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RETROFIT SOLUTIONS TO ACHIEVE 55% GHG REDUCTION BY 2030

Exploitation and Bridge-to-Market Plan

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List of acronyms

ALS	Air Lubrication Systems
BESS	Battery energy storage systems
CFD	Computational fluid dynamics
CBA	Cost-Benefit Analysis
EEDI	Energy Efficiency Design Index
RTS	EU Emissions Trading System
EEIG	European Economic Interest Grouping
GHG	Greenhouse gas
IMO	International Maritime Organization
KPI	Key Performance Indicators
LNG	Liquefied natural gas
R&D	Research and Development
ROI	Return of Investment
EMS	Smart energy management systems
SDGs	Sustainable Development Goals
WASP	Wind-assisted ship propulsion

Executive Summary

The main goal of this report is to perform a detailed Cost-Benefit Analysis (CBA) and to investigate of possible business models to establish a solid background for business planning and detailed work for the commercialisation of the RETROFIT55 project[1] results. This work is of great importance in terms of ensuring a deep consideration and elaboration of all the economic aspects of the project, which are the basis of the project Sustainability and Exploitation Plan. This plan serves as a tool to ensure the visibility and impact of the project's results in the long term by means of strategic planning work to ensure the continuation and further development of the project.

The CBA will provide a detailed economic analysis of the RETROFIT55 solutions, which will consider the direct and indirect costs and benefits. It will investigate financial indicators such as return on investment (ROI), payback periods, and long-run financial sustainability. There will be an assessment of sensitivities to understand the impact from different economic scenarios on the sustainability of the project.

A set of models for business will be investigated, with a specific reference to the commercialisation possibilities for RETROFIT55 solutions. The elaboration of a compelling value proposition that is adjusted to the different needs of the stakeholders will be a major part of this. Key elements of alternative business models will be defined, based on sources of revenues, customer segments, and cost structures.

An 'open' approach will be adopted to ensure the input of all categories of stakeholders into the process of development. At least one business model workshop will be planned to gather insights and improve cooperation between the interested parties. Sustained contact will be made and maintained with potential partners and organisations to help allow the long-term exploitation and commercialisation of the project results.

The work will determine future governance structures and policies to manage the technical development and business management of the project after EU funding. Policies will also be developed to ensure the sustainability and scalability of the RETROFIT55 solutions and to enable their uptake within the maritime sector.

The CBA will provide clear understanding of the economic advantage and potential return on investment for stakeholders, illustrating the appeal of RETROFIT55 solutions in an economic context. The examination of business models will deliver a strategic pathway for commercialisation to ensure that RETROFIT55 technologies are able to enter the market and compete successfully. The engagement activities and workshops will provide a stakeholder alignment with stakeholder expectations and the development of strong partnerships that are required for successful commercialisation. The development of future governance structures and policies will ensure the continued progression and impact of the project to deliver the sustainability of the project long term.

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[1] https://cordis.europa.eu/project/id/101096068

1 Overview of RETROFIT55 Project Achievements

The RETROFIT55 project aims to significantly reduce the greenhouse gas (GHG) emissions of existing ships through a combination of innovative retrofitting solutions and an advanced decision-support system. The project has made several key achievements.

In the development of retrofitting solutions, RETROFIT55 has focused on:

1. Air Lubrication System: A significant advancement in reducing ship resistance, the Air Lubrication System injects compressed air bubbles along the hull, effectively lowering water friction. This innovative technology enhances fuel efficiency and contributes to substantial reductions in greenhouse gas emissions, marking a crucial step towards more sustainable maritime operations.
2. Wind Assisted Ship Propulsion: The development and validation of digital twin models for both rigid and flexible sails represent a breakthrough in operational efficiency. Wind Assisted Ship Propulsion harnesses the power of the wind to supplement conventional propulsion systems, thereby decreasing fuel consumption and emissions. This achievement underscores the potential of hybrid solutions in achieving greener maritime transport.
3. Ship Electrification: The incorporation of advanced electrification solutions, including batteries, fuel cells, and photovoltaic systems, maximizes operational efficiency and significantly reduces GHG emissions. Ship electrification not only promotes cleaner energy use but also enhances the overall sustainability of maritime operations by reducing reliance on fossil fuels. This integration of cutting-edge technologies is pivotal in driving the industry towards zero-emission shipping.

A sophisticated web-based Decision Support System (DSS) has been developed to assist ship owners and operators in evaluating and selecting the best retrofitting options. This system leverages artificial intelligence and surrogate models to optimize retrofitting combinations based on various operational, safety, ecological, and financial key performance indicators (KPIs).

The project aims to accelerate climate neutrality in waterborne transport by retrofitting existing fleets, targeting to reduce GHG emissions by at least 55% by 2030 compared to original designs. Technological demonstrations include the integration of energy-saving solutions into operational tools, with both physical and virtual testing based on real ship data to validate the effectiveness of these solutions.

RETROFIT55 has actively engaged with stakeholders such as ship design companies, shipyards, and technology providers to promote the adoption of these solutions. The project also aims to create a European Economic Interest Grouping (EEIG) to support market growth and sustainability beyond its duration.

Training and knowledge dissemination are key components of the project, with organized workshops, training events, and participation in industry conferences to encourage the adoption of retrofitting technologies. These achievements are expected to significantly contribute to the decarbonization of the maritime sector, making it more environmentally friendly and cost-effective, while supporting the transition towards zero-emission waterborne transport by 2050.

1.1 Purpose and Scope of the Cost-Benefit Analysis

The purpose of Cost-Benefit Analysis for RETROFIT55 is to present a comprehensive economic evaluation of the project's proposed decarbonization solutions and green technologies for the shipping industry. It seeks to quantify the monetary and non-monetary benefits from implementing RETROFIT55 technologies, compared to the costs incurred in their implementation and operation. The CBA will be a critical input for strategic decision-making, enabling stakeholders to understand the financial viability, returns, and long-term sustainability of the project. Additionally, the CBA will serve as a foundation for developing business models and commercialization strategies, ensuring all economic dimensions are thoroughly considered and managed.

The scope of the CBA encompasses several key areas to ensure a thorough and balanced assessment of the economic feasibility and potential benefits of the proposed technologies. The CBA will evaluate both direct and indirect costs associated with the RETROFIT55 technologies. Direct costs include all expenses related to the development, installation, and maintenance of these technologies. This covers capital expenditures, operational expenditures, and any infrastructure investments required. Indirect costs will also be examined, such as potential downtime during retrofitting, the need for crew and staff training, and any disruptions to ongoing operations.

The analysis will estimate the financial benefits derived from various sources. Fuel savings will be calculated based on the reduced fuel consumption achieved through the installation of technologies like Air Lubrication Systems, Wind Assisted Ship Propulsion, and Smart Energy Management. Maintenance savings will be estimated by considering reduced maintenance requirements and extended maintenance intervals due to increased operational efficiency and reduced wear and tear. Additionally, the financial valuation of reduced greenhouse gas emissions and compliance with environmental regulations will be assessed, including potential savings from avoided penalties and carbon credits.

The CBA will also evaluate non-financial benefits. Environmental impacts will be assessed by evaluating the positive effects of reduced GHG emissions and other pollutants, contributing to global sustainability goals. Improvements in operational efficiency, such as better route optimization, performance monitoring, and reduced environmental footprint, will be considered. Furthermore, the competitive advantage and improved market positioning gained from the early adoption of state-of-the-art green technologies will be analysed.

The analysis will calculate the Return of Investment (ROI) and payback periods for various RETROFIT55 technologies, providing stakeholders with clear timelines for recouping their investments. This will help in understanding the financial viability and attractiveness of these technologies.

The CBA will include inputs and perspectives from all relevant stakeholders, ensuring a comprehensive analysis. This includes shipowners, operators, shipyards, technology providers, regulatory bodies, and industry associations. Their insights will help in understanding the practical implications and acceptance of the proposed technologies.

2 Introduction

2.1 Objectives of the Sustainability and Exploitation Plan

The primary objective of the Sustainability and Exploitation Plan for RETROFIT55 is to ensure the long-term viability, commercial success, and industry adoption of the project's innovative decarbonisation technologies. This plan aims to create a strategic roadmap for transitioning from a research-focused initiative to a commercially viable set of solutions that can be widely adopted across the maritime industry. By establishing a clear framework for sustainability and exploitation, the plan seeks to maximize the project's impact on reducing greenhouse gas emissions and improving the operational efficiency of ships.

One of the key objectives of the Sustainability and Exploitation Plan is to guarantee the ongoing relevance and applicability of RETROFIT55 technologies beyond the project's initial funding period. This involves developing strategies to continuously update and improve the technologies in response to evolving market demands, regulatory requirements, and technological advancements. By fostering a culture of continuous innovation and adaptation, the plan aims to maintain the project's momentum and ensure its long-term success, also beyond project’s lifetime.

The plan aims to outline clear pathways for the commercialization of RETROFIT55 technologies. This includes identifying potential markets, developing business models, and creating marketing strategies to effectively position the technologies in the competitive maritime sector. The objective is to achieve significant market penetration by demonstrating the economic and environmental benefits of the technologies, thereby encouraging widespread adoption by shipowners, operators, and shipyards.

Engaging with all relevant stakeholders is a critical objective of the plan. This includes shipowners, operators, technology developers, regulatory bodies, and industry associations. By fostering strong partnerships and collaborations, the plan seeks to ensure that the needs and expectations of all stakeholders are addressed. Regular communication and feedback mechanisms will be established to involve stakeholders in the decision-making process, ensuring their support and commitment to the project's goals.

