

**EXPLORING CHALLENGES AND  
OPPORTUNITIES FOR GREEN SHIPBUILDING IN  
SOUTH AFRICA**

**A MARITIME ENERGY MANAGEMENT  
PERSPECTIVE**

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A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of Master of Science in Maritime Affairs

2025

## Declaration

I certify that all the material in this dissertation that is not my own work has been identified and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views and are not necessarily endorsed by the University.

(Signature): **22 September 2025**

(Date):

A handwritten signature in black ink, appearing to be 'A. Ölçer', written over the date field.

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VENI, VIDI, VICI - I CAME, I SAW, I CONQUERED!!!

## Abstract

Title of Dissertation: **Exploring Challenges & Opportunities for Green Shipbuilding in South Africa – A Maritime Energy Management Perspective**

Degree: **Master of Science**

Is South Africa capable of becoming a green shipbuilding nation? This study aims to answer this question, from a maritime energy management perspective by exploring the challenges and opportunities for green shipbuilding in South Africa. An evaluation of the current state of the ship building industry in South Africa is presented as well as a case study on Turkish shipyards that have successfully implemented green ship building practices, to determine the desired state for the South African shipbuilding industry to thrive.

A MEM perspective encompasses the implementation of principles which are aimed at aligning the maritime industry with global decarbonisation goals and URN reduction. These include energy efficiency, use of renewable energy sources, digitalization and the use of alternative fuels.

The study uses a mixed methods approach and analyses quantitative data collected from 20 survey responses and qualitative data from 18 semi-structured interviews, case studies and a literature review. Data was analysed using descriptive statistic, rank-order analysis, and thematic coding in NVivo.

The key findings indicate that the top three barriers to MEM adoption in South Africa are lack of financing (18% of survey responses), inadequate regulatory framework (18%) and lack of economies of scale (18%). Major strengths identified included abundant renewable energy sources (31% of survey responses), existing shipyard infrastructure (31%) and a strategic location along a major shipping route (27%).

The study proposes a detailed strategy which provides guidelines on the integration of MEM principles in South African shipyards, with a particular focus on URN mitigation and efficient energy use. This strategy is meant to provide guidance for South African shipbuilding stakeholders (regulatory bodies, shipyards, ship owners, etc) in the decision-making process when it comes to venturing into green shipbuilding, hence answering the initial question with a yes, South Africa is capable of becoming a green shipbuilding nation.

**KEYWORDS:** Shipbuilding, Green Shipbuilding, Regulatory Framework, Decarbonisation, Underwater Radiated Noise (URN), MEM Principles

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## List of Abbreviations

|                       |                                                                   |
|-----------------------|-------------------------------------------------------------------|
| <b>CFD</b>            | Computational Fluid Dynamics                                      |
| <b>CMTTP</b>          | Comprehensive Maritime Transport Policy                           |
| <b>CNC</b>            | Computer Numerical Control                                        |
| <b>CO<sub>2</sub></b> | Carbon Dioxide                                                    |
| <b>dB</b>             | Decibel                                                           |
| <b>DNV</b>            | Det Norske Veritas                                                |
| <b>DoT</b>            | Department of Transport                                           |
| <b>EEDI</b>           | Energy Efficiency Design Index                                    |
| <b>EIA</b>            | Environmental Impact Assessment                                   |
| <b>EMS</b>            | Environmental Management System                                   |
| <b>EMSA</b>           | European Maritime Safety Agency                                   |
| <b>ESKOM</b>          | Electricity Supply Commission                                     |
| <b>EU</b>             | European Union                                                    |
| <b>GHG</b>            | Greenhouse Gas                                                    |
| <b>GISBIR</b>         | Turkish Shipbuilders Association                                  |
| <b>HVAC</b>           | Heating, Ventilation, and Air Conditioning                        |
| <b>IDC</b>            | Industrial Development Corporation                                |
| <b>ILS</b>            | Integrated Logistics Support                                      |
| <b>IMO</b>            | International Maritime Organization                               |
| <b>IORA</b>           | Indian Ocean Rim Association                                      |
| <b>IPS</b>            | Indoor Positioning System                                         |
| <b>IRENA</b>          | International Renewable Energy Agency                             |
| <b>ISO</b>            | International Organization for Standardization                    |
| <b>LCA</b>            | Life Cycle Assessment                                             |
| <b>LED</b>            | Light Emitting Diode                                              |
| <b>LNG</b>            | Liquefied Natural Gas                                             |
| <b>MBC</b>            | Maritime Business Chamber                                         |
| <b>MEM</b>            | Maritime Energy Management                                        |
| <b>MEPC</b>           | Marine Environment Protection Committee                           |
| <b>NATMAP</b>         | National Transport Master Plan                                    |
| <b>NDA</b>            | Non-Disclosure Agreement                                          |
| <b>NDC</b>            | Nationally Determined Contributions                               |
| <b>NDP</b>            | National Development Plan                                         |
| <b>NEMA</b>           | National Environmental Management Act                             |
| <b>NGOs</b>           | Non-Governmental Organisations                                    |
| <b>NO<sub>x</sub></b> | Nitrogen Oxides                                                   |
| <b>NPCC</b>           | National Ports Consultative Committee                             |
| <b>OECD</b>           | Organisation for Economic Co-operation and Development            |
| <b>OPS</b>            | Onshore Power Supply                                              |
| <b>PDCA</b>           | Plan, Do, Check, Act                                              |
| <b>PESTLE</b>         | Political, Economic, Social, Technological, Legal, Environmental  |
| <b>PM</b>             | Particulate Matter                                                |
| <b>PPP</b>            | Public-Private Partnership                                        |
| <b>R&amp;D</b>        | Research & Development                                            |
| <b>REC</b>            | Research Ethics Committee                                         |
| <b>REIPPPP</b>        | Renewable Energy Independent Power Producer Procurement Programme |

|                       |                                                    |
|-----------------------|----------------------------------------------------|
| <b>SA</b>             | South Africa                                       |
| <b>SAIMI</b>          | South African International Maritime Institute     |
| <b>SAMSA</b>          | South African Maritime Safety Authority            |
| <b>SEEMP</b>          | Ship Energy Efficiency Management Plan             |
| <b>SHEQ</b>           | Safety, Health, Environment & Quality              |
| <b>SO<sub>x</sub></b> | Sulphur Oxides                                     |
| <b>STS</b>            | Ship-to-Ship                                       |
| <b>SWOT</b>           | Strengths, Weaknesses, Opportunities & Threats     |
| <b>TNPA</b>           | Transnet National Ports Authority                  |
| <b>TPT</b>            | Transnet Port Terminals                            |
| <b>TVET</b>           | Technical and Vocational Education and Training    |
| <b>UNCTAD</b>         | United Nations Conference on Trade and Development |
| <b>URN</b>            | Underwater Radiated Noise                          |
| <b>WMU</b>            | World Maritime University                          |

# 1. Chapter 1: Introduction

## 1.1 Background

“The shipping industry contributes 3% to the global green-house gas (GHG) emissions (well-to-wake)” and more than “80% of the world’s trade is transported through shipping” ([UNCTAD, 2021](#)). The emissions from the shipping industry contribute significantly to global warming and climate change and the International Maritime Organisation (IMO), has set targets aimed at the reduction of these emissions. The IMO now targets net-zero greenhouse gas emissions from international shipping by or around 2050, with interim goals of at least 20% reduction by 2030 and 70% by 2040, aligning more closely with the Paris Agreement ([IMO, 2025](#)).

The measurement of GHG emissions and underwater radiated noise (URN) impacts, should not be restricted to the ship's operating phase. There are emissions throughout the ship's life cycle that also significantly contribute to the total emission and it is therefore important that the shipbuilding, ship maintenance and repair as well as the ship disposal or recycling phases are also taken into consideration in decarbonisation efforts ([EMSA, 2021](#)).

Green shipbuilding involves the use of environmentally friendly materials, minimization of waste, emissions reduction and utilization of energy efficient technologies. Maritime energy management provides a systems-based approach to improving energy efficiency across the maritime value chain, including design, construction, operation and end-of-life management ([Scipioni et al., 2023](#)). Exploring the challenges and opportunities for green shipbuilding from a Maritime Energy Management (MEM) perspective allows for the development of energy efficient and sustainable solutions which reduce emissions and operational costs throughout a ship’s life cycle.

South Africa is strategically located along a major trading route, the Cape of Good Hope and has been in the shipbuilding and repair industry for a significant number of years (TNPA, 2022). The country's shipbuilding industry has declined due to various factors including outdated infrastructure, lack of financing for upgrades and no economies of scale. Initiatives to upgrade the shipbuilding industry in South Africa such as Operation Phakisa, which is a government programme aimed at refurbishing and upgrading existing ship repair facilities including dry docks, slip ways, repair quays and boat lift facilities (TNPA, 2014), are currently in progress. This shows a vested interest in the shipbuilding and repair industry which motivates further research and development in the sector.

## 1.2. Problem Statement

The global maritime industry is moving towards not only the use of green ships, but also the implementation of green shipbuilding practices and mitigation of URN, in an attempt to comply with the IMO's decarbonisation goals and reduce the environmental impact of the shipping industry (OECD, 2023). South Africa has fallen behind not because of a lack of commitment and intention, but due to various challenges which include inadequate regulatory frameworks, high cost of green technologies, limited industry awareness of energy efficient measures and a lack of resources (Stopford, 2008). This gap in green shipbuilding adoption and URN mitigation highlights the need for an integrative approach grounded in Maritime Energy Management principles. If these challenges are not addressed, South Africa risks losing the economic, environmental and social benefits in the developing green maritime economy.

## 1.3. Aim and Objectives

The aim of this study is to draw attention to South Africa's green shipbuilding and URN mitigation challenges and opportunities, from the standpoint of maritime energy management.

The objectives of the study are to:

- 1.3.1. Identify the challenges for implementation of green shipbuilding in South Africa.

- 1.3.2. Conduct an analysis of the strengths, weaknesses, opportunities and threats (SWOT) for green shipbuilding and URN mitigation in South Africa by analysing Türkiye's strategies and extracting transferable insights.
- 1.3.3. Assess the environmental impacts of traditional shipbuilding practices and URN in South Africa, whilst exploring the integration of MEM principles to mitigate them.
- 1.3.4. Develop a strategy for shipbuilders, ship owners and regulatory bodies to implement in order to promote green ship building and URN mitigation in South Africa.

#### 1.4. Research Questions

The research aims to provide an answer to: "what are the main challenges and opportunities for green shipbuilding in South Africa?" by answering the following questions:

- 1.4.1. What are the main barriers to the implementation of green shipbuilding practices in South Africa?
- 1.4.2. What opportunities exist for South Africa in the green shipbuilding industry?
- 1.4.3. What are the environmental impacts of URN and traditional ship building practices in South Africa and how can MEM principles contribute to mitigating these impacts?
- 1.4.4. What strategies can shipbuilders, ship owners and regulatory bodies implement in order to promote green shipbuilding and URN reduction methods in South Africa and what lessons can be learned from Türkiye in this regard?

#### 1.5. Methodology

This study used a mixed-methods approach to give a more thorough understanding of the subject (Creswell, 2009; Plano Clark et al., 2018), through a systematic literature review which focuses on shipyard energy efficiency, alternative fuels, and MEM principles, including global decarbonisation frameworks, URN sources, impacts, and mitigation technologies and a case study of green shipbuilding and URN mitigation in the emerging economy of Türkiye.

Primary data collection included responses from semi-structured interviews with various stakeholders in the shipbuilding industry such as shipbuilders, government officials, class societies and academia, a survey which targeted marine engineers, naval architects, policy makers and energy/technology providers and a case study using selected shipyards from Türkiye which have implemented green shipbuilding practices.

Secondary data includes a comprehensive literature review and an evaluation of participating shipyards' latest policy documents.

The findings lead to the development of PESTLE and SWOT analyses which assess broad, internal and external factors (Namugenyi et al., 2017) that affect the implementation of green shipbuilding and URN mitigation in South Africa. Thematic coding was used to analyse qualitative data and comparative benchmarking was used to compare South Africa's shipbuilding practices with those of Türkiye.

## 1.6. Key Assumptions and Limitations

### **Key Assumptions**

#### Stakeholder collaboration

This study requires inputs from all stakeholders in the South African shipbuilding industry and it was assumed that they would be willing to collaborate and share their insights.

#### Technology feasibility

It was assumed that the green shipbuilding and URN reduction technologies discovered through the literature review and case studies, would be feasible for implementation in the South African context.

### **Limitations**

#### Time limitations

Data collection in South Africa was limited to fourteen days and thirty days in Türkiye. These short periods affected the depth of data collected and impacted the ability to engage with more participants.

### Limited number of participants

The survey was completed by twenty (20) participants and eighteen (18) people were interviewed. This small number of participants affected the validity of the results as the sample size is not representative of the entire South African shipbuilding industry and this could skew the results disproportionately. A bigger sample size would have provided more diverse insights.

### Geographic limitations

The research focused on only South African and Turkish shipyards. Including more countries would have expanded the scope and allowed for a comprehensive understanding of green shipbuilding practices and URN mitigation methods from different shipyards.

### 1.7. Research Scope

This research only focuses on the South African shipbuilding industry with guidance from established shipbuilding companies in Türkiye, which are already using green shipbuilding practices. The shipbuilding value chain is not explored in full detail, this research will focus on ship designs, the use of renewable energy and URN reduction methods. The research also uses a case study to ascertain how South Africa compares to the Turkish shipbuilding industry. The participants engaged are shipbuilders & engineering professionals, ship owners, ship building regulators, financiers, ship operators, researchers and trade unions.

### 1.8. Ethical Considerations

The study was approved by the World Maritime University (WMU) Research Ethics Committee (REC). All the participants were given the opportunity to read the information sheet about the study and choose whether to participate through a survey or a semi-structured interview. The data collected was stored securely through encryption and participants' anonymity was guaranteed.

### 1.9. Dissertation Structure

The dissertation is presented over six chapters as outlined in [Figure 1](#).

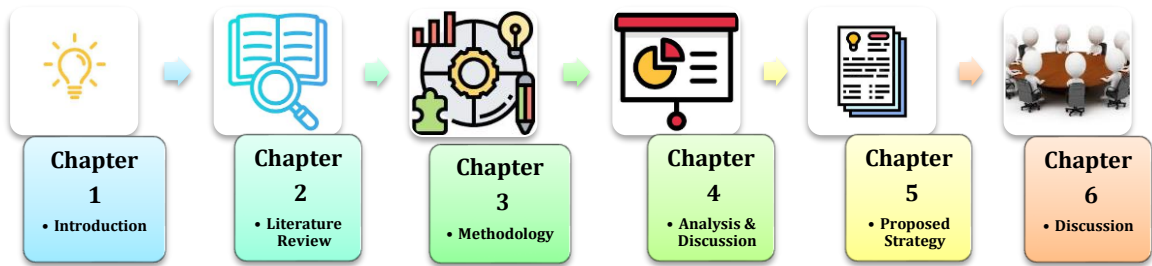


Figure 1: Dissertation Structure

(Created by the author)

*Chapter one* introduces the study; it includes the background and problem statement to set the tone for the rationale behind exploring the topic. The aim and objectives of the study are highlighted along with the research questions. The research methodology, key assumptions and limitations, research scope, ethical considerations and finally, the dissertation structure are all covered.

*Chapter two* is a review of the existing literature on the current state of shipbuilding and URN mitigation in South Africa. Green shipbuilding, regulatory frameworks, maritime energy management principles and challenges for green shipbuilding in SA are explored in detail.

*Chapter three* details the research methodology, highlighting the chosen research design, data collection mechanisms and the analysis techniques employed.

*Chapter four* presents the detailed data analysis from the interviews, surveys, literature review and case studies. The data is divided into themes and coded.

*Chapter five* sums up the findings in relation to the literature and collected data, leading to the development of a detailed strategy for South African shipbuilding stakeholders to follow in order to successfully venture into green shipbuilding.

*Chapter six* provides the final insights of the study, consolidating the results and their implications thereof. Recommendations for future studies are made, guaranteeing that the study continues to serve as a launching pad for further research in the exploration of challenges and opportunities for green shipbuilding in South Africa from a maritime energy management perspective.

## 2. Chapter 2: Literature Review

### 2.1. Introduction

Shipbuilding is an ancient trade that has evolved over the years. Technological advancements, environmental issues and regulations governing the shipping industry, have encouraged naval architects and ship design engineers to become innovative in improving shipbuilding processes (Stopford, 2008; Rizwan et al., 2021; IMO, 2020). Traditional shipbuilding practices have been adjusted to reduce environmental impacts whilst ensuring safety, increasing productivity and efficiency as well as increasing profits (Papanikolaou et al. 2024). This literature review highlights key factors in the evolution of shipbuilding from a MEM perspective and how South Africa can use MEM principles to venture into green shipbuilding. This chapter is structured to achieve the following objectives:

1. Define and compare traditional and green shipbuilding practices.
2. Explain MEM principles and their relevance to energy efficiency, emissions reduction and URN mitigation.
3. Detail the impacts of URN on marine ecosystems and discuss mitigation strategies.
4. Benchmark Türkiye's green shipbuilding initiatives.
5. Analyse the South African shipbuilding industry contextually.
6. Identify gaps addressed by the study.

URN, an important environmental issue, is also addressed in the study as it has recently become a growing concern in the maritime industry. The environmental impacts of URN in both shipbuilding (shipyard operations) and ship operation are notable and should be considered alongside major issues such as GHG emissions (Duarte et al., 2021; Frisk, 2012). This chapter highlights the sources of URN in shipyards, the environmental impact and the requirement for mitigation strategies.

Additionally, MEM principles are reviewed to explore how they can contribute to decarbonising the South African shipbuilding industry.

In order to develop an implementation strategy for green shipbuilding in South Africa, it is important to understand the country's shipbuilding capabilities, including the vessel types, technologies used, customers and infrastructure available, these are all explored in this review. Finally, South Africa's complex regulatory framework which includes the country's national laws, international conventions and enforcement of these laws is scrutinized.

The literature review aims to demonstrate how the topics discussed provide the foundation for the framework developed to guide South Africa in venturing into green shipbuilding and concludes with identifying research gaps addressed by the study and more for further research.

## 2.2. Traditional Shipbuilding Practices

Traditional shipbuilding is a phased process of constructing ships through manual labour, using wood or steel as the main material. It involves a step-by-step assembly procedure which includes design, manufacturing, construction, trials and launching, with limited use of advanced technologies (Stopford, 2008). Most of the vessels in the nineteenth century were mainly constructed from wood and their propulsion system was wind or manual rowing. There was no consideration of issues such as emissions, ergonomics, energy efficiency or noise. The main focus was on getting the vessel to sea. (Rizwan et al., 2021; Papanikolaou et al., 2024; Harish & Sunil 2015)

Traditional shipbuilding methods are labour-intensive, use limited automation, have long construction periods and a disregard for environmental impact (Rizwan et al., 2021). Over the years, shipbuilding methods have improved to ensure that the vessels are stronger, can withstand harsh environmental conditions and go on longer voyages without the need to dock (Bertram, 2011). The traditional shipbuilding process is explained in detail and summarized in Figure 2.

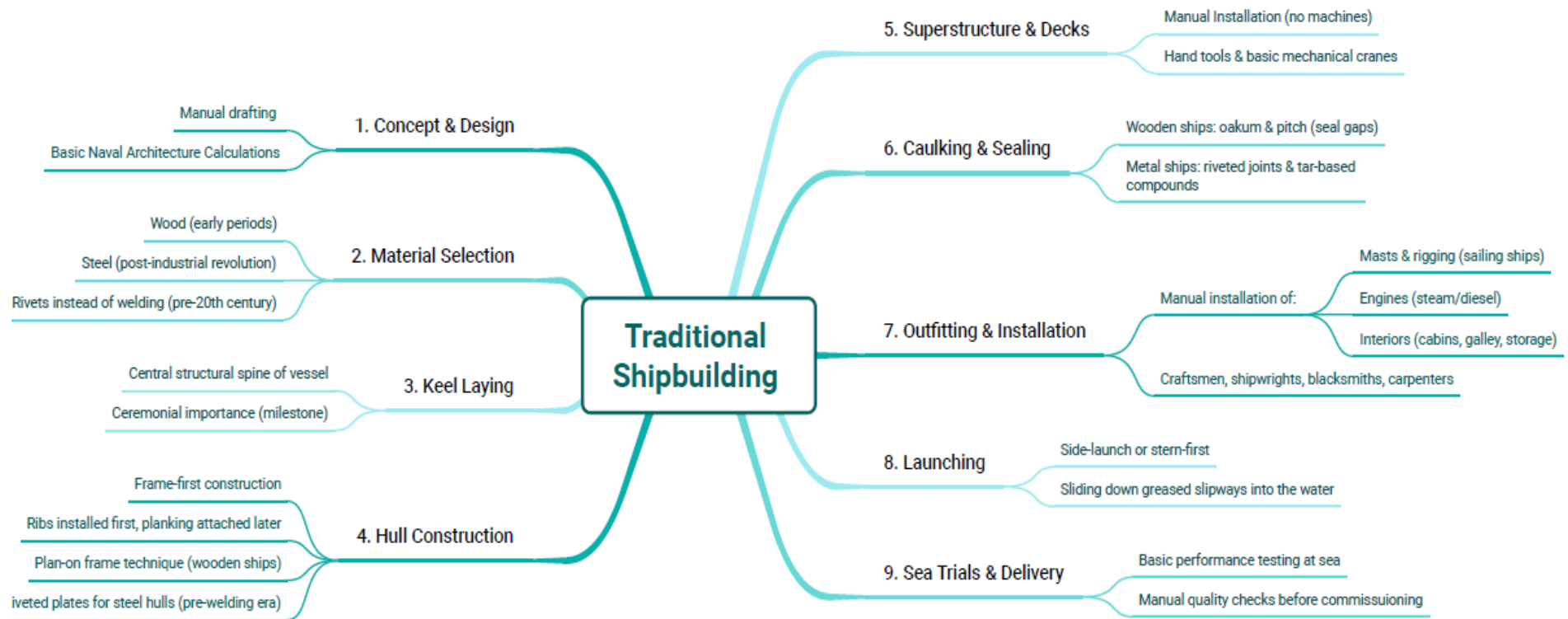


Figure 2: Traditional Shipbuilding Summary  
(Created by the author)

### *2.2.1. Concept & Design Phase*

In the concept and design phase, a plan detailing the requirements of the vessel is compiled. Manual drafting of the design and basic naval architecture calculations are the main tasks ([Papanikolaou et al., 2024](#)). The designs had to be structurally sound and have a large cargo carrying capacity, whilst minimizing any costs associated with building the vessels. The main focus was on the vessel's performance and compliance with regulations with limited consideration of life cycle emissions and underwater noise ([Papanikolaou et al., 2024](#)).

