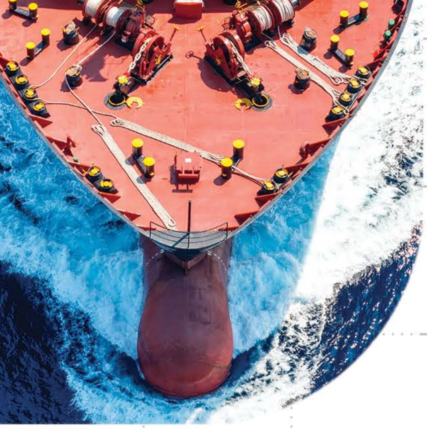

RETROFITS

for ENERGY AND EMISSIONS IMPROVEMENT

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INTRODUCTION

The maritime industry is facing a wave of change as evolving regulations from the International Maritime Organization (IMO) and European Union (EU) drive the industry toward reducing greenhouse gas (GHG) emissions from ships.

While newbuilds tend to take the spotlight, older vessels may run into compliance hurdles as regulations ratchet in intensity over time. Retrofitting for alternative fuels and energy efficiency technologies (EETs) offers these vessels a lifeline and an avenue to compliance at a very dynamic time for the industry. Shifting market demands and interest in cleaner voyages may also create a competitive advantage for early adopters of more efficient systems and operations.

> **This publication aims to help the maritime industry better understand the related classification and statutory requirements for retrofitting, as well as provide best practices and further insights.**

GENERAL

Shipowners looking to improve their existing assets are faced with an array of retrofit options, each offering varied potential dependent on a range of factors. These factors can include competing technologies, vessel age and design, the evolving regulatory environment and specific fleet compliance challenges, among others.

Meanwhile, charterers often have changing or diverse requirements depending on cargo type, routing, operational conditions and market factors. As the industry trends toward more efficient operations and lower emissions, charterers are increasingly analyzing the performance of vessels to prioritize options that best align with their environmental and cost goals.

Adding to these challenges even further is the dynamic nature of vessel operating profiles, which require nearly constant optimization at technical and operational levels. Timely and informed decisions are essential to adapt to changing conditions and maximize efficiency.

With ambitious emissions targets on the horizon, retrofitting can play a critical role in achieving compliance and maintaining economic viability. Such upgrades could potentially enhance a fleet or vessel's environmental performance, optimize energy consumption, extend service life and increase appeal to potential charterers.

Still, shipowners must carefully evaluate retrofit solutions to verify they align with their operational profiles and long-term goals while maintaining safety and reliability. In addition, EETs requiring drydock space or time for ordering and manufacturing to a specification will need advance project planning.

The industry's efforts to improve efficiency and reduce emissions can broadly fall into one of two categories: energy management and/or energy transition.

ENERGY MANAGEMENT

Enhancing operational measures or using EETs for hull, propeller and shipboard systems to optimize a vessel's energy demand.

ENERGY TRANSITION

Implementing alternative fuels, renewable energy sources and emission abatement technologies to reduce the GHG intensity of the global fleet.

Energy management efforts can enhance a vessel's performance as it relates to the IMO Data Collection System or EU Monitoring, Reporting and Verification, including the EU Emissions Trading System (EU ETS). Energy transition efforts influence a vessel's performance related to FuelEU Maritime and the upcoming IMO Net-Zero Framework (NZF).

REGULATORY PRESSURE

Still-evolving international and regional regulations are the primary catalysts for increased interest in EETs, alternative fuels and onboard carbon capture and storage (OCCS) systems.

During the 83rd meeting of the Marine Environment Protection Committee (MEPC) in April 2025, the committee approved the IMO Net-zero Framework (NZF), setting emissions limits and GHG pricing for ships over 5,000 gross tonnage (gt).

As these regulations take shape, shipowners are actively trying to benchmark their performance against IMO trajectories and peer vessels. Improving performance on both operational and technical fronts will be crucial for vessels to stay competitive in the evolving industry.

While the NZF aims to promote the use of alternative fuels with much lower GHG intensity on a Well-to-Wake (WtW) basis, several barriers remain that will take time to overcome. These include the scaling of renewable energy sources for green fuel production, development of storage and bunkering infrastructure, and addressing the higher costs compared to conventional fuels. These challenges are shifting attention toward EETs, which can bridge the gap to alternative fuels while mitigating the financial impact of compliance penalties and rising fuel costs.

RETROFITS RELATED TO ENERGY MANAGEMENT AND ENERGY TRANSITION

To support the industry's ambitious emissions targets, both operational and technical improvements will be needed. Operational improvements can include optimized weather routing, trim, tank heating and setting of variable frequency drives (VFD), among others. Technical improvements can include wind propulsion technologies (WPT), lower-friction hull coatings, propulsion improvement devices, waste heat recovery (WHR) systems and much more.

A selection of retrofit scenarios and their relevance to energy management and transition is shown below.

Energy Management   Energy Transition

Retrofit Scenario	Impact
PROPULSION EFFICIENCY	
Propeller modification	Increase propulsive efficiency by improving the flow around the blade.
Propeller replacement	Increase propulsive efficiency at the vessel's operating profile.
Bulbous bow optimization	Reduction of resistance at the intended vessel speed and draft.
Bow foils	Reduction of resistance by dampening the vessel's pitch motion.
Bow wind shield/deflector	Reduction of resistance by improving the vessel's aerodynamics.
Containership side gap protector	Reduction of resistance by improving the vessel's aerodynamics.
Propeller cap fin	Reduction of propeller hydrodynamic losses.

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Duct, primarily for slower vessels, e.g., tankers and bulk carriers **Duct with twisted fin, primarily for faster vessels, e.g., containerships**	A duct with integrated fins is placed in front of the propeller. The duct accelerates the wake, producing a net forward thrust. The fins provide a pre-swirl to the wake, which reduces the losses in the propeller slipstream, increasing propeller thrust.
Wake equalizing and flow separation alleviating devices	Homogenization of the wake field by redirecting the flow to the upper part of the propeller disk. By homogenizing the flow, the propulsion efficiency is increased. The flow is also accelerated due to the lift created because of the aerofoil shape of the duct cross-section.
Rudder bulb	The rudder bulb minimizes the hub vortex, regaining some of the rotational losses.
Lower friction coatings	Reduction of frictional resistance by applying advanced coatings to the hull and/or propeller.
Air lubrication system (ALS)	Reduction of frictional resistance is achieved by pumping air beneath the hull, thus reducing the area of hull in direct contact with the liquid flow.
TRANSMISSION EFFICIENCY	
Multi-sloped aftmost bearing	Prevention of bearing failure. Reduction of transmission losses.
COMBUSTION EFFICIENCY	
Propulsion engine new nozzles	Reduction of specific fuel oil consumption.
AUXILIARY ENGINE LOAD REDUCTION	
Variable frequency drives (VFD) for pumps, fans and other electrical equipment	Variable frequency drives allow a pump's flow to be regulated by varying the speed of the pump rather than throttling the flow, thus leading to lower consumption at lower loads. Similarly, VFDs can be fitted to fans and other equipment operating at variable capacity.
Heat, ventilation and air conditioning (HVAC) automated control systems	Provide a variable capacity sufficient to meet needs rather than operating at full capacity all the time.
Solar films/screens on bridge windows	Reduction of the energy demand for cooling, thus saving on HVAC electrical consumption. Improved blocking of solar radiation, thus better working conditions for the crew.
Light-emitting diode (LED) lighting	Reduction of the electrical energy demand by replacing inefficient incandescent bulbs with low-power LED lighting, with or without automatic motion sensors.
Onshore power supply (OPS)	Reduction of auxiliary engine load at port.

Continued on next page

WASTE HEAT RECOVERY	
Microboiler or auxiliary engine exhaust gas economizer	Taking the excess exhaust heat from auxiliary engines. The microboiler reduces the energy required to generate steam on board the vessel. It is normally utilized when the vessel is at port during cargo discharge or at sea when additional steam is required. Moreover, this retrofit may be combined with other retrofits, such as an OCCS, where the original steam capacity is insufficient.
WHR system	Taking the excess exhaust heat and using it to power an exhaust gas turbine and/or to generate additional steam to power a steam turbine to generate additional electricity and for heating water systems and fuel tanks.
RENEWABLE ENERGY	
Photovoltaic (PV) solar panel	Conversion of solar energy to auxiliary power.
Wind turbine	Conversion of wind energy to auxiliary power.
WPT	Conversion of wind energy to propulsion power.
ALTERNATIVE FUEL	
Propulsion engine modification for new fuel	Reduction of WtW GHG emissions.
EMISSIONS ABATEMENT FUEL	
OCCS	Reduction of onboard GHG emissions.
ENERGY OPTIMIZATION VIA SOFTWARE/HARDWARE	
VFD optimization	Reduction of electrical energy demand.
Energy/power management, including HVAC optimization	Reduction of electrical energy demand.
Trim optimization	Reduction of propulsion energy demand.
Optimum cargo tank heating	Reduction of steam energy demand.
CAPACITY	
Increase of deadweight via deeper draft	Improve operational efficiency.

WORKFORCE

While new technologies have a key part to play in enabling the maritime industry's trend toward reducing emissions, the industry also needs a dedicated workforce of experienced people to enable successful implementation. There is a growing slice of the industry's broader workforce that is dedicated to performance assessment, prediction, in-service evaluation and in-service optimization. These specialists require continual training and updating on the latest techniques and methodologies to help companies get the most out of their improvement measures.

ABS SUPPORT FOR ENERGY EFFICIENCY TECHNOLOGIES

ABS helps clients address environmental objectives with a range of sustainability services, including assessments of alternative fuels and energy efficiency measures. In addition, ABS drives awareness of new technologies and measures by engaging the industry with seminars, informative meetings and advisory publications. ABS has supported the industry's trend toward improving energy efficiency since the beginning. The ABS *Advisory on Ship Energy Efficiency Measures* was one of the industry's first to provide comprehensive guidance to owners and operators on the wide range of options being promoted to improve vessel efficiency, reduce fuel consumption and lower emissions.

ABS has a dedicated team of subject matter experts who work with stakeholders while they evaluate retrofit solutions for their vessels. Exploring EETs means investigating the impact on a vessel's energy profile without compromising safety. To achieve this, shipowners must take key steps when implementing EETs:

- Assess the present performance of shipboard systems and identify energy savings from specific improvements based on the vessel's operational characteristics.
- Predict the savings derived from additional EETs for anticipated operating conditions through modeling and simulation based on routes, automatic identification system (AIS) and hindcast metocean data.
- Identify and address any potential hazards to the vessel and crew through hazard identification (HAZID) and hazard and operability study (HAZOP) workshops.
- Evaluate energy savings based on in-service measurements through vessel performance modeling and analysis.
- Optimize the energy demand by deploying mathematical techniques, such as computation fluid dynamics (CFD) for a bulbous bow optimization study or non-heuristic optimization algorithms for a voyage optimization study.

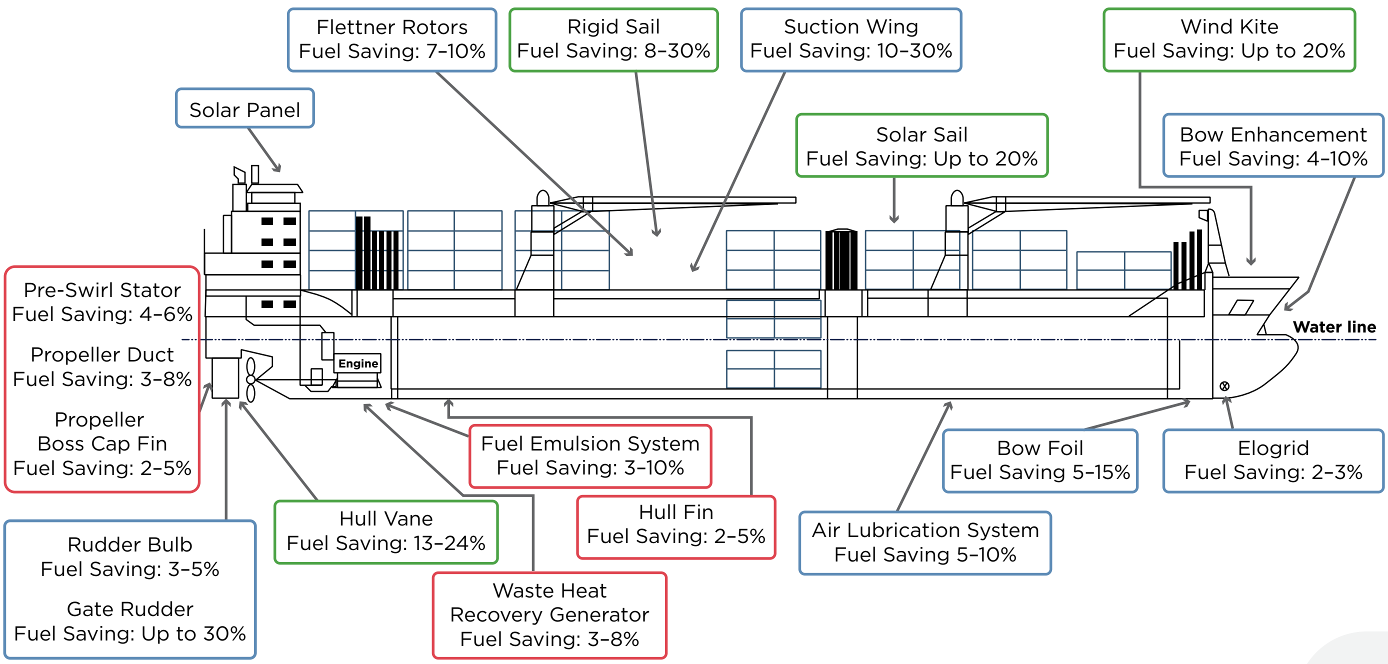


Figure 1: Growing range of energy-saving technologies. Fuel savings are based on marketing claims and do not account for fitting multiple technologies. (Source: Various market sources, Clarksons Research, October 2024)

CLASSIFICATION AND STATUTORY REQUIREMENTS

Shipowners and managers considering energy and emissions-based retrofits need to understand the applicable classification and statutory requirements.

SOLAS CHAPTER II-1, REGULATIONS 5.4 AND 5.5

In relation to Chapter II-1, Part B-1 stability, regulations 5.4 and 5.5 read as follows:

4. *Where any alterations are made to a ship so as to materially affect the stability information supplied to the master, amended stability information shall be provided. If necessary, the ship shall be re-inclined. The ship shall be re-inclined if anticipated deviations exceed one of the values specified in paragraph 5.*

5. *At periodical intervals not exceeding five years, a lightweight survey shall be carried out on all passenger ships to verify any changes in lightship displacement and longitudinal centre of gravity. The* ship shall be re-inclined whenever, in comparison with the approved stability information, a deviation from the lightship displacement exceeding 2% or a deviation of the longitudinal centre of gravity exceeding 1% of L is found or anticipated.

MSC.1/Circ.1362/Rev.2, unified interpretation reads as follows:

Scenario as Calculated by Lightweight Calculation	Requirement for Inclining Test	Update of Stability Information
Lightweight change > 2%	Yes	Yes, using new incline result
Longitudinal center of gravity (LCG) change > 1% of L (either forward or aft)	Yes	Yes, using new incline result
Vertical center of gravity (VCG) change > 1%	Yes	Yes, using new incline result
1% < Lightweight change ≤ 2%	No	Yes, using lightweight calculation
0.5% of L < LCG change ≤ 1% of L (either forward or aft)	No	Yes, using lightweight calculation
0.5% < VCG change ≤ 1%	No	Yes, using lightweight calculation
Lightweight change ≤ 1%	No	No
LCG change ≤ 0.5% of L (either forward or aft)	No	No
VCG change ≤ 0.5%	No	No

The term "lightweight calculation" means a detailed calculation of weights on and weights off a ship, resulting from all alterations to the ship since the date of the last approved inclining test, to determine the adjusted lightship properties. Lightship properties include weights and the center of gravity. The documented weights and their centers of gravity should be verified on board/on site by the attending class surveyor.