The plan aims to provide a comprehensive economic analysis of the RETROFIT55 technologies, ensuring that all cost-benefit aspects are thoroughly considered and addressed. This involves conducting a detailed cost-benefit analysis, identifying potential financial risks, and developing mitigation strategies. By providing a clear understanding of the economic viability and potential return on investment, the plan seeks to attract investors and secure funding for future development and deployment.

Another objective of the plan is to maximize the positive environmental and social impacts of the RETROFIT55 technologies. This includes reducing GHG emissions, improving air quality, and contributing to global sustainability goals. Additionally, the plan aims to create social benefits, such as job creation, skills development, and improved working conditions in the maritime industry. By highlighting these benefits, the plan seeks to build broad-based support for the technologies and ensure their acceptance by the wider community.

Establishing robust governance structures and policies for the ongoing management and development of RETROFIT55 technologies is a key objective. This includes defining roles and responsibilities, setting up decision-making processes, and creating policies for technology development, intellectual property management, and commercialization. The goal is to ensure that the project remains well-coordinated and effectively managed, facilitating its long-term progression and success.

The plan aims to provide a framework for the demonstration and validation of RETROFIT55 technologies in real-world settings. This involves conducting pilot projects, gathering performance data, and validating the technologies' effectiveness in reducing fuel consumption and emissions. By providing empirical evidence of the technologies' benefits, the plan seeks to build confidence among potential adopters and accelerate market uptake.

2.2 Methodology and Approach

The methodology and approach for the Sustainability and Exploitation Plan of RETROFIT55 are designed to systematically ensure the project's long-term viability, economic feasibility, and market adoption. This comprehensive strategy involves a multi-faceted and iterative process encompassing market analysis, stakeholder engagement, economic assessment, risk management, and continuous innovation (as represented in Figure 1).

Figure 1: Sustainability and Exploitation Plan

The initial phase involves a thorough market analysis to identify the potential demand for RETROFIT55 technologies within the maritime sector. This includes examining current exploitation possibilities, regulatory environments, and competitive landscapes. By understanding these dynamics, the plan can develop targeted commercial strategies that align with market needs and opportunities. This phase also involves segmentation analysis to tailor marketing and sales efforts to different customer groups, ensuring a focused and effective market entry.

Engaging with stakeholders is pivotal for the successful implementation and adoption of RETROFIT55 technologies. The methodology includes identifying key stakeholders, such as shipowners, operators, technology developers, regulatory bodies, and industry associations. Regular consultations, workshops, and feedback sessions will be organized to incorporate their insights and address their concerns. This collaborative approach ensures that the solutions developed are aligned with stakeholder needs and expectations, fostering a supportive ecosystem for commercialization.

A detailed economic assessment is central to the sustainability plan. This involves conducting a comprehensive CBA to evaluate the financial implications of implementing RETROFIT55 technologies. The CBA will assess both direct costs (development, installation, maintenance) and indirect costs (downtime, training, operational disruptions). It will also quantify the financial benefits, including fuel savings, maintenance cost reductions, and emissions reductions. By providing clear ROI and payback period calculations, this analysis will offer stakeholders a transparent view of the economic viability of the project.

Identifying and mitigating risks is a crucial component of the methodology. The approach involves a systematic risk assessment to identify potential technical, financial, and market risks associated with the adoption of RETROFIT55 technologies. For each identified risk, mitigation strategies will be developed to minimize their impact. This proactive approach ensures that potential obstacles are addressed early, enhancing the project's resilience and stability.

The sustainability plan emphasizes the importance of continuous innovation. This involves regularly updating and improving RETROFIT55 technologies to keep pace with advancements in maritime technology and changes in regulatory requirements. A dedicated R&D framework will be kept in place for the future EEIG, ensuring that the solutions remain cutting-edge and competitive. This iterative process includes gathering feedback from pilot implementations, conducting performance evaluations, and integrating new findings into subsequent development phases.

The methodology includes defining clear roles and responsibilities, decision-making processes, and policies for technology development and commercialization. This framework will ensure coordinated efforts across all phases, from development to exploitation of RETREOFIT55 results. Policies related to intellectual property management, data sharing, and stakeholder collaboration will also be developed to support transparent and effective project management.

The approach includes extensive demonstration and validation of RETROFIT55 technologies in real-world maritime settings. Pilot projects will be conducted to gather empirical data on the performance and benefits of the technologies. These demonstrations will provide concrete evidence of fuel savings, emissions reductions, and operational efficiencies, building confidence among potential adopters. The results from these pilots will be documented and disseminated through industry publications, conferences, and stakeholder meetings to showcase the tangible benefits of RETROFIT55 solutions.

The final phase involves developing and implementing sustainable business models for the commercial exploitation of RETROFIT55 technologies. This includes identifying revenue streams, cost structures, and value propositions that align with market demands. Business models will be tested and refined through pilot implementations and stakeholder feedback, ensuring they are viable and scalable. The plan also includes strategies for securing funding and investment to support the commercial rollout and long-term sustainability of the project.

This holistic strategy ensures that RETROFIT55 technologies are not only viable and competitive but also poised for long-term success and industry-wide adoption.

3 Market Analysis

3.1 Overview of the Maritime Decarbonization Market

The maritime decarbonization market is an essential segment within the broader scope of global efforts to combat climate change. Given that shipping emits approximately 1 billion tons of CO2. Emissions are projected to increase by 20–50% between 2008–2050. Ships entering EU ports emit 13% of the total EU transport emissions.

3.1.1 Key Technologies and Strategies

Alternative fuels

1. Hydrogen and Ammonia: These fuels are promising due to their zero-carbon emissions when used in fuel cells or internal combustion engines. However, challenges include storage, safety, and the development of a global supply infrastructure [1].
2. Biofuels: Derived from renewable biological sources, biofuels like biodiesel and bio-LNG can be integrated with existing infrastructure but may face supply limitations and competition with food production [2].
3. Methanol and Ethanol: These alcohol-based fuels offer a lower carbon footprint and can be produced from renewable sources. The infrastructure for methanol is relatively mature, facilitating easier adoption [3].

Renewable Energy Integration

1. Wind and Solar Power: Utilizing wind-assisted propulsion and solar panels can reduce fuel consumption. Ships equipped with these technologies can harness natural energy during voyages, contributing to lower emissions [4].
2. Onshore Power Supply: Also known as cold ironing, this technology allows ships to plug into the electrical grid while docked, reducing the need to run auxiliary engines and thereby cutting emissions [5].

Operational Measures

1. Speed Optimization (Slow Steaming): Reducing ship speeds significantly cuts fuel consumption and emissions. This operational measure is simple yet effective in decreasing the carbon footprint of shipping [6].
2. Voyage Optimization: Advanced navigation and route planning technologies can enhance efficiency by optimizing travel routes, thus reducing unnecessary fuel use [7].

3.1.2 Regulatory and Policy Framework

1. Targets and Regulations: The Green Dealsets out the Commission’s commitment to tackle climate and environmental challenges. To achieve climate neutrality, the European Green Deal envisages cutting transport emissions by 90% by 2050 at the latest. In addition, it sets out the ambition to reduce GHG emissions by at least 55% by 2030 compared to 1990, as part of the Fit for 55 package. The EU's 2021 "Smart and Sustainable Mobility Strategy, together with its related action plan, includes gradual reduction of greenhouse gas emissions and it sets out the pathway for EU transport to achieve the 2050 target of cutting transport GHG emissions by at least 90% with the intermediate waterborne objective of the first zero-emission vessels being market ready

by 2030. Policies include the Energy Efficiency Design Index (EEDI) and mandatory reporting of fuel consumption [8].

2. Market-Based Measures: The IMO is considering various MBMs, including carbon taxes and emissions trading schemes, to create economic incentives for reducing emissions [9].

3.1.3 European Union Initiatives

1. EU Emissions Trading System (ETS): The EU has included maritime emissions in its ETS, requiring ship operators to buy allowances for their emissions, thus encouraging investment in cleaner technologies [10].
2. European Green Deal: This policy aims to make Europe climate-neutral by 2050, impacting maritime transport by promoting the use of sustainable fuels and technologies [11].

3.2 Economic and Technical Challenges

1. High Costs: The transition to low-carbon fuels and technologies is capital-intensive. Investments are needed in new infrastructure, R&D, and retrofitting existing fleets. This financial burden can be a significant barrier, especially for smaller shipping companies [12].
2. Supply Chain Readiness: Developing a reliable supply chain for alternative fuels is critical. This includes establishing production facilities, distribution networks, and refueling infrastructure globally [13].
3. Technological Maturity: Many alternative fuels and technologies are still in the early stages of development. Ensuring they are commercially viable and safe for widespread use is a significant challenge [14].
4. Regulatory Alignment: Coordinating regulations across different jurisdictions is complex. Ensuring that international, regional, and national policies are aligned is essential for effective implementation [15].

3.2.1 Financial Incentives and Investments

Decarbonizing the maritime industry requires substantial financial investment. Future directions must include the development of robust financial incentives to support the transition to cleaner technologies. Governments and international bodies should consider subsidies, grants, and tax breaks to lower the financial barriers for companies investing in alternative fuels and renewable energy sources. Public-private partnerships can also play a significant role in mobilizing the necessary funds. Additionally, creating green financing mechanisms, such as green bonds and sustainable investment funds, can attract private investment into the sector .

