means of access for safe working location	40		EUR/hr	€ 100	€ 4,000
Cleaning/removing obstructions from working locations	40		EUR/hr	€ 100	€ 4,000
Installation/removal of scaffolding on working locations	40		EUR/hr	€ 100	€ 4,000
Application, initial coating and grit blasting costs		7072.08	EUR/m2	€ 25	€ 176,802
Non-destructive testing of coating	40		EUR/hr	€ 100	€ 4,000
Commissioning	**40**				**€ 4,000**
Training and familiarising of crew	40		EUR/hr	€ 100	€ 4,000
Class/Certification	**40**				**€ 7,680**
Approval costs of drawings/calculations	24		EUR/hr	€ 120	€ 2,880
Surveyor attendence during fabrication/installation incl. travelling expenses	20		EUR/hr	€ 120	€ 2,400
(Writing) Operational manuals and procedures	20		EUR/hr	€ 120	€ 2,400

All numbers are indicative. Ask your supplier for fixed numbers.

It is assumed transportation costs for all equipment is included in the pricing.



3.9 CAPEX Breakdown Change Fuel n.a.

None chosen

None chosen

3.10 Future OPEX Breakdown Lady Ice Cold

The below table shows the current and future OPEX breakdown for Lady Ice Cold, based on the representative daily operational profile. Depreciation of equipment has not been taken into account (neither for existing or newly purchased equipment). Rental of equipment will be made available soon.

		Current	Future
Max Power	[kW]	24,195	24,195
Average Power	[kW]	14,943	13,790
Energy Required	[kWh]	358,622	330,970
Fuel Consumption	[liter]	55,118	51,388
Engine Hours	[hrs]	24	24

Fuel	[€]	€ 33,071	€ 30,833
Lease / Rental	[€]	€ 0	€ 0
Engine Maintenance	[€]	€ 480	€ 480
Spares / Consumables	[€]	€ 48	€ 48
ETS Costs	[€]	€ 14,443	€ 13,466
Coating	[€]	€ 248	€ 723

OPEX	**daily**	**€ 48,290**	**€ 45,549**
	yearly	**€ 17,625,814**	**€ 16,625,445**

3.11 Potential suppliers

The below partners can assist in implementing the proposed measures on-board your vessel. You can contact them directly, or contact the helpdesk for further guidance. In case you prefer to work with (local) partners on your own, feel free to use this report as a guideline for their input.

Preferred Suppliers		
Technology	**Supplier**	**Contact**
-	-	
Hull Coating	Subsea Industries	**mvanruiten@subind.net**
-	-	

4.0 APPENDIX I – ASSUMPTIONS AND CALCULATIONS

4.1 Input values and assumptions

Parameter	Value	Unit
Fuel Price	€ 0.60	[€/l]
ETS	€ 85	[€/mT]
Engine Maintenance Costs	€ 20	[€/hr]
Spares / Consumables Costs	€ 2	[€/hr]
Parasitic Load Engine	15%	[-]
(Engineering) Hour External	€ 120	[€]
(Engineering) Hour Internal	€ 100	[€]
Depreciation Time	10	[years]
Annual (Fuel) Price Increase	1	[-]

HFO density	0.99	[kg/l]
CO2 Emission Factor HFO	3.114	[kg/kg]
NOx Emission Factor HFO	0.07726	[kg/kg]
SOx Emission Factor HFO	0.04773	[kg/kg]
PM Emission Factor HFO	0.00725	[kg/kg]
CH4 Emission Factor HFO	0.00005	[kg/kg]

Fuel after change	-	[-]
Fuel density after change measures	0.99	[kg/liter]
Fuel price after change measure	€ 0.60	[€/liter]
Shore-side kWh price	€ 0.35	[€/kWh]
CO2 Emission Factor	3.114	[kg/kg]
Nox Emission Factor	0.07726	[kg/kg]
Sox Emission Factor	0.04773	[kg/kg]
PM Emission Factor	0.00725	[kg/kg]
CH4 Emission Factor	0.00005	[kg/kg]

4.2 CII Calculation

Lady Ice Cold CII Scores	2023	2024	2025	2026
Baseline	D	D	D	D
After reduction measures	C	C	D	D

CII Input Values		
Operational Mode	Combined	
CO2 Emissions	62,020,934,921	[g/year]
Capacity	51,388	[mT]
Distance Sailed	84,260	[nm/year]
a	7,540.00	for Reference line
c	0.587	for Reference line
CII ref	12.94	Reference line
Required CII 2023	12.30	5% reduction
Required CII 2024	12.04	7% reduction
Required CII 2025	11.78	9% reduction
Required CII 2026	11.52	11% reduction
Attained Current CII	14.32	Baseline
Attained CII	13.35	After modifications

Learn more about CII

CII Scores per Technology	2023	2024	2025	2026
Shore_Power	C	D	D	D
Shore_Battery	C	D	D	D
Solar_PV	D	D	D	D
Wind_Power	D	D	D	D
Hull_Coating	C	C	D	D
Battery_Hybrid	n.a.	n.a.	n.a.	n.a.
Biofuels	A	A	A	A
Ammonia	A	A	A	A
Methanol	A	A	A	A
Hydrogen	A	A	A	A
Full_Electric	A	A	A	A
Carbon_Capture	n.a.	n.a.	n.a.	n.a.