The term "stability information" includes any document (whether on paper or electronic) or electronic means of calculation of stability which includes lightship properties. This could include, but is not limited to, the approved stability book, computer software for onboard calculation of stability, the approved strength book and the loading instrument. Refer to relevant requirements included in 3-3-1, 3-3-A1, 3-3-A4, 3-3-A7, 3-2-1/7, 3-2-A2 and 3-2-A3 of ABS *Rules for Building and Classing Marine Vessels* (Marine Vessel Rules).

LIGHTWEIGHT CALCULATION REPORT

Even if an inclining test is not required and the stability information is not required to be updated, the lightweight calculation report should still be endorsed and placed on board with the stability booklet for future reference.

When multiple alterations are made to a ship in service over a period of time, and each alteration is within the deviation limits specified above, the cumulative total changes to the lightship properties from the most recent inclining also should not exceed the deviation limits; otherwise, the ship should be reinclined.

MARPOL ANNEX VI, REGULATION 2.2.17

In relation to Chapter 4 regulations on carbon intensity, regulation 2.2.17 reads as follows:

Major conversion means in relation to Chapter 4 of this Annex a conversion of a ship:

1. *which substantially alters the dimensions, carrying capacity or engine power of the ship; or*
2. *which changes the type of the ship; or*
3. *the intent of which in the opinion of the Administration is substantially to prolong the life of the ship; or*
4. *which otherwise so alters the ship that, if it were a new ship, it would become subject to relevant provisions of the present Convention not applicable to it as an existing ship; or*
5. *which substantially alters the energy efficiency of the ship and includes any modifications that could cause the ship to exceed the applicable required EEDI as set out in regulation 24 of this Annex or the applicable required EEXI as set out in regulation 25 of this Annex.*

Interpretation:

2.1 For regulation 2.2.17.1, any substantial change in hull dimensions and/or capacity (e.g., change of length between perpendiculars (LPP) or change of assigned freeboard) should be considered a major conversion. Any substantial increase of total engine power for propulsion (e.g., 5% or more) should be considered a major conversion. In any case, it is the Administration's authority to evaluate and decide whether an alteration should be considered a major conversion, consistent with chapter 4.

> ***Note:*** *Notwithstanding paragraph 2.1, assuming no alteration to the ship structure, both decrease of assigned freeboard and temporary increase of assigned freeboard due to the limitation of deadweight or draft at calling port should not be construed as a major conversion. However, an increase of assigned freeboard, except a temporary increase, should be construed as a major conversion.*

2.2 Notwithstanding paragraph 2.1, for regulation 2.2.17.5, the effect on Attained EEDI as a result of any change of ships' parameters, particularly any increase in total engine power for propulsion, should be investigated. In any case, it is the Administration's authority to evaluate and decide whether an alteration should be considered a major conversion, consistent with chapter 4.

2.3 A company may, at any time, voluntarily request re-certification of the EEDI, with IEE Certificate reissuance, on the basis of any new improvements to the ships' efficiency that are not considered to be major conversions.

2.4 In regulation 2.2.17.4, the terms "new ship" and "existing ship" should be understood as they are used in MARPOL Annex I, regulation 1.9.1.4, rather than as the defined terms in regulations 2.2.13 and 2.2.18.

2.5 The term "a ship" referred to in regulation 5.4.2 is interpreted as "new ship".

ALTERNATIVE ARRANGEMENTS, NOVEL CONCEPTS AND NEW TECHNOLOGIES

The ABS *Rules for Alternative Arrangements, Novel Concepts and New Technologies* (Part 1D), is applicable to and an integrated part any set of ABS Rules, Requirements and Guides.

Due to the rapid development and adoption of new technologies, goal-based standards have been incorporated into the ABS Rules. Goal-based standards offer a path for class approval for alternative and novel concepts. Existing class requirements often prescribe a specific technical solution. Since goal-based standards do not dictate specific technical solutions, they are better suited to accommodate future technological developments.

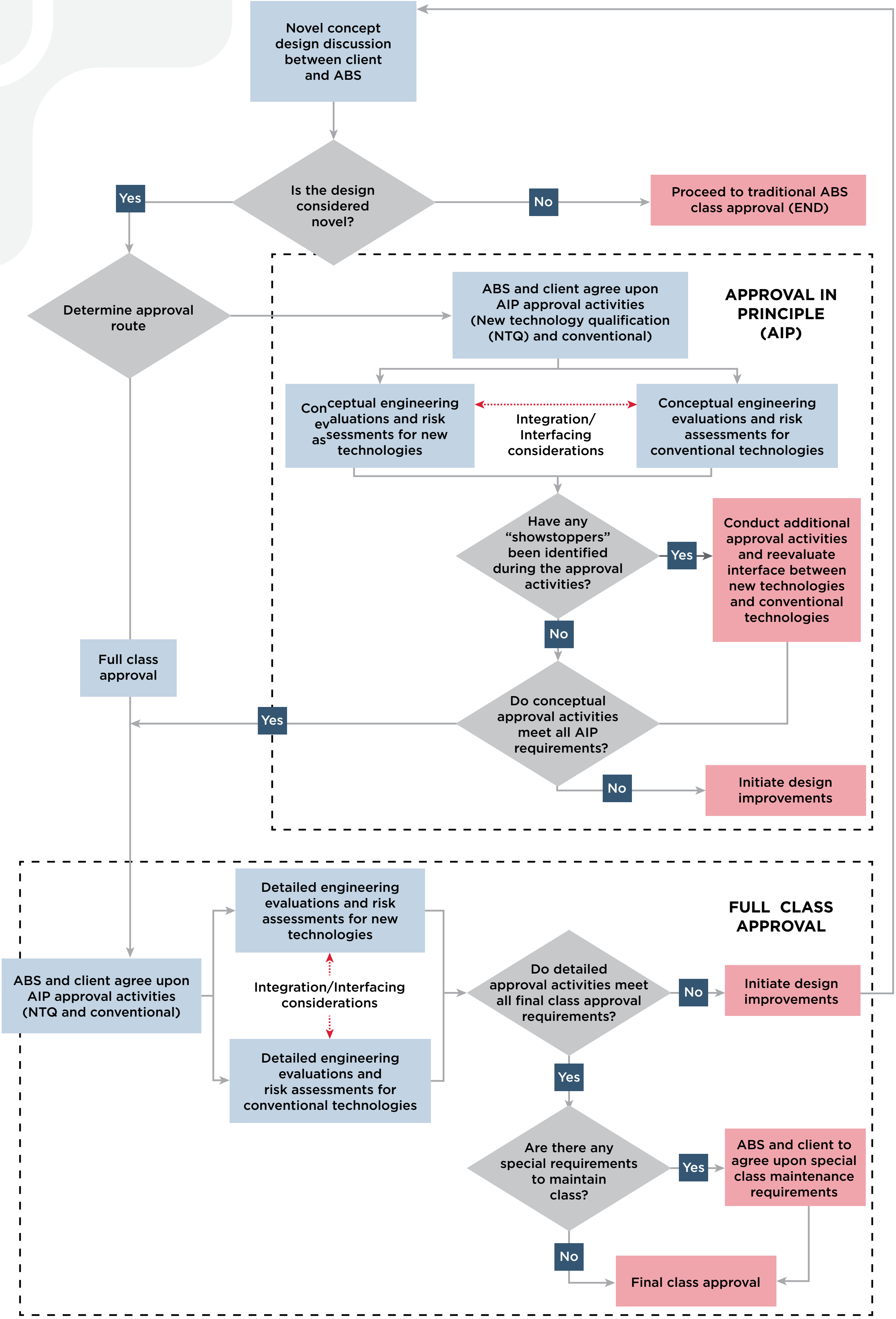


Figure 2: Process flow for ABS approval of novel concepts.

REDUCING RISK

New technologies start as ideas, often undefined and uncertain until they are refined using available tools. Figure 3 illustrates this progression. The goal is that the product meets the same standards for asset integrity, environmental protection and safety as conventional projects

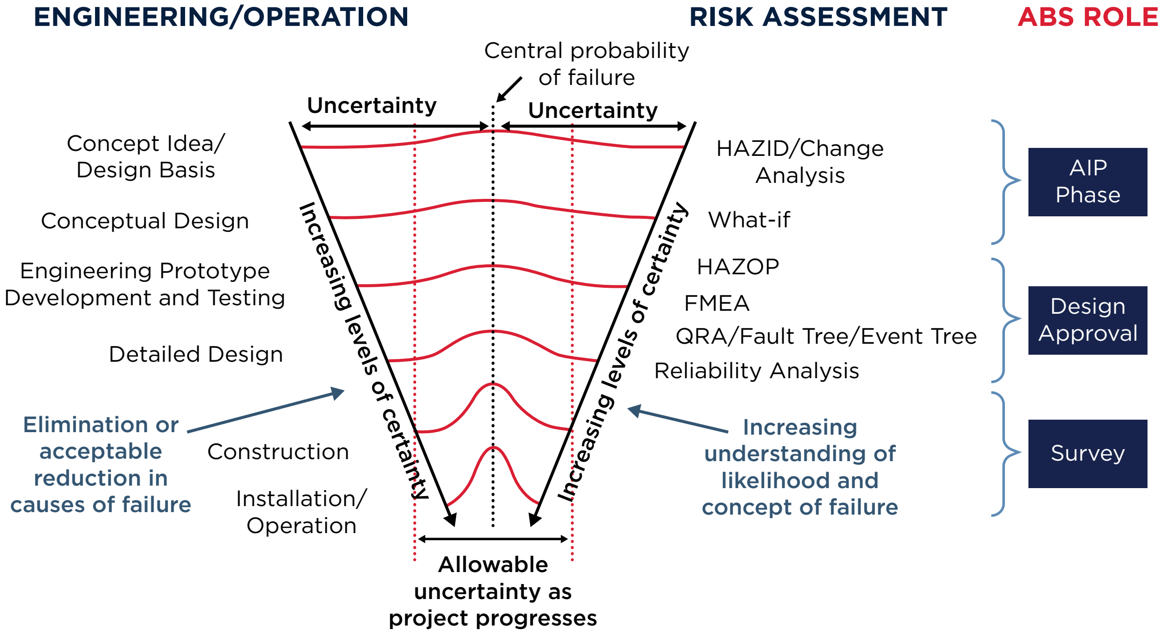


Figure 3: Idea refinement progression.

ISM, ISPS, MLC

Under the International Safety Management (ISM) Code, potential hazards should be identified and addressed in ship operating procedures (see ISM Code).

In accordance with the International Ship and Port Facility Security (ISPS) Code, a new ship security assessment (SSA) may be required to determine if there are any new security vulnerabilities due to the retrofit. This may also require revisions to the ship security plan (SSP) based on the results of the SSA (see ISPS Code, Part B/8 and 9).

As per the Maritime Labour Convention (MLC), a new MLC inspection may be required if substantial changes are made to the ship's structure or equipment covered under Title 3 of the convention (see MLC, Standard A 5.1.3, Para 14 (e)).

RETROFIT SCENARIOS

While every effort has been made to identify class and statutory-related requirements for the following retrofit scenarios, additional requirements may be identified once the details of the retrofit project are reviewed by ABS.

SCENARIO →	EXISTING PROPELLER MODIFICATION OR REPLACEMENT WITH A NEW PROPELLER
Class-related requirements	For existing propeller modification or replacement with a newly designed propeller, see relevant requirements in 4-3-3 of the Marine Vessel Rules, 2024.
Statutory-related requirements	MEPC.1/Circ.850/Rev.3, Guidelines for determining minimum propulsion power to maintain the maneuverability of ships in adverse conditions, applicable to bulk carriers, tankers and combination carriers of equal or more than 20,000 deadweight (dwt). ABS approval and equipment certification report for the new propeller

SCENARIO →	BULBOUS BOW
Class-related requirements	The requirements for hull structural strength are included in the Marine Vessel Rules, 2024 (3-2-2/5, 3-2-9/3.1, 3-2-A2/5.3, 5C-3-6/5, 5C-5-6/5, 5C-12-6/3). The requirements for anchoring and mooring equipment in association with the increased displacement of the hull are included in 3-5-1 of the Marine Vessel Rules with applicable Rules.
Statutory-related requirements	The requirements for lightship determination and stability information are included in 3-3-1, 3-3-A1, 3-3-A4 and 3-3-A7 of the Marine Vessel Rules, 2024, and the following regulations based on the ship type and freeboard type, which may not be mandatory subject to the lightship determination. • International Code on Intact Stability, 2008, as amended • Load Lines 1966 and Protocol of 1988, as amended • International Convention for the Safety of Life at Sea (SOLAS) Consolidated Edition 2020, as amended • International Convention for the Prevention of Pollution from Ships (MARPOL) Consolidated Edition 2017, as amended • International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC) Code, 2016 Edition, as amended • International Bulk Chemical (IBC) Code, 2020 Edition, as amended

SCENARIO →	BOW FOILS
Class-related requirements	3-2-7/15 of ABS *Rules for Building and Classing High-Speed Craft* ABS *Rules for Alternative Arrangements, Novel Concepts and New Technologies* (Part 1D)
SCENARIO →	BOW WIND SHIELD/DEFLECTOR
Class-related requirements	While there are no specific ABS Rules or Requirements for wind shield structures, the following requirements may be used for the strength of structures, with some adjustments for the proposed design. 5C-5-6/27 "Breakwater" and 3-2-11/3 "Exposed Bulkheads" of the Marine Vessel Rules, 2024
Statutory-related requirements	SOLAS V/22 "Navigation bridge visibility"
SCENARIO →	PROPELLER CAP FIN
Class-related requirements	4-3-3/1.5.5, 4-3-3/3.1 and 4-3-3/5.17 of the Marine Vessel Rules, 2024 Shaft alignment analysis and torsional vibration analysis are to be reconsidered in case there is a change of 4 percent or more in the propeller mass or in the polar moment of inertia of the propeller (including boss cap, hub, etc.) of a conventional propulsion shafting arrangement.
SCENARIO →	DUCT, WAKE EQUALIZING AND FLOW SEPARATION ALLEVIATING DEVICES
Class-related requirements	3-2-13/11 of the Marine Vessel Rules, 2024

SCENARIO →	RUDDER BULB OR ASYMMETRIC RUDDER
Class-related requirements	The requirements for rudder bulbs are included in 3-2-14 of the Marine Vessel Rules, 2024.
Statutory-related requirements	Sea trial for turning characteristics

SCENARIO →	AIR LUBRICATION SYSTEM INCLUDING ADDITIONAL AUXILIARY, PIPING AND STRUCTURAL MODIFICATIONS
Class-related requirements	The requirements for hull supporting structures are included in the Marine Vessel Rules, 2024. The requirements for piping are included in 4-6-2 of the Marine Vessel Rules, 2024. ABS *Requirements for Air Lubrication System Installation* lists the class requirements.
Statutory-related requirements	MEPC.1/Circ.896, *Guidance on Treatment of Innovative Energy Efficiency Technologies for Calculation and Verification of The Attained Energy Efficiency Design Index (EEDI) and Energy Efficiency Existing Ship Index (EEXI)*

SCENARIO →	DOUBLE OR MULTISLOPED AFTMOST BEARING
Class-related requirements	4-3-2/7.3.3 and 4-3-2/11.1.2(b) of the Marine Vessel Rules, 2024 or ABS *Enhanced Shaft Alignment (ESA) Guide* and in conjunction with relevant assigned ABS class notations

SCENARIO →	PROPULSION ENGINE NEW NOZZLES
Class-related requirements	4-2-1 of the Marine Vessel Rules, 2024
Statutory-related requirements	NO_x Technical Code — *Technical Code on Control of Emission of Nitrous Oxides from Marine Diesel Engines*

SCENARIO →	VFD
Class-related requirements	The requirements for semiconductor converter motor drives having a rated power of 100 kilowatts (kW) and over, intended for essential services, etc., are included in sections 4-8-3/8 of the Marine Vessel Rules, 2024.

SCENARIO →	HVAC AUTOMATED CONTROL SYSTEMS
Class-related requirements	ABS *Guide for Crew Habitability on Ships* and ABS *Guide for Passenger Comfort on Ships* in conjunction with relevant assigned optional ABS class notations
Statutory-related requirements	International Labour Organization Maritime Labour Convention, 2006 (MLC, 2006), as amended

SCENARIO → LED LIGHTING

Class-related requirements	4-8-2/7.13 of the Marine Vessel Rules, 2024 ABS *Guide for Crew Habitability on Ships* and ABS *Guide for Passenger Comfort on Ships* in conjunction with relevant assigned optional ABS class notations
Statutory-related requirements	IMO Maritime Safety Committee (MSC) Resolution 253(83), as applicable

SCENARIO → OPS

Note: From January 1, 2030, FuelEU Maritime will require passenger ships and containerships above 5,000 gt to use cold ironing when berthing at EU ports for more than two hours, unless they use an alternative zero-emission technology.