3.2.2 Evaluating the Costs of Decarbonizing the Shipping Industry

Decarbonizing maritime transport is among the top priorities of regulators and continuously attracts significant research attention. However, the cost of renewing and greening the fleet has not been explored in detail. To address this gap, the paper provided a bottom-to-top estimation of the financial need associated with decarbonizing the global shipping fleet for the next 5 years, i.e., until 2026. By developing a model focusing on the main asset classes, the paper approximated the expenditure implied in the short-term fleet renewal (newbuilding and vessel demolition) as well as the expenditure linked to retrofitting the existing fleet. The results indicated an aggregate financial need of USD 317 billion until 2026. Thereof, USD 235 billion are associated with building new ships, while USD 114 billion are allocated to retrofitting. Furthermore, proceeds of USD 33 billion can be generated via demolition sales of old tonnage, reducing the total financial burden. The results entail important policy implications, as they document the monetary impact on investors, lenders, and shipping companies regarding distinct segments of the fleet. Considering the declining overall supply of capital towards shipping, the given results provide a transparent account of the absolute financial implications of decarbonization policies [17].

3.3 Key Market Trends and Drivers

3.3.1 Market Trends

One of the most significant trends in maritime decarbonization is the shift towards alternative fuels. Liquefied natural gas (LNG) has gained popularity due to its ability to reduce CO2 emissions by 20-30%, although its methane slip remains a challenge. Other promising alternatives include hydrogen, ammonia, methanol, and biofuels. These fuels offer substantial emissions reductions, but face challenges related to economic viability, production scalability, and public acceptance [18].

The development of new technologies is crucial for improving fuel efficiency and reducing emissions. Stern hydrodynamic energy-saving devices, fuel cells, and hybrid propulsion systems are among the innovative solutions being explored. These technologies can optimize fuel efficiency and reduce greenhouse gas emissions, with ESDs alone potentially improving fuel efficiency by up to 15% [19].

Digital technologies are increasingly being integrated into maritime operations to enhance efficiency and reduce emissions. Real-time monitoring, predictive maintenance, and advanced analytics for route and speed optimization can significantly cut fuel consumption. Digital twins and Internet of Things solutions are also being leveraged to monitor and manage emissions more effectively [20].

Regulations are becoming stricter, with the International Maritime Organization (IMO) and the European Union (EU) setting ambitious targets for GHG emissions reduction as presented in Strategic Research and Innovation Agenda (SRIA) Zero Emission Waterborne Transport[2]. Policies such as the Energy Efficiency Design Index (EEDI) and mandatory fuel consumption data collection are driving the adoption of greener technologies. Market-based measures (MBMs), like carbon pricing and emissions trading schemes, are also being considered to incentivize reductions in emissions [21].

3.3.2 Market Drivers

Financial incentives play a crucial role in driving the adoption of decarbonization solutions. Subsidies, grants, and tax breaks can lower the financial barriers for shipowners investing in alternative fuels and green technologies. Additionally, green financing mechanisms, such as green bonds and sustainable investment funds, are attracting private investments into the sector [22].

Continuous advancements in technology are essential for reducing the costs and improving the efficiency of green solutions. Innovations in fuel cells, energy-saving devices, and renewable energy integration are making it more feasible for shipowners to adopt sustainable practices. The development of hydrogen and ammonia propulsion systems, which offer near-zero emissions, exemplifies the potential of these technologies [23].

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[2] https://www.waterborne.eu/images/230505_SRIA_Zero_Emission_Waterborne_Transport_2.0_clean_public_consultation_final.pdf

Regulatory frameworks are a major driver for the adoption of decarbonization technologies. The IMO's targets to reduce GHG emissions by at least 50% by 2050 are pushing shipowners to invest in cleaner technologies. Compliance with these regulations not only helps reduce emissions but also avoids potential penalties and improves the industry's sustainability credentials [24].

There is increasing pressure from consumers and stakeholders for more sustainable and environmentally friendly practices. Companies are becoming more conscious of their environmental impact, and there is a growing market demand for green shipping solutions. This demand is driving investments in sustainable technologies and practices within the maritime industry [25].

3.4 Competitor Analysis

A.P. Moller-Maersk[3], one of the largest shipping companies globally, is at the forefront of maritime decarbonization. Maersk is investing heavily in methanol-powered ships and has ordered a fleet of methanol-fuelled vessels expected to be delivered by 2023-2024. The company is also exploring the use of ammonia and biofuels as part of its broader strategy to reduce carbon emissions. Additionally, Maersk is implementing various energy-saving technologies and optimizing vessel operations to further decrease fuel consumption and emissions. Maersk's strengths lie in its strong financial position, which enables significant investments in research and development, and its leadership in sustainability, with ambitious targets for zero carbon shipping by 2050. However, the company faces challenges, such as dependency on the successful scaling of methanol and other alternative fuels, and potential regulatory hurdles in different markets.

CMA CGM[4], a major global shipping company based in France, is known for its strong commitment to sustainability. The company has invested significantly in LNG-powered vessels, positioning LNG as a transition fuel while working towards more sustainable alternatives like hydrogen. CMA CGM also adopts digital tools for route optimization and fuel efficiency improvements. The company's early adoption of LNG technology provides a competitive edge in reducing emissions, and it has established strong partnerships with technology providers and fuel suppliers. However, the methane slip associated with LNG could undermine its long-term sustainability goals, and the high initial investment costs and infrastructure requirements present significant challenges.

Hapag-Lloyd[5], a leading global liner shipping company based in Germany, is actively exploring biofuels and LNG as transitional fuels while evaluating other green technologies. The company is also focused on improving energy efficiency through retrofitting programs and optimization measures. Hapag-Lloyd's strengths include its strong focus on operational efficiency and cost management, as well as active participation in industry coalitions and environmental initiatives. However, the company has been slower in adopting alternative fuels compared to some competitors and may need greater investment in innovative technologies to keep pace.

MSC[6] (Mediterranean Shipping Company), a global leader in container shipping, is known for its extensive network and large fleet. The company is investing in LNG-powered ships and exploring other sustainable fuels such as hydrogen and ammonia. MSC is also committed to continual upgrading and retrofitting of vessels to improve energy efficiency and reduce emissions. The

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[3] https://www.maersk.com/about
[4] https://www.cma-cgm.com/
[5] https://www.hapag-lloyd.com/en/home.html
[6] https://www.msc.com/

company's large-scale operations and economies of scale provide significant advantages, and it has a strong focus on technological innovation and sustainability. However, MSC's dependence on the availability and scalability of alternative fuels and regulatory compliance challenges across different regions remain critical issues.

3.4.1 Comparative Analysis

Maersk and CMA CGM are leading in the adoption of alternative fuels, with significant investments in methanol and LNG, respectively. Hapag-Lloyd and MSC are also exploring alternative fuels but are more focused on operational efficiency and fleet modernization as interim measures. Maersk has set ambitious targets for zero-carbon shipping by 2050, reflecting a strong commitment to sustainability. CMA CGM and MSC have also set significant decarbonization goals but may face challenges related to LNG's methane slip and fuel infrastructure. Hapag-Lloyd focuses on gradual improvements and cost-effective measures, potentially lagging behind in the rapid adoption of new technologies.

In terms of market position, Maersk and MSC benefit from their large-scale operations and financial strength, enabling substantial investments in R&D and green technologies. CMA CGM leverages its strong partnerships and early adoption of LNG to maintain a competitive edge, while Hapag-Lloyd's strength lies in its operational efficiency and industry collaborations. All competitors face challenges related to the high costs of new technologies and infrastructure development, regulatory compliance, and the need for international cooperation. The scalability and economic viability of alternative fuels remain significant concerns across the industry.

The maritime decarbonization market is highly competitive. Each company has its unique strengths and strategies, but common challenges include high costs, regulatory compliance, and fuel availability. Understanding these dynamics is crucial for navigating the competitive landscape and identifying opportunities for innovation and collaboration in the pursuit of a sustainable maritime industry.

3.5 Market Opportunities for RETROFIT55 Solutions

The maritime decarbonization market offers numerous opportunities for innovative solutions such as Air Lubrication Systems, Wind Assisted Ship Propulsion, Ship Electrification Solutions, and Smart Energy Management Systems. These technologies can significantly reduce fuel consumption and greenhouse gas emissions, providing both environmental and economic benefits. However, successful integration and deployment require addressing challenges related to costs, infrastructure, standardization, and regulatory compliance. By overcoming these challenges, the maritime industry can achieve substantial progress towards sustainability and climate goals.

3.5.1 Air Lubrication Systems Market Opportunities

Air Lubrication Systems (ALS) present a significant opportunity to reduce fuel consumption and greenhouse gas emissions in the maritime industry by decreasing the frictional resistance between a ship's hull and water. This technology can result in fuel savings of up to 8-15%, translating to substantial cost reductions and lower CO_2 emissions. As fuel prices rise and environmental regulations tighten, the adoption of ALS can provide shipowners with a competitive edge by enhancing operational efficiency and sustainability. Recent studies have demonstrated the practical benefits of ALS, with commercial ships equipped with this technology showing significant improvements in fuel efficiency [26].

Despite the potential benefits, deploying ALS faces challenges such as the need for significant initial capital investment and the complexity of retrofitting existing vessels. Additionally, the efficiency of ALS depends on optimal air injection methods, which require advanced technology and precision engineering. Ensuring the durability and reliability of ALS components under harsh marine conditions is also a concern that needs addressing [27].

3.5.2 Wind-Assisted Ship Propulsion Market Opportunities

Wind-assisted ship propulsion (WASP) technologies, including Flettner rotors, kites, and sails, offer substantial potential for fuel savings and emissions reduction. With fuel savings ranging from 1-20%, WASP can significantly lower operational costs and enhance the environmental profile of shipping companies. As global trade continues to grow, the need for sustainable and cost-effective propulsion solutions will drive the adoption of WASP technologies. The increasing regulatory pressure to reduce greenhouse gas emissions further incentivizes the implementation of these technologies [28].