### *2.2.2. Material Selection*

The vessel's material of construction is one of the key factors considered during the early stages of the shipbuilding process. Shipyards mostly use carbon steel due to its properties which allow it to withstand harsh marine environments. In addition to steel, other materials such as aluminium, petroleum-based paints and insulation materials were used ([Bertram, 2011](#)). The structure was held together by rivets because welding only came into play in the 20<sup>th</sup> century. The materials selected increase embedded energy consumption and emissions throughout the shipbuilding supply chain ([Harish & Sunil, 2015](#)).

### *2.2.3. Keel Laying*

The keel is the ship's back bone, the central structural spine and during the keel laying stage, it is placed onto position on the building blocks. This is a formal ceremonial milestone in the shipbuilding industry and is still being done in modern shipbuilding. Keel laying is crucial in establishing structural alignment of the ship ([Stopford, 2008](#)).

### *2.2.4. Hull Construction*

The hull is the main body of a ship, it provides structural strength and buoyancy ([Bertram, 2011](#)). Hull construction was traditionally done using wooden planks or steel plates and it involves the assembly of the bottom shell, internal frames and sides to be joined to the keel ([Stopford, 2008](#)).

#### *2.2.5. Superstructure & Decks*

The superstructure is the external part of the ship, built above the main deck and the decks are the floors of the vessel, dividing it into levels from the bottom-up. The design of the superstructure and decks affect the stability and aerodynamics of the ship and are therefore critical (Rawson et al., 2001). Their installation was traditionally done manually, using hand tools and basic mechanical cranes.

#### *2.2.6. Caulking & Sealing*

Caulking and sealing are traditional methods used to make ship joints watertight. Wooden ships used oakum or pitch and metal ships used riveted joints and tar-based compounds, these ensured that the vessel remains seaworthy for long periods (Stopford, 2008; Rizwan et al., 2021; Bertram, 2011).

#### *2.2.7. Outfitting & Installation*

This stage involves the installation of systems such as machinery (engines), Heating Ventilation and Air Conditioning (HVAC), electrical and navigational equipment which enable the ship to function as a complete unit (Stopford, 2008). On sailing ships, masts and sails were installed and as times changed and technology developed, steam and diesel engines were used. The equipment was selected based on performance and cost, with little to no consideration of sustainability.

#### *2.2.8. Launching*

The launching process was performed by sliding the vessel down a greased slipway, either on its side or stern-first (Stopford, 2008; Bertram, 2011).

#### *2.2.9. Sea trials & Delivery*

During sea trials, basic performance tests are conducted to assess the vessel's navigational performance, propulsion and operational systems. This stage is the final validation of the vessel's design and quality before it is delivered (Bertram, 2011).

In contrast, green shipbuilding uses advanced technologies and materials as discussed in the following section.

### 2.3. Understanding Green Shipbuilding Practices

Green shipbuilding is the process of designing, constructing and assembling ships using environmentally friendly and energy-efficient methods (Rahman & Karim, 2015). There are various solutions in the shipping industry aimed at reducing emission and pollution. These could either be technical (ship resistance, propulsion efficiency), operational (slow steaming, cold ironing, voyage optimization), use of alternative fuels (biofuels, e-fuels) or renewable energy (solar, wind, fuel cells). Emission reduction could also be achieved through “better design, decrease in design speed or increase in capacity, or through a combination of any of the options” (Rehmatulla et al., 2017), finding the balance is an important part of the iterative process in ship building decision-making. Figure 3 depicts a ship being built in a dry dock with cranes and various other shipbuilding technologies in place, a typical setup of a modern-day shipyard.



Figure 3: Modern Shipbuilding Illustration

(Source: Airlines & Aviation, 2023)

The concepts of “green” and “clean” ship building must not be confused. While “green ship building uses environmentally friendly methods, clean ship building is when any production and supporting processes in manufacturing a ship have zero environmental impacts”. (Vakili, 2022). “Both the green and clean aspects of the ship or the ship building process, contribute to sustainability in shipping, however, green ships address long term decarbonisation and energy efficiency, whereas clean ships

focus on immediate pollution prevention and environmental compliance” (Vakili, 2022). This study focuses on the green ship and shipbuilding process, taking the life cycle phases of the ship i.e. “ship design, construction, operation and scrapping” as depicted in Figure 4, into consideration. (Mondello et al., 2023).

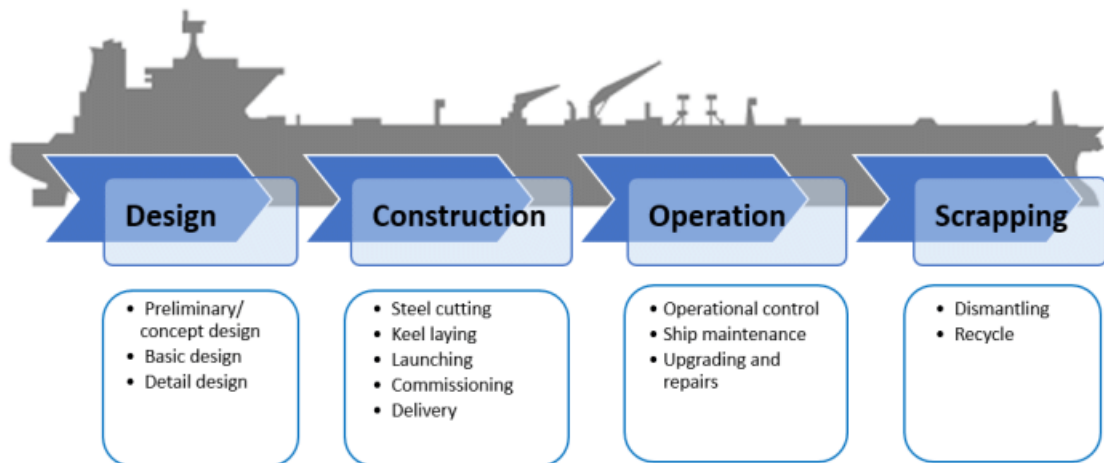


Figure 4: Typical ship life cycle and key processes

(Source: Ang et al., 2018)

Green shipbuilding methods incorporate sustainability from vessel design to delivery, using digital tools and automation, minimizing waste during construction, ensuring energy efficiency and using renewable energy sources (Vakili et al., 2023). The green shipbuilding process is explained in detail below and summarized in Figure 5.

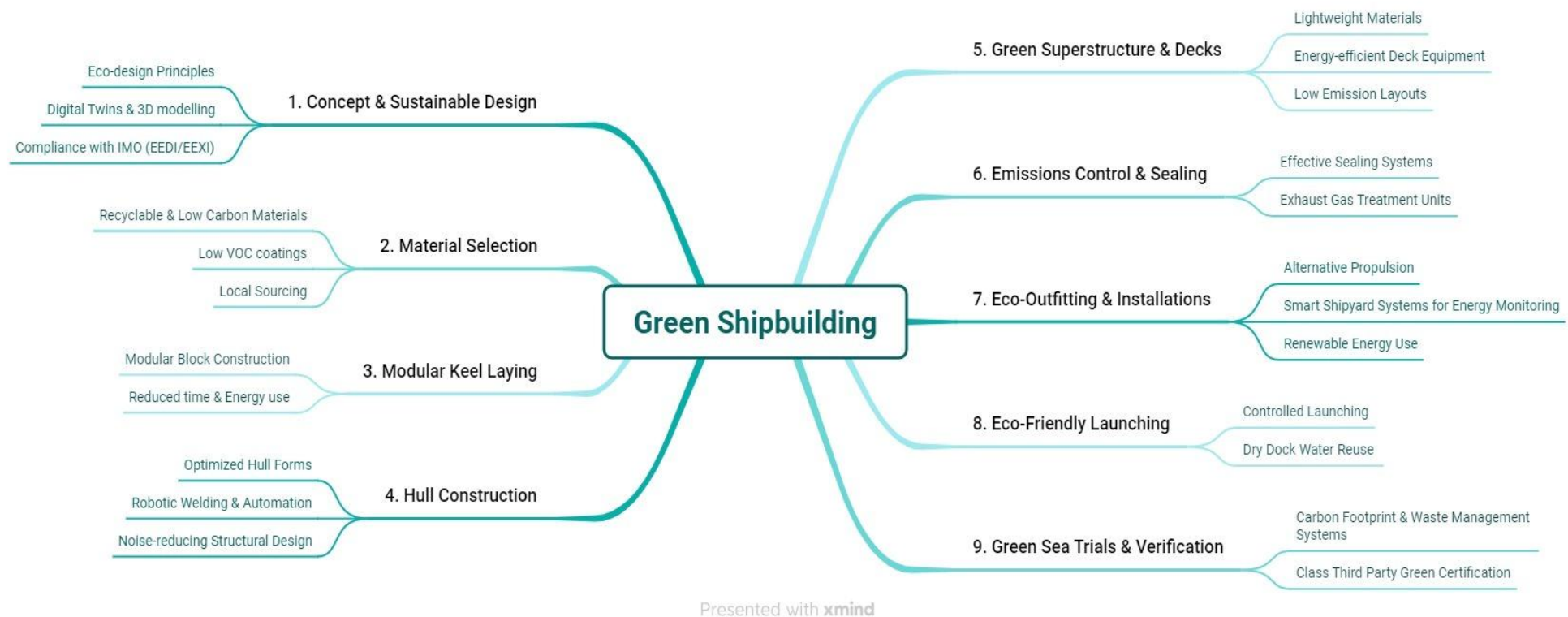


Figure 5: Summary of Green Shipbuilding Phases.  
(Created by the author)

### *2.3.1 Conceptual and Sustainable Design*

Green shipbuilding encompasses the use of digital twins which are virtual models of actual ships. Digital twins allow for the simulation of performance parameters including fuel consumption, emissions and hydrodynamic efficiency during the design phase. These simulations enable design engineers to run numerous iterations for optimization, ensuring reduced environmental impact and compliance with regulations from the onset ([Kunkera et al., 2025](#)). Integrating digital twinning with IMO standards such as the Energy Efficiency Design Index (EEDI), guarantees reduction in emissions per transport work ([IMO, 2020](#)).

### *2.3.2 Material Selection*

In green shipbuilding, the use of recyclable, low-carbon and locally sourced materials is essential ([Cucinotta et al., 2024](#); [Suer et al., 2022](#)). Instead of using heavy steel, high-strength low-alloy steels or aluminium composites are used as replacements, to reduce the total amount of energy consumed to manufacture the vessel ([Lowde et al., 2022](#)). Additionally, low-VOC paints are used to reduce emissions during construction and maintenance ([Xia et al., 2023](#); [Carrier et al., 2023](#)). Supply chain management plays a key role in the material procurement process, by giving preference to vendors with eco-labels and environmental certifications such as ISO 14001 ([Caniëls et al., 2016](#)).

### *2.3.3 Modular Keel Laying*

Green shipyards use modular block construction techniques which allow for parallel outfitting and prefabrication of components. This reduces waste and energy consumption in contrast to linear construction which proceeds in sequence ([Hořínková, 2021](#)). The use of robotic welding and Computer Numerical Control (CNC) cutting machines assist in this method, improving safety and quality with the added benefit of human error reduction ([Masood et al., 2024](#)).

#### *2.3.4 Hull Construction*

In green shipbuilding, the hull is redesigned for maximum fuel efficiency, low drag, strength and stability (Zha et al., 2021). Hull forms are improved by digital twin validation and Computational Fluid Dynamics (CFD) modelling, to reduce resistance and lower propulsion energy requirements (Serani et al., 2024).

#### *2.3.5. Green Superstructure and Decks*

In modern green shipbuilding, superstructures and decks are designed to reduce aerodynamic resistance, improve stability, and maximize energy efficiency. Lightweight composite materials and high-strength, low-alloy steels are increasingly used to reduce vessel weight and fuel consumption (Lowde et al., 2022). Superstructures are also integrated with renewable energy features such as solar panels and wind-assist devices. Advanced insulation materials reduce HVAC loads, thereby improving onboard energy efficiency (Cucinotta et al., 2024).

#### *2.3.6. Emissions Control and Sealing*

Instead of tar-based compounds or riveted joints, green shipyards adopt advanced sealing techniques that use eco-friendly adhesives and corrosion-resistant materials (Carrier et al., 2023). Emissions during construction are minimized through dust collection systems, low-VOC coatings, and wastewater capture. During the build, sealing is also extended to systems such as ballast water treatment, greywater management, and vapor recovery systems to ensure MARPOL Annex VI compliance (IMO, 2020).

#### *2.3.7. Eco-Outfitting and Installations*

Green shipbuilding outfitting includes the installation of energy-efficient equipment such as Waste Heat Recovery (WHR) units, smart HVAC systems; and hybrid propulsion (LNG-battery combinations) (Jung et al., 2023; Inal et al., 2022). In order to assist operators in modifying procedures accordingly, advanced monitoring systems track energy consumption, emissions and waste management in real-time. During construction, sealed fuel compartments and ballast water treatment are incorporated to guarantee environmental protection and regulatory compliance.

#### *2.3.8. Environmentally Friendly Launching*

Green shipyards reduce environmental impact through the use of closed-loop water recycling, which captures and reuses water within the shipyard (Vakili et al., 2023). This involves water treatment to remove pollutants prior to reusing the water, reducing reliance on fresh water and preventing contamination (Mentes et al., 2025). Another green shipyard method is the use of controlled launching platforms which minimize the impact of vessel launching which disturbs the seabed and releases pollutants. These involve using engineered systems to manage water flow and reduce disturbance (Byrnes & Dunn, 2020). These practices align with ISO 14001 standards, showing commitment to environmental sustainability.

#### *2.3.9. Green Sea Trials and Verification*

In green shipbuilding, sea trials include testing emissions under real operational conditions. The measuring tools not only detect NO<sub>x</sub>, SO<sub>x</sub>, CO<sub>2</sub> and particulate matter, but speed and manoeuvrability as well. Classification societies such as Det Norske Veritas (DNV) and Lloyd's register, offer certification for vessels which comply with GHG intensity and overall sustainability performance standards. (IMO, 2020)

#### *Renewable Energy Integration in Shipyards*

In addition to the above-mentioned processes, green shipbuilding involves the use of renewable energy sources. (Vakili et al., 2023). This can be to supplement power already provided through the national grid or they shipyard can rely entirely on solar, wind, tidal or wave power sources. Some shipyards go the extra mile by using LED lighting systems and sensors to detect when power is not needed (Inal et al., 2022). The use of energy storage devices (batteries) enables self-sufficient operation even in developing country concepts.

In the European Union (EU), South Korea and Japan, leading shipbuilding nations, the use of technological advances such as air lubrication, advanced hull coatings and hybrid-electric propulsion, is gaining popularity (UNCTAD, 2023). These technologies are supported by regulatory financial incentives, R&D funding, and public procurement policies. In Europe, the European Green Deal and Fit-for-55 package

incentivise the adoption of green technologies across maritime infrastructure, while in Asia, government–industry coordination ensures rapid uptake of new propulsion systems (OECD, 2021).

## 2.4. Comparing Traditional and Green Shipbuilding Practices

Table 1 provides a comparative overview of traditional and green shipbuilding practices to consolidate findings from previous research. Key publications on ship design, construction techniques, and sustainability transitions (e.g., Stopford, 2008; Rizwan et al., 2021; Vakili, 2022; Cucinotta et al., 2024; Suer et al., 2022) are cited in the synthesis. The table illustrates how cost and functionality have traditionally been given top priority in traditional shipbuilding, while sustainability, digitization, and lifecycle efficiency are all integrated into contemporary green shipbuilding.

Table 1: Comparison of traditional and green shipbuilding practices across key phases of the shipbuilding process

| Stage                  | Traditional Shipbuilding                                                                                    | Green Shipbuilding                                                                                           |
|------------------------|-------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|
| Concept & Design       | Manual drafting, basic naval architecture, focus on performance and cost; no emissions/noise consideration. | Digital twins, CFD, IMO EEDI compliance; optimization for fuel efficiency, emissions, and lifecycle impact.  |
| Materials              | Wood (early), later carbon steel, rivets, tar-based compounds; high embedded energy and emissions.          | Lightweight composites, HSLA steel, aluminium alloys, recyclable and low-carbon materials, low-VOC coatings. |
| Keel Laying            | Manual alignment on building blocks; sequential construction.                                               | Modular block construction, robotic welding, CNC cutting; parallel prefabrication reduces waste.             |
| Hull Construction      | Wooden planks or steel plates; hand tools and simple cranes.                                                | CFD-optimized hull forms, hydrodynamic validation with digital twins; reduced drag and fuel consumption.     |
| Superstructure & Decks | Manual installation with basic cranes; heavy structures.                                                    | Lightweight composites, solar/wind integration, advanced insulation to cut HVAC loads.                       |

| Stage                     | Traditional Shipbuilding                                                     | Green Shipbuilding                                                                                                                   |
|---------------------------|------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|
| Sealing                   | Oakum, pitch, tar, riveted joints.                                           | Eco-friendly adhesives, corrosion-resistant seals, ballast water treatment, vapor recovery systems.                                  |
| Outfitting & Installation | Engines, HVAC, navigation; installed post-launch, focus on cost/performance. | Energy-efficient systems, WHR, smart HVAC, hybrid propulsion, real-time monitoring for emissions/waste.                              |
| Launching                 | Greased slipway, uncontrolled seabed disturbance.                            | Controlled launching platforms, closed-loop water recycling, ISO 14001 compliance.                                                   |
| Sea Trials                | Basic navigational and propulsion checks.                                    | Full emissions verification (NO <sub>x</sub> , SO <sub>x</sub> , CO <sub>2</sub> , PM), sustainability certification (DNV, Lloyd's). |
| Energy Use in Shipyard    | Fossil fuels, manual labour, inefficient processes.                          | Integration of renewables (solar, wind, tidal), LED lighting, energy storage, smart grids.                                           |

*Adapted from Stopford (2008), Rizwan et al. (2021), Vakili (2022), Cucinotta et al. (2024), Suer et al. (2022), Lowde et al. (2022).*

The difference between the two methods is noticeable at every phase of shipbuilding, from conceptual design to sea trials, as [Table 1](#) illustrates. While green shipbuilding places an emphasis on modularity, renewable integration, and regulatory compliance, traditional methods continue to be labour-intensive, carbon-intensive, and environmentally destructive. The South African shipbuilding sector, which still mostly displays traditional traits, is placed in context by this comparison.

## 2.5. URN & Marine Ecosystems

### *Understanding URN*

URN is the sound emitted into the marine environment from ships and shipyard operations. This includes construction equipment, engine vibrations, hull work, and testing procedures ([Nolet, 2017](#)).

The emerging requirement to manage URN is highlighted by various stakeholders, having noticed a significant decline in species such as the African penguin and

commercial fish, which can be attributed to an increase in shipping traffic on South African waters ([Pichegru et al., 2022](#); [Joubert, 2021](#)).

URN has attracted more interest recently and research is being conducted to measure its effect on marine ecosystems, globally. South Africa is also playing a major role as there are empirical soundscape and ship-noise studies (e.g., Algoa Bay / St Francis Bay soundscape work), and research linking vessel noise to impacts on wildlife (African penguins) ([Koper & Plön, 2012](#)).

### *The environmental impact of URN*

Shipping is now the leading contributor to ocean noise pollution, and URN is a growing concern for marine life. Chronic exposure to elevated URN levels has been shown to interfere with the communication, navigation, and feeding of marine fauna, particularly cetaceans ([Leaper, 2019](#)).

Global analyses show shipping noise has risen by roughly 3 dB (decibel) per decade on average ([Frisk, 2012](#)), and this trend is strongly linked to negative impacts on marine ecosystems. In shipyards, construction activities (e.g. pile driving, metal cutting, hydraulic hammers) can transmit noise into the water, although this is less documented. The cumulative effect is that URN can mask communication, induce stress or hearing damage in fish and marine mammals, and cause animals to abandon important habitat areas. ([Erbe & Thomas, 2022](#)).

### *Sources of URN in shipyards*

Key URN contributors within shipyard contexts, include high-powered industrial machinery, metal fabrication processes, blast cleaning, onboard engine testing, and hydraulic systems. Construction and outfitting stages, particularly welding and heavy equipment use near dockside areas, expose marine habitats to elevated acoustic levels.

The main sources of URN in shipyards may be classified into three major activities: construction, machinery testing and commissioning; and traffic from shipyard and support vessels. The sources are explained below and summarised on [Figure 6](#).

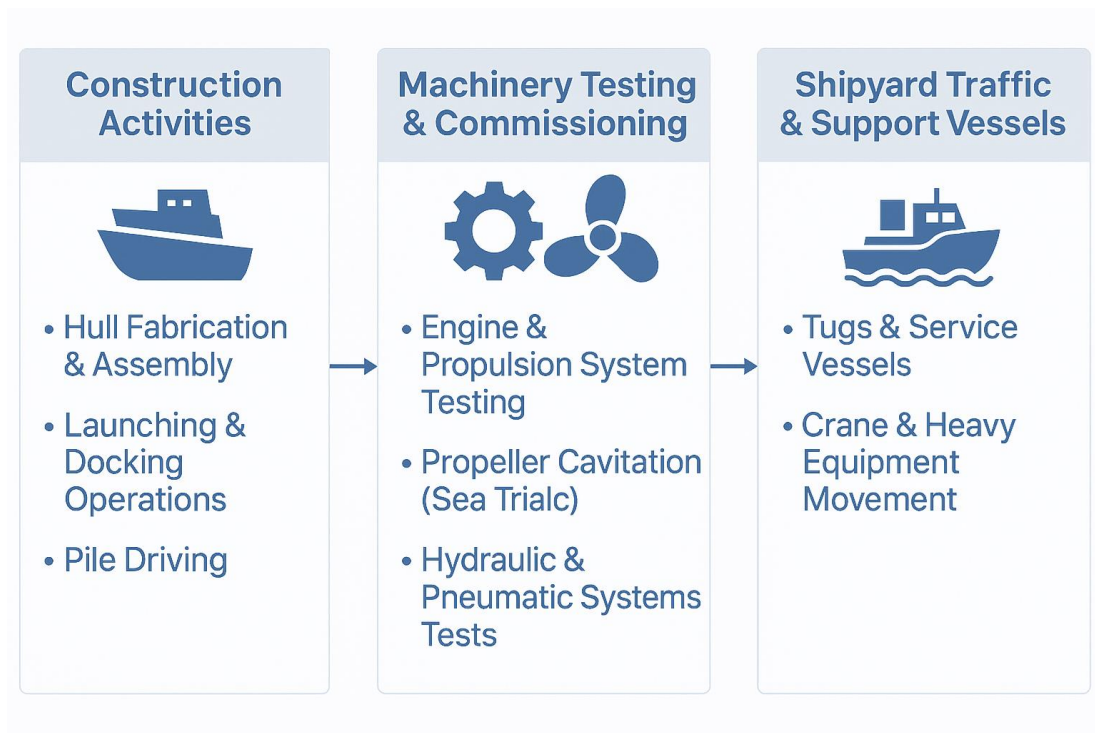


Figure 6: Sources of URN in shipyards  
(Created by the author)

#### Construction activities (Hull fabrication & assembly, launching & docking, pile driving)

Shipyard construction transmits energy to water through impulsive (pile driving, impact hammering) and continuous (welding, heavy metal cutting, grinding) sources. Impulsive sources (pile driving) create high-amplitude broadband pulses that propagate long distances and can cause physical injury or behavioural disturbance in fishes and marine mammals (Popper & Hastings, 2009). Even non-impulsive activity (heavy fabrication, launching) couples vibrations into water via the pier, piling and hull structures, increasing local ambient noise (Duarte et al., 2021).