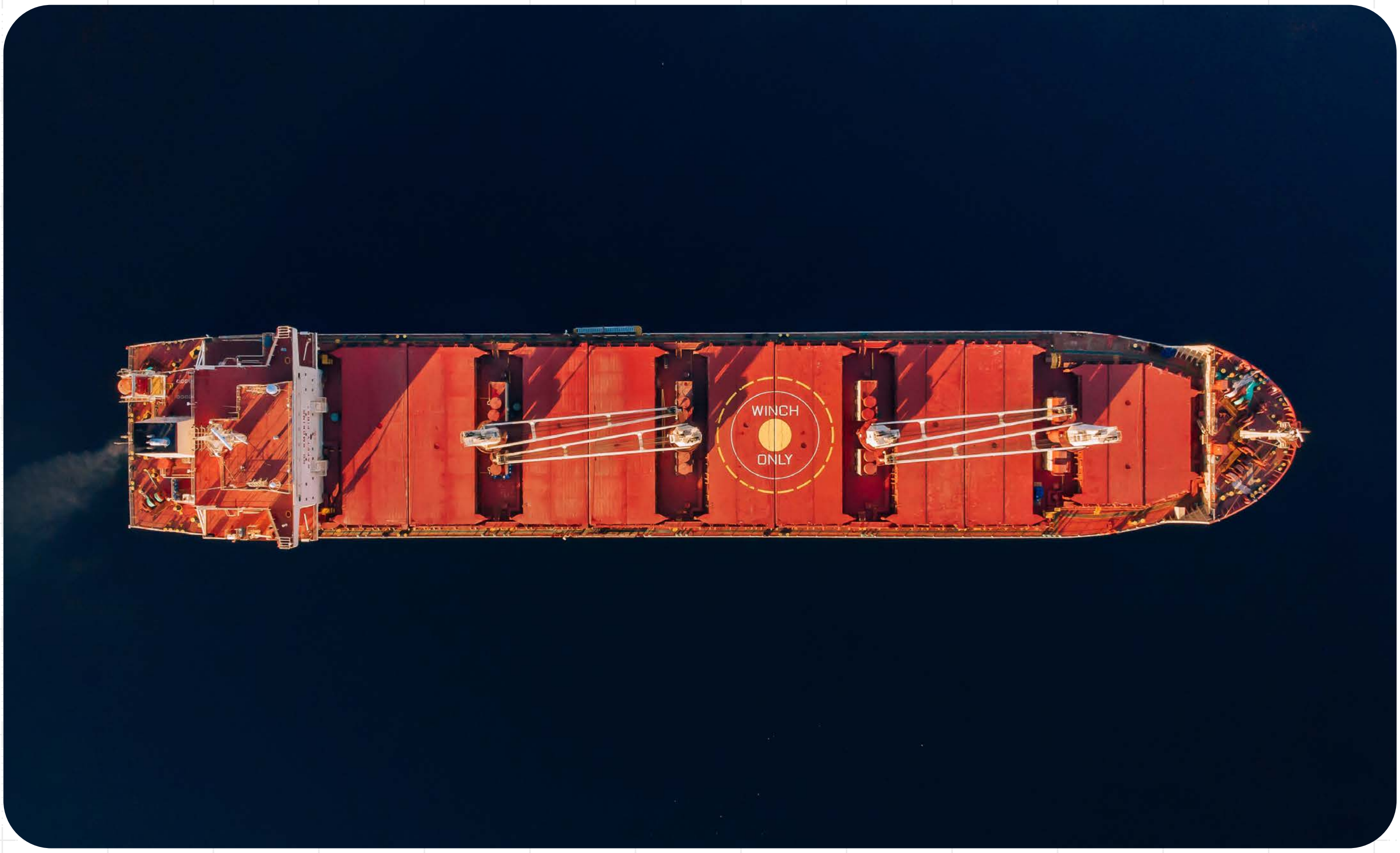
Class-related requirements	The requirements for shore connection systems are included in sections 6-4-1 of the Marine Vessel Rules, 2024. Low-voltage shore connection system and high-voltage shore connection system are relevant notations with requirements.
Statutory-related requirements	IMO/MSC. Circ. 1675

SCENARIO →	EXHAUST GAS ECONOMIZER
Class-related requirements	4-4-1 and 4-6 of the Marine Vessel Rules, 2024

SCENARIO →	WHR SYSTEM
Class-related requirements	4-4-1 and 4-8-1 of the Marine Vessel Rules, 2024, as applicable

SCENARIO →	PV SOLAR PANELS
Class-related requirements	ABS *Requirements for Hybrid Electric Power Systems for Marine and Offshore Applications*

SCENARIO →	WIND TURBINE
Class-related requirements	ABS *Requirements for Hybrid and All-Electric Power Systems for Marine and Offshore Applications*



SCENARIO →	WPT, ROTOR OR SAIL
Class-related requirements	ABS *Requirements for Wind Assisted Propulsion System Installation*, July 2022. The ABS *Requirements for Survey After Construction for WPT* are included in Part 7, Chapter 9 of the Marine Vessel Rules, 2024.
Statutory-related requirements	• SOLAS Chapter V, Regulation 22 - Navigational Bridge Visibility • SOLAS CHAPTER II-1, Regulations 5.4, 5.5. – Stability • MSC.1/Circ.1362/Rev.1 - Annex - Unified Interpretation of SOLAS Regulations II-1/5.4 and II-1/5.5, Relating to the Amendment to the Stability/Loading Information in Conjunction with the Alterations of Lightweight • MSC.1/Circ.1627 - Interim Guidelines on the Second Generation Intact Stability Criteria • Circular MEPC.1/Circ.850/Rev.3 - Guidelines for determining Minimum Propulsion Power to maintain the maneuverability of ships in adverse conditions • MARPOL ANNEX VI, Regulation 2.2.17 - Definition of “Major Conversion” • IGC Code, 2016 Edition, as amended • IBC Code, 2020 Edition, as amended • IMO MSC.137(76) - Standards for Ship Maneuverability • COLREG - Requirements for Navigational Lights • IMO MSC.1/Circ.1574 - Interim Guidelines for Use of Fiber Reinforced Plastic (FRP) Elements Within Ship Structures: Fire Safety Issues • ISM Code - Potential hazards in ship’s operational procedures • ISPS - A new Ship Security Assessment (SSA) may be required to determine if there are any new security vulnerabilities due to retrofit and potentially new Ship Security Plan (SSP). • MLC - Inspection may be required if substantial changes are made to ship’s structure or equipment covered under Title 3 of the convention. The addition of WPT does not render the vessel a “sailing vessel” under COLREG.

SCENARIO →	PROPULSION ENGINE MODIFICATION FOR NEW FUEL
Class-related requirements	4-2-1 of the Marine Vessel Rules, 2024. In addition to the propulsion engine modification for the new fuel, the fuel delivery system, fuel containment system, bunkering system, safety system and other systems as applicable will need to be modified and/or installed as part of the retrofit for the new fuel. 1. For vessels intended to carry liquefied gases in bulk (gas carriers) using gases or other low-flashpoint fuels: 5C-8-16 of the Marine Vessel Rules. 2. For vessels other than gas carriers using gases or other low-flashpoint fuels: 5C-13 of the Marine Vessel Rules (for Gases or other Low-Flashpoint Fuels). ABS *Requirements for Ammonia Fueled Vessels*, July 2022 ABS *Requirements for Methanol and Ethanol Fueled Vessels*, July 2022
Statutory-related requirements	International Code of Safety for Ships using Gases or other Low-Flashpoint Fuels (IGF Code), MSC.1/Circ.1621 for methyl/ethyl alcohol MSC.1/Circ 1666 for liquefied petroleum gas (LPG) For Gas Tankers using LPG cargo as fuel, see MSC.1/Circ. 1679 IMO *Interim Guidelines for the safety of ships using ammonia as fuel*, see MSC.1/Circ.1687

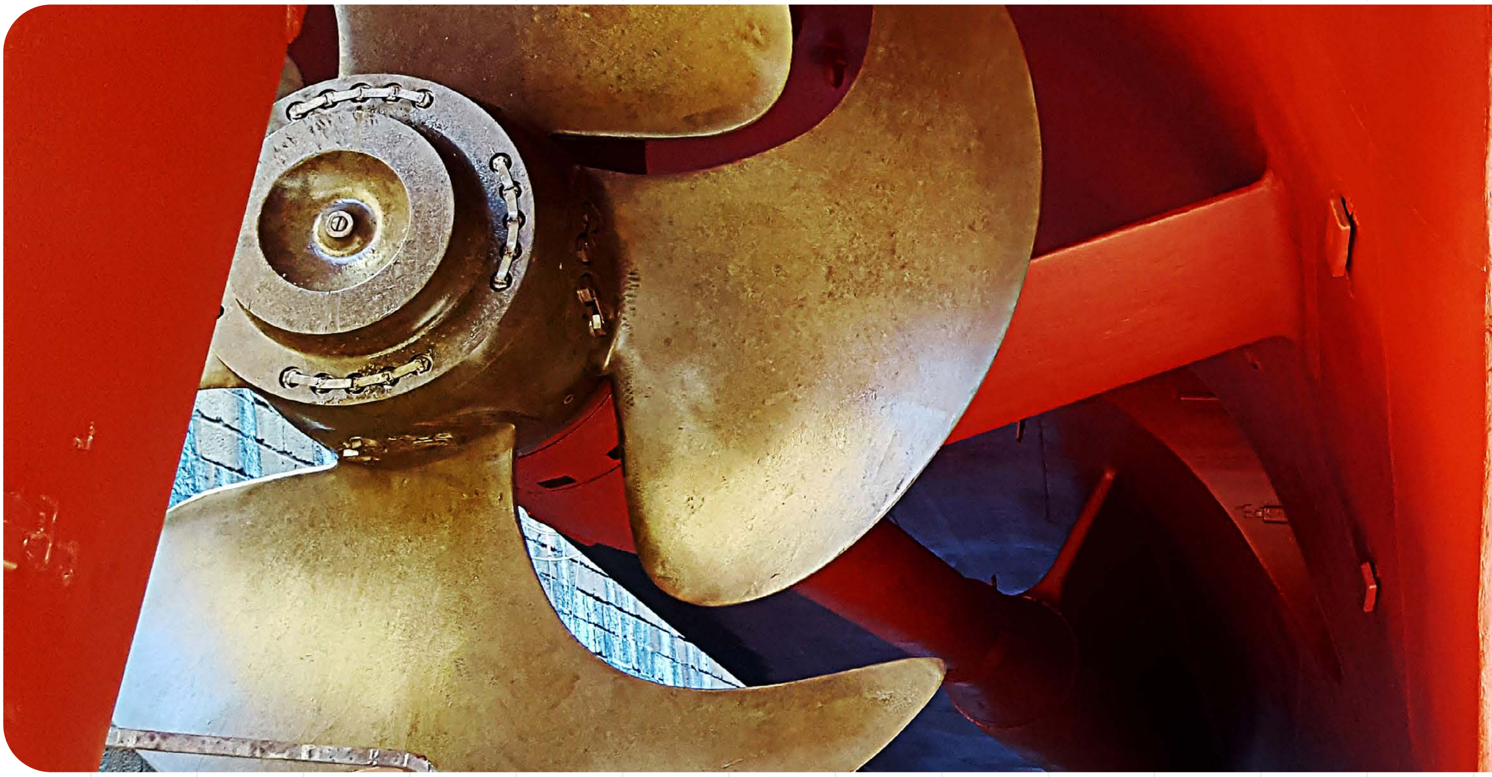
SCENARIO →	OCCS
Class-related requirements	ABS *Requirements for Onboard Carbon Capture and Storage*, July 2023. Onboard carbon capture exhaust gas cleaning systems that cause diesel engines to operate outside the exhaust backpressure limits detailed in the approved IMO MARPOL Annex VI Regulation 13 NO_x Technical Files may invalidate the emissions certification and will require a re-approval of the engine NO_x certification by the Administration or Recognized Organization responsible for the original certification.
Statutory-related requirements	NO_x Technical Code 2008 if applicable IMO Resolution MEPC.307(73), the 2018 *Guidelines for the Discharge of Exhaust Gas Recirculation Bleed-Off Water*, if applicable. IMO Resolution MEPC.340(77), the 2021 *Guidelines for Exhaust Gas Cleaning Systems*, if applicable

SCENARIO →	IMPLEMENTING NEW SOFTWARE FOR ENERGY/ POWER MANAGEMENT
Class-related requirements	The management of change for software is to be documented in sections 4-9-3/10.21 of the Marine Vessel Rules, 2024.
Statutory-related requirements	International Association of Classification Societies (IACS) E22 IACS E26 and 27 for Cyber Resilience are covered in 4-9-3, 4-9-13 and 4-9-14 of the Marine Vessel Rules, 2024.

SCENARIO →	IMPLEMENTING NEW SOFTWARE FOR TRIM OPTIMIZATION
Class-related requirements	The requirements for the loading computer are included in 3-2-A2/A3 of the Marine Vessel Rules, 2024.

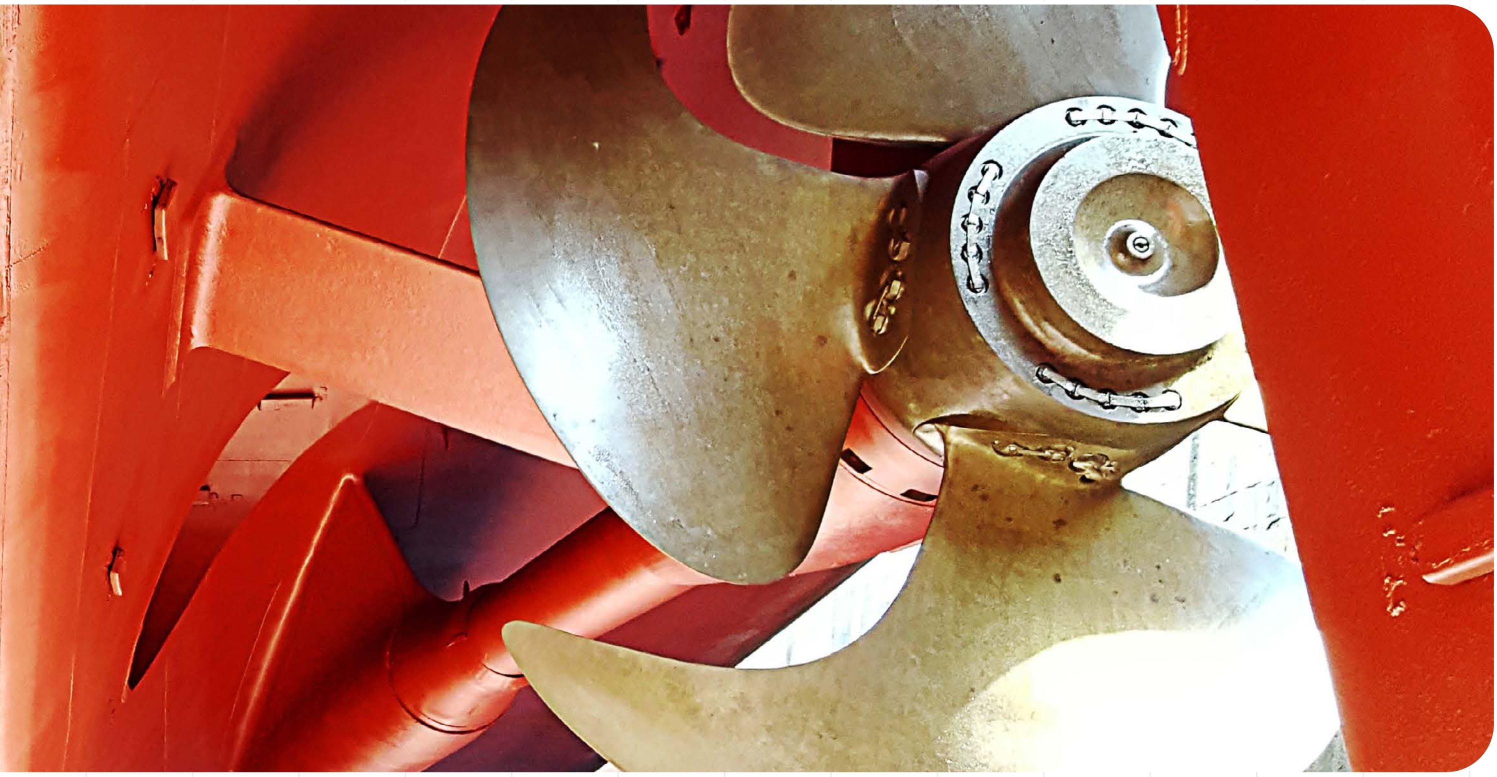
SCENARIO →	INTRODUCING NEW SOFTWARE FOR OPTIMUM CARGO TANK HEATING
Class-related requirements	The management of change for software is to be documented in sections 4-9-3/10.21 of the Marine Vessel Rules, 2024.
Statutory-related requirements	IACS E22 IACS E26 and 27 for Cyber Resilience are covered in 4-9-3, 4-9-13 and 4-9-14 of the Marine Vessel Rules, 2024.