The primary challenges for WASP include the variability of wind conditions and the technical integration of wind systems with existing ship designs. Economic barriers, such as high initial costs and the need for specialized maintenance, also hinder widespread adoption. Overcoming these challenges requires collaboration between technology providers, shipowners, and policymakers to develop standardized solutions and financial incentives to support the deployment of wind propulsion systems [29].

3.5.3 Ship Electrification Solutions Market Opportunities

Electrification of ships, including the use of battery energy storage systems (BESS) and hybrid propulsion technologies, offers a pathway to achieving zero-emission shipping. The growing number of battery/hybrid vessels in operation demonstrates the feasibility and benefits of these technologies. Ship electrification can provide significant reductions in fuel consumption, emissions, and operational costs, especially for short-range vessels. The integration of local renewables and shore connection systems further enhances the sustainability of these solutions [30].

The deployment of electrification solutions faces challenges related to the high costs of batteries and fuel cells, the need for extensive infrastructure development, and the limitations of current battery technology in terms of energy density and range. Additionally, integrating these systems with existing ship designs and ensuring compatibility with various operational profiles requires significant engineering expertise and investment [31].

3.5.4 Smart Energy Management Systems Market Opportunities

Smart energy management systems (EMS) are crucial for optimizing energy use and reducing emissions in maritime operations. These systems can integrate data from various sources, including real-time monitoring of fuel consumption, weather conditions, and route optimization algorithms, to enhance operational efficiency. The use of advanced analytics and artificial intelligence can further improve decision-making processes, leading to substantial cost savings and emissions reductions.

Challenges for EMS include the complexity of integrating various data sources and systems, the need for robust cybersecurity measures, and the requirement for significant upfront investment in technology and training. Additionally, ensuring the reliability and accuracy of data and analytics is essential for the effective functioning of EMS [32].

3.5.5 Smart Energy Management Systems Market Opportunities

Scalability and adaptability of green technologies are critical for their widespread adoption in the maritime industry. Technologies that can be easily retrofitted to existing vessels or scaled up for larger ships offer significant market opportunities. Modular solutions that allow for gradual implementation and integration with other systems can enhance the attractiveness of these technologies to shipowners looking for flexible and cost-effective decarbonization options [33].

Scalability challenges include the need for standardized designs and components, ensuring compatibility with diverse ship types and operational profiles, and managing the logistical complexities of large-scale implementation. Adaptability issues involve the ability to customize solutions to meet specific regulatory requirements and operational needs across different regions and markets [34].

4 Stakeholder Analysis

The maritime decarbonization market involves a diverse range of stakeholders, each playing a critical role in driving the transition towards sustainable practices. This analysis identifies and evaluates the key stakeholders, their interests, and the challenges they face in the maritime decarbonization process.

4.1 International Maritime Organization

The IMO, a specialized agency of the United Nations, is the primary regulatory body responsible for setting global standards for the safety, security, and environmental performance of international shipping. The IMO has set ambitious targets to reduce greenhouse gas (GHG) emissions by at least 50% by 2050 compared to 2008 levels. Its interests lie in enforcing regulations, such as the Energy Efficiency Design Index (EEDI) and the Carbon Intensity Indicator (CII), to ensure compliance and promote sustainability in the maritime industry.

The IMO faces challenges in achieving global consensus among member states, each with varying economic interests and levels of technological advancement. The enforcement of regulations across different jurisdictions and the monitoring of compliance are also significant hurdles.

4.1.1 Sustainable and Smart Mobility Strategy

This strategy sets a target for zero-emission vessels to be market-ready by 2030. The Fit for 55 Package: Introduced on July 14, 2021, this package comprises various proposals by the European Commission aimed at reducing net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. It includes updates to the EU Emission Trading System, the Renewable Energy Directive, the Revised Alternative Fuel Infrastructure Regulation, and the Fuel EU Maritime Initiative.

New measures like the Carbon Intensity Indicator emphasize the need to green the operations of existing vessels. This involves focusing on retrofitting, energy efficiency, and implementing digital green measures. Additionally, the IMO's Initial Strategy on reducing greenhouse gas emissions from shipping, initiated in 2018, is expected to be revised.

Tabled in June 2021, this 35-point plan aims to increase the role of inland waterways in mobility and logistics, shifting more cargo to Europe’s rivers and canals, and achieving zero-emission barges by 2050. This aligns with the European Green Deal and the Sustainable and Smart Mobility Strategy.

4.2 National Governments

National governments are responsible for implementing IMO regulations within their jurisdictions and supporting domestic maritime industries in the transition to low-carbon operations. They provide financial incentives, subsidies, and infrastructure investments to facilitate the adoption of green technologies.

Governments face the challenge of balancing economic growth with environmental sustainability. They need to address the economic impact on their maritime industries and ensure that small and medium-sized enterprises (SMEs) can compete in a decarbonized market. Additionally, there is a need for international cooperation to harmonize regulations and standards.

4.3 Shipping Companies and Shipowners

Shipping companies and shipowners are at the forefront of implementing decarbonization measures. Their interests include reducing fuel consumption, lowering operational costs, and complying with environmental regulations. Investing in alternative fuels, energy-efficient technologies, and digital solutions are key strategies for achieving these goals.

The high initial capital investment required for new technologies and retrofitting existing fleets is a significant barrier. Additionally, there is uncertainty regarding the future availability and cost of alternative fuels. Shipping companies also need to manage the operational challenges associated with integrating new technologies into existing systems.

4.4 Technology Providers

Technology providers develop and supply the green technologies and alternative fuels necessary for maritime decarbonization. Their interests lie in innovation, market penetration, and forming partnerships with shipping companies to implement their solutions.

Technology providers face challenges related to research and development costs, scaling up production, and ensuring the reliability and efficiency of their technologies under varying maritime conditions. They also need to navigate regulatory approvals and demonstrate the economic viability of their solutions to potential customers.

4.5 Key Stakeholder Needs and Expectations

The IMO expects RETROFIT55 to provide quantifiable improvements in energy efficiency and emissions reduction, aligning with international regulations. The solution should facilitate easy monitoring and reporting of compliance to ensure that shipowners and operators meet the required standards. Governments need technologies that support their national decarbonization policies and commitments under international agreements like the Paris Agreement. RETROFIT55 should help reduce national GHG emissions from the maritime sector and promote sustainable economic growth. Governments expect our project’s solutions to be cost-effective, supporting economic viability for domestic shipping companies. Additionally, it should be scalable and adaptable to various ship types and sizes to maximize its impact across the national fleet. Financial incentives and subsidies for early adopters may also be expected to encourage widespread implementation.

Shipping companies and shipowners seek solutions that enhance fuel efficiency, reduce operational costs, and ensure compliance with environmental regulations. They require technologies that can be retrofitted to existing vessels to extend their service life and improve sustainability.

Our solutions should offer a high return on investment by significantly lowering fuel consumption and maintenance costs. Shipowners expect the solution to be reliable, easy to integrate with current operations, and to provide tangible performance improvements. Additionally, the solution should minimize downtime during installation and be supported by robust after-sales service and technical support.

Technology providers need innovative solutions to maintain competitive advantage and meet the increasing demand for green technologies. They seek opportunities for collaboration with shipowners and regulatory bodies to develop and deploy effective decarbonization technologies.

Providers expect RETROFIT55 solutions to be technologically advanced and capable of integration with other green technologies. The solution should be scalable, allowing for customization to meet the specific needs of different clients. Continuous research and development support to enhance the technology's effectiveness and adaptability are also anticipated.

5 Economic Analysis

The aim of the economic analysis is to provide a first insight into the Costs and Benefits of each RETROFIT55 technology and therefore an estimation of the Return on Investment (ROI) value. The analysis is based mainly on a comprehensive literature review, and it shall be updated once results start to emerge from the project.

5.1 Cost Analysis of RETROFIT55 Technologies and Financial Benefits and Savings

Air Lubrication Systems (ALS) offer significant fuel savings, providing payback in just over 3 years assuming that a passive system is installed, as summarized in Table 1. Currently available systems deliver between 3% and 7% net, contingent on vessel type and operating conditions. Net performance is significantly reduced for these systems due to the high energy demand of their industrial compressors which deliver the air to reduce drag. It is considered that ALS has the potential to deliver significantly better results than is currently being achieved and that 10% reduction in GHG emissions is possible with a passive, low energy demand, system.

Table 1: Air Lubrication System Cost Analysis

Air Lubrication Systems
Total Initial Cost: €3,025,000
Total Maintenance Cost (10 years): €230,000
Total Fuel Savings (10 years): €9,176,000
Net Savings (10 years): €6,152,000, pay back, 3.4 years, IRR 28%[7]
GHG Reduction: 10%

Smart Energy Management systems are cost-effective with net savings of 200,000 over 10 years and a 7% reduction in GHG emissions, as reported in Table 2.

Table 2: Smart Energy Management Cost Analysis[8]

Smart Energy Management
Total Initial Cost: € 1,000,000
Total Maintenance Cost (10 years): € 300,000
Total Fuel Savings (10 years): € 1,500,000
Net Savings (10 years): € 200,000
GHG Reduction: 7%

Hydrodynamic and Operational Optimization provides similar net savings to Smart Energy Management at 200,000 over 10 years and offers an 8% reduction in GHG emissions, see Table 3 as reference.

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[7] Assumes consumption 50 tonnes day, 275 days steaming / year, US$ 747 / tonne1 ULS delivered inc US$150 tonne carbon tax. US$ 25,000 m&r cost per year. Assumes passive system.