#### Ecological and operational impacts

Impulsive pile driving has been linked to temporary or permanent threshold shift (hearing loss) in fishes and marine mammals and to behavioural displacement of animals over hundreds of metres to kilometres depending on pile size and substrate (Duarte et al., 2021; Leunissen & Dawson, 2018). Chronic elevated background noise

from fabrication/launching can mask communication and navigation ([Duarte et al., 2021](#)).

#### Mitigation & MEM co-benefits

For pile driving, bubble-curtains and other air-bubble barriers are an effective, widely used mitigation: they reduce received sound levels substantially (often tens of dB under optimized conditions) and are the best practicable mitigation for impact piling ([Nehls et al., 2016](#); [Gerlach et al., 2024](#)). Modelling and field studies support multi-line bubble curtains and optimized air flux for best attenuation ([Beelen et al., 2025](#); [Zhu et al., 2023](#)).

Many noise mitigation steps also save energy or lower indirect emissions: e.g. reducing idle time of heavy machinery, consolidating tasks to reduce crane/launch cycles and using electric or hybrid shore-powered equipment reduce fuel use and mechanical vibration ([Acciaro et al., 2014](#)). Implementing an energy audit of construction workflows is a MEM measure that often shows both GHG and URN reductions.

#### Machinery testing & commissioning

Engine testing and commissioning create continuous low-frequency sound (machinery) and propeller cavitation during trials produces comparatively high broadband noise dominated by cavitation collapse events ([Harding & Cousins, 2022](#)). Cavitation noise usually increases during off-design conditions (high pitch/low submergence) and is highly dependent on propeller design, loading and hull wake ([Lidtke et al., 2022](#); [Lafeber et al., 2022](#)).

#### Ecological and operational impacts

Cavitation and machinery noise can mask biological signals and induce stress responses in fauna; during sea trials nearshore these effects are concentrated and can be acute if tests use high revs for long periods ([Duarte et al., 2021](#)). For operators, cavitation can also indicate inefficiency, higher fuel use and reduced propulsion efficiency, therefore noise is both an environmental and operational performance signal.

### Mitigation & MEM co-benefits

**Design and operational controls:** optimized propeller design (blade geometry, skew, boss cap fins), ducted propulsors and wake-equalizing devices reduce cavitation and increase propulsive efficiency (thus lowering fuel use and URN). Propeller treatments that suppress cavitation also reduce fuel consumption per transport work (Korkut & Atlar, 2012).

**Prairie/Masker and air-injection approaches** (air injection around propeller or hull bubble layers) show promise to reduce cavitation noise in trials and naval applications (up to several dB in favourable bands), but cost/maintenance trade-offs must be considered (Kendrick, 2019).

**Testing protocols:** perform high-power engine/propeller tests offshore or in deep water where possible, limit full-power runs in sensitive nearshore areas, use shore power for auxiliary systems during dock trials, and schedule sea trials outside biologically sensitive periods (Duarte et al., 2021; Ge, 2021). These measures can be codified in SEEMP and shipyard commissioning checklists (Acciaro et al., 2014).

### Shipyard traffic & support vessels

Support vessels (tugs, workboats) produce widespread, often continuous low-frequency noise that contributes to the ambient soundscape; small craft numbers are often high in harbours, and although individual sources are small, they are numerous and persistent (Andersson & Larsson, 2023). On-site movement of heavy cranes and handling equipment produces intermittent impulsive vibrations transmitted to the water column.

### Ecological and operational impacts

Chronic noise from harbour vessels alters acoustic habitat, potentially causing reduced communication ranges for cetaceans and fishes and altering their spatial use patterns (Duarte et al., 2021). Operationally, high tug activity increases fuel use and emissions; inefficient tug operations can be both noisy and carbon-intensive.

### Mitigation & MEM co-benefits

**Fleet electrification / hybridization** of tugs and harbour craft is an effective dual-benefit measure: it markedly reduces low-frequency engine noise, PM/NO<sub>x</sub> and CO<sub>2</sub> and often lowers operating costs in the long run (Acciaro et al., 2014).

**Operational best practice:** optimized scheduling to reduce unnecessary harbour movements, slow-steaming in confined waters, and shore-power for idling vessels lower both noise and fuel consumption (Lathwal et al., 2021).

On the yard side, vibration isolation for cranes and floating work platforms, floating floors in workshops and shipboard resilient mounting for generators reduce structure-borne noise transmission into water (Kirill et al., 2018).

South Africa has shipyard and repair facilities all along its coastline as illustrated on Figure 7.

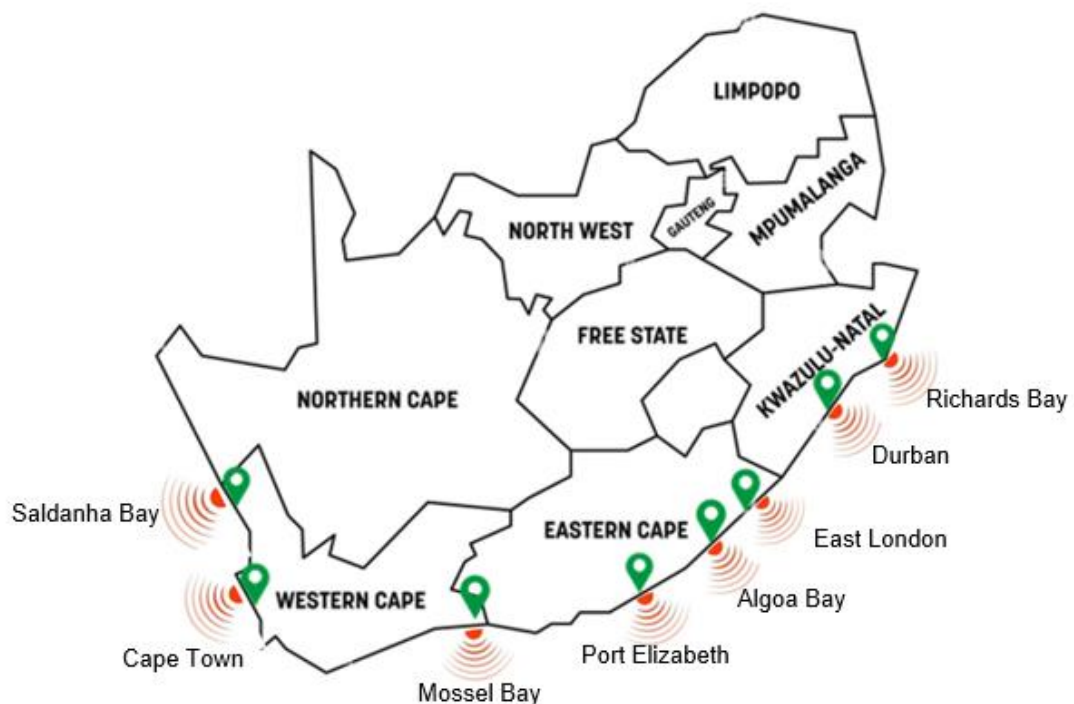


Figure 7: Shipyard Locations and URN Impact  
(Created by the author)

The locations, although strategic, raise URN concerns, discussed in detail below and the locations with the most impact are summarised on [Table 2](#).

Table 2: Summary of URN issue highlights by location

| Location     | Shipyards & Ports                  | URN Issue Highlights                                           |
|--------------|------------------------------------|----------------------------------------------------------------|
| Durban       | Southern African Shipyards, Dormac | Machinery testing, busy shipping lanes, potential URN hotspot  |
| Cape Town    | Damen, Dormac, 6Sigma              | Vessel trials, equipment noise, growing manufacturing activity |
| Saldanha Bay | Dormac                             | Deep harbour construction, marine infrastructure activities    |
| East London  | East London Shipyard, 6Sigma       | Repair operations and docking noise transmission               |
| Richards Bay | Dormac                             | Offshore support/vessel servicing nearshore                    |
| Algoa Bay    | (STS bunkering & port traffic)     | Direct evidence of noise doubling and wildlife impact          |

## 1. Durban

**Shipyards:** Southern African Shipyards, Dormac Marine & Engineering

**URN Concerns:** High-volume repair and new build activity, machinery testing, and vessel trials generate low-frequency hull and engine noise. Although no direct URN measurements are reported, Durban lies on one of the busiest shipping routes in Africa, intensifying ambient noise.

**Ecological note:** Proximity to coastal ecosystems and nearshore marine traffic likely contributes to acoustic habitat degradation. ([Forney et al., 2017](#)).

## 2. Cape Town

**Shipyards:** Damen Shipyards, Dormac, 6Sigma Marine

**URN Concerns:** Ongoing construction and trials of inshore patrol vessels, plus equipment testing, raise URN levels. Cape Town's growing maritime manufacturing ecosystem (tourism, repairs, new builds) compounds underwater noise exposure.

**Strategic significance:** Vessel noise may affect the marine biota in nearby Table Bay and False Bay.

### 3. Saldanha Bay

**Shipyards:** Dormac Marine & Engineering Saldanha

**URN Concerns:** Deep natural harbour used for offshore support; launching and maintenance activities could transmit construction and machinery noise. Although specific URN data are lacking, Operation Phakisa-driven upgrades signal intensified operations.

### 4. East London

**Shipyards:** East London Shipyard, 6Sigma Marine (repair & build)

**URN Concerns:** Repair infrastructure includes dry docks and equipment testing, likely producing machinery and docking noise in nearshore environments

### 5. Richards Bay

**Shipyards:** Dormac operations

**URN Concerns:** Major focus on ship repair and offshore support, often involving heavy equipment. Bunkering and ship-to-ship operations near coast can elevate URN; stakeholders have noted public concerns and calls for better assessment.

### 6. Ecosystem Case Study: Algoa Bay (Port Elizabeth / near Ngqura)

Though not a major shipyard per se, Algoa Bay has become a critical URN hotspot. A temporary halt in bunkering in 2023 corresponded with a 70% rebound in penguin numbers, strongly indicating causation. (Pichegru et al., 2022).

#### *URN Reduction Methods in Shipbuilding*

There are proven URN mitigation strategies which are well documented in literature, detailed below:

- **Machinery vibration isolation** (e.g., silent mounting systems and floating floors) to reduce noise from structures mounted to floors (Smith & Rigby, 2022; Song et al., 2017).
- **Acoustic barriers and insulation** placed around usual noise emitting machinery (Smith & Rigby, 2022).

- [Hydrodynamic optimizations](#) of hulls and propellers to reduce cavitation and noise propagation (Leaper, 2019).
- [Quieter propulsion systems](#), including electric drives and improved engine mounts (Smith & Rigby, 2022).

The IMO provides URN guidance through the GloNoise Partnership and circular MEPC.1/Circ.906 (IMO, 2023). These frameworks establish best practices for URN monitoring and mitigation globally but South Africa currently does not have domestic regulations or enforcement mechanisms aimed at URN in shipbuilding operations. The IMO's Revised Guidelines for the Reduction of Underwater Radiated Noise from Shipping (MEPC.1/Circ.906/Rev.1) provide non-mandatory best practices, encouraging integration of noise reduction at the design stage and monitoring during vessel operation. However, uptake remains voluntary, and enforcement at the national level is minimal in many jurisdictions, including South Africa.

## 2.6. Maritime Energy Management (MEM) Principles

MEM is described as the “study of energy flows such as supply, transformation, storage, production and consumption in the extensive maritime domain, which includes ships, ports, shipbuilding yards and ship-breaking activities, as well as (b) how this energy and its sources are optimised to manage consumption and reduce wastage in order to limit environmental and economic impacts of energy use” (Ölçer et al., 2017). It is the methodological application of measures aimed at the optimization of energy use, emissions reduction and integration of renewable energy technologies throughout the life cycle of a ship. This includes design, operation, maintenance and end-of-life management. MEM adopts a comprehensive life approach to energy use in shipyards and on ships.

A transdisciplinary MEM framework was proposed by (Vakili, 2022), it includes clean and green shipyard design. The framework allows for strategic energy planning to reduce life cycle carbon footprint. Additionally, when implemented holistically, the idea of integrated, multi-energy shipyards as energy hubs that produce and control energy, rather than just consume energy, has shown advantages for both operations and the environment. (Vakili et al., 2023).

Key MEM principles are summarized in Figure 8 and discussed in detail below:



Figure 8: Maritime Energy Management Principles Summary

### Energy efficiency in design and operation

Compliance with regulatory measures such as the IMO's EEDI and Ship Energy Efficiency Management Plan (SEEMP) along with improvements to engines, boilers, hull form and the use of energy-saving equipment, has steadily increased ship efficiency. New ships having to adhere to IMO regulations, encourages the use of technologies such as wind-assisted propulsion, waste heat recovery and hull air lubrication. Additionally, optimizing operational practices such as proper trim, timely maintenance and voyage planning, may further reduce fuel consumption. (Duan et al., 2023).

### Alternative and renewable fuels

One of the main characteristics of MEM is the transition to low- and zero-carbon fuels which include Liquefied Natural Gas (LNG), methanol, ammonia and hydrogen. These alternatives have the potential to reduce life cycle GHG emissions significantly. (Choudhury et al., 2024; Griffiths & Uratani, 2022). Additionally, fuel use can be supplemented by using onshore power supply (OPS), for when vessels are alongside or using renewable sources onboard the vessel, such as solar panels and wind-assisted propulsion technologies. (Vasilescu et al., 2020; Cotorcea et al., 2014)

## Digitalization and data analytics

MEM leverages digital tools; automated energy monitoring, digital twins and AI-based maintenance to fine-tune performance. Continuous improvement is achieved through the collection and analysis of fuel use, engine loads and environmental conditions data (Duan et al., 2023; Jung et al., 2023; Vakili et al., 2023). The fleet, shipyard and ports end up having a standard practice of energy audits and Key Performance Indicators (KPIs) (Herce et al., 2021). Digital integration ensures the human element (crew training, performance incentives) is fully engaged in efficiency.

These ideas come together to create a framework for MEM which aims to reduce carbon emissions. Systematically applying them to ship design, operation, and shipyard management, allows the industry to align with global climate goals while often reducing costs (Vakili et al., 2023).

## 2.7. South African Shipbuilding Landscape

This study was motivated by the urgent need for intervention in reducing the emissions which contribute to climate change and the opportunities that exist for South Africa in becoming one of the leaders in green ship building & maintenance. South Africa has an established, though modest, shipbuilding and repair sector concentrated in Cape Town, Durban, and Richards Bay, with competencies in niche segments such as patrol vessels, fishing vessels, and offshore supply craft (DoT, 2017).

Table 3 offers a summary of the country's available infrastructure, main uses and status of the infrastructure. The country benefits from a strategic geographic location along the Cape of Good Hope shipping lanes and an abundance in renewable energy resources such as solar, wind, tidal and wave (Winter, 2023). However, the SA maritime industry is faced with outdated infrastructure, low economies of scale, and a lack of dedicated green shipbuilding regulations (OECD, 2021).

Table 3: Summary of Shipbuilding Infrastructure in South Africa

| Serial Number | Shipyard                                               | Location                              | Main Use                                                 | Infrastructure Status                                                                                                                                                                        |
|---------------|--------------------------------------------------------|---------------------------------------|----------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1             | Sandock Austral Shipyards (Southern African Shipyards) | Durban (Bayhead area)                 | New build and repair (commercial & naval)                | Purpose-built for naval programmes; ISO 9001-certified; operates large dry docks and floating docks; dual-shift build capacity; ongoing government focus on industrial-strength shipbuilding |
| 2             | Dormac Marine & Engineering                            | Durban & Cape Town (and Saldanha Bay) | Major repair and maintenance; also new build & scrapping | Floating docks (Durban 155 m; Cape Town up to 360 m) and one large graving dock in Durban (up to 352 m length). Facilities accredited by ClassNK                                             |
| 3             | Damen Shipyards Cape Town                              | Cape Town                             | New builds & naval repair                                | Modern build yard; meeting >60% local content; delivered vessels under Project Biro since 2019–2022                                                                                          |
| 4             | 6Sigma Marine                                          | Cape Town & East London               | Repair and new build                                     | Cape Town dock up to 360 m; East London dock up to 200 m length, 31 m width, 10.2 m depth                                                                                                    |
| 5             | EbH / Elgin Brown & Hamer                              | Durban & East London                  | Repair (graving & floating docks)                        | East London graving dock ~200 m; Durban graving dock ~352 m plus floating docks                                                                                                              |

The South African government has already started making advances towards upgrading the shipbuilding and repair capacity through a programme called Operation Phakisa (meaning “hurry up” in Sotho), released in 2014, under which the Transnet National Ports Authority (TNPA) is running a number of projects to “refurbish and upgrade existing ship repair facilities including dry docks, slip ways, repair quays and boat lift facilities (TNPA, 2014).

Figure 9 shows the various ship building and repair facilities undergoing the upgrades as part of Operation Phakisa.

### SHIP REPAIR FACILITIES IN SOUTH AFRICAN PORTS

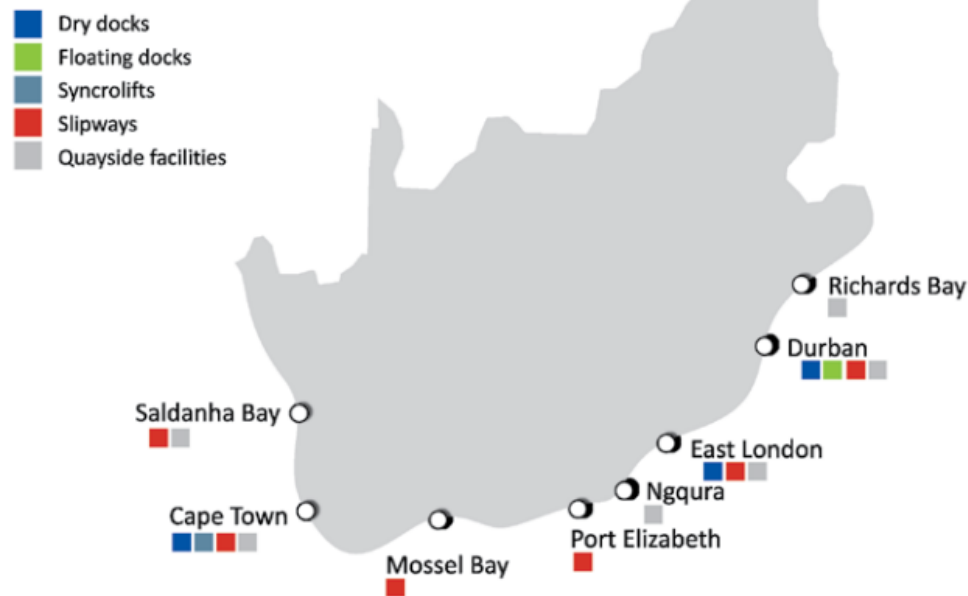


Figure 9: Map of SA showing shipbuilding and repair facilities  
(Source: TNPA Port Handbook 2015)

National maritime policy is set out in the Comprehensive Maritime Transport Policy (CMTP) and operationalised through initiatives like Operation Phakisa's Oceans Economy programme (DoT, 2017). While these frameworks recognise sustainability as a strategic objective, they do not yet prescribe binding emissions or URN mitigation standards for shipbuilding activities.

## 2.8. South African Shipbuilding Industry & Regulatory Framework

The South African shipbuilding industry focuses mainly on the construction of small to medium sized vessels such as patrol boats, tugs, survey vessels and ship repair operations (Du Plessis et al., 2021; SAMSA 2022). Major shipyards include Damen shipyards Cape Town, Sandock Austral shipyards in Durban, Nautic Africa and some private yards. Repair yards in East London, Richard's Bay and Saldanha Bay work alongside the major shipyards to cater for both local and international customers.

The industry has been strengthened by government initiatives under Operation Phakisa, Oceans Economy (launched in 2014), which channelled over R2 billion through Transnet and other agencies into refurbishing port-based repair infrastructure

(dry docks, slipways, quays) (Du Plessis et al., 2021; SAMSA 2022). Operation Phakisa also established a procurement policy for sourcing new naval and patrol vessels from local yards, exemplified by the multi-vessel Project BIRO and Project HOTEL programs. These contracts have assisted in keeping local yards in business as well as improved technical capabilities.

Despite these improvements, there are still significant barriers to overcome such as low production volumes, low economies of scale and high prices of domestic steel and aluminium (Du Plessis et al., 2021).

### Regulatory and Institutional Landscape

A network of governmental entities, trade associations and technical organisations govern the South African maritime industry, major players are highlighted on Figure 10 and the rest are included in Appendix 5: Maritime Institutions in South Africa.

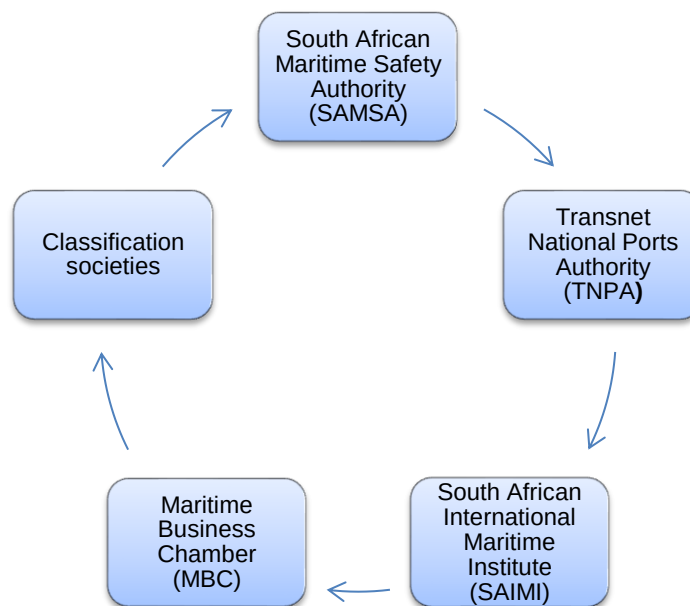


Figure 10: South African Maritime Industry Key Players Network

**South African Maritime Safety Authority (SAMSA):** Established by the SAMSA Act, 1998, this statutory body under the Department of Transport is responsible for the maintenance of the national ship registry, supervision of statutory surveys and vessel certification, as well as enforcement of international maritime conventions in South

African waters. Additionally, SAMSA is becoming the primary national body for regulating URN.