SCENARIO →	INSTALLATION OF DOUBLE OR MULTI-SLOPE AFTMOST BEARING
Class-related requirements	4-3-2/7.3.3 and 4-3-2/11.1.2(b) of the Marine Vessel Rules, 2024 or ABS *ESA Guide* for optimized double slope and in conjunction with relevant assigned notations.



SCENARIO → INCREASING THE DWT VIA A DEEPER DRAFT

Class-related requirements	The requirements for hull-girder strength, local strength and total strength reevaluation are included in Part 3, Part 5A, 5B and 5C of the Marine Vessel Rules, 2024. The requirements for anchoring and mooring equipment are included in 3-5-1 of the Marine Vessel Rules, 2024.
Statutory-related requirements	The requirements for freeboard calculations are included in Load Line, 1966, and the Protocol of 1988, as amended. The requirements for stability information are included in 3-3-1, 3-3-A1, 3-3-A4 and 3-3-A7 of the Marine Vessel Rules, 2024 and the following Regulations based on ship and freeboard type: • International Code on Intact Stability, 2008, as amended • Load Lines 1966 and Protocol of 1988, as amended • SOLAS Consolidated Edition 2020, as amended • MARPOL Consolidated Edition 2017, as amended • IGC Code, 2016 Edition, as amended • IBC Code, 2020 Edition, as amended The requirements for updating the Damage Control Plan and booklet are included in SOLAS Consolidated Edition 2020, as amended. Update of the applicable tonnage certificates.



A retrofit scenario will trigger a check or a revision against a statutory regulation or guidance. The following table is indicative of how many different regulations can be considered during a retrofit project, unless otherwise agreed by the flag Administration.

Retrofit Scenario	Attained EEXI	EEXI Technical File	IEEC and IEEC Supplement (When Applicable)	Ship Energy Efficiency Management Plan (SEEMP) Part III	Minimum Propulsion Power (MEPC1, Circ. 850, Rev.3)
New Bulbous Bow	Mandatory check. New bulbous bow means a new speed-power curve, which means a change in the Attained EEXI. Must confirm the new Attained EEXI has been determined acceptably and that it does not exceed the Required EEXI.	Revision of the EEXI technical file may be required if attained value exceeds required value.	If the EEXI technical file is revised, then a new International Energy Efficiency Certificate (IEEC) Supplement to be issued.	Optional (improvement measure)	--
New Propeller	Mandatory check. New propeller means a new speed-power curve, which means a change in the Attained EEXI. Must confirm the new Attained EEXI has been determined acceptably and that it does not exceed the Required EEXI.	Revision of the EEXI technical file may be required if attained value exceeds required value.	If the EEXI technical file is revised, then a new IEEC Supplement to be issued.	--	Mandatory check of Level 2 as applicable due to change of propeller characteristics.
Deeper Draft	Mandatory check. New deeper draft means a permanent change of Capacity, which means a change in the Attained EEXI. Must confirm the new Attained EEXI has been determined acceptable and that it does not exceed the Required EEXI	Both attained and required EEXI values are impacted by the permanent Capacity change, so technical file needs to be revised.	Mandatory issuance of IEEC and IEEC Supplement.	Mandatory revision of SEEMP Part III due to permanent change of capacity. The new annual required CII targets are changed due to the new Capacity.	Mandatory check as applicable due to permanent change of Capacity.
WPT	Optional	Optional	If the EEXI technical file is revised, then a new IEEC Supplement to be issued.	Optional (improvement measure)	Mandatory check of Level 2 as applicable due to change of wind resistance.
Propulsion Improvement Device (PID)	Optional	Optional	If the EEXI technical file is revised, then a new IEEC Supplement to be issued.	Optional (improvement measure)	--
Shore Power connection	--	--	--	Optional (improvement measure)	--
Microboiler/ WHR	Optional	Optional	Optional	Optional (improvement measure)	--
OCCS	--	--	--	--	--
Air Lubrication System	Optional	Optional	If the EEXI technical file is revised, then a new IEEC Supplement to be issued.	Optional (Improvement Measure)	--

Table 1 (continues below): Retrofit scenarios and statutory or regulatory guidance revisions.

Finnish-Swedish Ice Powering	Maneuverability	Visibility	Navigation Lights	SOLAS (Stability, Inclining Experiment)	Load Line	Equipment Number	MLC (Noise and Vibration
Mandatory check to confirm compliance with Finnish-Swedish Ice Powering requirement.	Mandatory revision of m\ Maneuvering Information (turning circle and zig zag), as bulbous bow influences maneuvering.	--	--	Stability calculations updated due to hydrostatics change. Updated plans (drawings) and loading instrument, loading information (trim and stability) and emergency response provider's model.	--	--	--
Mandatory check to confirm compliance with Finnish-Swedish Ice Powering requirement.	Mandatory revision of Maneuvering Information, as new propeller influences maneuvering.	--	--	--	--	--	Mandatory check due to new propeller, as well as where an MLC-ACCOM notation is applied.
Mandatory check to confirm compliance with Finnish-Swedish Ice Powering requirement.	Mandatory revision of Maneuvering Information due to new full load draft.	Mandatory check of visibility due to change of draft.	--	Due to new permanent draft, all stability documents and plans to be revised.	Mandatory revision of Load Line.	Mandatory revision of Equipment Number calculation due to permanent change of draft.	--
--	Mandatory revision of Maneuvering Information, as WPT influences maneuvering.	Mandatory check of visibility.	Mandatory check to see if COLREG is complied with.	Vessel's stability documents revised due to extra weight of WPT, including effect of WPT on heeling angle (GZ curve). Lightweight calculation, intact stability criteria, plans and loading instrument, loading information, and emergency response provider's model.	Mandatory revision of Load Line.	Mandatory revision of Equipment Number calculation due to change of projected area.	Mandatory check if positioned near accommodation or on superstructures, as well as where an MLC-ACCOM notation is applied.
--	Optional, depending on PID.	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--
--	--	--	--	Plans updated to show OCCS. Stability calculations checked due to extra weight of OCCS. Update plans (drawings) and loading instrument and loading information (trim and stability).	--	Mandatory check of Equipment Number due to potential change of projected area.	--
--	Optional revision of Crash Stop Test.	--	--	Update lightweight information.	--	--	Optional check due to use of air compressors.

Notes on Table 1:
- *In the case where the retrofit affects the engine power limitation of the vessel, the EEXI technical file may need to be updated, and the International Energy Efficiency Certificate (IEEC) reissued.*
- *Additional checks may need to be considered based on the technology to be installed, e.g., power demand in the electrical load analysis, lightning protection, radar blind sectors, etc.*

REGULATORY TRACKING

Planning a retrofit requires understanding both current requirements and those coming into force. ABS regularly issues the *Convention Amendment Matrix*, providing a summary of upcoming and recent amendments to key maritime conventions. The latest version includes outcomes up to MSC 108 and MEPC 82.

ABS also offers a Regulatory Tracker tool in the ABS MyFreedom™ Portal. The tracker features an easy-to-search database that helps users quickly identify the latest regulatory requirements impacting vessel design and operations.

EXPLORATORY BEST PRACTICES BY SHIPOWNERS

Shipowners and managers continually seek ways to enhance fleet performance through technological and operational improvements. They typically focus on energy-intensive systems like propulsion, cargo handling, ballasting/de-ballasting and auxiliary systems to boost efficiency.

PROJECT RECOMMENDATIONS

While there is no formal process, best practices for energy improvement projects offer several key tips:

1. Derive the vessel's current operational profile by combining AIS with Metocean Hindcast Data.
2. Assess the vessel's operation within or away from the as-built design range.
3. Prepare a specific vessel-system-technology mathematical performance model.
4. Assess current performance and reasons for degradation, if any.
5. Investigate technology compatibility and its impact on energy use and fuel consumption through performance simulations on actual trading routes or hypothetical operating conditions.
6. Evaluate the impact of alternative fuel implementation on emissions.
7. Liaise with the respective designer or technology provider, attain the design characteristics and redo the performance prediction.
8. Consider a CFD study, if applicable.
9. Derive performance reference values for predefined conditions, if needed for charter-party agreements.
10. Understand the actions required for compliance with classification and statutory requirements.
11. Carry out HAZID/HAZOP workshops as applicable and ensure that findings are followed up.
12. Consider the time required for the vessel to stay off-service for completion of the potential improvement.
13. Perform a life-cycle cost analysis (LCCA). Shipowners may need to consider the following:
    a. Capital expenditures (capex), including design, manufacturing, transportation, storage, installation and commissioning tests.
    b. Operating expenditures (opex), including periodic maintenance, personnel training and additional energy requirements, if any.
    c. Charter income differential.
14. Request clarifications from the technology provider regarding contractual warranties, in-service performance and reliability, and the availability, supply, and installation of hardware and software for online recording and guidance for optimum use. The recording should address both performance aspects and compliance with environmental regulations. Establish an agreement with the technology provider on how the solution will be evaluated during service.
15. Maintain sufficient and knowledgeable in-house manpower for planning and project execution.
16. Apply the experience gained and lessons learned from other improvement projects.

THE NEED FOR TRANSPARENT MODELING

Technologies where the provider is unable to provide a transparent engineering model for response in variable operating conditions are not suited for multi-parametric prediction simulation studies.

THE NEED FOR PROJECT MILESTONES

To avoid delays, consider setting milestones relating to risk assessment, design integration with other ship systems, hardware and software integration, production, classification and statutory approvals, installation and testing, surveys and certification, documentation for operation and maintenance, training and in-service performance evaluation.

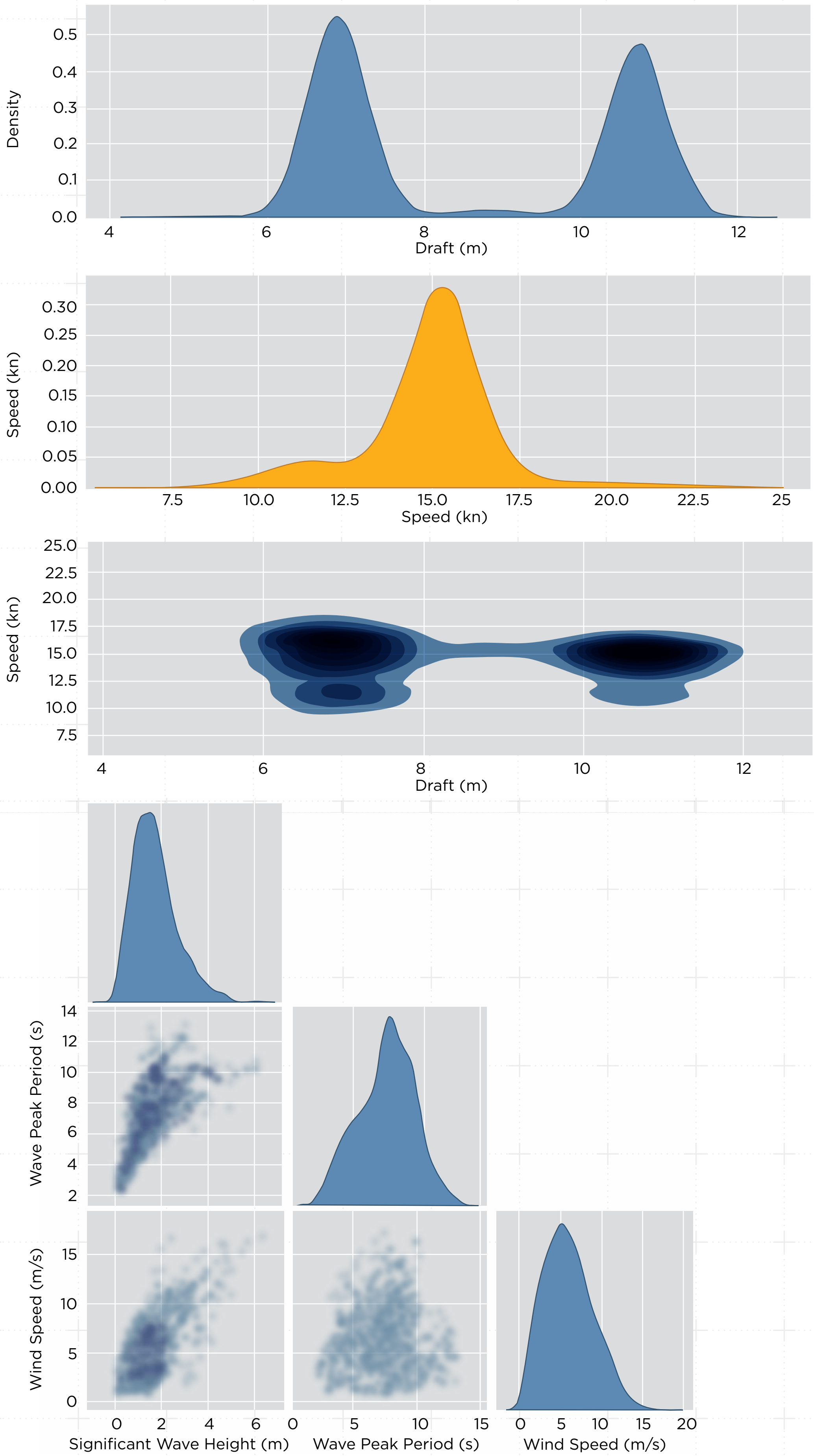


Figure 4: Example of advanced profiling.

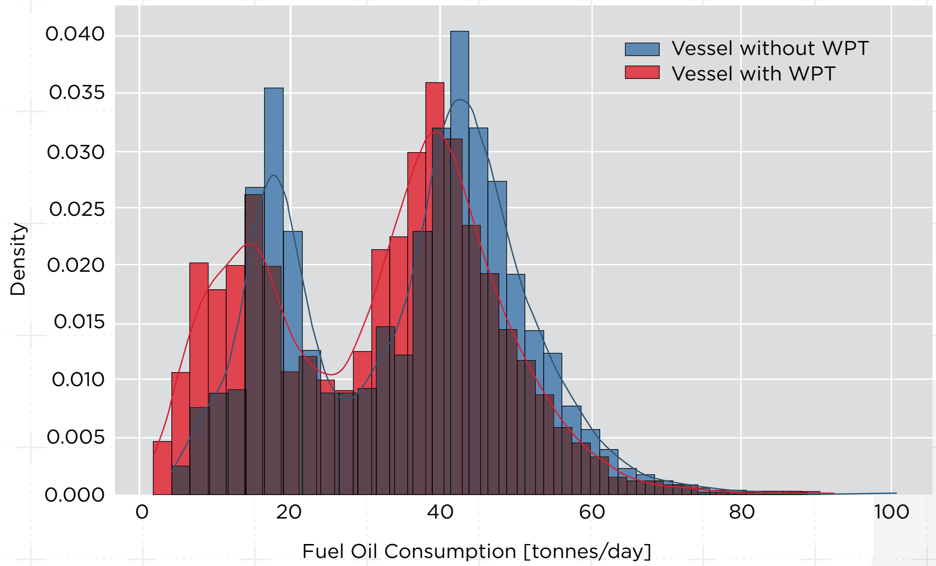


Figure 5: Example of fuel consumption histogram with and without WPT.