Table 3: Hydrodynamic and Operational Optimization Cost Analysis[8]

Hydrodynamic and Operational Optimization
Total Initial Cost: € 1,200,000
Total Maintenance Cost (10 years): € 400,000
Total Fuel Savings (10 years): € 1,800,000
Net Savings (10 years): € 200,000
GHG Reduction: 8%

Fuel Cells and Hybridization show the highest potential for GHG reduction at 15%, but with a net loss of 300,000 over 10 years due to the high initial and maintenance costs. Details are reported in Table 4.

Table 4: Fuel Cells and Hybridization Cost Analysis[8]

Fuel Cells and Hybridization
Total Initial Cost: € 3,000,000
Total Maintenance Cost (10 years): € 800,000
Total Fuel Savings (10 years): € 3,500,000
Net Savings (10 years): € -300,000
GHG Reduction: 15%

Table 5 summarizes info related to WASP installation. Wind Assisted Propulsion systems show a higher initial and maintenance cost with a slight net loss of 100,000 over 10 years, but they provide a significant 12% reduction in GHG emissions.

Table 5: Wind Assisted Propulsion Cost Analysis[9]

Wind Assisted Propulsion (Suction Sails)
Total Initial Cost: € 2,440,000
Total Maintenance Cost (10 years): € 488,000

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[8] The numbers presented for Total Initial Cost, Total Maintenance Cost, Total Fuel Savings, and GHG Reduction are estimations derived from a comprehensive literature review and current market trends. These estimations were meticulously compiled by analysing data retrieved from detailed industry reports, financial analyses, and market forecasts. The literature review provided insights into historical data and projections which helped to deliver a realistic and well-founded estimation of the costs and savings associated with the implementation of decarbonisation solutions in the maritime industry. While these estimations offer a valuable projection, it is important to acknowledge that they are estimations and should be interpreted within the context of the inherent uncertainties in market dynamics and technological advancements.

[9] The Total Initial Cost is based on a standard configuration of suction sails for a MR Tanker, for more information (confidential) please contact the corresponding members of the project consortium. The Total Maintenance Cost is based on an annual OPEX cost of 2% of CAPEX/year. The Total Fuel Savings is calculated considering 225 days at sea per year and the average fuel savings generated by the above-mentioned sails configuration for that particular vessel. The average value of fuel savings is 554 Tn/year, averaging four different trading routes: (1) Houston-Qatar, (2) Houston-Rotterdam, (3) Qatar-Shanghai and (4) Houston-Hong Kong. The analysis considers fuel price of 700 €/Tn and a CO2 price of 70 €/Tn. The GHG Reduction is calculated considering a fuel consumption for a standard MR Tanker of 17 Tn/day.

Total Fuel Savings (10 years): € 5,099,958
Net Savings (10 years): € 2,171,958
GHG Reduction: 14.48%

The cost analysis for the RETROFIT55 solutions was based on a literature review of maritime green technologies market trends provided in the following.

The adoption of green technologies and retrofitting solutions in the maritime industry presents significant opportunities for improving operational efficiency and reducing environmental impact. Studies indicate that while there are high initial costs, the long-term benefits in terms of fuel savings and emissions reductions are substantial. Collaborative efforts, regulatory compliance, and continuous innovation are key to achieving sustainability goals in maritime operations.

Wu et al. (2022) explore the adoption of green technologies for both new and aged ships, focusing on the economic viability and operational decisions related to fleet deployment. Their study suggests that despite the high initial costs, green technologies offer substantial environmental benefits and can become competitive as fuel and operating costs increase. This highlights the potential for significant improvements in fuel efficiency and emissions reduction through the adoption of green technologies [35].

Ling-Chin and Roskilly (2016) conduct a life cycle assessment (LCA) to evaluate the environmental and economic performance of retrofitting conventional power plants on Roll-on/Roll-off cargo ships with emerging technologies like photovoltaic systems and lithium-ion batteries. Their findings reveal that such retrofits can significantly reduce emissions of CO2, NOx, SOx, and particulate matter, emphasizing the importance of integrating advanced technologies to achieve sustainability in maritime operations [36].

Yalama et al. (2022) address the challenges faced by shipowners with older fishing carriers in meeting new environmental regulations. They emphasize the need for energy efficiency projects and retrofitting marine systems to comply with regulations like the Ship Energy Efficiency Management Plan (SEEMP). The study underscores the importance of energy audits and tailored efficiency programs to achieve substantial reductions in fuel consumption and emissions [37].

Zhen et al. (2020) present a model to optimize fleet deployment and the adoption of green technologies within Emission Control Areas (ECAs). Their research demonstrates how technologies like scrubbers and shore power can effectively reduce emissions and operational costs, highlighting the importance of integrating green technologies into shipping networks to meet regulatory requirements and enhance sustainability [38].

Mosgaard and Kerndrup (2016) analyze Danish demonstration projects aimed at promoting energy-efficient retrofitting technologies. These projects are essential for testing and developing new technologies, reducing economic risks for stakeholders, and facilitating the diffusion of energy-efficient solutions. The study highlights the role of collaboration between stakeholders in overcoming barriers and driving the adoption of cleaner technologies in the maritime sector [39].

5.2 Return on Investment (ROI) Calculation

The Return on Investment for each decarbonization solution over a 10-year period has been calculated based on the initial costs, maintenance costs, and fuel savings.

The results are summarized in the following tables (Table 6 - Table 9).

Air Lubrication Systems offer significant fuel savings over a 10-year period, resulting in a net ROI of IIR 28% (Table 6).

Table 6: Air Lubrication System ROI

Air Lubrication Systems
Total Initial Cost: €3,025,000
Total Maintenance Cost (10 years): €230,000
Total Fuel Savings (10 years): 13,750 tonnes
Net Savings (10 years): €6,152,000
ROI: Pay back 3.4 years IIR 28%

Smart Energy Management systems provide net savings of 200,000 over 10 years with an ROI of 20%, making them a cost-effective investment for improving energy efficiency and reducing operational costs (Table 7).

Table 7: Smart Energy Management ROI

Smart Energy Management
Total Initial Cost: € 1,000,000
Total Maintenance Cost (10 years): € 300,000
Total Fuel Savings (10 years): € 1,500,000
Net Savings (10 years): € 200,000
ROI: 20%

Hydrodynamic and Operational Optimization offers net savings of 200,000 over 10 years with an ROI of 16.67%. This solution is effective in enhancing operational efficiency and achieving cost savings (Table 8).

Table 8: Hydrodynamic and Operational Optimization ROI

Hydrodynamic and Operational Optimization
Total Initial Cost: € 1,200,000
Total Maintenance Cost (10 years): € 400,000
Total Fuel Savings (10 years): € 1,800,000
Net Savings (10 years): € 200,000
ROI: 16.67%

Fuel Cells and Hybridization show a net financial loss of 300,000 over 10 years with an ROI of -10%. While the financial return is negative, this solution provides the highest GHG reduction, making it valuable for long-term environmental goals (Table 9).

Table 9: Fuel Cells and Hybridization ROI

Fuel Cells and Hybridization
Total Initial Cost: € 3,000,000
Total Maintenance Cost (10 years): € 800,000
Total Fuel Savings (10 years): € 3,500,000
Net Savings (10 years): € -300,000
ROI: -10%

Wind Assisted Propulsion results in a offers net savings of 2,171,958 over 10 years with an ROI of -89%, making them a cost-effective investment for improving energy efficiency and reducing operational costs (Table 10).

Table 10: Wind Assisted Propulsion ROI

Wind Assisted Propulsion (Suction Sails)
Total Initial Cost: € 2,440,000
Total Maintenance Cost (10 years): € 488,000
Total Fuel Savings (10 years): € 5,099,958
Net Savings (10 years): € 2,171,958
ROI: 89%

In conclusion, the ROI analysis reveals that Air Lubrication Systems, Smart Energy Management, Hydrodynamic and Operational Optimization and Wind Assisted Propulsion offer positive returns on investment while Fuel Cells and Hybridization have negative ROIs but offer significant environmental benefits. Shipowners should consider a balanced approach, combining these technologies to optimize both financial and environmental outcomes in their decarbonization strategies.

6 Social impact

6.1 Job Creation and Skills Development

The utilization of various decarbonization solutions in the maritime industry not only helps reduce fuel consumption and greenhouse gas (GHG) emissions but also presents significant opportunities for job creation and skills development.

The implementation of Air Lubrication Systems requires skilled labour for installation, maintenance, and continuous monitoring. The growing demand for ALS in the shipping industry can lead to the creation of new jobs in the areas of engineering, manufacturing, and technical services. Companies involved in the development and deployment of ALS will need to hire engineers, technicians, and operational staff.

Workers will need training in advanced maritime engineering, including the principles of hydrodynamics and air lubrication. Additionally, technical skills in system integration, monitoring, and maintenance will be crucial. Training programs and certifications specific to ALS technologies will be developed to ensure the workforce is equipped with the necessary skills [40].

The adoption of Smart Energy Management systems in maritime operations will create jobs in software development, data analysis, and system integration. These systems require continuous monitoring and optimization, leading to the need for energy managers and IT professionals who can analyse energy usage patterns and implement efficiency measures.

Professionals will need to develop skills in energy management, data analytics, and the use of advanced software tools for monitoring and optimizing energy consumption. Training in the integration of smart systems with existing maritime infrastructure will also be essential [41].

Optimizing hydrodynamic performance and operational practices involves extensive research and development, which will create jobs for naval architects, marine engineers, and operational researchers. Additionally, the implementation of these optimizations will require skilled technicians and support staff.

Training in advanced hydrodynamics, computational fluid dynamics (CFD), and operational efficiency will be necessary. Professionals will also need to understand the integration of optimization technologies with existing maritime operations and regulatory compliance requirements [42].

The deployment of wind-assisted propulsion technologies, such as sails and kites, will create jobs in design, manufacturing, and installation. Additionally, there will be ongoing maintenance and operational roles, leading to job opportunities in maritime engineering and technical services.