**Transnet National Ports Authority (TNPA):** Oversees port and shipyard infrastructure and markets ship repair facilities.

**South African International Maritime Institute (SAIMI):** Supports maritime education, research and development (R&D), and workforce training.

**Maritime Business Chamber (MBC):** Advocates for policy, competitiveness, and investment.

**Classification societies** such as Bureau Veritas provide certification and technical guidance.

### Policy and Regulatory Framework

South Africa's national objectives for the oceans economy are outlined in the CMTP and Operation Phakisa identifies maritime manufacturing as a priority industry (DoT, 2017). The National Environmental Management Act (NEMA), established in 1999, requires Environmental Impact Assessment (EIA) approval for large shipyard expansions and offshore fuelling.

URN awareness is growing in South Africa. SAMSA conducted the country's first EIA, focused on URN in Algoa Bay and proposed draft regulations on offshore bunkering that address noise pollution. These developments are in line with the IMO's GloNoise programme which provides voluntary guidelines for lowering URN from commercial vessels. Additionally, NGOs, researchers and South African authorities participated in IMO GloNoise workshops and started using noise monitoring using hydrophones at selected ports.

### Shipyard Locations and URN Impacts

The major shipbuilding and repair hubs: Durban, Cape Town, Saldanha Bay, Richards Bay, and East London are potential URN hotspots due to their mix of vessel construction, repair, machinery testing, and sea trials. For example:

- [Durban](#): Hosts large repair and newbuild facilities (Sandock Austral Shipyards, Dormac) adjacent to a high-traffic shipping lane, contributing to elevated background noise.
- [Cape Town](#): Damen Shipyards and others conduct sea trials and commissioning close to ecologically sensitive areas like Table Bay.
- [Saldanha Bay](#): A deep natural harbour where marine infrastructure activities and support vessel operations can propagate noise over long distances.
- [Richards Bay](#): Offshore support operations and vessel servicing create both continuous and impulsive noise nearshore.
- [East London](#): Smaller scale repair operations but close to important coastal ecosystems.

A case study worth mentioning was conducted in Algoa Bay, where a rise in vessel traffic and bunkering from 2016 increased noise level which caused a decrease in African penguin populations in the vicinity, specifically the St. Croix Island ([Pichegru, 2022](#); [SAMSA, 2022](#)). In 2023, bunkering was temporarily stopped, resulting in an increase in penguin populations. This indicated a strong link between marine life health and URN.

### Gaps and Opportunities

Currently, there is no binding national legislation specifically targeting green shipbuilding or URN mitigation. High-level initiatives such as the CMTP and Operation Phakisa establish strategic maritime objectives, but they don't provide low-carbon or low-noise shipyard operations with enforceable targets. Although they are voluntary and need country adaptation, international frameworks like the IMO's 2023 Revised GHG Strategy and GloNoise standards offer structured options. By incorporating these frameworks into national policies and offering financial incentives (like those in Türkiye), South Africa may be able to implement low-carbon, low-noise shipbuilding techniques more quickly, enhancing its environmental performance and global competitiveness.

## 2.9. Research Gaps

Despite strong global research on MEM and green shipbuilding, South Africa faces several critical and well-documented gaps:

### 1. Lack of integrated research on MEM and URN in African shipyards

Literature reviews on URN emphasize urgent global needs but highlight limited empirical data specific to developing regions like South Africa, especially in combined MEM+URN frameworks (Smith & Rigby, 2022).

### 2. Absence of stakeholder-focused investigations

Even robust African renewable energy initiatives such as Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), often lack direct engagement with the maritime industry's plural stakeholders, including shipbuilders, regulators, financiers, and unions.

### 3. No tailored operational frameworks or policy models

South Africa's broader energy transition (e.g., Risk Mitigation Independent Power Producer Procurement Programme (RMIPPP), offshore wind assessments) is advancing, yet there remain no operational models specific to green shipbuilding in the local development context (Rae & Erfort, 2020).

### 4. Evidence-based assessments of technologies and financing are lacking

Renewable energy rollouts in South Africa have shown success through REIPPPP programmes; however, similar rigorous evaluations are absent for energy and noise reduction technologies in shipyards.

### 5. Unproven pilot-to-scale operational strategy

While green corridor concepts (e.g., South Africa–Europe route) are emerging, most remain at early planning or feasibility stages rather than being tested or operational at scale (Song et al., 2025).

This dissertation addresses these gaps and a summary of work done by other authors is highlighted in [Table 4](#):

Table 4: Literature gaps against study contributions

| Area                                        | What studies other authors have conducted                                                                                                                                   | Gap                                                                               | How this study fills the gap                                                                                          |
|---------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| Green Shipbuilding Practices                | Studies in Asia and Europe highlight eco-friendly shipbuilding methods, lifecycle efficiency, and sustainability (Vakili, 2022; Cucinotta et al., 2024; Suer et al., 2022). | Very limited research on South African shipyards implementing green shipbuilding. | Provides a South African case study identifying opportunities and challenges for transitioning to green shipbuilding. |
| Maritime Energy Management (MEM) Principles | MEM frameworks explored globally for energy efficiency, emissions reduction, and IMO compliance (Ölçer et al., 2017; Duan et al., 2023; Herce et al., 2021).                | No localized adaptation of MEM principles to South African shipyards.             | Explores MEM principles in South Africa's shipbuilding and repair sector context.                                     |
| Underwater Radiated Noise (URN)             | Strong focus in developed nations on URN impacts and mitigation (Leaper, 2019; Duarte et al., 2021; Erbe & Thomas, 2022).                                                   | Limited research on URN in South Africa, research in infancy stages.              | Introduces URN as a new environmental dimension in South African shipbuilding discussions.                            |
| Regulatory Framework                        | Literature emphasizes IMO, EU, and Asian policy frameworks supporting green transition (IMO, 2020; OECD, 2021).                                                             | Lack of analysis of South African regulatory readiness for green shipbuilding.    | Evaluates South Africa's policy and regulatory landscape against international benchmarks.                            |

| Area                     | What studies other authors have conducted                                                                                                    | Gap                                                                   | How this study fills the gap                                                                   |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| Comparative Benchmarking | Comparative studies exist between international shipyards (e.g., Korea, Japan, Türkiye) on sustainable practices (UNCTAD, 2023; OECD, 2021). | No benchmarking of South African yards against global best practices. | Provides comparative benchmarking analysis between South African and Turkish shipyards.        |
| Strategic Roadmaps       | Authors propose roadmaps and strategies for Europe and Asia towards decarbonization (Vakili et al., 2023a; Mondello et al., 2023).           | No context-specific roadmap for South Africa's green shipbuilding.    | Develops a tailored strategy and roadmap for South Africa, integrating MEM and URN mitigation. |

## 3. Chapter 3: Methodology

### 3.1. Introduction

This chapter details the research methodology adopted for the study. A mixed-methods approach provides a more thorough understanding of the subject, and due to the complex nature of the shipbuilding process, both stakeholder experiences and measurable data are required (Creswell, 2009).

### 3.2. Research design

The study employs a convergent mixed methods approach (Creswell & Plano Clark, 2018) which incorporates both quantitative and qualitative data. The quantitative data was obtained from surveys, policy documents and industry reports. The qualitative data was collected through interviews, case studies and a comprehensive literature review. The quantitative data was analysed using Excel and the qualitative data was thematically coded using NVivo to extract key themes. The research design illustrated in Figure 11, showing the step-by-step process towards the development of the proposed strategy.

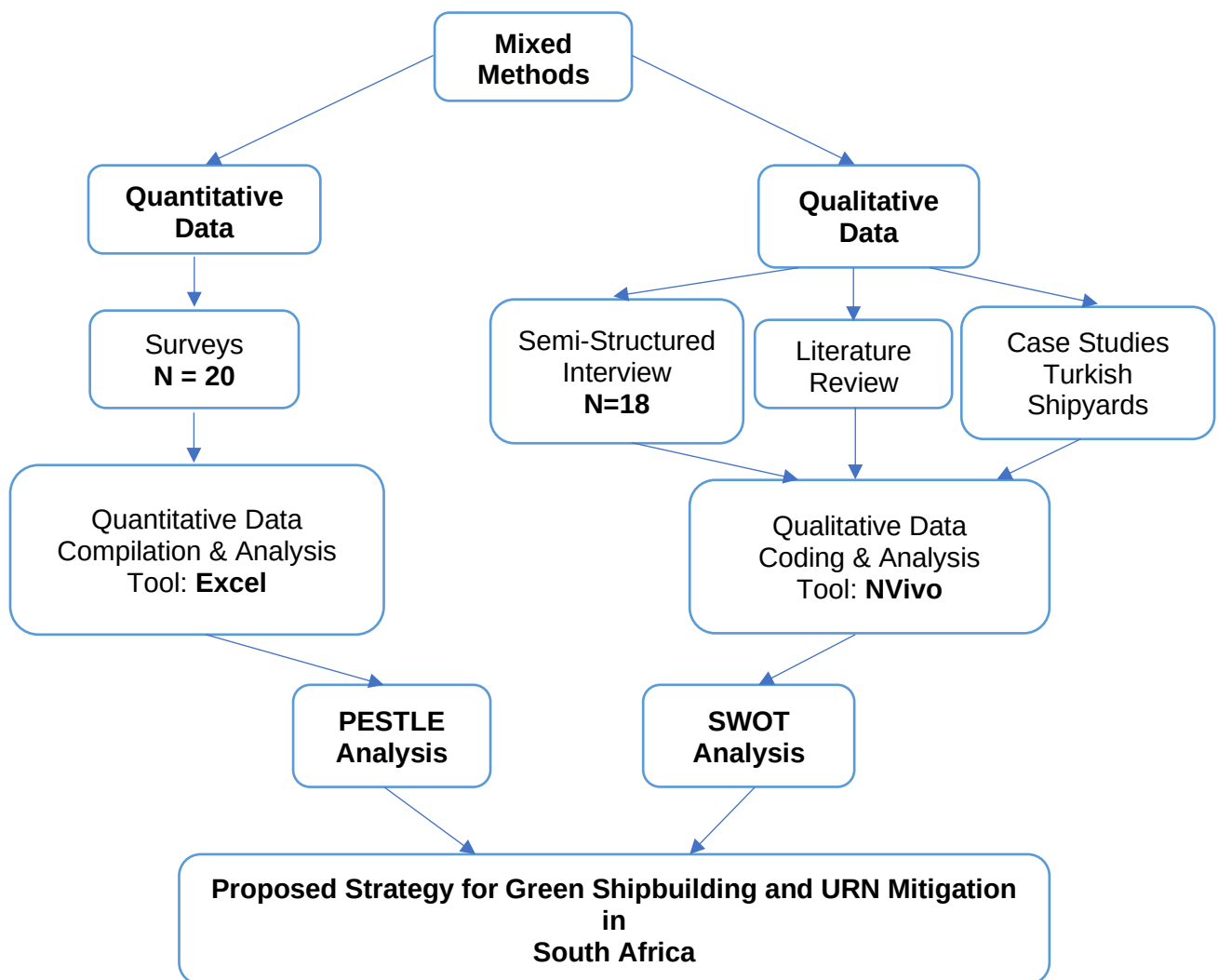


Figure 11: Research Design Framework

### 3.3. Data Collection

#### *Quantitative Data*

The quantitative research data included a stakeholder survey, shipbuilding companies' policy documents and industry reports as the sources of data:

#### *Survey*

**Instrument:** The survey ([Appendix 1: Survey Questions](#)) included twenty-two (22) questions, with 5-point Likert-scale type questions, multiple choice and open-ended

responses. The questions covered awareness, feasibility and challenges of green shipbuilding and URN mitigation in South Africa.

**Distribution:** The survey was created on Google Forms and distributed through email, social media (LinkedIn) and professional networks.

**Participants:** The survey was completed by twenty (20) stakeholders representing shipbuilders, engineers, ship owners, financiers, regulators and technology providers with a prerequisite of at least three (3) years' experience in the shipbuilding industry.

#### *Document Review*

**Policy and Strategic Documents:** The study reviewed the Comprehensive Maritime Transport Plan (CMTP), the National Development Plan (NDP) and the Operation Phakisa Oceans Economy Programme for an indication of the South African shipbuilding industry's alignment with international maritime decarbonisation efforts.

**Regulatory Frameworks:** The National Environmental Management Act (NEMA) and the South African Maritime Safety Authority (SAMSA) Act, 1998, were also reviewed alongside international conventions which South Africa has ratified i.e. MARPOL Annex VI and the Hong Kong Convention on Ship Recycling.

**International Regulations:** To compare South Africa with other shipbuilding nations, international regulations were consulted including the IMO Revised GHG strategy, MEPC1/Circ906/Rev1 URN Guidelines, United Nations Conference on Trade and Development (UNCTAD), European Maritime Safety Agency (EMSA) and OECD reports.

#### *Qualitative Data*

The following resources were used to gather qualitative data in this study:

##### *Interviews*

A semi-structured interview was used to compile inputs from various stakeholders including shipbuilders, ship owners, regulatory bodies and academics (researchers). The interview questions were structured to motivate discussion and were tailored to

South African and Turkish shipbuilding stakeholders. Country specific questions were asked as per the literature reviewed on shipbuilding in the particular country. Most of the questions required elaboration from the participant and this brought out valuable insights based on the participants' years of experience.

#### *Case Studies*

Examples of green shipbuilding and URN reduction methods which are considered effective for inputs into the strategy for South Africa were witnessed through a research visit to various shipyards in Türkiye from 01 to 30 July 2025.

The case study was used as a benchmark in the analysis. The data obtained was used as guidelines in the compilation of the strategy for South African green shipbuilding.

#### *Literature Review*

A comprehensive literature review was conducted, providing an analysis of research already covered for green shipbuilding and URN mitigation in South Africa. Company policy documents were reviewed along with industry reports to guide the development of the roadmap.

### **3.4. Sample Selection**

Participants with specific knowledge and experience in shipbuilding were identified through purposive sampling. The information needed required a particular target audience due to the exploratory nature of the study.

#### *Participants Selection Criteria*

The participants were selected based on the following:

- Three or more years of working experience in the shipbuilding industry.
- Knowledge of and involvement in ship design, construction, operation, maintenance, energy systems and regulations.
- Representatives from regulatory bodies, classification societies and academia.

### *Sample Composition*

The sample consisted of 38 participants:

- Eighteen (18) interviewees from shipbuilding companies, a mix of technical and support staff, as well as classification societies.
- Twenty (20) survey respondents made up of a combination of technical experts, regulators, shipbuilders and shipyard managers.

Snowball sampling was used to reach specialists within the shipyard networks and to ensure geographical and institutional representation, the study makes an effort to include a variety of perspectives from both South Africa and Türkiye.

### *Sample Size Rationale*

The sample size for the interviews was enough to reach adequate data saturation and preserved the representativeness of survey responses. Thematic saturation in qualitative research frequently occurs within the first 12 interviews, especially if the participants have similar technical expertise (Guest et al., 2006). The study is able to provide deeper insight into the topic by using both methods, increasing the credibility of the findings by allowing for triangulation.

## **3.5. Data Analysis**

This section delves into the analysis of the data collected, validity and reliability of the findings and finally, integration of the findings.

### *Qualitative Data Analysis*

The semi-structured interviews with stakeholders in South Africa, were recorded and transcribed, then participants' responses were converted to written format to provide an accurate account of their views. The responses were analysed and grouped into common themes using NVivo by identifying similar statements. The challenges and opportunities for green shipbuilding and URN mitigation were identified based on the responses from the interviews using deductive coding from themes in the literature.

### *Quantitative Data Analysis*

The quantitative data was collected through a survey. Tables, pie and bar charts were used to present the data on Excel, supporting trends in the themes identified in the qualitative data.

### **3.6. Validity and Reliability**

Mixed methods research combines quantitative survey data and qualitative interview insights, ensuring that the results are credible, dependable and reliable is essential. Quantitative data validity was established through the compilation of survey questions from existing literature (Bocken et al., 2014; Rehfeld et al., 2007), followed by pilot testing of the survey to ensure alignment with the research aim and objectives. The survey and interview questions were reviewed by experts including shipbuilding industry professionals and academics, to ensure validity. Triangulation of the quantitative and qualitative data enables cross-verification of findings from multiple perspectives (Kane & Denzin, 2012). To ensure repeatability of the study and reduce researcher bias, standardized processes were followed for data collection, transcription and coding.

### **3.7. Integration of Findings**

This study uses a triangulation approach which ensures that the findings are valid by integrating the qualitative and quantitative data. The analysis combines the stakeholders' opinions with field data through side-by-side comparison, enhancing the reliability of the conclusions reached, as well as supporting the compilation of a South African content-specific strategy for venturing into green shipbuilding.

## 4. Chapter 4: Analysis and Discussion

### 4.1. Introduction

This chapter presents the findings from the research. The literature and document review, stakeholder surveys and field observations from the case study were instrumental in corroborating the key challenges and opportunities, understanding the impact of URN and the feasibility of implementing the mitigation strategies, in line with the literature reviewed. The role of MEM principles in the South African shipbuilding context is discussed in depth. The findings lead to the development of both a PESTLE and a SWOT analysis, the combination of which provides a comprehensive understanding of the South African context.

Chapter 4 presents findings organized by thematic areas. [Appendix 4: Mapping of Research Instruments to Analytical Themes](#), outlines the specific survey and interview questions that informed each topic. The methodology link to the findings is illustrated in [Figure 12](#). The figure links every objective to the research tools used in data collection and analysis, as well as integration of the findings to arrive at the final outcome.

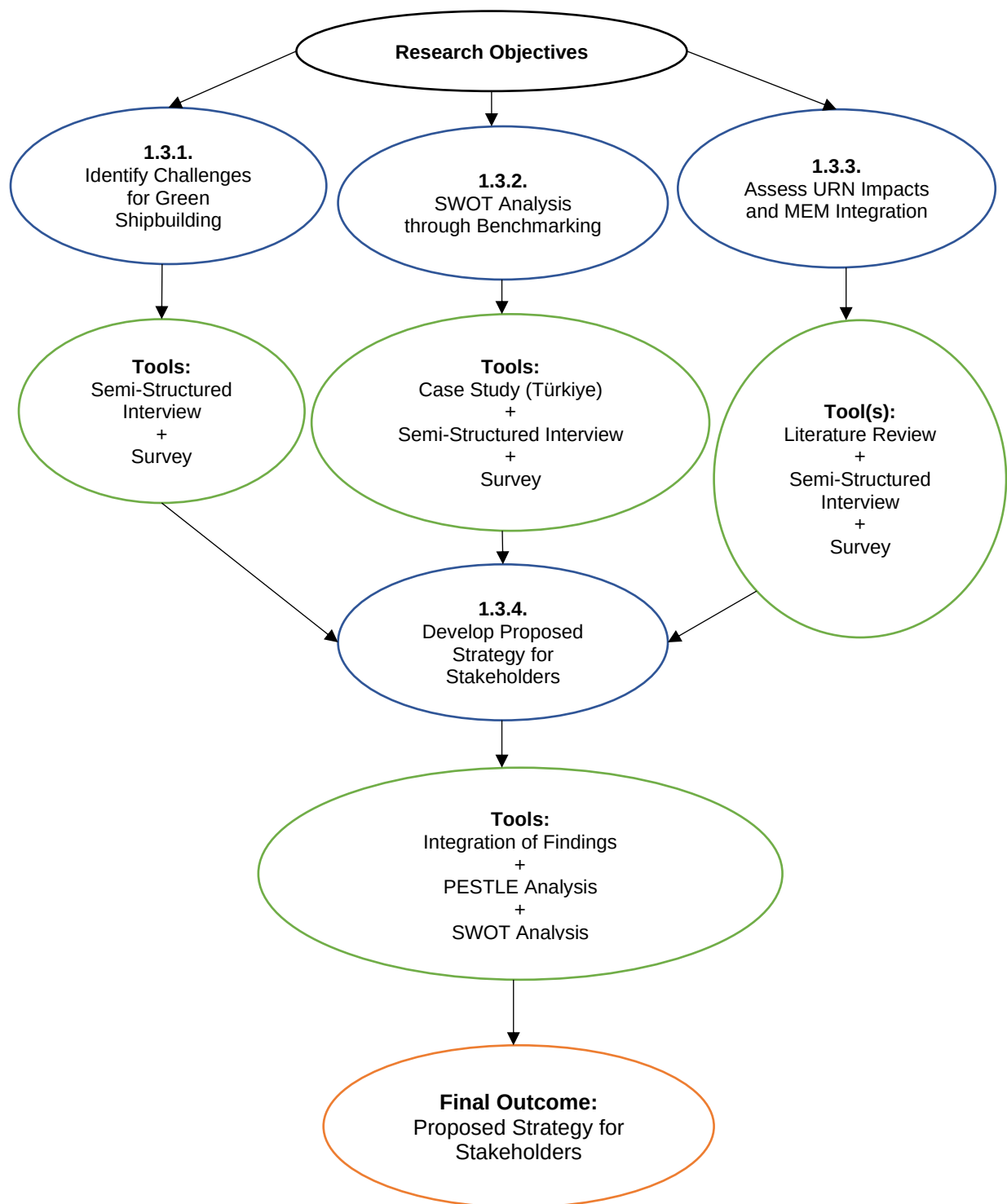


Figure 12: Contribution of research tools to objectives  
(Created by the author)

## 4.2. Demographics

The survey and interview participants consisted of stakeholders who play key roles in the South African shipbuilding industry.

### 4.2.1. Survey Participants

Figure 13 illustrates the percentages of survey participants per role. The majority of the survey participants (40%) were in the shipbuilding, repair and design roles. The credibility of the information presented is increased because the insights offered by these individuals represent the real-world difficulties as they are personally encountered via their everyday work activities.