THE NEED FOR DESIGN CHARACTERISTICS

To achieve a higher confidence level in the performance results, whether for prediction or in-service evaluation, all relevant vessel-system-technology design characteristics should be identified and sourced as required by the transparent analytical methodologies to be applied.

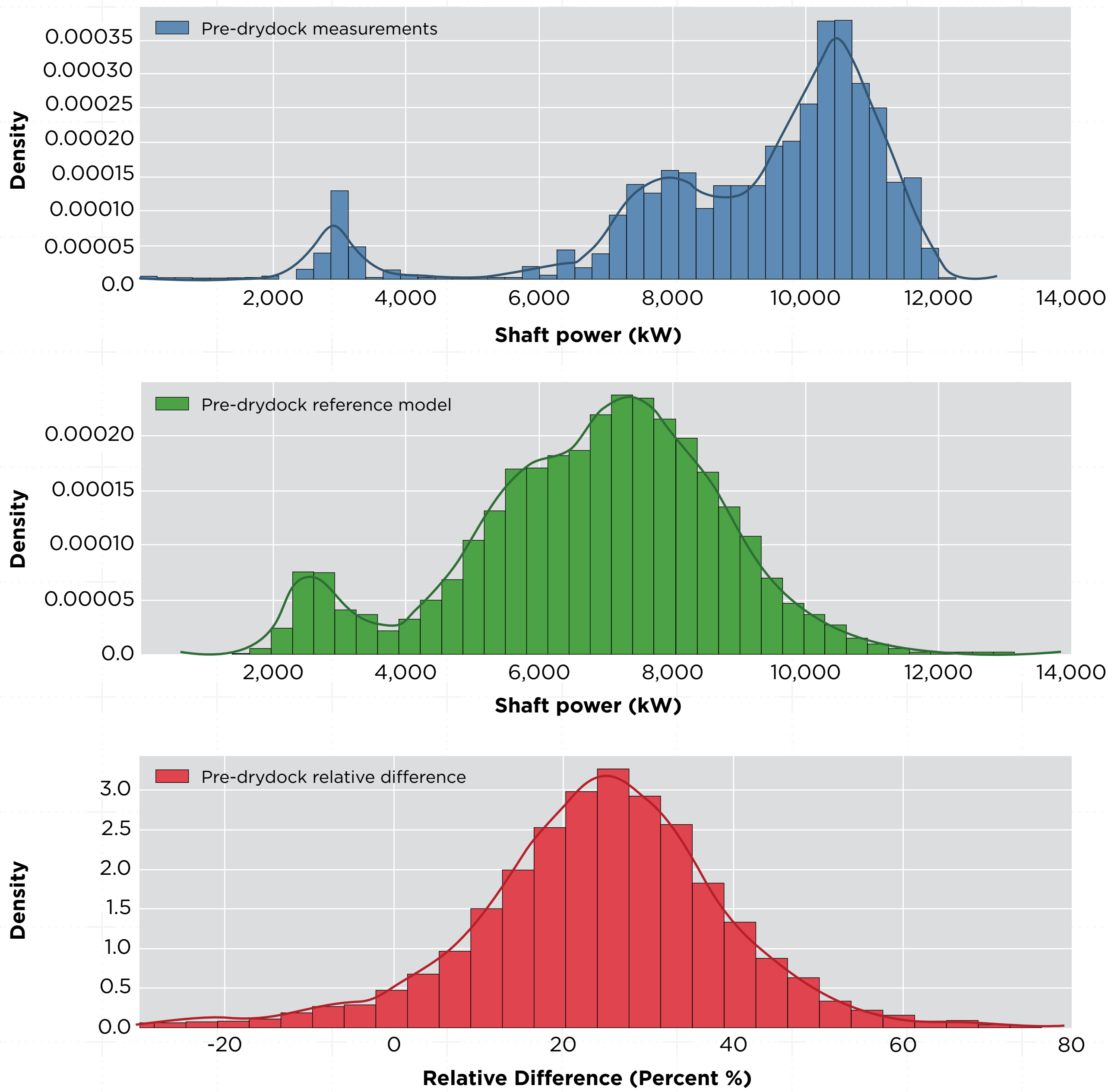


Figure 6: Example of pre-drydock performance.

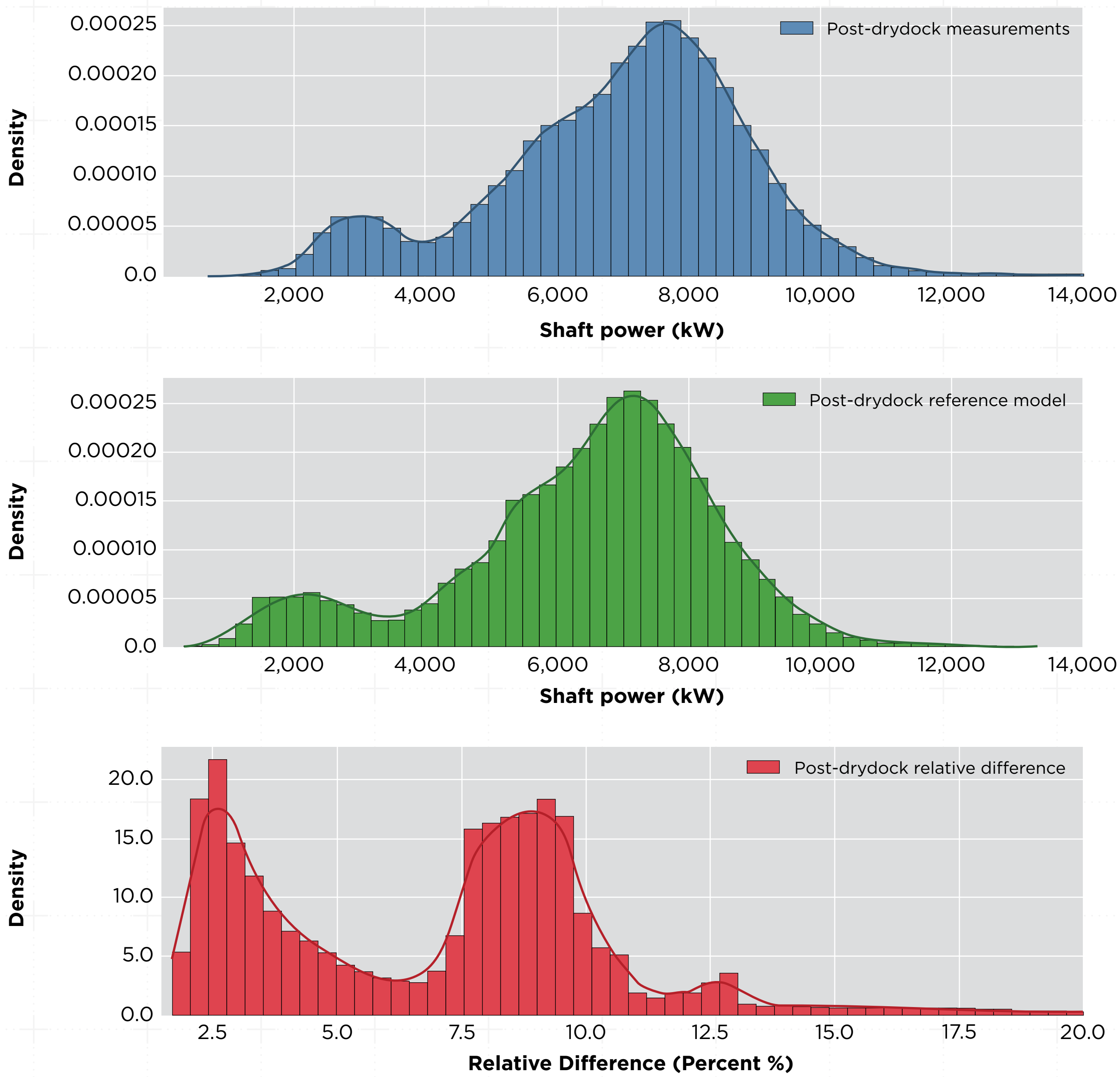


Figure 6 (continued): Example of post-drydock performance.

OPTIMAL USE DURING OPERATION

The predicted savings for the same improvement solution will depend on the specified parameters in the scope of work and whether the solution is optimally utilized during operation to adapt to dynamically changing conditions.

Is optimal use during operation a prerequisite?	Recommendation
No	The prediction study should be based on the vessel's operating profile.
Yes	In addition to the above, the solution should be accompanied by the proper optimization software/hardware on deployment.

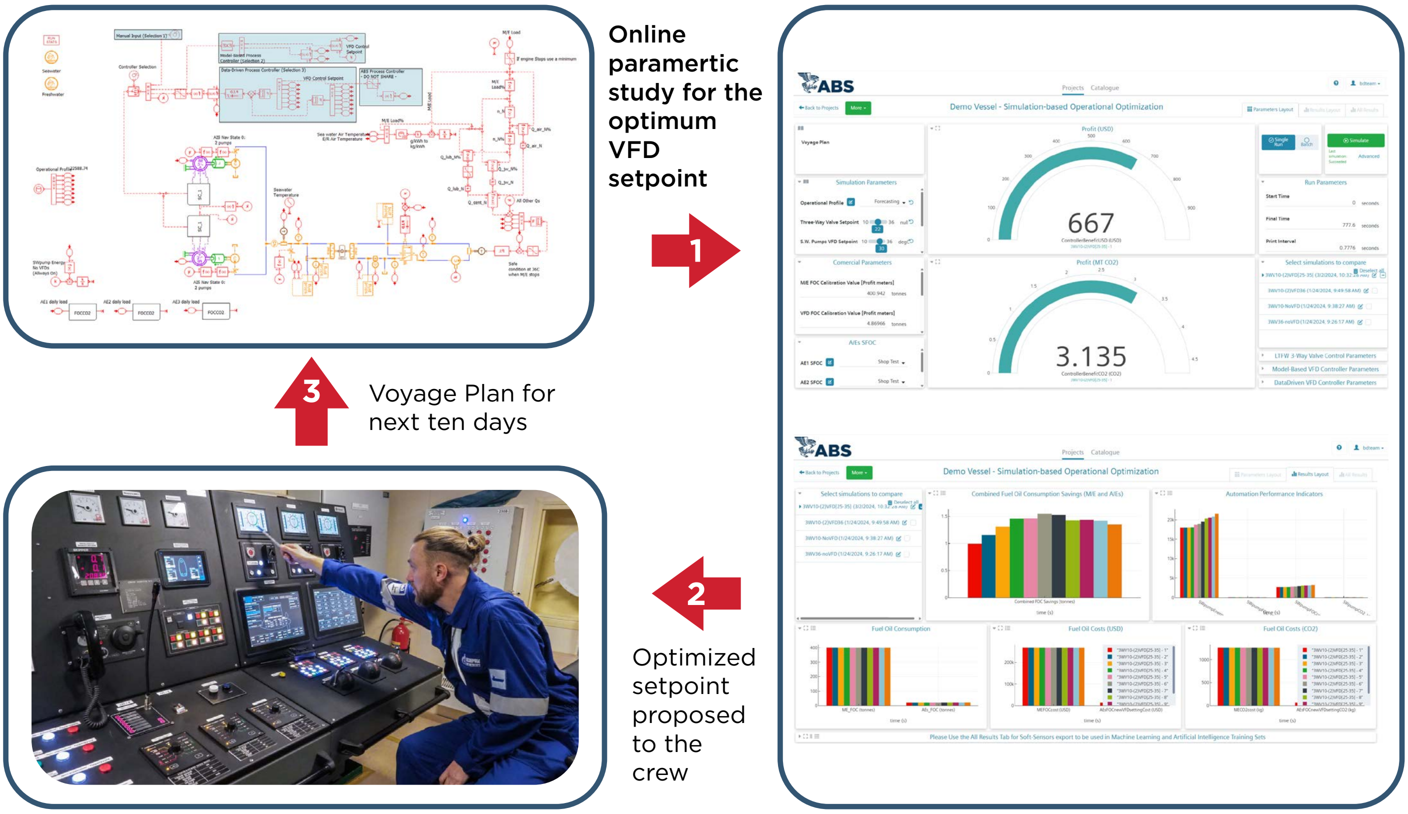
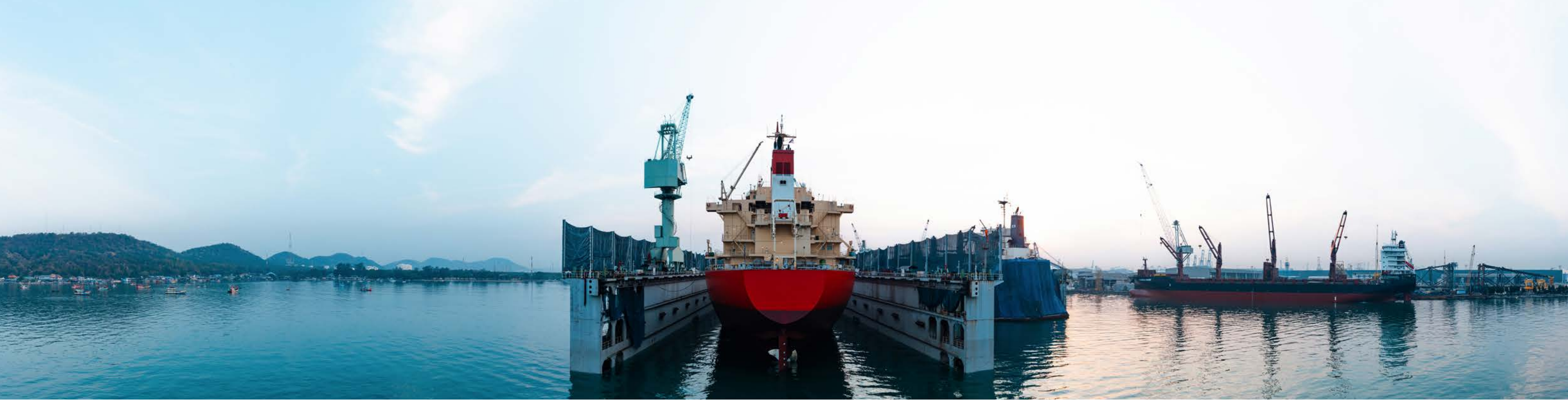


Figure 7: Example of VFD optimum setpoint during operation.

SOME IMPROVEMENTS COULD BE CONSIDERED AT THE INITIAL DESIGN STAGE

Proactive shipowners of prospective newbuildings assess the off-design performance of vessels, including shipboard systems, recognizing that most ships rarely operate only under design conditions. Builders, however, face the dilemma of balancing vessel design improvements with added production time and costs, while avoiding disruption of current and committed workflow. For example, designers know that single screw vessels will achieve higher propulsive efficiency with an asymmetric stern construction. However, this is not a standard design feature in the current market. This highlights an untapped opportunity that could be pursued in future.



HIGH-LEVEL ASSESSMENT

Shipowners and managers evaluating new technology providers should consider a broad range of factors beyond capex and opex before making a high-level assessment. It is common to ask competing providers the same set of questions.

Typical questions for technology providers:

- Is the technology compatible with existing arrangements on the retrofit candidate vessel?
- Are the reported savings for a vessel type similar to the retrofit candidate?
- Do the reported savings include or exclude any additional energy needed for the operation of the technology?
- Have the performance claims been systematically and independently validated for different cases?
- How many retrofits have been delivered to date similar to the candidate vessel?
- Have there been repeat orders?
- When was the company established and how does the company ensure product quality?
- Does the technology have an AIP or full approval from a classification society?
- Does the company apply testing protocols during the manufacturing and installation stages?
- Is the installed technology tailored to a specific operating profile, or can it adapt to variable operating profiles? If it can adapt, does it include a software-hardware solution for optimal use?
- What level of added maintenance and added crew training is required?
- Does the technology solution degrade over time, even with required maintenance?
- How will the technology's performance be evaluated during service and what is the performance warranty period?
- Are there warranties for the technology's reliability during operation?
- If the technology suffers damage, what kind of support is provided in terms of responsiveness and location?
- Is the installation dependent on shipyard availability and preparation of production drawings?
- Are classification and statutory approvals required for implementation?
- What is the project's time frame and milestones, including the lead time required for order placement?