Professionals will require training in aerodynamics, materials science, and the mechanics of wind-assisted systems. Skills in installation, maintenance, and operational optimization of these systems will also be crucial [43].

The shift towards fuel cells and hybrid propulsion systems will generate jobs in R&D, manufacturing, and system integration. The ongoing operation and maintenance of these systems will also require a skilled workforce, creating opportunities in technical and engineering fields.

Professionals will need to develop expertise in electrochemistry, fuel cell technology, and hybrid propulsion systems. Training programs will be essential to equip the workforce with the skills needed to design, install, and maintain these advanced systems. Additionally, knowledge of environmental regulations and compliance will be important [44].

6.2 Contribution to Sustainable Development Goals (SDG)

6.2.1 Air Lubrication Systems

1. Affordable and Clean Energy (SDG 7): Reduces fuel consumption, making energy use more efficient and affordable.
2. Industry, Innovation, and Infrastructure (SDG 9): Promotes the adoption of innovative technologies and enhances the efficiency of maritime infrastructure.
3. Climate Action (SDG 13): Reduces greenhouse gas (GHG) emissions, contributing to efforts against climate change.
4. Life Below Water (SDG 14): Minimizes environmental impact on marine ecosystems by reducing emissions and pollutants.

6.2.2 Smart Energy Management

1. Affordable and Clean Energy (SDG 7): Optimizes energy usage, reducing costs and improving energy efficiency.
2. Decent Work and Economic Growth (SDG 8): Creates new jobs in energy management and technical services.
3. Industry, Innovation, and Infrastructure (SDG 9): Fosters innovation through the integration of advanced energy management systems.
4. Climate Action (SDG 13): Contributes to the reduction of GHG emissions through efficient energy use.

6.2.3 Hydrodynamic and Operational Optimization

1. Affordable and Clean Energy (SDG 7): Enhances fuel efficiency, leading to lower energy costs.
2. Industry, Innovation, and Infrastructure (SDG 9): Encourages the development and adoption of innovative maritime technologies.
3. Climate Action (SDG 13): Reduces emissions by optimizing ship design and operations.
4. Life Below Water (SDG 14): Reduces the environmental footprint of maritime activities, protecting marine life.

6.2.4 Wind Assisted Propulsion

1. Affordable and Clean Energy (SDG 7): Utilizes renewable wind energy to reduce fuel consumption.
2. Industry, Innovation, and Infrastructure (SDG 9): Promotes the use of innovative propulsion technologies in the maritime industry.
3. Climate Action (SDG 13): Significantly cuts GHG emissions by harnessing wind power.

6.2.5 Fuel Cells and Hybridization

1. Affordable and Clean Energy (SDG 7): Provides a cleaner and more efficient energy source, reducing reliance on fossil fuels.

2. Industry, Innovation, and Infrastructure (SDG 9): Supports the advancement of hybrid and fuel cell technologies.
3. Climate Action (SDG 13): Reduces GHG emissions by utilizing low-emission energy sources.

7 Business Model Canvas for RETROFIT55 Solutions

7.1 Value Proposition

The business model for RETROFIT55's decarbonization solutions offers a compelling value proposition cantered on environmental compliance, cost savings, operational efficiency, and sustainability. As international regulations on greenhouse gas (GHG) emissions become increasingly stringent, maritime companies are under pressure to adopt greener technologies. RETROFIT55 addresses this need by providing innovative solutions that help companies meet these regulations while also achieving significant cost savings. The reduction in fuel consumption and maintenance costs not only improves the bottom line but also enhances the operational efficiency of maritime vessels. Additionally, the emphasis on sustainability and the use of renewable energy sources aligns with global efforts to combat climate change, positioning RETROFIT55 as a forward-thinking and socially responsible brand.

7.2 Customer Segments

The business model targets a diverse range of customer segments within the maritime industry, including shipowners, operators, shipyards, retrofit service providers, and regulatory bodies. By addressing the specific needs of each segment, the model ensures broad market appeal and relevance. Shipowners and operators, for instance, are primarily concerned with reducing operational costs and ensuring compliance with environmental regulations. Shipyards and retrofit service providers, on the other hand, are interested in integrating advanced technologies that can be offered to their clients as value-added services. By engaging regulatory bodies and industry associations, RETROFIT55 can also influence policy development and ensure that its solutions are aligned with current and future regulatory requirements.

7.3 Revenue Streams

The business model incorporates multiple revenue streams to ensure financial sustainability and profitability. Revenue from sales of retrofit kits and equipment provides a solid foundation, while installation and integration services offer an additional income source. Subscription services for data analytics, performance monitoring, and optimization software generate recurring revenue, enhancing financial stability. Maintenance and support contracts ensure ongoing customer engagement and satisfaction, while consulting services provide expert guidance on compliance and technology implementation. Licensing and royalties from patented technologies further diversify the revenue base and extend market reach.

7.4 Key Activities

The success of the business model hinges on several key activities, including continuous research and development (R&D), market analysis, customer engagement, and effective sales and marketing strategies. Ongoing R&D efforts are crucial for maintaining technological leadership and ensuring that the solutions remain cutting-edge and competitive. Market analysis and customer engagement activities help identify emerging trends, customer needs, and potential opportunities, guiding strategic decision-making. Sales and marketing efforts, including targeted campaigns and participation in industry events, are essential for building brand awareness and driving adoption of the solutions. Additionally, providing professional installation and integration services ensures seamless implementation and maximizes customer satisfaction.

7.5 Key Partnerships

Strategic partnerships play a critical role in the business model, facilitating the development, deployment, and commercialization of RETROFIT55 solutions. Collaborations with shipyards and retrofit service providers ensure efficient installation and integration of the technologies. Partnerships with maritime technology providers allow for the integration of complementary solutions, enhancing the overall value proposition. Engaging regulatory bodies and industry associations helps align the solutions with current and future regulatory requirements, while collaborations with academic and research institutions support ongoing innovation. Partnerships with financial institutions and investors provide the necessary funding for scaling and expansion.

7.6 Cost Structure

The cost structure of the business model includes R&D expenses, production and manufacturing costs, sales and marketing expenses, installation and integration costs, technical support and maintenance costs, and general administrative expenses. R&D expenses are crucial for continuous innovation and maintaining a competitive edge. Production and manufacturing costs must be managed efficiently to ensure profitability. Sales and marketing expenses are necessary for building brand awareness and driving adoption, while installation and integration costs ensure seamless implementation. Technical support and maintenance costs are essential for ongoing customer satisfaction, and administrative expenses cover general operational needs.

7.7 Implementation Roadmap

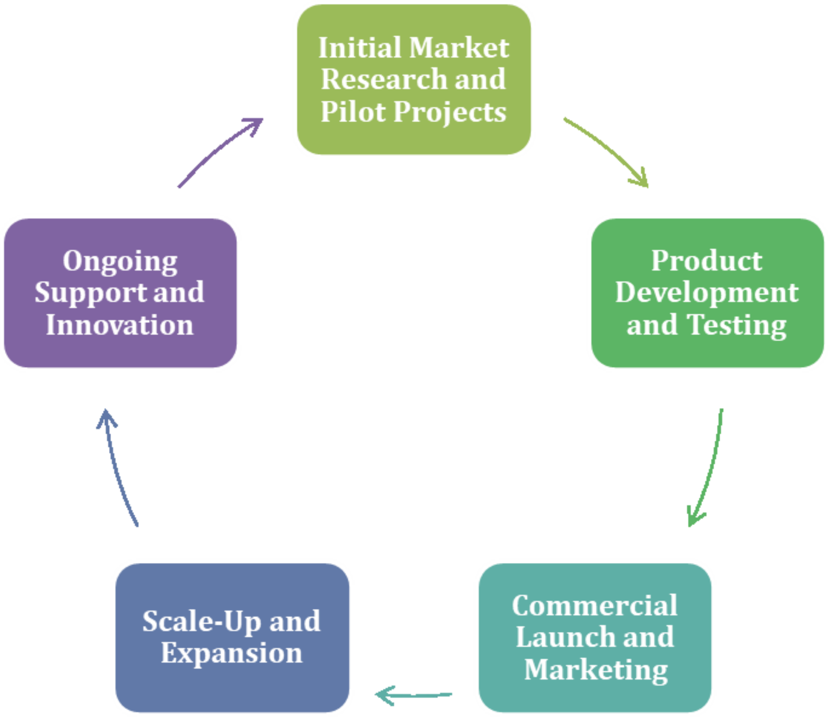

Figure 2: Business Model Implementation Roadmap

The implementation roadmap outlines the steps necessary for bringing RETROFIT55 solutions to market and ensuring their long-term success. The scheme, presented in Figure 2, is briefly summarized in the following. The initial phase involves conducting detailed market research and implementing pilot projects to validate the technologies. This is followed by product development and testing to ensure reliability and performance. The commercial launch phase includes a strong marketing campaign targeting key customer segments. Scaling up production and expanding market reach through partnerships and increased sales efforts are the next steps. Ongoing support and innovation ensure the solutions remain competitive and effective. The roadmap provides a clear, structured approach to achieving commercial success and sustainability.

8 Conclusions and Recommendations

8.1 Strategic Recommendations for Commercial Exploitation

To ensure the successful commercial exploitation of RETROFIT55 solutions, it is crucial to adopt a comprehensive strategic approach. First and foremost, market segmentation and targeting are essential. By identifying key market segments such as large shipping companies, ferry operators, and container ship owners, RETROFIT55 can focus on those most likely to adopt decarbonization technologies. Targeted marketing campaigns tailored to each segment should emphasize the specific benefits of RETROFIT55 solutions relevant to their operations, thereby maximizing market penetration.