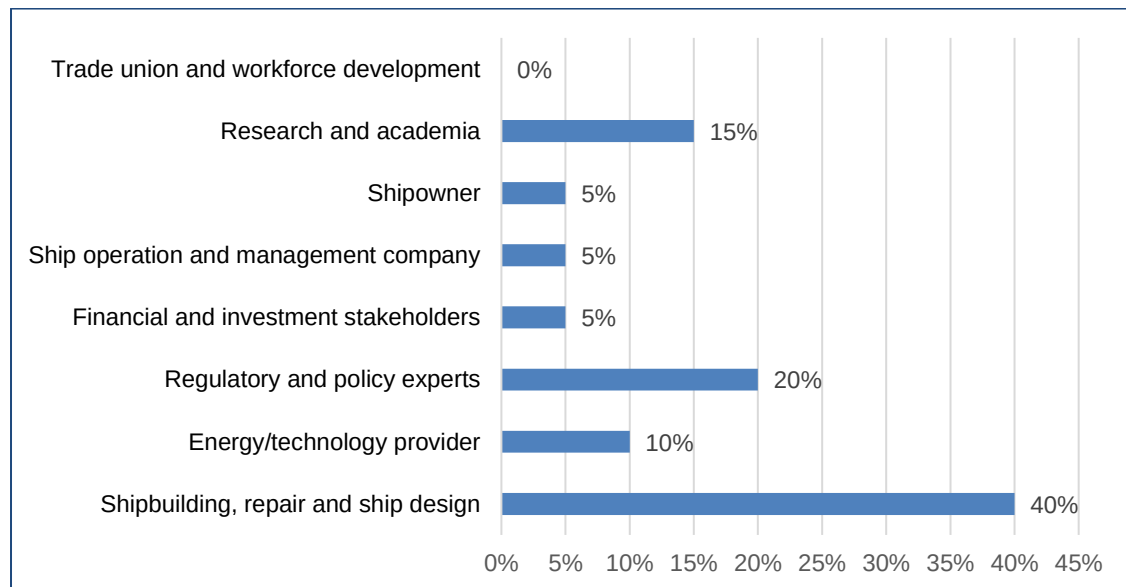


Figure 13: Survey participants roles in the shipbuilding industry (N=20)

### 4.2.2. Interview Participants

Face-to-face interviews were conducted with 18 participants and 55.6% were from shipbuilding, repair and design roles. These interviews provided a deeper understanding of the shipbuilding landscape in South Africa. Figure 14 illustrates the percentages of interview participants per role.

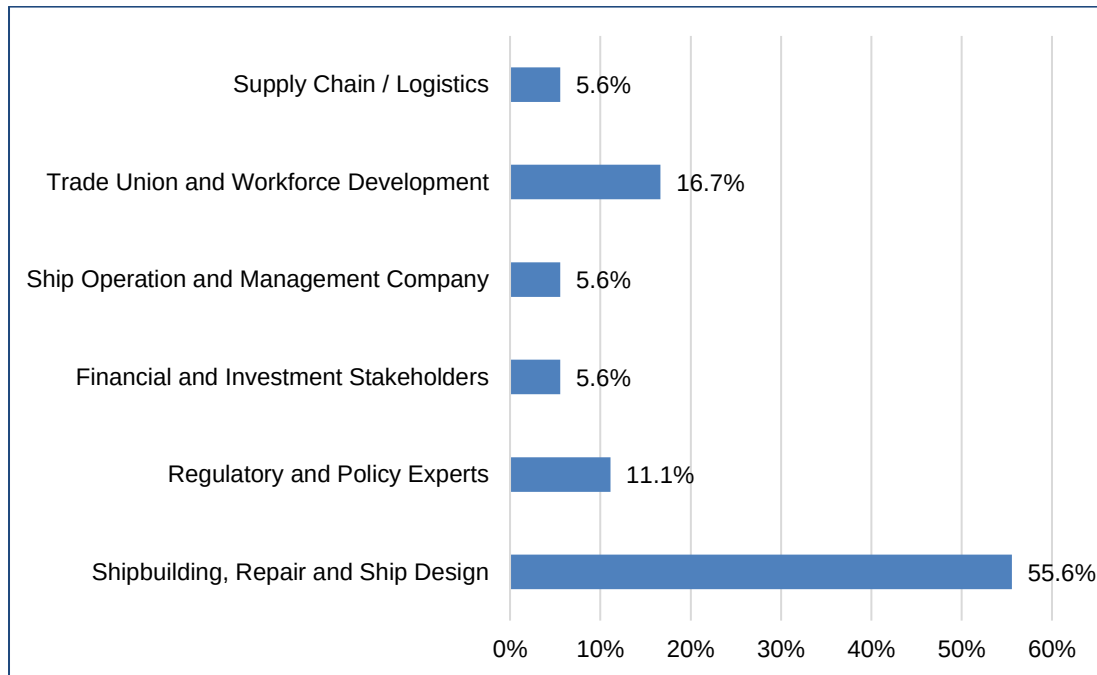


Figure 14: Interview participants categorization by roles (N = 18)

Table 5 provides details of the interviewed participants, indicating their interviewee codes, roles in the shipbuilding industry, organisation and the duration of their interviews. The interviews were recorded, transcribed and anonymized as per the ethical requirements of the study.

Table 5: Interview Participants' Details

| Serial Number | Interviewee Code | Organisation | Role                       | Interview Duration (minutes) |
|---------------|------------------|--------------|----------------------------|------------------------------|
| 1             | P1               | S1           | Production Planner         | 20                           |
| 2             | P2               | S1           | Health & Safety Supervisor | 15                           |
| 3             | P3               | S1           | Quality Control (Welding)  | 22                           |
| 4             | P4               | S1           | Paint Shop Supervisor      | 14                           |
| 5             | P5               | S1           | Pipe Shop Supervisor       | 15                           |
| 6             | P6               | S1           | Quality Control (Piping)   | 20                           |

| <b>Serial Number</b> | <b>Interviewee Code</b> | <b>Organisation</b> | <b>Role</b>                           | <b>Interview Duration (minutes)</b> |
|----------------------|-------------------------|---------------------|---------------------------------------|-------------------------------------|
| 7                    | P7                      | S1                  | Technician (Mechanical)               | 21                                  |
| 8                    | P8                      | S1                  | Senior Welding Foreman                | 15                                  |
| 9                    | P9                      | S1                  | Warehouse Supervisor                  | 14                                  |
| 10                   | P10                     | S1                  | Material Prep Supervisor              | 17                                  |
| 11                   | P11                     | S1                  | Maintenance Administrator             | 14                                  |
| 12                   | P12                     | S1                  | SHEQ Supervisor                       | 16                                  |
| 13                   | P13                     | CS                  | Marine Surveyor                       | 15                                  |
| 14                   | P14                     | S2                  | Supply Chain Manager                  | 18                                  |
| 15                   | P15                     | S2                  | Managing Director                     | 26                                  |
| 16                   | P16                     | CS                  | Regional Business Development Manager | 22                                  |
| 17                   | P17                     | S2                  | SHEQ Manager                          | 25                                  |
| 18                   | P18                     | S2                  | ILS Manager                           | 16                                  |

#### 4.3. Comparative Observations

In order to benchmark, the study used four Turkish shipyards as a case study to provide a clearer picture of how far South Africa is in the transition to green shipbuilding. The shipyard profiles are highlighted in [Table 6](#). The major similarities between the Turkish and South African shipyards were the new build and repair capabilities.

Table 6: Shipyard location, size, profile and code.

| Serial Number | Location     | Size   | Profile                          | Code |
|---------------|--------------|--------|----------------------------------|------|
| 1             | South Africa | Large  | New-build & Repair               | S1   |
| 2             | South Africa | Medium | Repair with fabrication          | S2   |
| 3             | Türkiye      | Medium | New-build (eco & hybrid vessels) | S3   |
| 4             | Türkiye      | Medium | Repair / refit (superyachts)     | S4   |
| 5             | Türkiye      | Large  | Naval/commercial new-build       | S5   |
| 6             | Türkiye      | Large  | Large-scale new-build & repairs  | S6   |

(Source: Author field observations, 2025)

Although South Africa has a small number of shipyards as compared to Türkiye, more similarities could be identified in accordance with the themes of the study including the fact that both countries are members of the IMO and are strategically positioned along major shipping routes; South Africa on the Cape of Good Hope, a gateway between the Atlantic and Indian oceans; and Türkiye at the crossroads of Europe and Asia, with access to the Black Sea, Aegean and Mediterranean.

The case study adds on to the stakeholder insights from the surveys and interviews, to identify best practices and possible implementation routes to be adopted into the South African shipbuilding context.

#### 4.3.1. Comparison of Shipyard Capabilities

The case study compared South African and Turkish shipbuilding industries under five categories, discussed below:

##### 4.3.1.1. Shipbuilding Capacity and Infrastructure

South Africa's shipbuilding capacity is limited. A total number of nine shipyards are registered on the shipyards directory and they focus largely on niche markets, leisure sailing catamarans, patrol boats, ferries, tugs and tenders. (DoT, 2017).

The Turkish shipbuilding industry on the other hand is much larger, with over 80 shipyards. The private sector is stronger and the shipyards are known globally for major ship repairs, new building, military ships and advances in the use of green technologies (OECD, 2021).

#### *4.3.1.2. Green Shipbuilding Practices Implementation*

Turkish shipyards have the support of national entities such as the National Energy Efficiency Action Plan, in piloting carbon-neutral and hybrid vessels (UNCTAD, 2023). The country has made advancements in the green transition through shore power infrastructure and ISO50001 certified energy systems (OECD, 2021).

South Africa lacks behind in implementation, limited to the use of some renewable energy sources, electrification of forklifts and automation of the steel cutting process. The lack of funding to invest in green technologies such as digitalized construction processes and waste heat recovery systems is common among domestic shipyards (DNV, 2022).

#### *4.3.1.3. Government Support and Regulatory Frameworks*

The Turkish government support includes public-private research and development (R&D) partnerships in low-emission shipbuilding (OECD, 2021). This plays a major role in the integration of green technologies in Turkish shipyards.

The South African government does not have a green shipbuilding regulatory framework nor offer support for investment in green technologies. There are no formal incentives or compliance standards for green shipbuilding or URN reduction (DoT, 2017).

#### *4.3.1.4. Capacity Building and Skills Development*

Türkiye has invested in maritime technical institutions such as Istanbul Technical University (ITU) and others which form partnerships with shipyards to provide shipbuilding-related courses and training (OECD, 2021). A list of more Turkish maritime institutions is provided in Appendix 6: Maritime Institutions in Türkiye ,

illustrating Türkiye's commitment to advancing the skills required by current and future shipbuilding professionals in the country.

South Africa is slowly catching up in this instance, historically largely driven by apprenticeship programs offered through Technical and Vocational Education and Training (TVET) colleges, the number of maritime institutions has increased over the years and curriculum content has the potential of being adjusted to include green shipbuilding technologies and URN reduction strategies (DoT, 2017). South African maritime institutions are listed in Appendix 5: Maritime Institutions in South Africa.

#### *4.3.1.5. Decarbonisation Awareness*

Decarbonisation has become a strategy in Türkiye, driven by the EU compliance measures. Turkish shipyards are conducting Life Cycle Assessments (LCAs), reinforced by regional initiatives like the EU Green Deal and increased participation in international projects. There is a growing level of awareness on decarbonisation goals in the shipbuilding sector, with a limited number of Turkish shipyards conducting energy audits or URN assessments (OECD, 2021). The IMO fourth GHG study indicates that South Africa has made significant progress in port electrification but not yet extended the efforts to shipyard operations (IMO, 2020).

#### *4.3.2. Detailed Operational Comparisons*

To get a clearer understanding of where South Africa is in term of green shipbuilding implementation from an operational level, a comparison of South African and Turkish shipyard processes, depicted on Figure 15, was conducted. Table 7 illustrates the factors used for the comparison, followed by detailed explanations of each.



Figure 15: Shipyard Operational Processes  
(Created by the author)

Table 7: Observations comparing South African and Turkish shipyards.

| Factor                                     | Turkish Shipyards | South African Shipyards |
|--------------------------------------------|-------------------|-------------------------|
| Optimized Yard layout                      | Yes               | Limited                 |
| Renewable energy use                       | Increasing        | Minimal                 |
| Energy management                          | Advanced          | Emerging                |
| Digital tools (automation, digitalisation) | Widespread        | Rare                    |
| URN awareness and mitigation               | Moderate          | Low                     |
| Waste management                           | Regulated         | Fragmented              |

(Source: Author's fieldwork, 2025)

#### 4.3.2.1. Optimized yard layout

Most Turkish shipyards have optimized layouts which maximize efficiency, minimize energy consumption and ensure smooth workflow (OECD, 2021). This is very limited in South African shipyards. (Dixit et al., 2020) proposed an ideal shipyard layout, Figure 16 and most of the Turkish shipyards mimicked this layout as opposed to South African shipyards.

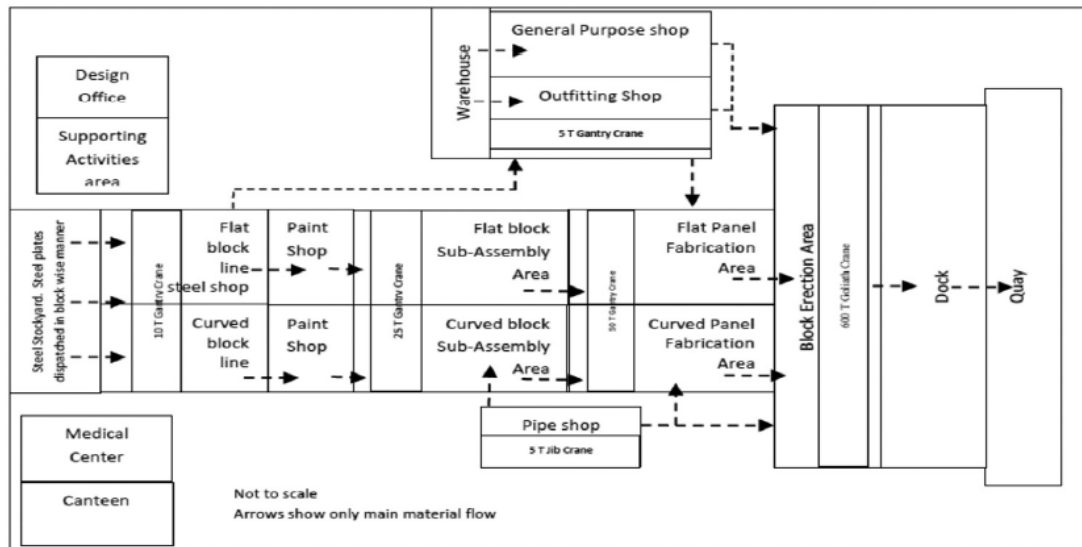


Figure 16: Ideal shipyard layout.

(Source: Dixit et al., 2020)

#### 4.3.2.2. Renewable energy use

In Türkiye, there is a notable rise in the use of renewable energy sources with a lot of the Turkish shipbuilding companies buying their electricity from an energy provider who uses renewable sources for generation (OECD, 2021). Whilst South Africans have been largely affected by the Electricity Supply Commission's (ESKOM's) loadshedding, which led many households and companies resorting to renewable energy sources (mainly solar), shipyards and ports have been exempt from loadshedding, which minimized their need to use renewable energy sources. (DoT, 2017)

#### 4.3.2.3. Energy Management

Turkish shipyards have energy monitoring devices in machinery and on the vessels built in the shipyards (OECD, 2021). Most of the shipyards are energy-conscious and demonstrate their commitment to reducing energy-use, adhering to energy-related requirements and consistently enhancing efficiency, by obtaining ISO50001 accreditation. South African shipyards are aware of ISO50001 and have begun making advances towards submitting application for accreditation. This is evident through the shipyards updated policies.

#### *4.3.2.4. Digital tools (automation and digitalisation)*

The use of digital tools is more common in Turkish shipyards than in South African shipyards. In South Africa, the CNC steel cutting process is the most widely used automated technology, whereas in Türkiye processes such as welding, painting, material handling and pipe fabrication are also automated. Digitalisation is widespread in Türkiye with the use of Internet of Things (IoT) sensors and Indoor Positioning Systems (IPS), which are not currently being used in South Africa.

#### *4.3.2.5. URN awareness and mitigation*

There is growing awareness of URN in Turkish shipyards, especially those catering for the European market where URN regulations are more advanced (OECD, 2021). In contrast, the level of URN awareness in South African shipyards is still very limited. It is worth mentioning, however, that both countries do not yet have direct regulations on URN mitigation in shipyards but there are awareness raising efforts currently in effect.

#### *4.3.2.6. Waste management*

Turkish shipyards have a higher level of compliance with EU-related environmental regulations and ISO14001 standards. A majority of Turkish shipyards have structured waste segregation systems and recycling programs as part of their Environmental Management Systems (EMS). Overall, Turkish shipyard waste management processes are more advanced than South Africa's. South African shipyards strive to comply with the National Environmental Management Act (NEMA), with larger facilities having more formal waste management protocols and limited recycling efforts. The smaller repair yards lack enforcement and have no formal environmental management systems (DoT, 2017).

### **4.4. Thematic Analysis**

This section presents the thematic analysis of the primary data obtained through 20 survey responses, 18 semi-structured interviews and site visits to Turkish shipyards, structured around the four key focus areas of the study (Figure 17).

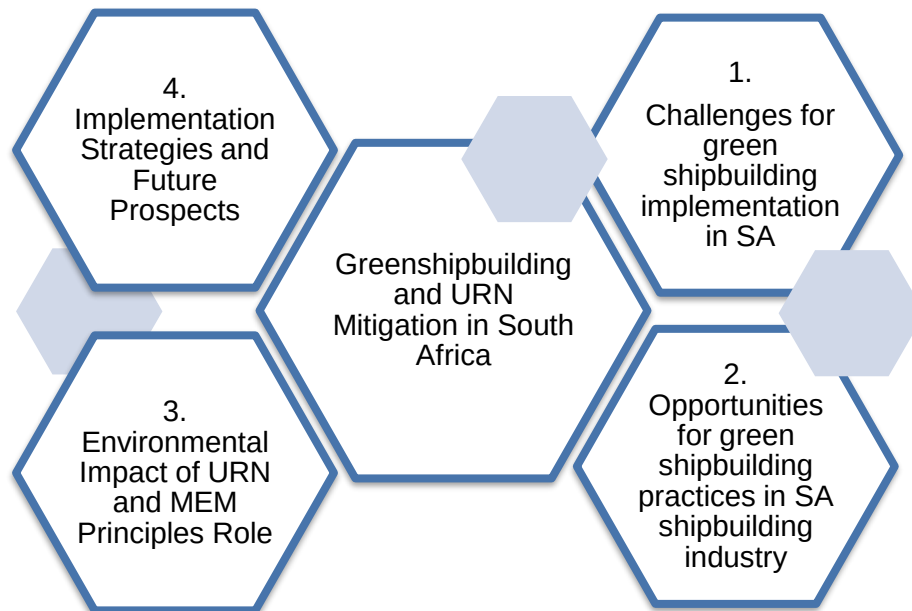


Figure 17: Themes for green shipbuilding and URN mitigation in SA

(Created by the author)

The findings provide answers to the research questions of the study in exploring challenges and opportunities for green shipbuilding and URN mitigation in South Africa from a Maritime Energy Management perspective.

#### 4.4.1. Challenges for Green Shipbuilding Implementation in SA

The key challenges for green shipbuilding implementation in South Africa provided by the literature were strongly supported by both the survey and interview responses. It was noted that a large number of the participants were familiar with green shipbuilding and MEM principles (78%) as illustrated in [Figure 18](#).

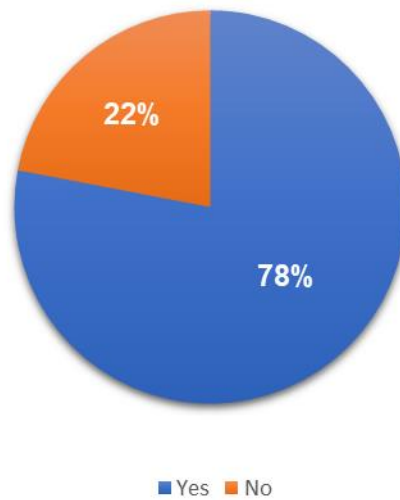


Figure 18: Familiarity with green shipbuilding and MEM principles (N=18)

The survey ranked lack of financing, inadequate regulatory framework and lack of economies of scale as the top three barriers with 18% each (Figure 19), followed by high cost of green technologies and limited awareness and knowledge each having been selected by 15% of the participants.

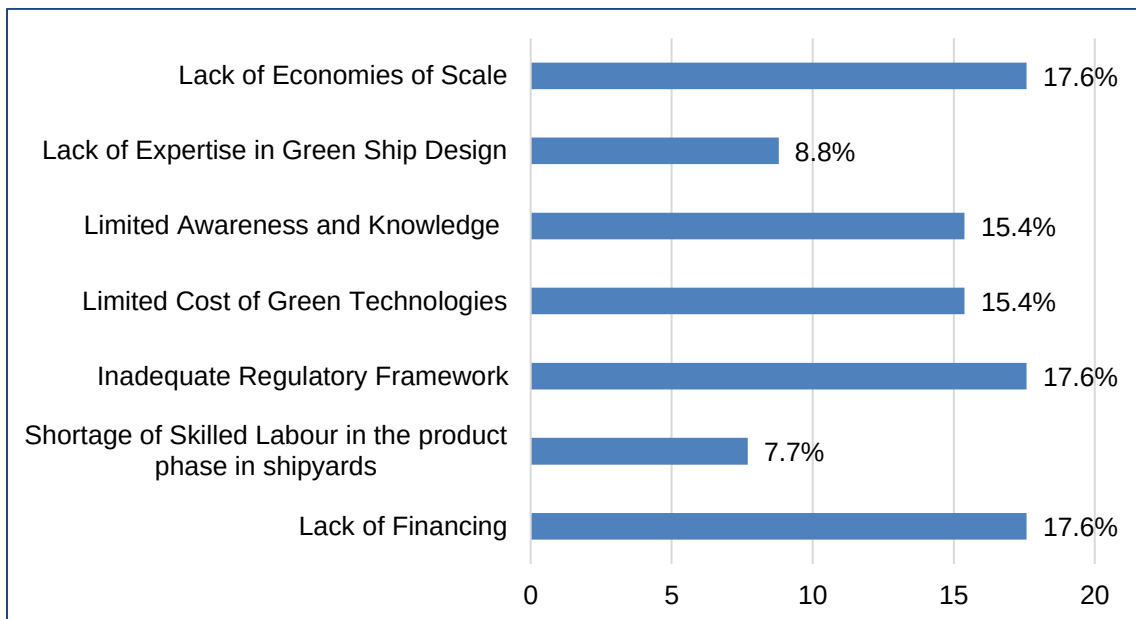


Figure 19: Barriers preventing adoption of green shipbuilding (N = 20)

The interviews backed up the survey by identifying finance, inadequate regulatory framework, limited ship orders (economies of scale) and outdated infrastructure,

technologies and lack of information and awareness as key barriers. Participants noted:

#### Financial

*“Finances - Going green is expensive”* (P1, Production Planner, S1, 2025)

*“Funding and clients not wanting to pay more for green ships”* (P17, SHEQ Manager, S2, 2025)

#### Inadequate regulatory framework

*“I think governmental support and policy is a barrier”* (P17, SHEQ Manager, S2, 2025)

#### Limited ship orders and outdated infrastructure

*“Most of the shipyards are very old, the equipment still being used is outdated and so is the infrastructure”* (P13, Marine Surveyor, CS, 2025)

*“The other barrier is that the industry is very small because as a big company, you can do things more efficiently with less environmental impact”* (P15, Managing Director, S2, 2025)

#### Limited awareness and knowledge

*“Our supply chain in South Africa, there’s not a lot of awareness and regulations that are prescribed on us to actually go green.”* (P14, Supply Chain Manager, S2, 2025)

*“Cost, lack of awareness and knowledge about these things”* (P10, Material Prep Supervisor, S1, 2025).