MAKING AN INFORMED DECISION

Questioning a technology's operating principles is standard and easily answerable. However, relying on reported performance from another vessel can be a challenge, which may be mitigated through an independent, vessel-specific study. Warranties after implementation are not always offered by technology providers or may include limitations.

IMPACT ASSESSMENT FOR INCENTIVE SCENARIOS

Shipowners should assess the impact of new technologies in relation to the ship's condition, service profile, remaining life cycle, and current and future regulations to identify viable retrofitting candidates. Based on the findings and a range of incentive scenarios, effective strategies can then be developed.

INCENTIVE SCENARIOS

Depending on the intended retrofit project's stakeholders (e.g., financier, sponsors, technology provider, shipowner, ship manager, charterer), the incentive scenarios may include:

- Reduction of fuel consumption
- Reduction of emissions
- Reduction of regulatory compliance cost
- Compliance with IMO Carbon Intensity Indicator (CII) targets
- Compliance with Poseidon Principles or Sea Cargo Charter trajectories

MAKING AN INFORMED DECISION

For EU ETS, FuelEU Maritime and IMO NZF, a percentage reduction in energy used will reduce a vessel's compliance cost commensurately.

IMPACT ASSESSMENT

An LCCA is conducted to evaluate various retrofit scenarios, considering the vessel's trade route, operational profile, fuel costs and operational expenses.

The LCCA assesses investment and operational costs associated with the vessel's operating profile (e.g., energy consumption, time at sea, running hours, etc.) to generate key performance indicators (KPIs) selected by stakeholders. These KPIs help quantify the feasibility and desirability of the investment. Common KPIs include:

- Discounted payback period
- Total cost of ownership
- Sensitivity analysis

LCCA OUTPUT

The following tables and graphs provide example outputs from LCCAs.

Retrofit Scenario	1. Lower Friction Coatings and Duct	2. Microboiler	3. OCCS
Capex ($ millions)	0.9	0.2	3.5
Discounted payback period (years)	5	6	12

Table 2: Chemical tanker 50k dwt example output.

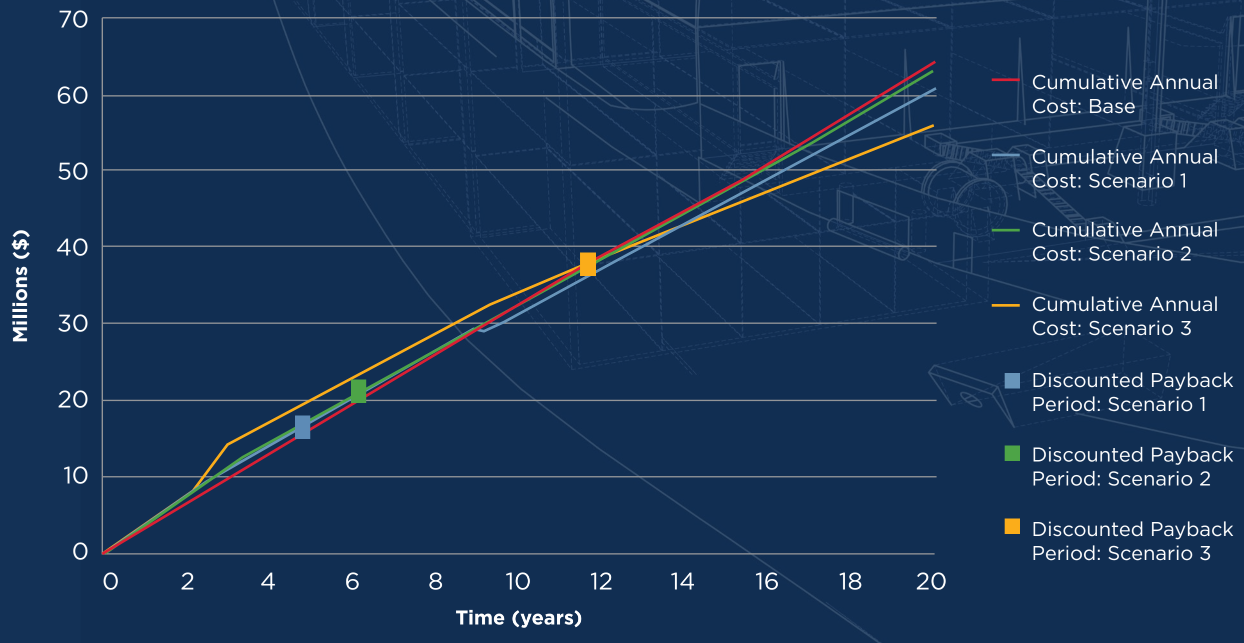


Figure 8: Total cost of ownership.

By varying each scenario's capex and fuel cost while keeping other parameters constant, the following payback periods (in years) are derived.

		Cost of Scenario 1				
		$3,400,000	$2,400,000	$1,700,000	$1,200,000	$600,000
VLSFO $/MT	$150	14.63	11.02	6.02	6.10	4.30
	$250	14.78	10.94	6.48	6.05	4.13
	$350	14.95	10.85	6.91	5.83	2.00
	$450	13.92	10.76	7.32	5.63	2.00
	$550	13.20	10.66	7.70	5.44	2.00
	$650	12.85	10.54	6.55	5.26	2.00
	$750	15.78	10.42	6.37	5.10	2.00
	$850	16.77	10.28	6.20	4.88	2.00
	$950	19.33	10.13	6.04	4.73	2.00
	$1,050	19.94	9.87	5.87	4.60	2.00
	$1,150	N/A	9.68	5.71	4.48	2.00
	$1,250	N/A	9.47	5.56	4.37	2.00

Table 3: Retrofit Scenario 1.

		Cost of Scenario 2			
		$2,710,000	$1,710,000	$1,010,000	$510,000
VLSFO $/MT	$150	N/A	N/A	20.91	9.22
	$250	N/A	N/A	21.24	9.16
	$350	N/A	N/A	21.59	9.11
	$450	N/A	N/A	21.95	9.06
	$550	N/A	N/A	22.34	9.00
	$650	N/A	N/A	22.75	8.95
	$750	N/A	N/A	N/A	8.89
	$850	N/A	N/A	N/A	8.83
	$950	N/A	N/A	N/A	8.77
	$1,050	N/A	N/A	N/A	8.71
	$1,150	N/A	N/A	N/A	8.65
	$1,250	N/A	N/A	N/A	8.59

Table 4: Retrofit Scenario 2.

		Cost of Scenario 3							
		$6,105,000	$5,105,000	$4,405,000	$3,905,000	$3,305,000	$2,805,000	$2,105,000	$1,105,000
VLSFO $/MT	$150	15.21	13.92	12.91	12.17	11.31	10.60	9.14	6.16
	$250	15.17	13.89	12.89	12.17	11.34	10.64	9.27	6.32
	$350	15.13	13.85	12.88	12.18	11.36	10.68	9.39	6.49
	$450	15.09	13.82	12.87	12.18	11.38	10.71	9.57	6.65
	$550	15.05	13.79	12.87	12.19	11.40	10.75	9.62	6.82
	$650	15.02	13.76	12.86	12.20	11.42	10.78	9.72	6.99
	$750	14.97	13.73	12.85	12.20	11.44	10.81	9.82	7.15
	$850	14.92	13.71	12.84	12.21	11.46	10.84	9.91	7.31
	$950	14.87	13.68	12.83	12.21	11.48	10.87	10.00	7.47
	$1,050	14.82	13.66	12.82	12.22	11.50	10.90	10.04	7.62
	$1,150	14.78	13.63	12.82	12.22	11.52	10.93	10.08	7.77
	$1,250	14.73	13.61	12.81	12.22	11.53	10.96	10.12	7.91

Table 5: Retrofit Scenario 3.

MARKET UPDATE

EXISTING FLEET WITH EETS

As shipping progresses toward 2030 and beyond, implementation is expected to grow. There are three notable takeaways from the adoption of EETs in the existing fleet (Table 6).

- The ship type with the highest EET uptake is bulk carriers, followed by containerships, liquefied natural gas (LNG) carriers and LPG carriers.
- Energy efficiency technologies with the highest adoption rates include those with relatively easy implementation (e.g., propeller ducts, rudder bulbs, etc.).
- Wind propulsion technology has some of the lowest levels of adoption. However, some vessel types are more suitable for renewable options. One such example is the Flettner rotor, a cylindrical structure that utilizes the Magnus effect to generate propulsion power, which is much more practical for a bulker than a containership.

It is important to note that each technology's effectiveness in reducing emissions varies based on factors such as vessel type and operational profile. A comprehensive approach that combines multiple EETs tailored to specific ship characteristics is often the most effective way to achieve significant emissions reductions.

EXISTING FLEET	ALS	Hull fin	Bulbous bow	Propeller cap fin	Propeller duct	Pre-swirl	Rudder bulb	Gate rudder	Solar	WPT	WHRS
Bulkers	0.12%	8.67%	13.31%	8.69%	13.42%	12.46%	19.44%	0.01%	0.06%	0.19%	0.08%
Containerships	1.60%	1.00%	9.21%	12.30%	0.77%	14.06%	17.80%	0.07%	0.03%	0.01%	0.30%
Gas carriers	0.18%	0.18%	6.61%	2.87%	7.31%	3.22%	6.55%	0.00%	0.00%	0.41%	0.00%
General cargo	0.01%	0.11%	1.03%	0.22%	0.18%	0.13%	0.37%	0.01%	0.02%	0.11%	0.05%
LNG	12.57%	0.00%	4.94%	5.76%	1.53%	0.59%	15.39%	0.00%	0.00%	0.00%	0.00%
Offshore	0.01%	0.01%	0.47%	0.01%	0.05%	0.00%	0.03%	0.00%	0.02%	0.01%	0.04%
Other	0.03%	0.03%	0.19%	0.00%	0.00%	0.00%	0.00%	0.00%	0.27%	0.03%	0.00%
Passenger	0.47%	0.10%	0.23%	0.22%	0.00%	0.00%	0.85%	0.00%	0.36%	0.03%	0.29%
PCC	1.03%	3.99%	13.11%	16.08%	0.00%	8.67%	9.12%	0.11%	3.99%	0.23%	0.00%
Roll on/roll off (ro/ro)	2.40%	0.36%	1.44%	1.44%	0.12%	0.72%	12.10%	0.00%	2.04%	1.20%	0.24%
Tankers	0.07%	1.24%	1.45%	3.85%	7.37%	2.71%	4.14%	0.00%	0.02%	0.14%	0.03%
Grand total	0.29%	1.42%	3.08%	2.72%	3.05%	2.99%	4.69%	0.01%	0.10%	0.09%	0.08%

Table 6: EETs uptake — existing fleet.
(Source: Clarksons Research, September 2025)

ORDERBOOK WITH EETS

The IMO proposed the penetration rate for EETs in its fourth GHG study, defining the percentage of ships expected to adopt each technology. The adoption rate of different EETs for ships in the global orderbook is in Table 7.

- The ship types with the highest EET uptake in the orderbook are ro/ro vessels and pure car carriers (PCCs), followed by containerships, LNG carriers and bulk carriers.
- Design considerations, such as bow enhancement and rudder bulbs, have a much higher adoption rate on new vessels.
- Air lubrication systems have a lower adoption rate overall, but containerships and gas carriers show an increasing trend.

EXISTING FLEET	ALS	Hull fin	Bulbous bow	Propeller cap fin	Propeller duct	Pre-swirl	Rudder bulb	Gate rudder	**Solar**	**WPT**	**WHRS**
Bulkers	1.32%	8.01%	24.10%	14.18%	9.33%	25.57%	15.87%	0.00%	0.88%	1.40%	0.15%
Containerships	8.27%	2.47%	31.37%	3.33%	0.48%	25.67%	29.85%	0.00%	0.57%	0.10%	4.28%
Gas carriers	0.63%	0.00%	23.82%	3.45%	7.21%	9.40%	16.93%	0.00%	0.00%	0.94%	0.00%
General cargo	0.00%	0.00%	25.22%	1.28%	1.02%	1.02%	5.76%	0.77%	0.13%	2.43%	0.77%
LNG	43.69%	0.00%	7.69%	4.62%	0.00%	0.31%	30.77%	0.00%	0.00%	0.00%	0.00%
Offshore	0.00%	0.00%	1.70%	0.00%	0.15%	0.00%	0.08%	0.00%	0.08%	0.00%	0.69%
Other	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.51%	0.00%	0.00%
Passenger	5.35%	0.00%	3.10%	0.00%	0.00%	0.00%	6.48%	0.00%	1.97%	1.13%	2.25%
PCC	21.12%	0.00%	41.61%	19.88%	0.00%	20.50%	17.39%	5.59%	14.29%	0.00%	0.00%
Ro/ro	0.00%	0.00%	23.08%	7.69%	0.00%	0.00%	53.85%	0.00%	0.00%	38.46%	0.00%
Tankers	0.00%	0.98%	10.27%	14.01%	6.09%	17.41%	13.02%	0.00%	0.07%	2.49%	0.72%
Grand total	4.09%	2.03%	16.46%	6.92%	3.49%	12.94%	13.36%	0.20%	0.70%	1.20%	1.10%

Table 7: EETs uptake — orderbook.
(Source: Clarksons Research, September 2025)

THE CASE FOR RETROFITS

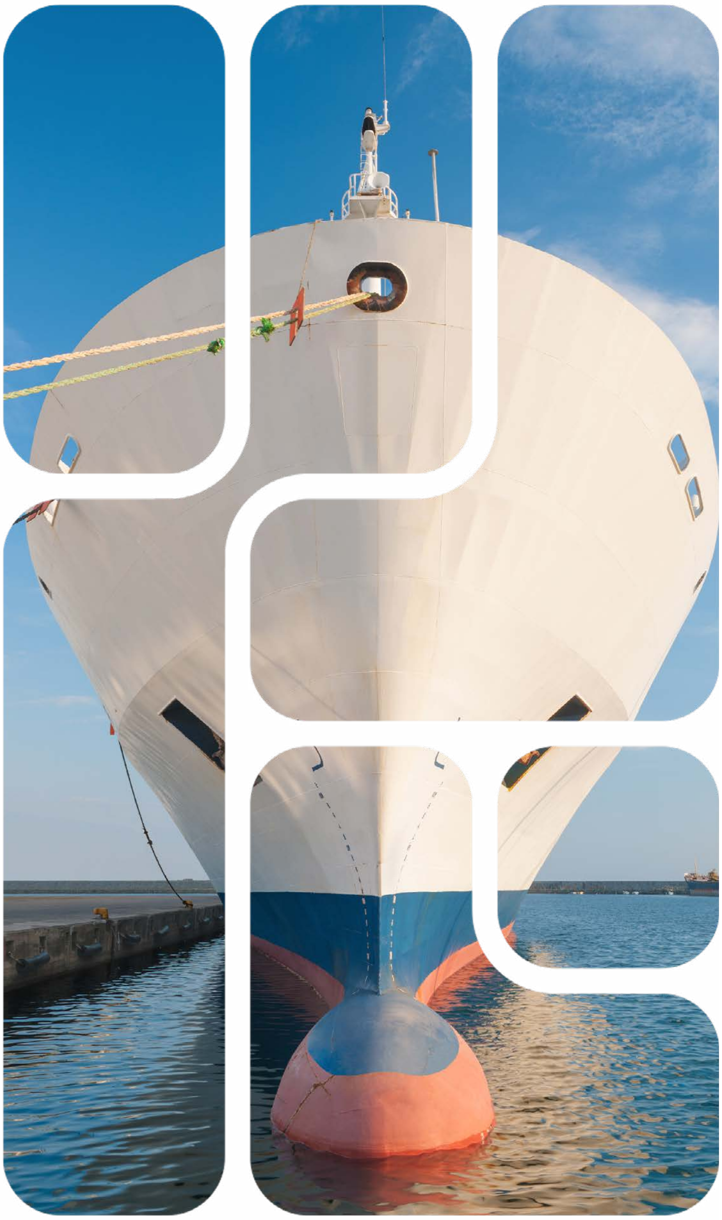
The ship repair sector is confronting a pressing issue: **Will global shipyard capacity be sufficient to satisfy the rising need for engine retrofits and EET installations?** Both types of work are crucial if the industry is to meet maritime decarbonization goals.

Historically, shipowners have relied on a dispersed network of yards to handle peaks in demand. However, recent market monitoring and scenario studies indicate that capacity constraints could become binding before 2030. If that happens under certain conditions, owners could face longer waiting times, higher prices, and a competitive edge for those who secure yards and slots sooner.