Strategic partnerships and alliances play a critical role in the commercial success of RETROFIT55. Collaborating with major shipyards will facilitate the integration of these technologies during both new builds and retrofitting projects. Engaging with regulatory bodies ensures compliance with environmental regulations and positions RETROFIT55 as a preferred solution for meeting these standards. Forming alliances with other technology providers to offer comprehensive, integrated solutions enhances overall vessel efficiency and emissions reduction, creating additional value for customers.

Conducting pilot projects and demonstrations is vital for showcasing the effectiveness and benefits of RETROFIT55 technologies. Real-world demonstrations provide concrete evidence of fuel savings, emissions reductions, and operational efficiencies, which can be used as compelling case studies. Leveraging data from these projects in marketing materials will build credibility and confidence among potential customers, driving adoption.

Offering flexible business models can lower the initial investment barrier for shipowners and operators. Subscription-based models for data analytics, performance monitoring, and optimization software create recurring revenue streams, while financing and leasing options make it easier for customers to adopt RETROFIT55 technologies. Exploring performance-based contracts, where payments are linked to actual fuel savings and emissions reductions, aligns incentives and builds trust with customers.

Continuous innovation and development are crucial for maintaining a competitive edge. Investing in ongoing research and development to refine existing technologies and develop new solutions ensures that RETROFIT55 remains at the forefront of the industry. Establishing a feedback loop with customers to gather insights and suggestions for improvement helps align future product development with market needs, ensuring long-term relevance and applicability.

Providing comprehensive support and maintenance services enhances customer satisfaction and ensures the smooth operation of RETROFIT55 technologies. Offering technical support and training services, including on-site support, remote assistance, and detailed user manuals, facilitates seamless implementation. Maintenance packages that include regular inspections, updates, and repairs help keep systems running optimally and extend their lifespan.

A robust marketing and communication strategy is essential for building brand awareness and driving market adoption. Positioning RETROFIT55 as a leader in maritime decarbonization solutions through strategic branding efforts and highlighting unique value propositions and success stories increases visibility. Participating in industry conferences, trade shows, and exhibitions, along with engaging industry media and publishing articles, white papers, and case studies, builds thought leadership. Utilizing digital marketing channels, including social media, email marketing, and search engine optimization (SEO), broadens reach and generates leads.

Performance monitoring and reporting using advanced data analytics provide continuous insights into the performance of RETROFIT55 technologies. Transparent and accurate reporting of performance metrics builds trust with customers and stakeholders, validating the effectiveness of the solutions and supporting marketing efforts.

Expanding geographical reach is also critical for maximizing market potential. Exploring opportunities to enter new markets with strong regulatory frameworks and significant maritime activity can enhance growth. Establishing local partnerships in key markets helps navigate regulatory environments, cultural differences, and market dynamics more effectively.

Lastly, developing a robust governance structure to manage the ongoing development and commercialization of RETROFIT55 technologies ensures clear roles, responsibilities, and decision-making processes. Aligning the business strategy with long-term sustainability goals ensures that environmental and social impacts are considered in all business decisions, supporting the overall mission of decarbonization in the maritime industry. By implementing these strategic recommendations, RETROFIT55 can effectively exploit its solutions commercially, achieving broad market adoption, financial sustainability, and significant contributions to environmental goals.

8.2 Long-term Sustainability and Project Progression

The RETROFIT55 can achieve long-term sustainability and project progression, ensuring that its innovative decarbonization solutions make a lasting impact on the maritime industry. This holistic approach combines continuous improvement, stakeholder collaboration, robust governance, financial stability, and a commitment to environmental and social responsibility.

8.2.1 Continuous Innovation and R&D

Investing in ongoing research and development (R&D) is crucial to keep RETROFIT55 technologies at the cutting edge of maritime decarbonization. Establish dedicated R&D teams to focus on improving existing solutions and developing new technologies. This will involve staying abreast of industry trends, regulatory changes, and technological advancements. Regularly updating the technology portfolio ensures that RETROFIT55 remains relevant and competitive.

8.2.2 Stakeholder Engagement and Collaboration

Engaging with stakeholders is vital for the project’s long-term success. This includes shipowners, operators, shipyards, technology providers, regulatory bodies, and industry associations. Regular consultations, workshops, and feedback sessions help incorporate stakeholder insights into project development. Building strong partnerships fosters a supportive ecosystem for the adoption and integration of RETROFIT55 technologies.

8.2.3 Robust Governance and Management Structure

Establishing a clear governance framework is essential for effective project management. Define roles, responsibilities, and decision-making processes to ensure coordinated efforts across all project phases. This structure should include a management board, technical advisory committees, and stakeholder representation. Regular reviews and audits help maintain accountability and transparency.

8.2.4 Financial Planning and Diversified Revenue Streams

Developing a comprehensive financial plan that includes diversified revenue streams to ensure financial sustainability. This can involve subscription-based models for software services, sales of retrofit kits, consulting services, and maintenance contracts. Additionally, explore funding opportunities through grants, partnerships, and investments to support ongoing development and expansion.

8.2.5 Market Adaptation and Scalability

Adapting to market needs and scaling the project effectively are key to long-term success. Conduct regular market analyses to understand emerging trends, customer needs, and competitive dynamics. This information can guide product development and marketing strategies. Develop scalable solutions that can be easily adapted to different ship types and operational contexts, ensuring broad market applicability.

8.2.6 Performance Monitoring and Continuous Improvement

Implement advanced performance monitoring systems to gather data on the effectiveness of RETROFIT55 technologies. Use this data to continually assess and improve the solutions. Providing customers with detailed performance reports enhances transparency and builds trust. Establish a culture of continuous improvement where feedback is regularly incorporated into product development.

8.2.7 Environmental and Social Responsibility

Align the project’s goals with broader environmental and social objectives. This includes not only reducing greenhouse gas (GHG) emissions but also improving air quality, promoting sustainable practices, and contributing to the maritime industry’s overall sustainability. Highlighting these contributions can enhance the project’s reputation and appeal to environmentally conscious stakeholders.

8.2.8 Education and Training Programs

Developing education and training programs to ensure that stakeholders understand the benefits and operation of RETROFIT55 technologies. This can include workshops, webinars, online courses, and hands-on training sessions. Educated stakeholders are more likely to adopt and effectively use the technologies, ensuring better outcomes and customer satisfaction.

8.2.9 Policy Advocacy and Regulatory Compliance

Active engagement in policy advocacy to shape regulations that supports maritime decarbonization. Work with regulatory bodies to ensure that RETROFIT55 technologies meet or exceed compliance standards. Proactive involvement in policy discussions can position RETROFIT55 as a leader in the industry and influence favorable regulatory frameworks.

8.2.10 Long-term Vision and Strategic Planning

Developing a long-term vision and strategic plan that outlines the project’s goals, milestones, and growth trajectory. This plan should be flexible to adapt to changing market conditions and technological advancements. Regularly review and update the strategic plan to reflect progress and new opportunities.

References

[1] Mallouppas, G., & Yfantis, E., 2021. Decarbonization in Shipping Industry: A Review of Research, Technology Development, and Innovation Proposals. Journal of Marine Science and Engineering.

[2] Aktas, T., Shi, J., Lim, G., Prousalidis, J., D'Agostino, F., & Liang, C., 2023. Decarbonization of the Maritime Transportation Systems: Recent Progress, Challenges, and Prospects. 2023 IEEE Electric Ship Technologies Symposium (ESTS), pp. 224-230

[3] Wang, Q., Zhang, H., Huang, J., & Zhang, P., 2023. The use of alternative fuels for maritime decarbonization: Special marine environmental risks and solutions from an international law perspective, 9.

[4] Aktas, T., Shi, J., Lim, G., Prousalidis, J., D'Agostino, F., & Liang, C., 2023. Decarbonization of the Maritime Transportation Systems: Recent Progress, Challenges, and Prospects. 2023 IEEE Electric Ship Technologies Symposium (ESTS), pp. 224-230.

[5] Agarwala, P., Chhabra, S., & Agarwala, N., 2021. Using digitalization to achieve decarbonization in the shipping industry. Journal of International Maritime Safety, Environmental Affairs, and Shipping, 5, pp. 161 - 174.

[6] Cullinane, K., & Yang, J., 2022. Evaluating the Costs of Decarbonizing the Shipping Industry: A Review of the Literature. Journal of Marine Science and Engineering.

[7] Mallouppas, G., & Yfantis, E., 2021. Decarbonization in Shipping Industry: A Review of Research, Technology Development, and Innovation Proposals. Journal of Marine Science and Engineering.

[8] Psaraftis, H., & Lagouvardou, S., 2023. Market Based Measures for the Reduction of Green House Gas Emissions from Ships: A Possible Way Forward. Samfundsøkonomen.

[9] Schinas, O., & Bergmann, N., 2021. Emissions trading in the aviation and maritime sector: Findings from a revised taxonomy., 1, pp. 100003.

[10] Dong, J., Zeng, J., Yang, Y., & Wang, H., 2022. A review of law and policy on decarbonization of shipping. , 9.

[11] Psaraftis, H., & Kontovas, C. (2020). Decarbonization of Maritime Transport: Is There Light at the End of the Tunnel?

[12] Grzelakowski, A., Herdzik, J., & Skiba, S., 2022. Maritime Shipping Decarbonization: Roadmap to Meet Zero-Emission Target in Shipping as a Link in the Global Supply Chains.

[13] Halim, R., Kirstein, L., Merk, O., & Martínez, L., 2018. Decarbonization Pathways for International Maritime Transport: A Model-Based Policy Impact Assessment.