These challenges are consistent with existing literature which states that developing countries face financial, regulatory and infrastructure barriers in implementing green shipbuilding. (Baştuğ et al., 2024; Yap et al., 2024).

#### 4.4.2. Opportunities for Green Shipbuilding Implementation in SA

The literature review mentioned South Africa’s abundant renewable energy sources and being strategically located on a busy global route as opportunities for the country to become a green maritime hub (DoT, 2017). These opportunities are supported by both the survey (Figure 20) and interview responses.

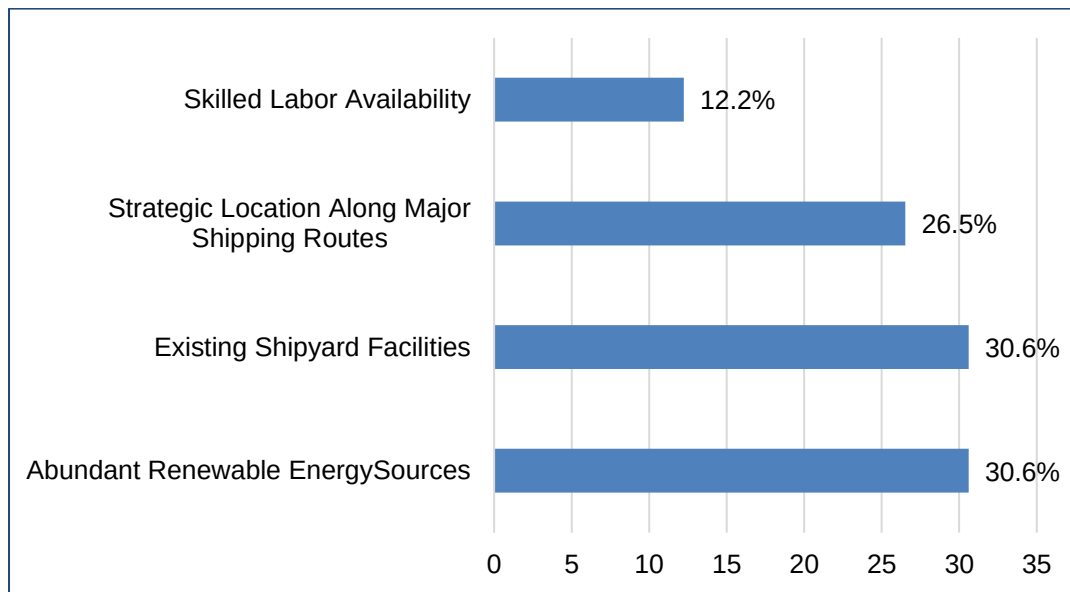


Figure 20: Opportunities for green shipbuilding in South Africa (N=20)

#### Abundant renewable energy sources

Survey participants ranked abundant renewable energy sources high (31%), [Figure 20](#), among the opportunities for green shipbuilding in South Africa. Participants were also asked if they were aware of any South African shipyards using renewable energy sources and 60% ([Figure 21](#)) confirmed they were.

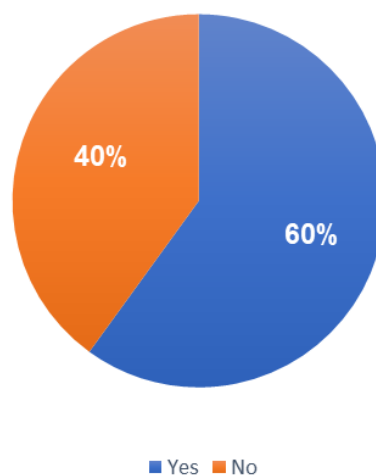


Figure 21: SA shipyards using renewable energy sources (N = 20)

Participants were asked which low or zero-emission green shipbuilding practices they believed had the most potential and why, the most common response was the use of

renewable energy sources. The participants linked the use of solar panels to the country's loadshedding issue, with one respondent explaining:

*"Use of renewable energy in shipyards because it will make more financial sense to use renewable electricity due to ESKOM's issues (loadshedding) and the general direction that the country is moving towards."* (Survey response, 2025)

Interviews supported the integration of renewable energy as an opportunity. Participants noted:

*"By using solar on building rooftops and installing more wind farms in places like the garden route where there is a lot of wind"* (P1, Production Planner, S1, 2025)

*"...so, we should start looking into solar and wind power for shipyards too, we have many roofs on which we can place the solar panels."* (P18, ILS Manager, S2, 2025)

*"If we start using the resource we have in abundance (for us it's the sun) then we can save on energy use and the money can be used to buy more green equipment."* (P9, Warehouse Supervisor, S1, 2025)

### Existing shipyard facilities

South Africa's existing shipyard facilities are an opportunity as they provide a foundation to build upon instead of starting from nothing. This is supported by 31% (Figure 20) of survey respondents. The technical expertise and skills are from current shipyard employees and this makes it easier and cheaper to upskill these employees on green shipbuilding practices than recruiting and training new shipbuilding professionals.

### Strategic location along major shipping route

Ranking third on the list of opportunities is South Africa's strategic location along a major shipping route (Figure 20). Ships sailing past the Cape of Good Hope route may need repairs or retrofits to comply with IMO decarbonisation regulations and South Africa could become the centre for construction and retrofits of energy-efficient ships. Some interview respondents also acknowledged South Africa's location as an advantage:

*"Our ports are very busy and we should be getting a lot of repair jobs"* (P5, Pipe Shop Supervisor, S1, 2025)

*"It will grow because we want it to. All these plans are laid out in the Oceans Economy Master Plan and **we are in a very strategic position to capitalize on our location.**"* (P14, Supply Chain Manager, S2, 2025).

### International partnerships

South Africa can accelerate the transition to green shipbuilding through international partnerships. Interview respondents stressed that collaboration with countries more experienced in green shipbuilding will provide resources that would take longer to develop in-house.

The interview data provided three key themes for international collaboration which align with literature and global case studies:

#### Theme 1: Skills and knowledge transfer

*"By sending students to learn from developed countries on green shipbuilding"* (P3, Quality Control (Welding), S1, 2025).

*"Bring some people from experienced companies overseas to come train us on going green in the shipyard"* (P4, Paint Shop Supervisor, S1, 2025).

#### Theme 2: Technology transfer

*"Technology transfer by collaborating with class societies (like us – Bureau Veritas), overseas green shipbuilding companies and the IMO"* (P13, Marine Surveyor, CS, 2025).

*"Collaboration, we can collaborate with overseas companies like Damen because their R&D department is doing a lot of work in developing green ships and green shipbuilding practices."* (P18, ILS Manager, S2, 2025).

#### Theme 3: Capacity building for young workers

*"Teach these youngsters about green shipbuilding because they are the future..."* (P5, Pipe Shop Supervisor, S1, 2025).

*"Train the shipbuilders on green shipbuilding and energy management"* (P11, Maintenance Administrator, S1, 2025).

#### Skilled labour availability

South Africa's existing skills within the shipbuilding industry provide a foundation towards the transition to green shipbuilding. These capabilities will ensure that the current workforce can adapt more easily to green shipbuilding practices. The cost and time factors will be reduced as the core technical skills are already in place. The country may target a niche area where skilled labour can be focused on meeting a specific international demand such as retrofitting ships for energy efficiency. One interview respondent indicated that the green shipbuilding skills are evident, the industry needs to grow however, for the impact to be seen:

*"Yes, I think the skills are there, we just need the industry to grow in order to see the impact"* (P15, Managing Director, S2, 2025)

Literature indicates that key enablers for sustainable shipbuilding transformation are skill availability and competency of the workforce. "Green supply chain adoption in shipyards is strongly linked to the skills and adaptability of the workforce." (Caniëls et al., 2016).

#### 4.4.3. Environmental Impact of URN and MEM Principles Role

This section presents the contribution of current shipbuilding practices to URN, viable mitigation strategies, implementation barriers and the role of MEM principles.

##### URN Awareness

There was higher awareness, 90% (Figure 22) of environmental impacts of URN from shipbuilding and operations among survey respondents than interviews.

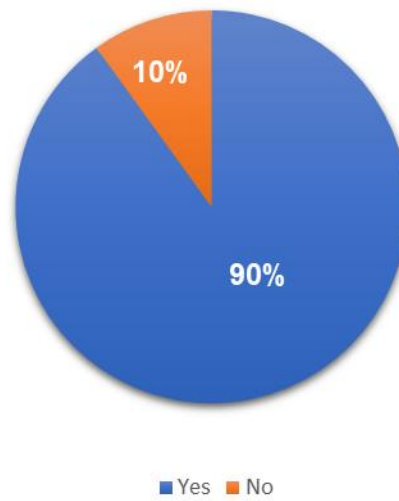


Figure 22: Awareness of environmental impacts of URN (N =20).

Many of the interview participants acknowledged lack of URN mitigation efforts and how the focus is more on the ergonomic rather than the underwater noise:

*“We mostly focus on how the noise affects humans and not so much the marine environment”* (P3, Quality Control (Welding), S1, 2025)

*“Yes, they are aware and they understand, the problem is that there are no rules against it.”* (P5, Pipe Shop Supervisor, S1, 2025)

*“At the moment I think it is just being ignored as the impact cannot be readily seen”* (P12, SHEQ Supervisor, S1, 2025)

*“It’s not being handled very well. I think we are only now starting to look at solutions and working together to try and mitigate this.”* (P17, SHEQ Manager, S2, 2025)

Survey respondents were also asked to rate the importance of URN reduction compared to GHG reduction and a combined total of 70% (Figure 23) respondents rated it between 4 and 5 on a scale where 1 = Not Important and 5 = Very Important.

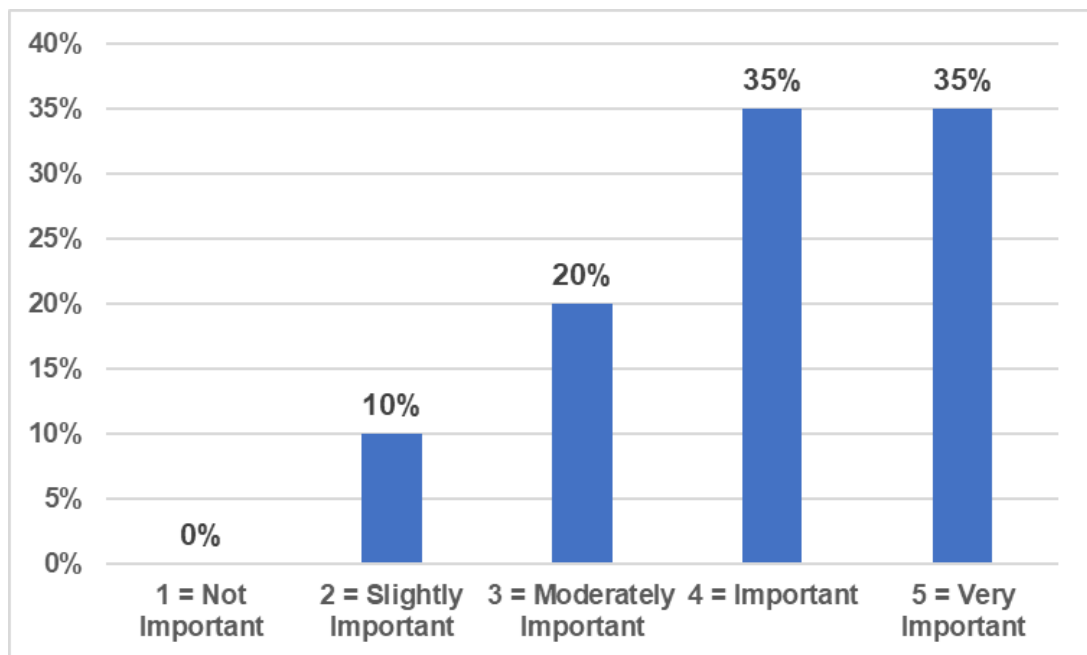


Figure 23: URN reduction compared to GHG reduction (N = 20)

Many interview respondents were either unaware of the impact of shipbuilding activities on marine life or did not believe that the shipyard processes were loud enough to affect the surrounding marine ecosystems. Awareness was however higher among stakeholders involved in the growing URN research groups or IMO projects:

*“Yes, they understand and more now with the emergence of this GloNoise workgroup.”* (P15, Managing Director, S2, 2025)

*“...but there is a growing concern about URN and the GloNoise project is actually working on it at an international level...”* (P17, SHEQ Manager, S2, 2025)

#### Viable URN mitigation technologies

Survey participants rated vibration mitigation measures (23%), followed by noise barriers and insulation (21%) and optimized hull design (19%) (Figure 24), high as viable URN mitigation technologies for South African shipyards. Similar solutions are recommended in literature (Javier et al., 2023).

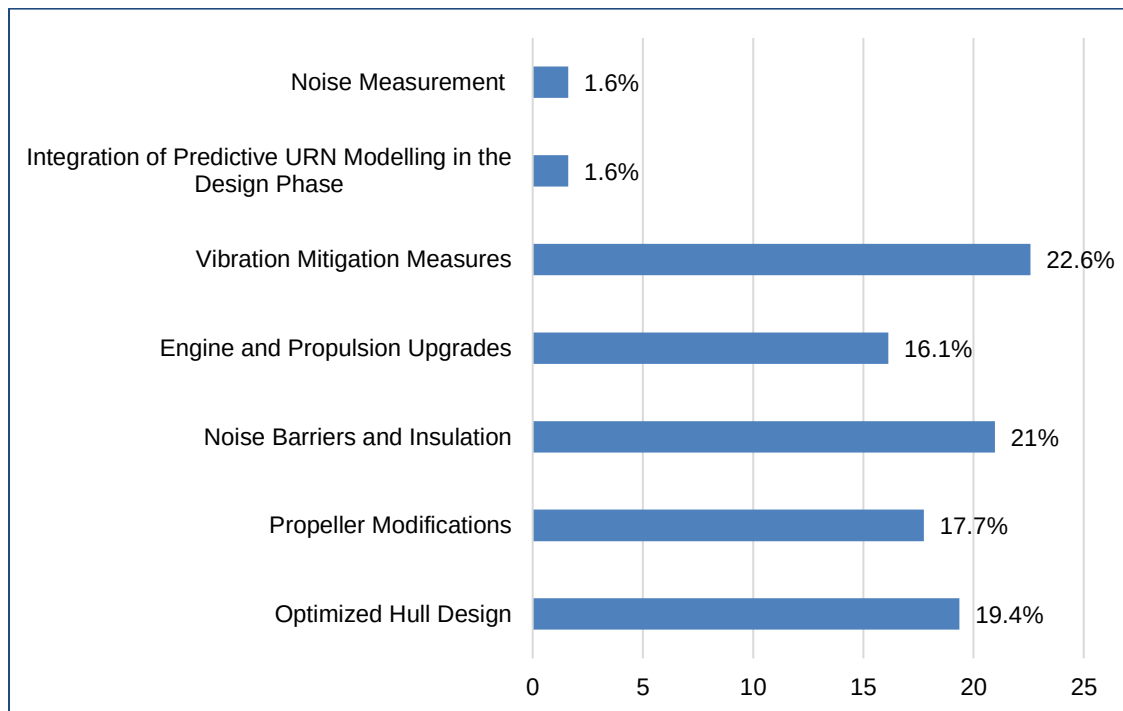


Figure 24: URN mitigation technologies. (N =19)

Interview participants were in agreement and suggested more solutions:

*"I think we are still at the beginning stages. In order for South African shipbuilders to really contribute to the mitigation of URN, we need to start incorporating quieter propulsion."* (P17, SHEQ Manager, S2, 2025)

*"Mounts for loud machines and floating floors where feasible"* (P13, Marine Surveyor, CS, 2025).

#### Implementation barriers

Figure 25 illustrates the biggest challenges to implementing URN mitigation strategies in South Africa. The key barriers identified were high cost of noise reduction technologies, limited research and development in the field and insufficient industry awareness each at 24%.

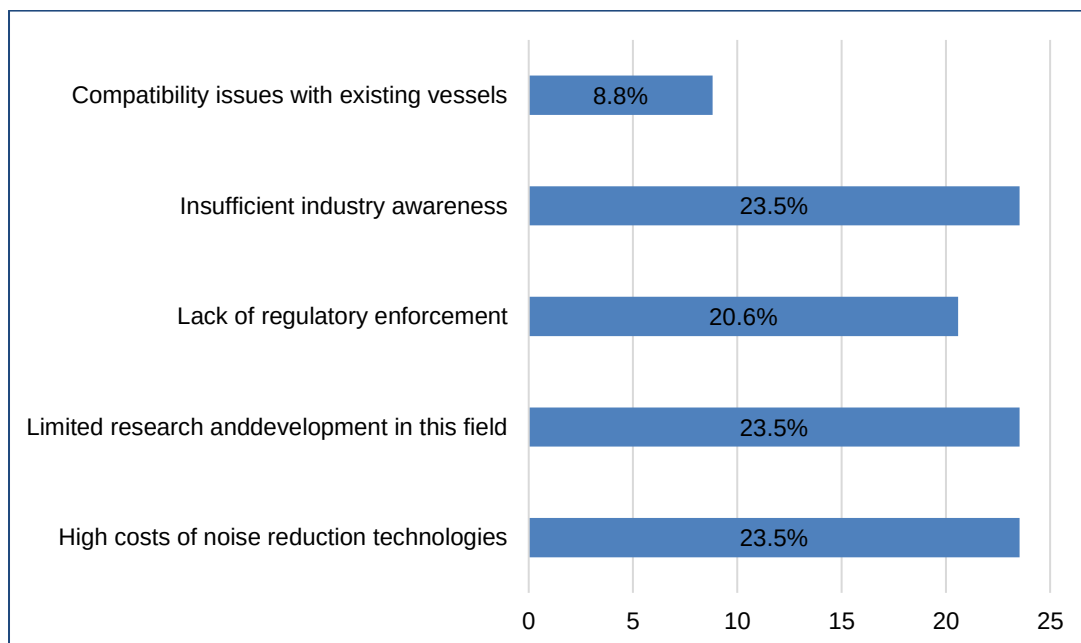


Figure 25: Challenges to implementing URN strategies in SA (N = 19)

Lack of regulatory enforcement followed closely behind (21%). One interview participant said:

*“I believe there are many options and that some will come up in the near future as well, but I also believe that the solutions are probably **expensive** and unless **regulations** require the use of the tools, only a few ship owners will consider them.”* (P15, Managing Director, S2, 2025)

The cost and lack of regulatory enforcement barriers align with findings by (Laursen, 2023) who observed that URN mitigation is often not prioritized unless regulations or market demand raises the requirement.

#### Potential of MEM Principles to address URN

Regarding the application of MEM principles, suggestions included:

*“Energy audits which will include URN surveys can help shipyards determine their impact and find ways to reduce it.”* (P13, Marine Surveyor, CS, 2025)

*“Electrifying transport within the shipyard might help”* (P7, Technician (Mechanical), S1, 2025)

*“We should take care of the noise issue in the design phases already, so all equipment used in the yard should be evaluated to see if there are quieter designs out there.”* (P18, ILS Manager, S2, 2025).

These observations echo the work of (Leaper, 2019) and IMO MEPC guidelines, which call for lifecycle noise impact assessments and integrated MEM strategies to address URN. They also align with the MEM framework suggested by (Acciaro et al., 2014), integrating operational efficiency, emissions reduction and noise mitigation into shipyard management systems.

#### 4.4.4. Implementation Strategies and Future Prospects

Figure 26 indicates that 75% of survey participants believe the shipping industry is moving in the right direction towards reducing its overall emission profile.

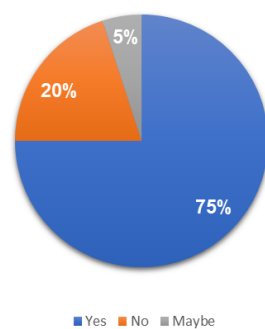


Figure 26: Industry movement towards emissions reduction (N = 20)

There is however still a need for further action in certain areas including provision of financial incentives for going green, raising awareness and establishing regulatory frameworks for green shipbuilding as illustrated by the word cloud on Figure 27.



Figure 27: What more could be done for the industry to move towards reducing its emissions (N = 20)

This is also supported by Figure 28 where regulations, market demand and corporate social responsibility, were ranked high as key drivers behind the transition to low or zero-carbon emission operations.

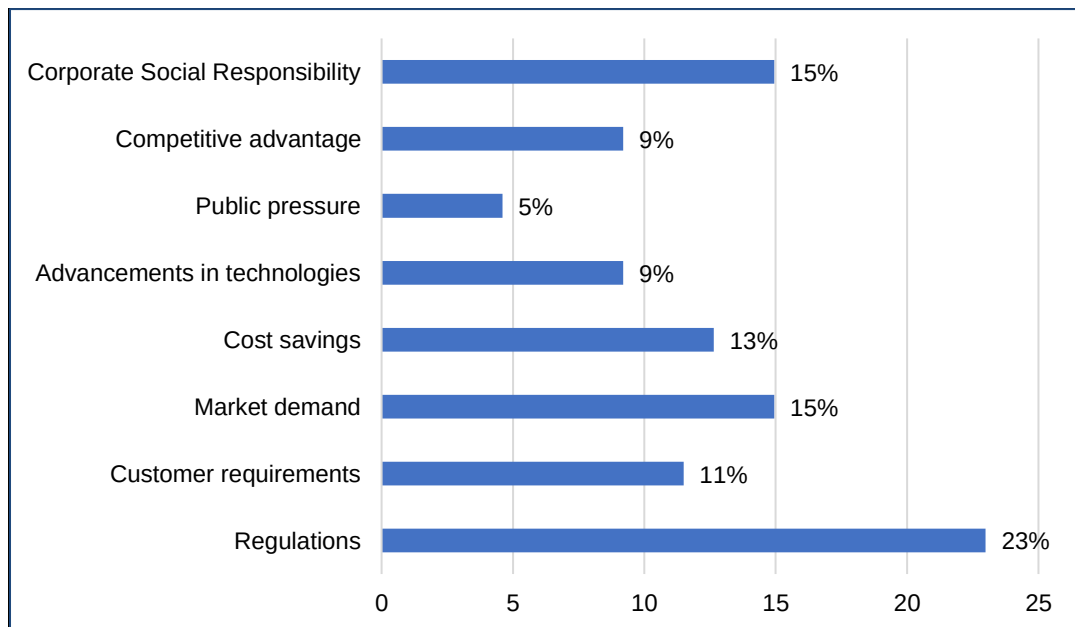


Figure 28: Key driving forces behind transition to low/zero emission operations (N=20)

The interview insights provided several themes which contribute to the development of the strategy:

#### Policy and regulatory frameworks

Several interview respondents emphasised the need for policy and regulatory frameworks:

*"We must start with regulations, then provide funding and make facilities available"* (P15, Managing Director, S2, 2025)

*"Create national policies that govern green shipbuilding in SA"* (P6, Quality Control (Piping), S1, 2025).