4.3 EEXI Calculation

$$EEXI = \frac{CO2\ emissions}{Transportation\ work}$$

$$EEXI = \frac{Main\ engine\ emissions + Auxiliary\ engine\ emissions + (PTI - Innovative\ electrical\ energy\ technologies) - Innovative\ propulsion\ energy\ technologies}{Capacity * Reference\ speed * Reduction\ factors}$$

$$EEXI = \frac{\left(\prod_{j=1}^{n} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} C_{ME(i)} SFC_{ME(i)}\right) + \left(P_{AE} C_{AE} SFC_{AE}\right) + \left(\left(\prod_{j=1}^{n} f_j \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} P_{AEeff(i)}\right) C_{FAE} SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} P_{eff(i)} C_{FME} SFC_{ME}\right)}{Capacity\ V_{ref} f_i f_c f_l f_w f_m}$$

EEXI Input values		
Ship Type	Ro-ro passenger	
Operational Mode	Sailing	
CO2 Emissions	10,762,882	[gram/hour]
Capacity	7,445	[mT]
Reference Speed	19	[knts]
fi	1	
fc	0.957293342	
fl	1	
fw	1	
fm	1	
Reduction factor	0.05	

EEXI	**28.83**	**[gram/mT mile]**
EEXI After	**26.87**	**[gram/mT mile]**
EEXI Required	**28.71**	**[gram/mT mile]**

Learn more about EEXI

4.4 EU ETS Calculation

Yearly ETS Costs	2024	2025	2026	2027
Current	€ 0	€ 2,108,712	€ 3,690,246	€ 5,271,779
Shore_Power	€ 0	€ 2,015,580	€ 3,527,266	€ 5,038,951
Shore_Battery	€ 0	€ 2,015,580	€ 3,527,266	€ 5,038,951
Solar_PV	€ 0	€ 2,095,992	€ 3,667,986	€ 5,239,980
Wind_Power	€ 0	€ 2,100,303	€ 3,675,531	€ 5,250,759
Hull_Coating	**€ 0**	**€ 1,966,038**	**€ 3,440,567**	**€ 4,915,096**
Battery_Hybrid	n.a.	n.a.	n.a.	n.a.
Biofuels	€ 0	€ 788,663	€ 1,380,160	€ 1,971,657
Ammonia	€ 0	€ 0	€ 0	€ 0
Methanol	€ 0	€ 183,079	€ 320,388	€ 457,697
Hydrogen	€ 0	€ 0	€ 0	€ 0
Full_Electric	€ 0	€ 0	€ 0	€ 0
Yearly Gains	**€ 0**	**-€ 142,673**	**-€ 249,679**	**-€ 356,684**

Year	% Phase-in
2024	0%
2025	40%
2026	70%
2027	100%

Learn more about EU ETS

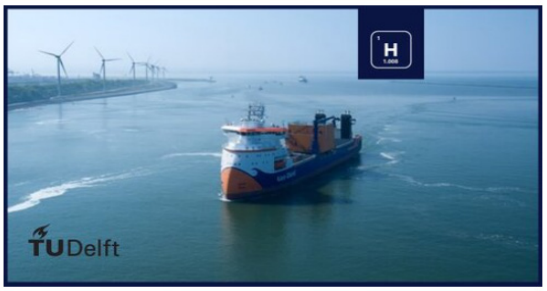
5.0 APPENDIX II - CASE STUDIES SIMILAR TO LADY ICE COLD

This section is under development. In the future, case studies similar to your vessel type will be taken from sustainable-ships.org/stories as reference. Feel free to browse or contact the helpdesk for more stories!

4/30/21

Hydrogen Powered Propulsion for an Offshore Crane Vessel

This thesis performs a technical, economical and environmental feasibility study of three dense hydrogen carriers as a fuel to power the largest semi-submersible offshore crane vessel in the world – Heerema's Sleipnir.



3/12/21

Methanol Hybrid Offshore Working Vessels

This thesis by J.M. Rozendaal at van Oord focuses on the technical, environmental and economic impact of a methanol hybrid power plant design for new-build offshore working vessels. Its conclusion is that a methanol solution has a CO2 reduction potential up to 99% and a CO2 price of 78 euro per ton CO2 reduction.