Today's retrofit investments tend to focus on low-cost, low-risk measures that produce only modest emissions reductions and are unlikely to align fully with IMO decarbonization pathways. Much of this caution stems from regulatory uncertainty. Much of this caution stems from current regulatory uncertainty.

For OCCS solutions, a larger wave of retrofits is likely to depend on forthcoming regulation that formally recognizes onboard CO_2 reductions. Dual-fuel (DF) conversions, meanwhile, remain costly and technically demanding; they involve engine modifications, fuel storage and supply systems, revised piping, and additional safety systems tailored to the chosen alternative fuel.

Compounding the issue, the reduction factors for the potential IMO NZF Tier 1 and Tier 2 after 2035 have not been finalized, which complicates ship managers' decisions about which alternative fuel to adopt for conversions. Many may delay DF retrofits or opt to sell older tonnage and invest in DF newbuilds until regulatory clarity emerges. On the other hand, if new DF vessel deliveries are limited because shipyards are constrained, owners could be compelled to pursue complex retrofits to stay on track with decarbonization requirements.



1. Workload versus Drydock Time

Although uptake of energy-efficiency technologies has accelerated, more than a third of vessels now have at least one system fitted, the increase in drydock activity has been relatively modest. That's largely because many EETs can be installed without adding significant time in drydock.

For instance, makers of wake performance devices often say that, with good preplanning, the work can be finished within a week by specialist crews supplied by the vendor working alongside the shipyard team. Rudder alterations and other frequently installed EETs similarly tend to be fitted quickly.

Consequently, deployment of some retrofit measures may face fewer yard time limitations than expected. In contrast, more involved upgrades, such as engine conversions and ALS installations, need substantially longer dock periods. Air lubrication systems tend to be most applicable to LNG carriers and ro/ros, while engine retrofits have wider use across vessel types and play a key role in long-term emissions reduction.

2. Geographic Distribution of Retrofit Activity

The retrofit sector looks set for rapid growth, driven by tightening regulations, shifting fuel supply chains and the urgent need to cut emissions.

In 2022, Chinese shipyards handled just over 56 percent of observed global repair demand; by the first quarter of 2025, that rose to more than 73 percent, outpacing every other region. Europe's portion declined from roughly 18 percent to about 13 percent, while Southeast Asia and the Middle East also declined. Figure 9 illustrates this regional distribution of retrofit activity measured in gross tonnage days (gt days) (the vessel's gross tonnage multiplied by the number of days in the yard), which better captures throughput than a simple vessel count because it combines vessel size with time spent in dock.

The trend reflects both the scale and the growing technical capabilities of Chinese yards, which are now equipped to handle a mix of high volume routine work and more complex conversions. For shipowners, this concentration can mean lower costs and greater efficiency, but it also creates a dependency that could become a vulnerability if geopolitical or operational issues arise.

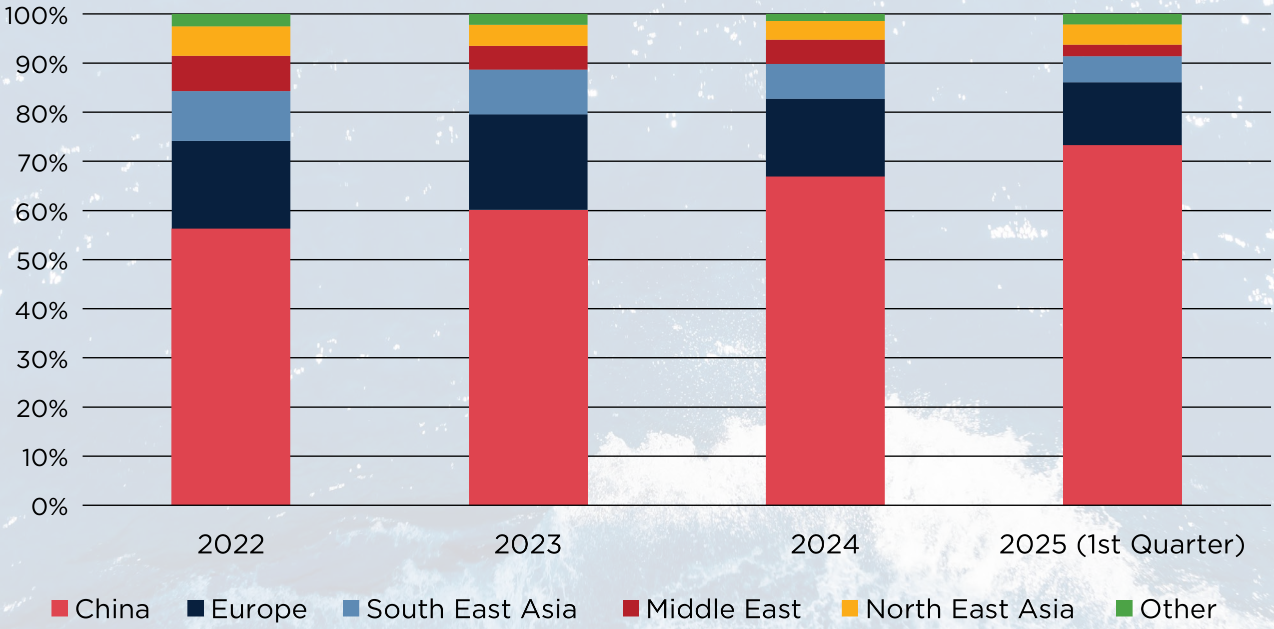


Figure 9: Regional shares trend. (Source: MSI, ABS)

3. Forecasts and Capacity Implications

The following assumptions guide the retrofits forecast (still in gt days):

1. Eligible fleet: Vessels built since 2013 with electronically controlled engines.
2. Vessel size thresholds: tankers ≥ 70k dwt; bulkers ≥ 120k dwt; containerships ≥ 7.6k TEU; car carriers ≥ 6k CEU; all ro/ro, roll on/roll off passenger (ro/pax) vessels and cruise ships.
3. Oil-fuelled vessels from 2025 onward are included.
4. Retrofit demand accelerates post-2030 with the IMO Mid-Term Measures coming into force and peaks in the early 2030s.
5. Newbuild retrofits begin at the first special survey (~2030) and peak in the late 2030s.
6. Average retrofit duration: Indicative averages from tracked projects suggest that full-scope retrofits take around 50 days.
7. The expansion of capacity in China has been accompanied by a sharp fall in activity elsewhere. This suggests that there is a latent capacity of up to 0.6 billion gt days, and we have accounted for this theoretical max capacity.

Not every retrofit carries the same time or complexity: simple energy-saving add-ons like wind-assisted systems can typically be fitted within a week with little interruption, whereas comprehensive works such as engine conversions or ALS installations may extend yard stays by several weeks.

With increasing investment by yards in retrofit capability worldwide, total project lead times are expected to fall from the current average of roughly 18 months toward a target of 14 months.

The ABS 2025 Outlook, *Beyond the Horizon: Vision Meets Reality*, sets out two possible retrofit-demand pathways (see Figure 10):

Scenario 1 — Full Conversion:

Assumes that rising oil prices drive the conversion of all oil-fired vessels that are eligible. Meeting this level of demand would require yard capacity to expand ahead of 2030.

Scenario 2 — Base Case:

Considered the more probable outcome, this assumes about half of the existing eligible fleet and roughly 80 percent of applicable newbuilds undergo conversion. Under these assumptions, demand would likely fit within current and planned yard capacity, particularly if average lead times can be shortened from about 18 months to roughly 14 months.

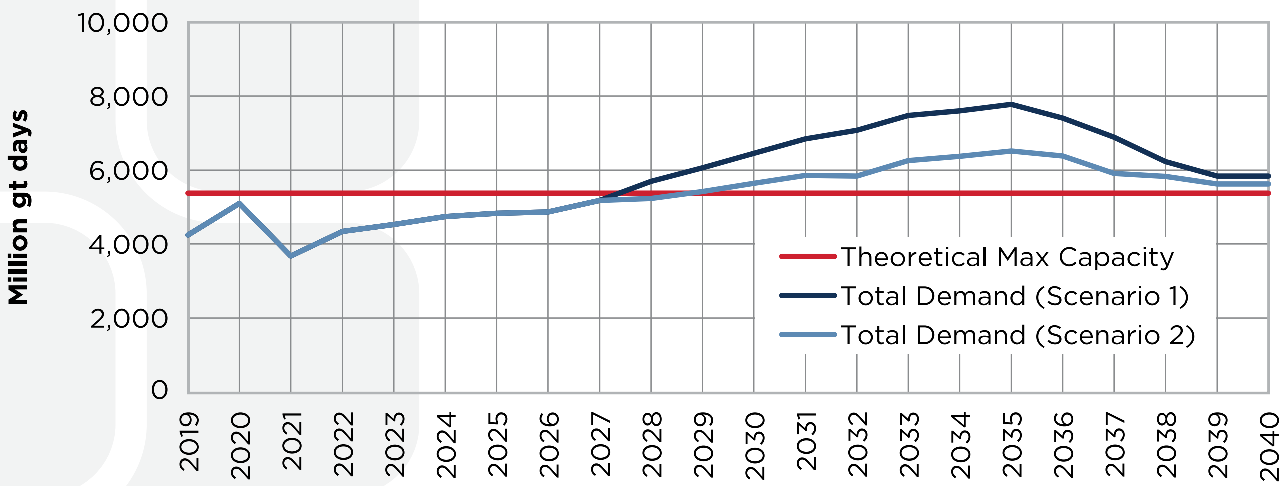


Figure 10: Total yard demand vs capacity (2025–2035). (Source: MSI, ABS)

The sharpest increase is projected in the late 2020s, when regulatory deadlines, fuel-switching plans and decarbonization pledges all align. Figures 11 and 12 show how retrofit capacity is stressed under the two scenarios analyzed.

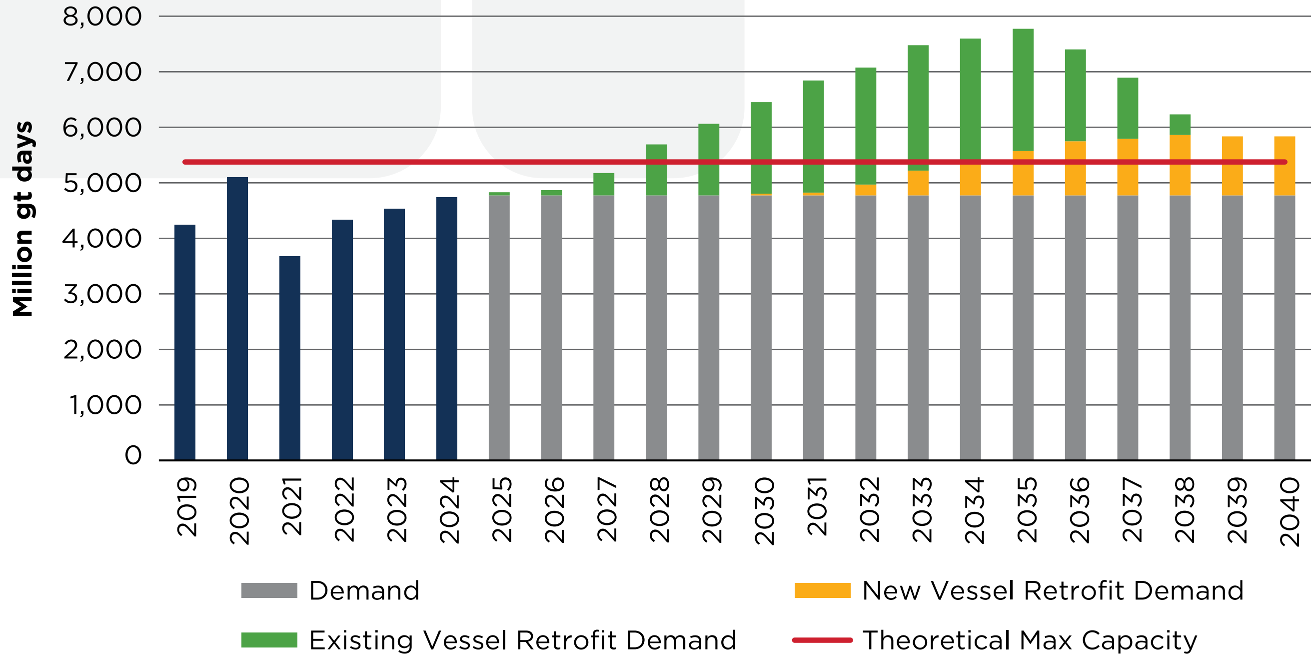


Figure 11: Retrofit projection — Scenario 1. (Source: MSI, ABS)

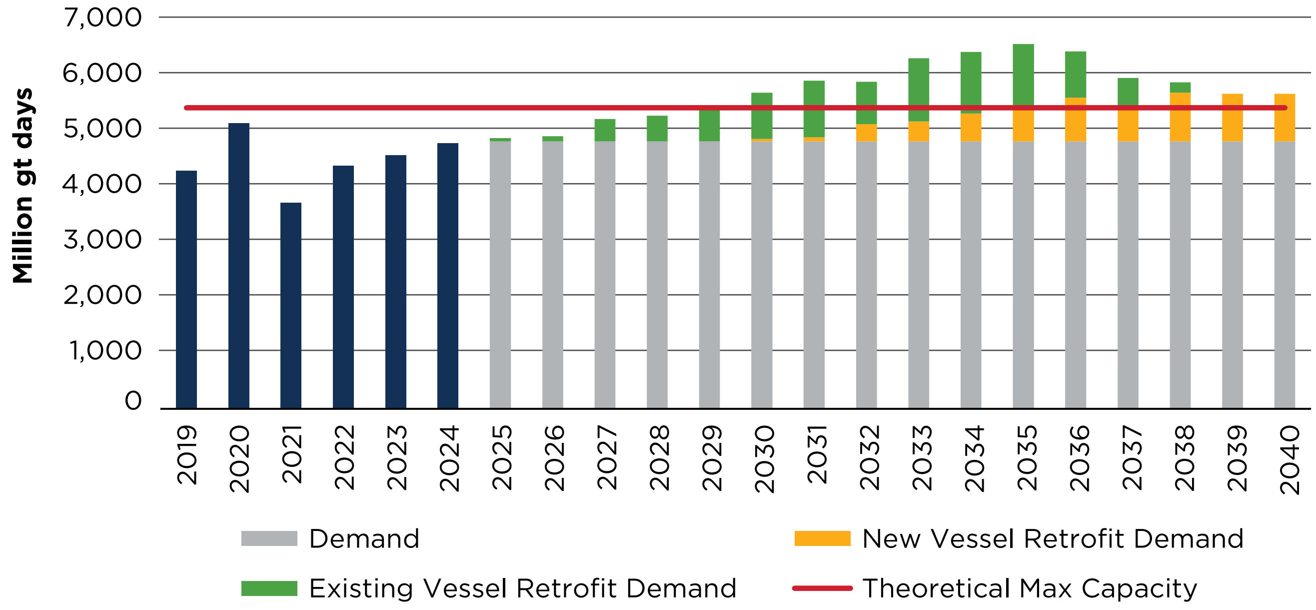


Figure 12: Retrofit projection — Scenario 2. (Source: MSI, ABS)

Comparing projected yard demand with estimated maximum capacity exposes when shortages will occur. If capacity only expands modestly (about +1.5 percent annually after 2030), the moderate scenario flips into deficit in 2029, producing a shortfall of roughly 43 million gt days and swelling to more than 400 million gt days by 2031. In the faster retrofit scenario, the shortfall appears a year earlier (2028) and accelerates to over 1 billion gt days by 2030. For shipowners, the years immediately before these shortfalls (notably 2027–2028) will be pivotal for securing yard slots on advantageous terms.

4. Implications for Engine Manufacturers

Engine makers need to view retrofit activity in the context of forecasts for alternative fuel newbuilds. Dual-fuel LNG engines are already being manufactured at scale, largely for LNG carriers, and as construction in that sector slows, this production capacity could be redirected toward other ship types. By contrast, engine production for methanol and ammonia will need to be ramped up to satisfy expected demand.