*"Stricter regulations and maybe tax refunds for purchasing green equipment and materials"* (P14, Supply Chain Manager S2, 2025)

*"If they make green shipbuilding a rule, then we as shipbuilders will have to follow it or bear the consequences. So, regulation is the way to go."* (P15, Managing Director, S2, 2025)

#### Collaboration and stakeholder engagement

Another recurring theme was collaboration and stakeholder engagement with participants noting:

*"The government must work hand in hand with the private sector"* (P1, Production Planner, S1, 2025)

*"We must learn from overseas companies that are already green"* (P9, Warehouse Supervisor, S1, 2025)

*"Knowledge sharing and learning from international partners who have been in the green shipbuilding space the longest"* (P17, SHEQ Manager, S2, 2025)

#### Capacity building and training

Capacity building and training were identified as key for long-term success, with suggestions to integrate green shipbuilding into maritime curricula:

*“Maritime institutions should start including green shipbuilding practices in their syllabus.”* (P13, Marine Surveyor, CS, 2025).

#### **Pilot projects and demonstrations**

Pilot projects were recommended in order to prove the feasibility of green technologies on a smaller scale before full-scale adoption:

*“Raise awareness, educate the shipbuilders and run pilot projects.”* (P5, Pipe Shop Supervisor, S1, 2025)

*“Education, collaboration, knowledge sharing, pilot programs”* (P17, SHEQ Manager, S2, 2025)

*“Pilot projects are always the best way to show that a system will work on a large scale.”* (P18, ILS Manager, S2, 2025)

#### **MEM principles for URN mitigation**

Participants linked the implementation of MEM principles for URN mitigation, with various recommendations:

*“Mounting loud machinery and using vibration reduction measures”* (P16, Regional Business Development Manager, CS, 2025)

*“We could try insulation and placing barriers between the machinery & the sea and maybe we need quieter engine designs.”* (P17, SHEQ Manager, S2, 2025)

*“Energy audits which will include URN surveys can help shipyards determine their impact and find ways to reduce it.”* (P13, Marine Surveyor, CS, 2025)

*“...through regular auditing and setting KPIs to check our progress on implementing the mitigation measures”* (P17, SHEQ Manager, S2, 2025)

Overall, the results suggest a multifaceted approach that combines data-driven decision-making, targeted capacity training, cooperative networks, financial incentives, regulatory clarification, and experimental projects. This holistic approach

is consistent with global decarbonisation roadmaps for maritime infrastructure (IMO, 2023), positioning South Africa to align its shipbuilding sector with emerging international sustainability standards while addressing its own unique economic and infrastructural context.

#### 4.5. PESTLE Analysis

The Political, Economic, Social, Technological, Legal and Environmental (PESTLE) analysis, is a powerful tool in providing a broader overview of the shipbuilding environment in South Africa. It looks beyond the internal factors of the shipbuilding operations, enabling stakeholders to plan for the long term. It encourages stakeholder engagement, leading to the development of a comprehensive roadmap with clear milestones taking the PESTLE factors into consideration for efficient planning.

Table 8 provides a summary of the PESTLE analysis conducted for the South African shipbuilding industry to transition to green shipbuilding and URN mitigation over three phases spanning 2025 to 2050, in alignment with international decarbonisation goals.

Table 8: PESTLE Analysis with key insights and key actions

| Category      | Key Insight                                                                        | Key Actions                                                                                                                                                                       |                                                                                                                 |                                                                                                                      |
|---------------|------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|
|               |                                                                                    | Phase 1<br>(2025 – 2030)                                                                                                                                                          | Phase 2<br>(2030 -2040)                                                                                         | Phase 3<br>(2040 – 2050)                                                                                             |
| Political     | No targeted legislation<br>International pressure to align with IMO strategies     | Draft a national green shipbuilding policy linked to Operation Phakisa and Oceans Master Plan<br>Set initial targets and incentives for pilot projects                            | Establish binding compliance milestones<br>Align national targets with IMO 2023 strategy                        | Position South Africa as a regional leader in green shipbuilding<br>Advocate for African maritime green standards    |
| Economic      | High costs and energy insecurity<br>Need for blended finance and public incentives | Introduce blended finance (public + private)<br>Offer tax relief for green retrofits and equipment<br>Stimulate demand via public procurement clauses                             | Expand concessional finance for retrofits and infrastructure<br>Create green investment funds for shipyards     | Attract international climate finance and private equity<br>Support export of green maritime technologies            |
| Social        | Skills exist but awareness is low<br>Training and public campaigns are essential   | Launch public awareness campaigns on URN and green shipbuilding<br>Develop vocational training modules and update curricula<br>Initiate exchange programs with advanced shipyards | Scale up training programs nationally<br>Partner with universities for research and innovation hubs             | Institutionalize green shipbuilding in maritime education<br>Foster a skilled workforce pipeline for future demand   |
| Technological | Limited automation<br>Prioritize low-cost tech<br>Establish shared R&D initiatives | Prioritize low-cost tech (solar, energy monitoring, vibration isolation)<br>Support shared R&D and equipment pools for small yards                                                | Pilot digital twin and energy management systems<br>Incentivize adoption of CNC and IoT tools                   | Fully digitize shipyard operations<br>Integrate AI and predictive maintenance systems                                |
| Legal         | No enforcement for URN<br>Align national policy with IMO guidance                  | Begin integrating IMO URN and MEM guidance into national regulations<br>Set voluntary compliance milestones for public contracts                                                  | Enforce URN mitigation standards for new builds and retrofits<br>Embed green compliance into maritime licensing | Harmonize national law with global maritime environmental standards<br>Create a compliance certification system      |
| Environmental | URN mitigation limited by cost<br>Integrate URN into compliance audits             | Pilot URN mitigation in selected yards<br>Include URN monitoring in MEM audits for funded projects                                                                                | Monitor GHG and URN reductions across pilot projects<br>Publish annual impact reports to guide future policy    | Achieve measurable reductions in URN and GHG emissions<br>Expand environmental audits to all maritime infrastructure |

#### 4.6. SWOT Analysis

This section presents the Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis for green shipbuilding and URN mitigation implementation in South Africa with a summarised version on Table 9.

Table 9: SWOT Analysis for green shipbuilding and URN mitigation in South Africa

| <b>S</b>                                                     | <b>W</b>                                                        | <b>O</b>                                                                                      | <b>T</b>                                                        |
|--------------------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-----------------------------------------------------------------|
| <b>Strengths</b>                                             | <b>Weaknesses</b>                                               | <b>Opportunities</b>                                                                          | <b>Threats</b>                                                  |
| Strategic geographical location along major shipping route   | High cost of green technologies and lack of financing           | Renewable energy integration (solar, wind, wave)                                              | Loadshedding, energy insecurity                                 |
| Increasing awareness of green shipbuilding practices         | Limited awareness and knowledge of green shipbuilding practices | International partnerships and knowledge transfer                                             | Few ship orders reduce motivation and investment capacity       |
| Abundant renewable energy resources                          | Regulatory gaps and lack of strict policy enforcement           | Growing global market demand for green ships and potential to attract international customers | Competition from large-scale foreign shipbuilders (e.g., China) |
| Existing shipyard facilities and skilled labour availability | Outdated infrastructure                                         | Cost benefits from using green technologies                                                   | Lack of national regulations on green shipbuilding              |

The inputs to the analysis were gathered from the literature review, secondary data analysis and triangulated with insights from shipbuilding stakeholders. The analysis conducted assesses South African shipyards' internal capabilities and limitations. External factors such as regulatory trends, market demand and environmental obligations are explored. The analysis concludes with the opportunities for technological discoveries as well as potential partnerships and finally, the threats posed by inaction or global competition.

### Strengths

South Africa's strategic geographical location along the Cape of Good Hope route provides an advantage for upcoming green shipbuilding opportunities. ([Invest SA, 2021](#)) Coupled with increasing awareness of green shipbuilding practices and an abundance of renewable energy sources, strengthen the country's potential to participate in the global green shipbuilding market. The existing shipyard facilities and availability of skilled labour add onto the strategic advantages that South Africa possesses.

### Weaknesses

The high cost of green technologies and lack of financing present major barriers towards the adoption of green shipbuilding practices in South Africa ([DoT, 2017](#)). Limited awareness and knowledge of green shipbuilding practices is still a gap, despite growing awareness. Lack of strict policies and regulations make the pace towards green transitioning, very slow. Finally, the effective transition to green shipbuilding in South Africa is hindered by outdated infrastructure which limits the country's ability to compete with global shipbuilding nations due to slower production cycles and an inability to meet evolving construction standards ([DoT, 2017](#)).

### Opportunities

South Africa has the strategic advantage of abundance in renewable energy sources (wind and solar), which present a major opportunity for the country to become a green energy hub. The country can take advantage of international partnership possibilities and engage in capacity building, workforce upskilling and knowledge transfer initiatives through partnerships with green shipbuilding nations. South Africa should take advantage of the growing demand for green ships in the global market and provide the service in order to gain international customers ([DoT, 2017](#)). A cost benefit analysis would show the financial gains that would be achieved through the use of green shipbuilding technologies.

### Threats

The energy security issue in South Africa, caused mainly by the country's energy provider, ESKOM, poses a major threat to reliability in production schedules and

operational continuity. This lowers the chances of shipyards receiving orders and demotivates potential investors. The country already has very few ship orders whilst competing with large-scale foreign shipbuilding nations such as China. The last threat is lack of national regulations on green shipbuilding which puts the country's shipbuilding industry at risk of falling behind on global standards.

#### 4.7. Synthesis of Results

The empirical findings (20 survey responses; 18 semi-structured interviews; site visits and comparative case study of Turkish shipyards) paint a consistent picture: South African shipbuilding has a credible foundation (skilled labour, existing yards and strategic location) but faces strong structural barriers to rapid green transition, primarily finance, policy or regulatory gaps and ageing infrastructure. These empirical results are reported throughout Chapter four (survey and interview counts, percentage rankings and verbatim quotes) and are summarised in the chapter's PESTLE, SWOT and thematic sections.

##### Key synthesized points:

- Barriers are mainly economic and regulatory. The survey and interviews rank “lack of financing / high cost of green technologies” and “inadequate regulatory framework” among the top barriers (the chapter reports finance, high costs, and regulatory weakness as dominant). This finding aligns with sector analyses showing capital intensity and financing gaps are principal constraints on shipyard decarbonisation and retrofits (DNV, 2022; OECD, 2021).
- Energy security (load-shedding) is a real operational threat but also an opportunity. The respondents tie the case for on-site renewables (solar/wind) to ESKOM problems; using local renewables to de-risk production and reduce operational energy cost is both logical and consistent with International Renewable Energy Agency (IRENA) and port decarbonisation literature. (IRENA, 2024).
- URN is well recognised by respondents as an environmental issue (high awareness in surveys) but practical mitigation is weak because of cost, limited R&D and lack of enforcement. The data shows priority mitigation options (vibration mitigation, noise barriers, optimized hull/propeller designs), which are consistent with the URN

technical literature that highlights machinery isolation, propeller design and cavitation management as primary mitigation levers (Smith & Rigby, 2022; Leaper, 2019).

- International collaboration and knowledge/technology transfer stand out as high-leverage opportunities. The Turkish case study supports this: Turkish yards have greater national/regulatory support and more mature adoption of digital and energy management practices (OECD, 2021; UNCTAD, 2023).
- MEM is a promising integrative framework. The respondents suggested energy audits, KPIs and lifecycle thinking, approaches that match port/yard energy management literature where authorities and yards coordinate energy use and renewables uptake (Acciaro et al., 2014).

Taken together, the quantitative (rankings, percentages) and qualitative (quotes, case observations) evidence in chapter four converge on a multi-pronged implementation approach (Figure 29):

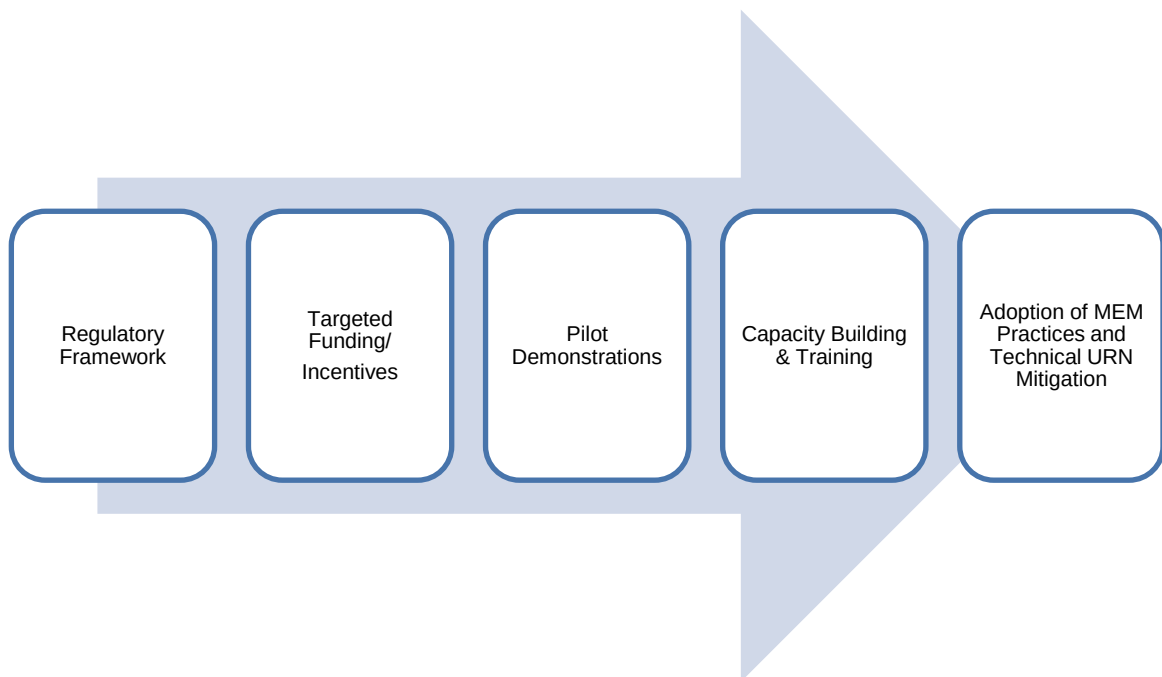


Figure 29: Multi-pronged approach to green shipbuilding and URN mitigation in South Africa

(Created by the author)

#### 4.8. Chapter Summary

Chapter 4 integrates survey (N=20), interview (N=18) and comparative case study evidence to evaluate the feasibility and barriers of green shipbuilding and URN mitigation in South Africa. The chapter finds that South Africa has important latent strengths; a strategic location, existing yards and technical skills, that make it a plausible candidate for niche green shipbuilding and retrofit services. However, the dominant constraints are financial (high capital costs, weak access to green finance), regulatory (lack of specific national green shipbuilding standards and enforcement), and infrastructural (outdated yards and constrained supply-orders). Stakeholders emphasised practical, short-term actions:

1. Create a clear national policy
2. Establish dedicated financial incentives for shipyards which adopt green practices early
3. Implement pilot projects and integrate MEM principles (audits, KPIs, life-cycle thinking) into practice shipyard operations.

These results demonstrate the distinct South African environment influenced by loadshedding and limited ship orders, while also being in line with international decarbonization roadmaps, the IMO's updated 2023 policy, and port energy transition literature.

#### 4.9. Limitations of the study

Chapter four offers insightful information into the challenges and opportunities for green shipbuilding and URN mitigation in South Africa; however, a number of limitations must be noted:

1. Purposive and convenience sampling techniques were used to gather data for the survey (N=20) and interview (N=18), both of which have comparatively small sample sizes. This sample size is therefore not statistically representative of the entire South African maritime industry and the results should be viewed as exploratory and indicative.

2. Efforts were made to include a variety of stakeholders; however, some groups including legislators and financial institutions were not well represented, which might have limited the range of insights on regulatory and investment matters.
3. There were no environmental impact assessments for the South African shipyards as the requirement only came in with the implementation of the NEMA and both shipyards were already in operation. Therefore, accurate measurements of URN were not accessible, which makes it difficult to determine the full extent of URN from the shipyard processes.

## Chapter 5: Proposed Strategy for South Africa

### 5.1. Introduction

The global maritime industry is under increasing pressure to reduce its environmental impact on the environment through GHG emissions reduction and recently, URN has become a pressing issue as it negatively affects marine ecosystems. The IMO's revised GHG strategy, with more ambitious targets, necessitates that shipowners either consider retrofitting their existing vessels or order greener vessels in order to become and remain compliant. This presents a business opportunity for South Africa, and since shipbuilding is not a foreign concept to the country, taking advantage of this opportunity is well worth the country pursuing. South Africa could achieve multiple strategic objectives through green shipbuilding, including but not limited to:

- Job creation
- Enhanced competitiveness in the global market
- Fulfilment of Paris Agreement and NDC commitments
- Just energy transition support

The **vision statement** for the proposed strategy is:

*“To build capacity for South Africa to become a global competitor in green shipbuilding and URN mitigation by 2050, through international partnerships, capacity building, regulations, innovation, and implementation of maritime energy management principles, while meeting global decarbonisation targets.”*

Various factors prevent South Africa from reaching its full potential in shipbuilding, these include a lack of policies which align with global maritime regulations, slow developments in infrastructure upgrades and a limited number of capacity building initiatives. The Turkish government supports investments in renewable energy, R&D, environmental certification systems and digitalization (Simsek & Simsek, 2013), which

has assisted the Turkish shipbuilding industry in implementing green shipbuilding practices effectively. The South African government has national frameworks in place such as Operation Phakisa and the CMTP which aim to revive the South African shipbuilding industry (DoT, 2017) however, these frameworks do not present an actionable implementation plan which focuses mainly on green shipbuilding and URN mitigation. This study therefore aims to address this gap.

## 5.2. Strategy Overview

The proposed strategy consists of clear milestones and responsibilities. It provides a comprehensive roadmap for South Africa to efficiently transition into green shipbuilding and URN mitigation by 2050. It is developed through a combination of inputs from industry professionals in both South Africa and Türkiye; and key insights from the literature reviewed. The strategy outlines five main pillars and is divided into three major phases illustrated on Figure 30:

- Phase 1 (2025 – 2030): Foundation and Pilots
- Phase 2 (2030 – 2040): Scale and Institutionalise
- Phase 3 (2040 – 2050): Market Leadership and Compliance

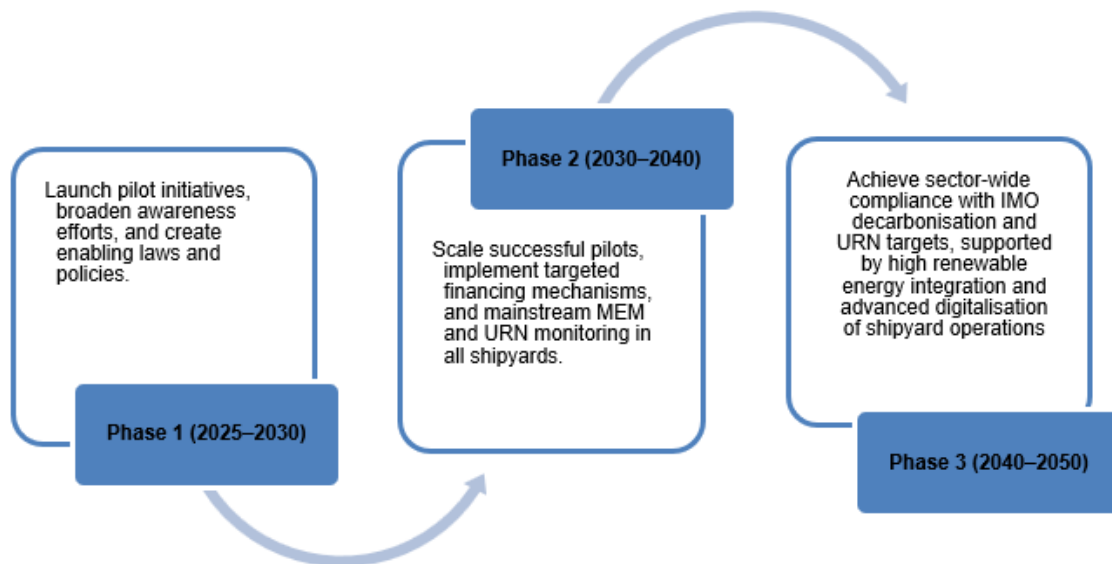


Figure 30: Three-phase strategy  
(Created by the author)

The effective implementation of the strategy will largely depend on the stakeholders engaged and the manner in which they are handled. Figure 31 illustrates a proposed stakeholder engagement matrix for the successful implementation of green shipbuilding and URN mitigation in South Africa.

|       |      |                                                                                                                                            |                                                                                                                                                                                                             |
|-------|------|--------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Power | High | <b>Keep Satisfied<br/>(Low Interest, High Power)</b><br><br>TPT<br>SAN<br>National Treasury<br>International Organisations (IMO, AU, IORA) | <b>Manage Closely<br/>(High Interest, High Power)</b><br><br>DoT<br>SAMSA<br>TNPA<br>DFFE<br>Shipyards & Marine Engineering Firms<br>Private Shipping Companies<br>DTIC<br>Invest SA/IDC                    |
|       | Low  | <b>Monitor<br/>(Low Interest, Low Power)</b><br><br>SARS - Customs                                                                         | <b>Keep Informed<br/>(High Interest, Low Power)</b><br><br>SAIMI<br>NPCC<br>Maritime Unions & Labour Organisations<br>Universities & Research Institutions<br>SAWS<br>Environmental NGO's & Advocacy Groups |
|       |      | Low                                                                                                                                        | High                                                                                                                                                                                                        |
|       |      | Interest                                                                                                                                   |                                                                                                                                                                                                             |