[14] Cullinane, K., & Yang, J. (2022). Evaluating the Costs of Decarbonizing the Shipping Industry: A Review of the Literature. Journal of Marine Science and Engineering.

[15] Dong, J., Zeng, J., Yang, Y., & Wang, H. (2022). A review of law and policy on decarbonization of shipping, 9.

[16] Cullinane, K., & Yang, J., 2022. Evaluating the Costs of Decarbonizing the Shipping Industry: A Review of the Literature. Journal of Marine Science and Engineering.

[17] Schinas, O., & Bergmann, N., 2021. The Short-Term Cost of Greening the Global Fleet. Sustainability.

[18] Balcombe, P., Brierley, J., Lewis, C., Skatvedt, L., Speirs, J., Hawkes, A., & Staffell, I., 2019. How to decarbonise international shipping: Options for fuels, technologies and policies. Energy Conversion and Management.

[19] Spinelli, F., Mancini, S., Vitiello, L., Bilandi, R., & Carlini, M., 2022. Shipping Decarbonization: An Overview of the Different Stern Hydrodynamic Energy Saving Devices. Journal of Marine Science and Engineering.

[20] Agarwala, P., Chhabra, S., & Agarwala, N., 2021. Using digitalisation to achieve decarbonisation in the shipping industry. Journal of International Maritime Safety, Environmental Affairs, and Shipping, 5, pp. 161 - 174.

[21] Cullinane, K., & Yang, J. (2022). Evaluating the Costs of Decarbonizing the Shipping Industry: A Review of the Literature. Journal of Marine Science and Engineering.

[22] Mallouppas, G., & Yfantis, E., 2021. Decarbonization in Shipping Industry: A Review of Research, Technology Development, and Innovation Proposals. Journal of Marine Science and Engineering.

[23] Lindstad, E., Eskeland, G., Rialland, A., & Valland, A., 2020. Decarbonizing Maritime Transport: The Importance of Engine Technology and Regulations for LNG to Serve as a Transition Fuel. Sustainability, 12, pp. 8793.

[24] Psaraftis, H., & Lagouvardou, S., 2023. Market Based Measures for the Reduction of Green House Gas Emissions from Ships: A Possible Way Forward. Samfundsøkonomen.

[25] Grzelakowski, A., Herdzik, J., & Skiba, S., 2022. Maritime Shipping Decarbonization: Roadmap to Meet Zero-Emission Target in Shipping as a Link in the Global Supply Chains.

[26] Fotopoulos, A., & Margaris, D., 2020. Computational Analysis of Air Lubrication System for Commercial Shipping and Impacts on Fuel Consumption. Comput., 8, pp. 38.

[27] Giernalczyk, M., & Kamiński, P., 2021. Assessment of the Propulsion System Operation of the Ships Equipped with the Air Lubrication System. Sensors (Basel, Switzerland), 21.

[28] Werner, S., Papanikolaou, A., Werner, S., Fagergren, C., Dessen, L., Kuttenkeuler, J., Santén, V., & Steinbach, C., 2023. The ORCELLE Project – Towards Wind-Powered Ships for Deep Sea Cargo Transport. Day 3 Fri, September 29, 2023.

[29] Rafaelova, Z., 2021. Accelerating the Uptake of Wind Propulsion in Shipping.

[30] Kolodziejski, M., & Michalska-Pożoga, I., 2023. Battery Energy Storage Systems in Ships' Hybrid/Electric Propulsion Systems.

[31] Haxhiu, A., Abdelhakim, A., Kanerva, S., & Bogen, J., 2022. Electric Power Integration Schemes of the Hybrid Fuel Cells and Batteries-Fed Marine Vessels—An Overview. IEEE Transactions on Transportation Electrification, 8, pp. 1885-1905.

[32] Hinatsu, M., 2013. Recent Activity on the Energy Saving for Ships Using Air Lubrication Method. Japanese Journal of Multiphase Flow, 27, pp. 4-10.

[33] An, H., Pan, H., & Yang, P., 2022. Research Progress of Air Lubrication Drag Reduction Technology for Ships. Fluids.

[34] Rehmatulla, N., Parker, S., Smith, T., & Stulgis, V. (2017). Wind technologies: Opportunities and barriers to a low carbon shipping industry. Marine Policy, 75, 217-226.

[35] Wu, Y., Huang, Y., Wang, H., Zhen, L., & Shao, W., 2022. Green Technology Adoption and Fleet Deployment for New and Aged Ships Considering Maritime Decarbonization. Journal of Marine Science and Engineering.

[36] Ling-Chin, J., & Roskilly, A., 2016. Investigating a conventional and retrofit power plant on-board a Roll-on/Roll-off cargo ship from a sustainability perspective – A life cycle assessment case study. Energy Conversion and Management, 117, pp. 305-318.

[37] Yalama, V., Yakovleva, O., Trandafilov, V., & Khmelniuk, M., 2022. Future Sustainable Maritime Sector: Fishing Carriers and their Adoption to the Environmental Regulations. Part I. Polish Maritime Research, 29, pp. 69 - 77.

[38] Zhen, L., Yiwei, W., Wang, S., & Laporte, G., 2020. Green technology adoption for fleet deployment in a shipping network. Transportation Research Part B-methodological, 139, pp. 388-410

[39] Mosgaard, M., & Kerndrup, S., 2016. Danish demonstration projects as drivers of maritime energy efficient technologies. Journal of Cleaner Production, 112, pp. 2706-2716.

[40] Giernalczyk, M., & Kamiński, P., 2021. Assessment of the Propulsion System Operation of the Ships Equipped with the Air Lubrication System. Sensors (Basel, Switzerland), 21.

[41] Agarwala, P., Chhabra, S., & Agarwala, N., 2021. Using digitalisation to achieve decarbonisation in the shipping industry. Journal of International Maritime Safety, Environmental Affairs, and Shipping, 5, pp. 161 - 174.

[42] Spinelli, F., Mancini, S., Vitiello, L., Bilandi, R., & Carlini, M., 2022. Shipping Decarbonization: An Overview of the Different Stern Hydrodynamic Energy Saving Devices. Journal of Marine Science and Engineering.

[43] Werner, S., Papanikolaou, A., Werner, S., Fagergren, C., Dessen, L., Kuttenkeuler, J., Santén, V., & Steinbach, C., 2023. The ORCELLE Project – Towards Wind-Powered Ships for Deep Sea Cargo Transport. Day 3 Fri, September 29, 2023.

[44] Biert, L., Godjevac, M., Visser, K., & Aravind, P., 2016. A review of fuel cell systems for maritime applications. Journal of Power Sources, 327, pp. 345-364.

Annex I

Table 11: RETROFIT55 Business Model Canvas

Value Propositions	**Customer Segments**
▪ Environmental Compliance: helps maritime companies meet stringent international GHG emissions regulations. ▪ Cost Savings: reduces fuel consumption and maintenance costs through advanced technologies. ▪ Operational Efficiency: enhances route optimization, performance monitoring, and energy management. ▪ Sustainability: contributes to global sustainability efforts by reducing the carbon footprint of maritime operations.	▪ Shipowners and Operators: Including bulk carriers, container ships, tankers, and ferries. ▪ Shipyards and Retrofit Service Providers: involved in the construction, maintenance, and retrofitting of ships. ▪ Maritime Technology Providers: companies developing and supplying maritime technologies. ▪ Regulatory Bodies and Industry Associations: organizations overseeing and supporting industry standards and regulations.
	Revenue Streams
	▪ Sales of Retrofit Kits: revenue from selling decarbonization retrofit kits and equipment. ▪ Installation and Integration Services: fees for installation and integration of technologies on vessels. ▪ Subscription Services: recurring revenue from data analytics, performance monitoring, and optimization software. ▪ Maintenance and Support Contracts: ongoing revenue from maintenance, technical support, and software updates. ▪ Consulting Services: fees for consultancy related to compliance, technology selection, and implementation. ▪ Licensing and Royalties: income from licensing technology patents and proprietary solutions.
Key Activities	**Key Partners**
▪ Research and Development (R&D): continuous innovation and improvement of decarbonization technologies. ▪ Market Analysis and Customer Engagement: identifying market needs and building relationships with stakeholders. ▪ Pilot Projects and Demonstrations: implementing pilot projects to validate and showcase the technologies. ▪ Sales and Marketing: promoting solutions through targeted campaigns and industry events. ▪ Installation and Integration: providing services for seamless installation and integration on ships. ▪ Technical Support and Maintenance: offering ongoing support and maintenance services.	▪ Shipyards and Retrofit Service Providers ▪ Maritime Technology Providers ▪ Regulatory Bodies and Industry Associations ▪ Academic and Research Institutions ▪ Financial Institutions and Investors
	Key Resources
	▪ Technological Expertise: skilled engineers and researchers specializing in maritime technologies. ▪ Intellectual Property: patents and proprietary technologies developed for RETROFIT55 solutions. ▪ Financial Resources: funding from investors, grants, and revenue from early sales and pilot projects. ▪ Partnerships and Collaborations: strategic partnerships with shipyards, technology providers, and regulatory bodies. ▪ Digital Infrastructure: advanced software platforms for data analytics and performance monitoring.

Cost Structure

- R&D Expenses: Costs related to research, development, and testing of technologies.
- Production and Manufacturing Costs: Expenses for producing and manufacturing retrofit kits and equipment.
- Sales and Marketing Costs: Costs for marketing campaigns, customer acquisition, and promotional activities.
- Installation and Integration Costs: Costs incurred for providing installation and integration services.
- Technical Support and Maintenance Costs: Ongoing expenses for support and maintenance services.
- Administrative and Overhead Costs: General operational expenses, including salaries, office rent, and utilities.