When retrofit demand under Scenario 2 is combined with projections for alternative fuel newbuilds, it produces clear engine demand curves. As illustrated in Figures 13–15, the retrofit market is set to grow strongly overall, driven by decarbonization imperatives, tightening regulation and changing fuel supply dynamics.

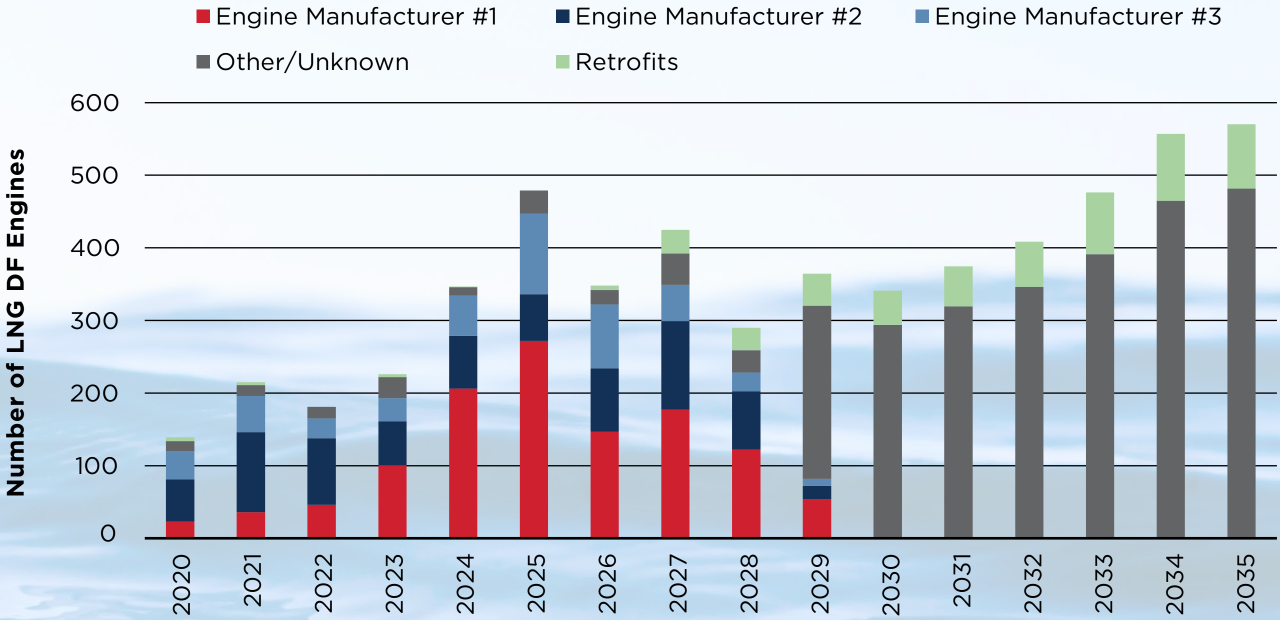


Figure 13: Demand for LNG DF engines. (Source: MSI, ABS)

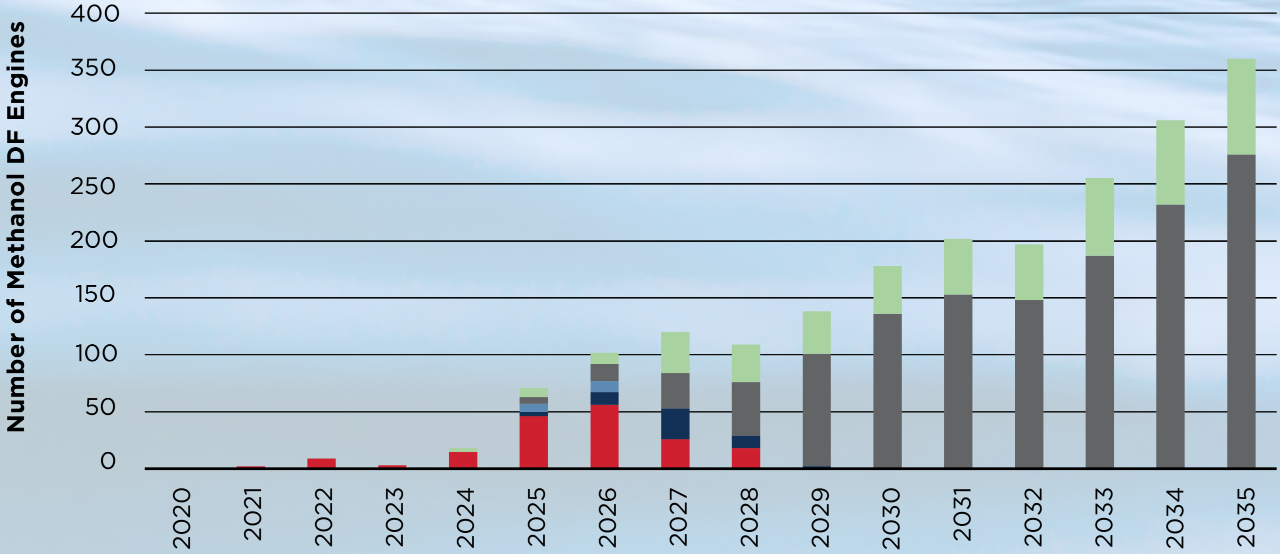


Figure 14: Demand for methanol DF engines. (Source: MSI, ABS)

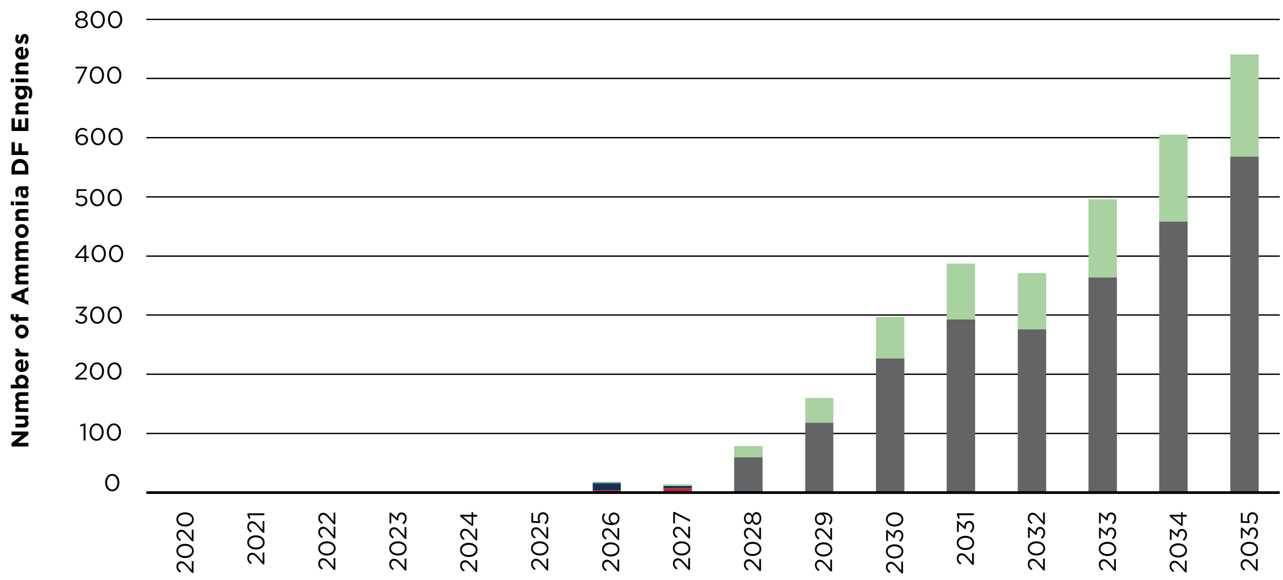


Figure 15: Demand for ammonia DF engines. (Source: MSI, ABS)

CRUISE VESSEL RETROFITS AND EETS

For vessel retrofits and EETs, the cruise industry is currently focusing on options that can provide the necessary short-term improvements until a selection for a different energy source is made.

1. Installation of WHR systems to recover and reuse heat from engine cooling.
2. Installation of ALS and low-friction hull coatings to reduce drag and improve fuel efficiency.
3. According to some cruise operators, HVAC systems typically use around 15 percent of a vessel's total electricity load. All major cruise lines are gradually upgrading to more energy-efficient HVAC systems on board existing vessels.
4. Installation of more energy-efficient LED lighting and dimming systems.
5. Upgrade to more efficient laundry and galley equipment. This can be achieved through various technologies, such as inverter motors, heat pump dryers, smart water management systems, automatic cut-off of power when not in use and galley demand-controlled ventilation. Ships can also encourage guests to reuse towels to reduce laundry energy load.
6. Upgrade chiller units to options with variable cooling capacity. A system with variable cooling capacity chillers allows for dynamic adjustments in cooling output on cruise vessels, optimizing energy efficiency and comfort. This is achieved by matching the chiller's output to the actual cooling demand, rather than running at full capacity constantly.
7. Installation of battery storage and fuel cell systems to meet the hotel's power load.
8. A few of the major operators have run trials using biofuels derived from used cooking oil and animal fat. They are also working with suppliers to establish a reliable biofuel supply infrastructure.
9. In addition to optimizing itineraries and voyage planning to reduce sailing times, cruise lines are also evaluating greater use of open jaw voyages in place of the more common closed-loop sailings. Open jaw voyages are those where the origin and destination differ. This eliminates the return leg and allows cruise lines to start a new voyage from the point of disembarkation.

CONCLUSION

Retrofitting for alternative fuels and EETs offers the maritime industry a crucial pathway to extending the life of existing and near-term newbuild vessels in the face of increasingly stringent regulations. This publication provides the industry with a clear understanding of classification and statutory requirements for retrofitting, explores options for improving efficiency, and offers best practices and market insights to support informed decision-making.

When considering retrofits, shipowners must:

- Never compromise on safety.
- Understand the applicability of current regulations and those coming into force.
- Assess the present performance of shipboard systems and identify energy savings from specific improvements based on a vessel's operational characteristics.
- Predict the savings of additional EETs for anticipated operating conditions through modeling and simulation (route and AIS-based simulations).
- Identify and address potential hazards for the vessel and crew through HAZID and HAZOP workshops.
- Evaluate the savings based on in-service measurements through vessel performance modeling and analysis.
- Optimize the energy demand by deploying mathematical techniques ranging from CFD (e.g., bulbous bow optimization study) to non-heuristic optimization algorithms (e.g., voyage optimization study).

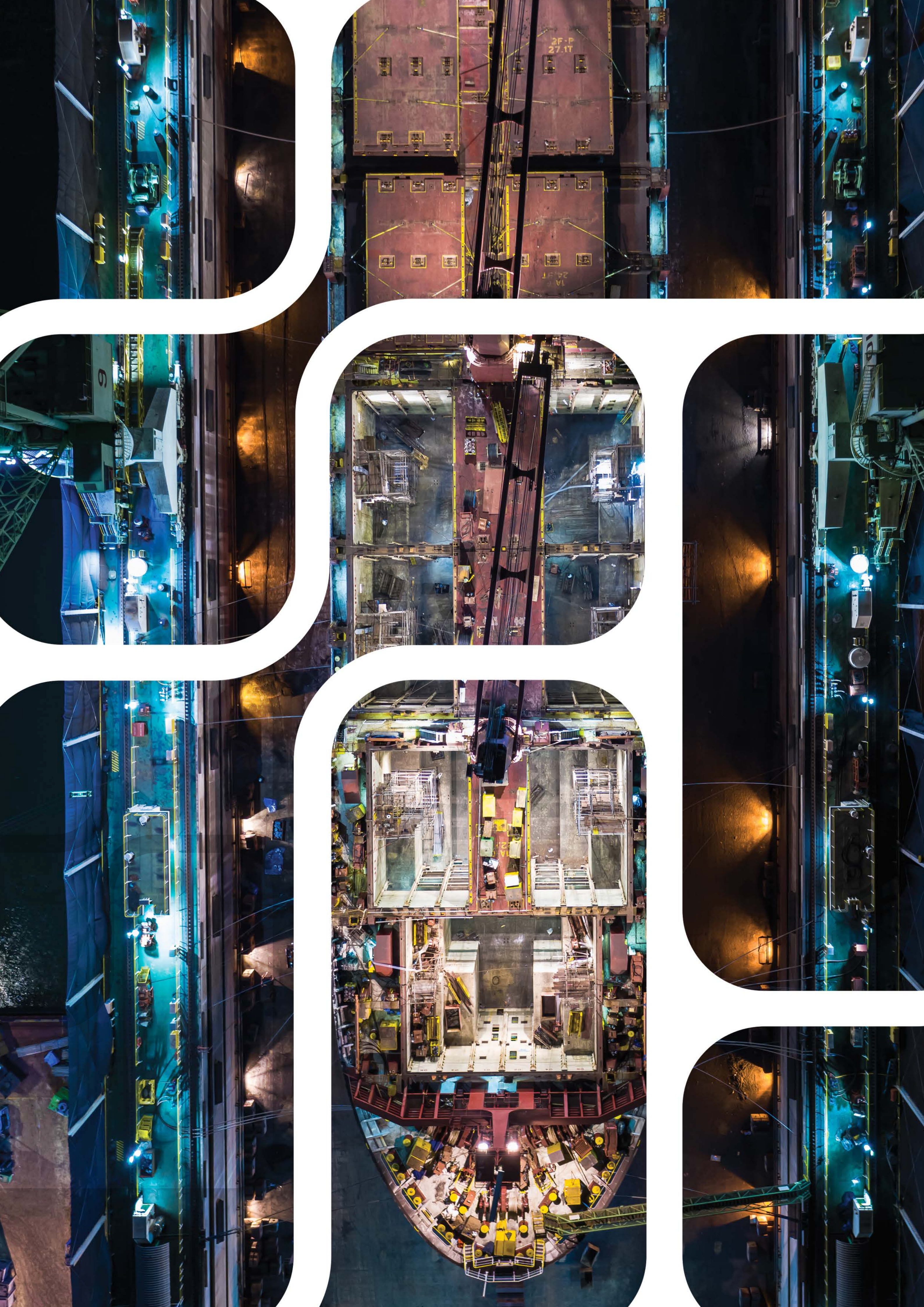
In addition, the field of vessel performance relies on both advanced technological systems (software and hardware) and a skilled workforce to support effective implementation. Alongside changes in the energy management and efficiency landscape, there has been a noticeable increase in professionals focused on performance assessment, prediction, in-service evaluation and optimization. The need for continual training and staying updated on the latest techniques and methodologies for this emerging workforce cannot be overstated.

Successful retrofits require a holistic approach that integrates advanced tools, skilled professionals and a commitment to safety and regulatory compliance. As the maritime industry evolves, innovation and collaboration will be key drivers in achieving both economic and environmental goals. The insights in this publication offer a solid foundation for making informed decisions in the industry's dynamic environment.

LIST OF ACRONYMS AND ABBREVIATIONS

ABS	American Bureau of Shipping
AIS	automatic identification system
ALS	air lubrication system
capex	capital expenditures
CFD	computational fluid dynamics
CII	Carbon Intensity Indicator
COLREG	International Regulations for Preventing Collisions at Sea
dwt	deadweight tons
EEXI	Energy Efficiency Existing Ship Index
EET	energy efficiency technology
EU	European Union
EU ETS	EU Emissions Trading Scheme
GHG	greenhouse gas
gt	gross tonnage
HAZID	hazard identification
HAZOP	hazard and operability study
HVAC	heat, ventilation and air conditioning
IACS	International Association of Classification Societies
IBC	International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk
IEEC	International Energy Efficiency Certificate
IGC	International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IGF	International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels
ISM	International Safety Management Code

ISPS	International Ship and Port Facility Security Code
KPI	key performance indicator
LCCA	life-cycle cost analysis
LED	light-emitting diode
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee
MLC	Maritime Labour Convention
MSC	Maritime Safety Committee
NO_x	nitrous oxides
NZF	Net-Zero Framework
OCCS	onboard carbon capture and storage
opex	operating expenses
OPS	onshore power supply
PCC	pure car carrier
PID	propulsion improvement device
PV	photovoltaic
ro/ro	roll on/roll off vessel
ro/pax	roll on/roll off passenger vessel
SEEMP	Ship Energy Efficiency Management Plan
SOLAS	International Convention for the Safety of Life at Sea
VFD	variable frequency drive
WHR	waste heat recovery
WPT	wind propulsion technology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