Figure 31: Stakeholder matrix for South African shipbuilding industry

(Created by the author)

The roadmap is depicted on Figure 32 highlighting five pillars for implementation throughout the next twenty-five (25) years:

1. Financing
2. Regulation and Policy
3. Skills and Capacity Development
4. Infrastructure and Technology
5. Niche Market Creation

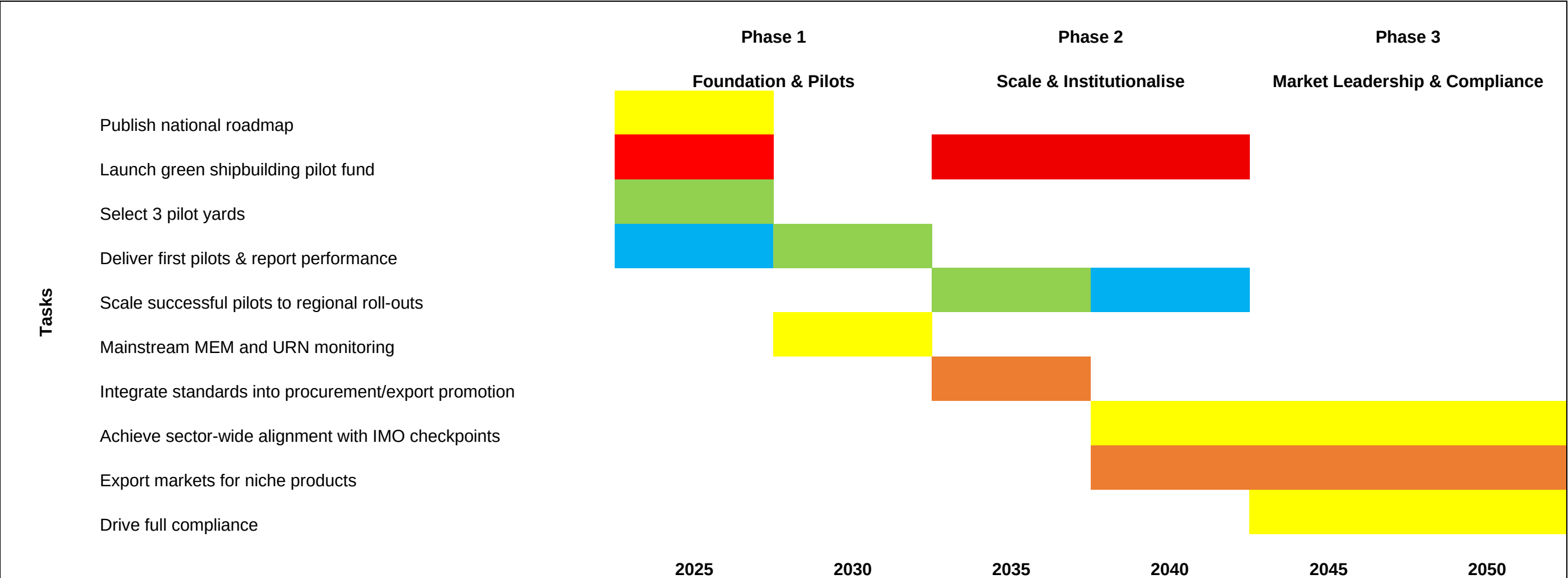
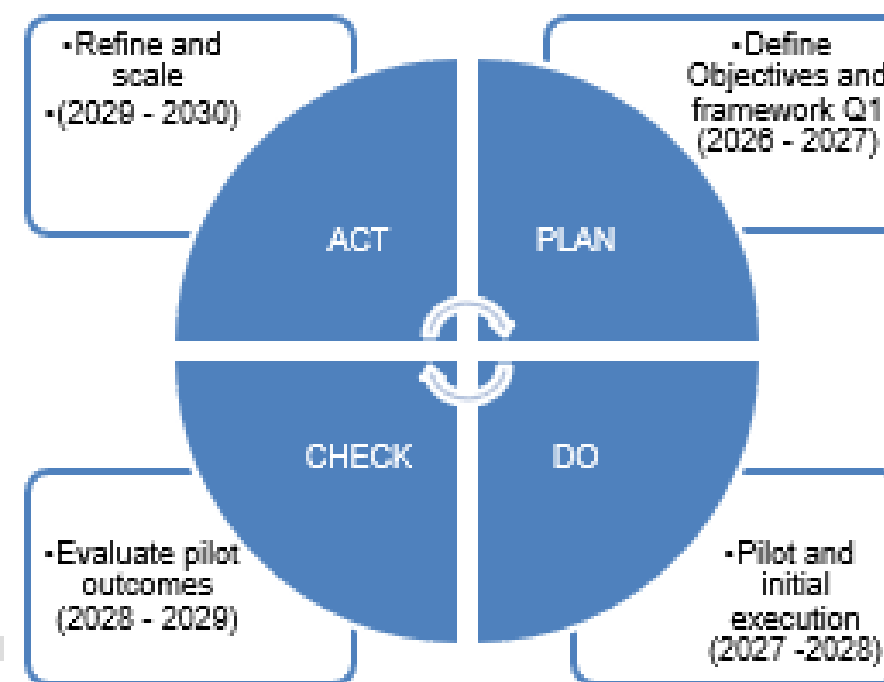


Figure 32: Green shipbuilding and URN mitigation roadmap (2025 - 2050)  
(Created by the author)



Phase two is broken down further on [Figure 33](#) in to a Plan-Do-Check-Act cycle for more efficient implementation of the proposed strategy. In the **PLAN** stage, objectives are refined and aligned with international standards like IMO GHG and URN mitigation, while financing models and workforce strategies are tailored for broader impact. The **DO** phase focuses on implementing these actions through capacity-building, partnerships, and pilot project expansion. During **CHECK**, outcomes such as GHG reductions and regulatory effectiveness are evaluated, with stakeholder engagement ensuring data validation. Finally, the **ACT** phase drives further refinement, launching retrofitting programs and URN monitoring frameworks to reinforce long-term sustainability.

- Revise strategies in all five pillars: update regulations, expand training, accelerate infrastructure upgrades, tailor financing models, refine niche-market entry (e.g., green vessel export).
- Publish standardized guidelines and scale successful pilots across South Africa.
- Institutionalize maritime energy management principles and URN mitigation standards.
- Prepare next PDCA iteration targeting expanded capacity until 2050



- Analyse measured GHG emissions reduction, URN mitigation success, workforce uptake, regulatory effectiveness.
- Review against planned performance metrics and regulatory compliance.
- Identify deviations: barriers, systemic inefficiencies, infrastructure gaps.
- Engage stakeholders—industry professionals from SA and Türkiye—for feedback and data validation.

- Build capacity via international partnerships, regulations, innovation.
- Set clear targets: green shipbuilding capacity, URN thresholds, job targets, emissions reduction consistent with IMO/GHG strategy.
- Identify gaps: policy misalignment, infrastructure shortfalls, skill shortages.
- Design regulatory, financial, capacity, infrastructure, and niche-market pillars.  
→ Align with Paris Agreement and South Africa national frameworks (e.g., CMTF, Operation Phakisa).

- Launch pilot initiatives: e.g., retrofitting one existing vessel, establishing URN monitoring routine.
- Begin capacity-building programs, seed infrastructure upgrades (e.g. one upgraded dock or local tech transfer via Türkiye partnerships).
- Implement draft regulations or incentives on small scale.
- Document implementation progress and gather data on emissions, URN levels, workforce readiness.

Figure 33: Proposed Strategy PDCA Cycle

Building on the analysis above, a multifaceted approach is required to achieve green shipbuilding in South Africa. This strategy must link policy, finance, technology, and education to simultaneously cut emissions and noise. Key elements include:

- **Strengthening Governance and Policy Alignment:** IMO workshops suggest the formation of specialised national maritime decarbonisation task forces to coordinate the incorporation of global environmental standards into national legislation across agencies. Building on SAMSA's recent noise initiative, the country should finalize the URN-EIA data and promulgate noise guidelines for all yards and ports.
- **Incentivizing Infrastructure and Finance:** Government incentives are needed to lower the cost barriers to clean technology. This could include tax credits or grants for green retrofit projects, loans for renewable energy installations at yards, and partial subsidies for low-emission fuel supply infrastructure. Demonstration projects, such on-site solar power systems or electric/hybrid yard cranes, can be funded in part through public-private partnerships.
- **Integrating MEM in Shipyard Operations:** Shipyards and their clients should be encouraged or required to adopt MEM processes. This means performing comprehensive energy audits and setting KPIs. Embedding a culture of continuous improvement will yield both decarbonisation and noise reduction gains, since many efficiency measures also cut mechanical noise.
- **Deploying Noise Mitigation Technologies:** To directly tackle URN, shipbuilders and operators must incorporate noise reduction in design and retrofit. Importantly, an energy-focused strategy naturally aids URN mitigation. As noted in recent studies and BIMCO guidance, the very measures that cut CO<sub>2</sub> (e.g. waste-heat recovery or efficient propellers) often reduce sound levels by several decibels (BIMCO & ICS, 2024).
- **Enhancing Skills and Awareness:** A just transition requires training the workforce and decision-makers. South Africa should incorporate MEM and URN management into maritime curricula at universities and technical colleges (leveraging SAIMI). Raising awareness among shipowners and financiers is also

key; for instance, sharing case studies where green retrofits paid back and opened export markets.

- **Fostering International and Regional Collaboration:** Given South Africa's maritime position, strategic partnerships are valuable. Participation in IMO initiatives (such as the GloNoise Partnership) provides expertise and funding support. South Africa can also learn from countries with similar shipbuilding ambitions: for example, Türkiye has pursued public-private reforms and scale-up measures (OECD analysis) that could inform SA strategy.

In summary, South Africa can establish a competitive, low-emission shipbuilding base by enforcing its own standards in accordance with IMO principles and by providing incentives for green innovation. Importantly, the strategy explicitly treats URN on par with GHGs, ensuring that as South Africa “moves from statements to strategies” on climate, it also safeguards its marine environment and complies with emerging noise standards.

## Chapter 6: Conclusion & Recommendations

The final chapter presents the key insights of the study, summarising key findings and outlining strategic recommendations for advancing green shipbuilding in South Africa. It reflects on the feasibility of integrating MEM and URN mitigation, and highlights the environmental, economic, and policy implications. The chapter closes with future research directions and a call to action for stakeholders.

### Key Message

The study has demonstrated that although South Africa still has many obstacles to overcome, green shipbuilding is feasible for implementation, particularly through methodological adoption of MEM principles and URN mitigation. The key to successful implementation lies in taking advantage of the country's abundant renewable energy sources, established maritime infrastructure and strategic geographical location. By addressing the identified challenges with funding, regulations and scalability, South Africa can transform its shipbuilding industry to becoming a globally competitive and sustainable enterprise.

### Key Research Findings

The study revealed the following:

1. South Africa's main challenges include limited financial support, inadequate regulatory framework and small number of ship orders (lack of economies of scale).
2. South Africa's key strengths are the abundance of renewable energy sources, well established shipbuilding and repair facilities; and a strategic location among a major shipping route.
3. URN and decarbonisation are becoming intertwined environmental concerns, with global research demonstrating that slow steaming, sophisticated hull designs and the use of alternative fuels, reduce both CO<sub>2</sub> emissions and URN.

4. There is momentum on URN mitigation from numerous ongoing initiatives such as IMO workshops and the URN-EIA led by SAMSA, which provide a foundation for coordinated efforts.

### Broader Implications

In South Africa, implementing green shipbuilding practices has two major benefits for the environment: it reduces GHG emissions and protects marine ecosystems by reducing URN.

Additionally, the economic contribution of a green shipbuilding industry includes the potential to speed up the achievement of the country's national development goals by attracting investment, promoting knowledge transfer and capacity building; and providing employment.

Finally, South Africa's experience in transitioning to green shipbuilding practices can serve as a model for other developing countries looking into decarbonising their maritime industries whilst remaining competitive in the global shipbuilding market.

### Main Research Contributions

The study produced the following main research contributions:

- Developed a structured strategy for incorporating MEM principles and URN mitigation methods into South African shipbuilding.
- Identified key enablers and barriers specific to the South African context.
- Demonstrated that the combination of decarbonisation and URN mitigation methods provide simultaneous environmental benefits.
- A detailed, phased roadmap was outlined, highlighting policy, funding requirements, capacity building and regulatory milestones to assist stakeholders in the transition to green shipbuilding.

### Future Direction

There are areas that require further research and it would be beneficial for South Africa to pursue the following route:

1. Conduct quantitative cost benefit analyses of MEM solutions such as renewable energy integration in the shipyards.
2. Conduct field measurements of URN in shipyards and major ports to create baselines and set reduction targets.
3. Conduct studies on the socioeconomic impacts of green shipbuilding with the main focus aligning with the Just-Energy-Transition framework.
4. Conduct case studies of green shipbuilding in other developing countries to benchmark and extract transferable strategies.

### Call to Action

As a call to action, the following final statements bring us to the end of this study:

1. The CMTP should be finalised and implemented with specific green shipbuilding and URN mitigation measures.
2. Enforce the requirement for shipyards to submit energy management plans and URN control strategies for registration through SAMSA, TNPA and other relevant organisations.
3. Make provision for incentives such as tax breaks, subsidies and green loans for companies adopting green shipbuilding practices and addressing URN.
4. Facilitate collaboration between academia and industry on pilot projects and demonstrations of green technologies.
5. Include MEM and URN mitigation in local maritime institutions' curricula.
6. Establish a collaborative "Green Shipbuilding Task Force" to supervise implementation, monitor progress using specific KPIs and continuously improving the transition through the PDCA cycle included in the proposed strategy.

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## Appendices

### Appendix 1: Survey Questions

#### **Exploring Challenges & Opportunities for Green Shipbuilding in South Africa – A Maritime Energy Management Perspective**

##### Survey

##### **Introduction**

1. Please select a category your work fits into.
  1. Shipbuilding & Engineering Professionals
    - a. Shipbuilding, repair & ship design
    - b. Energy/technology provider
  2. Regulatory & Policy Experts
  3. Financial & Investment Stakeholders
  4. Ship Operators & End-Users
    - a. ship operation & management company
    - b. Shipowner
  5. Research & Academia
  6. Trade Unions & Workforce Development
- Other – Please specify \_\_\_\_\_

##### **Underwater Radiated Noise (URN)**

2. Are you aware of the environmental impacts of underwater radiated noise (URN) from shipbuilding and operations?  
Yes / No
3. Which URN mitigation technologies do you think are viable for South Africa? (Select all that apply)
  - a. Optimized Hull Design
  - b. Propeller Modifications
  - c. Noise Barriers and Insulation
  - d. Engine and Propulsion Upgrades
  - e. Vibration mitigation measures
  - f. Other (Please specify) \_\_\_\_\_
4. What are the biggest challenges to implementing URN mitigation strategies in South Africa? (Select all that apply)
  - a. High costs of noise reduction technologies
  - b. Limited research and development in this field
  - c. Lack of regulatory enforcement
  - d. Insufficient industry awareness
  - e. Compatibility issues with existing vessels
  - f. Other (Please specify) \_\_\_\_\_
5. How important do you believe URN reduction is compared to GHG reduction? (Rate from 1 to 5, where 1 = Not Important and 5 = Very Important)

##### **Shipbuilding**

6. What are the key barriers preventing the adoption of green shipbuilding in South Africa? (Select all that apply)
  - a. Lack of Financing

- b. Shortage of Skilled Labor in the product phase in shipyards
  - c. Inadequate Regulatory Framework
  - d. High Cost of Green Technologies
  - e. Limited Awareness and Knowledge
  - f. Lack of expertise in green ship design
  - g. Lack of economies of scale
  - h. Other (Please specify) \_\_\_\_\_
7. What do you see as South Africa's greatest strength in green shipbuilding?  
(Select all that apply)
- a. Abundant Renewable Energy Sources
  - b. Existing Shipyard Facilities
  - c. Strategic Location Along Major Shipping Routes
  - d. Skilled Labor Availability
  - e. Other (Please specify) \_\_\_\_\_
8. What do you believe are the key driving forces behind the transition to low or zero-emission operations?
- a. Regulations
  - b. Customer requirements
  - c. Market demand
  - d. Cost savings
  - e. Advancements in technologies
  - f. Public pressure
  - g. Competitive advantage
  - h. Corporate Social Responsibility (CSR)
9. Do you believe the shipping industry is moving in the right direction towards reducing its overall emissions profile?  
Yes/No. Please elaborate.
10. If you think more could be done for the industry to move towards reducing its emissions, please share your thoughts here:

11. What are the top 5 energy sources you believe shipyards will use for operations in 2030 & 2050?

| Energy source                              | 2030                  | 2050                  |
|--------------------------------------------|-----------------------|-----------------------|
| Traditional fossil fuels (HFO, VLSFO, MGO) | <input type="radio"/> | <input type="radio"/> |
| Alternative fossil fuels (LNG, LPG)        | <input type="radio"/> | <input type="radio"/> |
| Ammonia                                    | <input type="radio"/> | <input type="radio"/> |
| Biofuels                                   | <input type="radio"/> | <input type="radio"/> |
| Hydrogen                                   | <input type="radio"/> | <input type="radio"/> |
| Methanol                                   | <input type="radio"/> | <input type="radio"/> |
| Low-emission fuels (other)                 | <input type="radio"/> | <input type="radio"/> |
| Batteries                                  | <input type="radio"/> | <input type="radio"/> |
| Nuclear                                    | <input type="radio"/> | <input type="radio"/> |

12. Please give more detail about your answer to question 12.

13. Are you aware of any South African shipyards that use renewable energy sources? (wind, tidal, wave, solar, etc)

Yes/No

14. How familiar are you with the following green ship building practices?

| Stage                                  | Green Shipbuilding Practice                               | Not familiar at all   | Slightly familiar     | More familiar         | Very familiar         |
|----------------------------------------|-----------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| <b>Design &amp; Materials</b>          | Energy-efficient hull design                              | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|                                        | Use of recycled & eco-friendly materials                  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|                                        | Smart hull coatings to reduce drag                        | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| <b>Construction Techniques</b>         | Modular shipbuilding to reduce waste                      | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|                                        | Lean manufacturing & robotic automation                   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|                                        | Sustainability-focused production planning                | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|                                        | Green welding techniques                                  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| <b>Digitalization &amp; Compliance</b> | Real-time emissions monitoring                            | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|                                        | Compliance with IMO Green Shipping Regulations            | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|                                        | AI-driven route optimization                              | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| <b>Facilities &amp; Infrastructure</b> | Layout optimization for energy efficiency                 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|                                        | Use of renewable energy (hydro, solar, wind) in shipyards | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
|                                        | Green transportation equipment for moving ship sections   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

15. Are there any green shipbuilding practices that are not included in the list above? Please share them here:

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16. Which low or zero-emission green shipbuilding practices do you believe have the most potential (and why)?

17. Where does your company source information on low or zero-emission green shipbuilding practices?

Please select in order of 1-10 to rate how likely your company is to use a particular information source, 1 representing least likely and 10 representing most likely.

|                                          | 1                     | 2                     | 3                     | 4                     | 5                     | 6                     | 7                     | 8                     | 9                     | 10                    |
|------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| IMO/ISO/Other official documentation     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Class Societies                          | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Industry Reports                         | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Maritime Media                           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Individual Company Publications/Websites | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Internal Research                        | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Academic Research                        | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Word of Mouth/Network                    | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Other                                    | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Other: Please specify:

18. Do you think better/greater information provision about green shipbuilding practices is needed?

Yes/No

19. If you answered "yes" to question 17, what kind of information?

20. Considering the following factors, how important will each be in driving the development and uptake of green shipbuilding practices in the future?

|                                     | Not important | Very low importance | Low importance | Moderate importance | Important | Very important |
|-------------------------------------|---------------|---------------------|----------------|---------------------|-----------|----------------|
| Energy price                        |               |                     |                |                     |           |                |
| Increased funding available for R&D |               |                     |                |                     |           |                |

|                                                        | Not important | Very low importance | Low importance | Moderate importance | Important | Very important |
|--------------------------------------------------------|---------------|---------------------|----------------|---------------------|-----------|----------------|
| and demonstration                                      |               |                     |                |                     |           |                |
| Increased access to information regarding technologies |               |                     |                |                     |           |                |
| Improvement in ROI                                     |               |                     |                |                     |           |                |
| Legislation tightened on emissions                     |               |                     |                |                     |           |                |
| Carbon emission controls – cap                         |               |                     |                |                     |           |                |
| Pressure from non-shipping stakeholders                |               |                     |                |                     |           |                |
| Social Pressure                                        |               |                     |                |                     |           |                |
| Environmental pressure                                 |               |                     |                |                     |           |                |
| Climate change & global warming                        |               |                     |                |                     |           |                |

Other: Please specify:

21. Consider the following factors, how important will each be in disabling barriers to green shipbuilding practices uptake? [Please rate the importance of each factor]

|                                          | Not important | Very low importance | Low importance | Moderate importance | Important | Very important |
|------------------------------------------|---------------|---------------------|----------------|---------------------|-----------|----------------|
| Highly ambitious decarbonisation targets |               |                     |                |                     |           |                |
| Strengthen regulatory measures           |               |                     |                |                     |           |                |
| Market-based measures                    |               |                     |                |                     |           |                |
| Regional/International Funding/Subsidies |               |                     |                |                     |           |                |
| National Government Funding/Subsidies    |               |                     |                |                     |           |                |
| Create a knowledge database              |               |                     |                |                     |           |                |
| Research Support                         |               |                     |                |                     |           |                |

Other: Please specify:

\_\_\_\_\_

22. Do you have any additional thoughts or insights on green shipbuilding in South Africa?

## Appendix 2: Interview Questions

### Exploring Challenges & Opportunities for Green Shipbuilding in South Africa – A Maritime Energy Management Perspective

#### Interview Questions

##### **1. General**

- a. Please describe your position & role in the shipbuilding industry.
- b. Are you familiar with MEM principles and green shipbuilding practices?
- c. What role does green shipbuilding play in South Africa's maritime industry?

##### **2. Challenges of green shipbuilding in South Africa**

- a. What are the main barriers to South Africa's adoption of green shipbuilding practices?
- b. Do you believe that South Africa possesses the technical expertise and skills set required for green shipbuilding? Please elaborate.
- c. Do current regulations in shipbuilding support or hinder the implementation of green shipbuilding practices? How?
- d. What challenges do businesses encounter when transitioning to green shipbuilding practices?
- e. How do supply chain constraints affect the use of eco-friendly materials in shipbuilding?
- f. What impact does South Africa's small number of new ship orders have on the viability and affordability of green shipbuilding?

##### **3. Opportunities for green shipbuilding in South Africa**

- a. How can South Africa promote green shipbuilding by using its renewable energy sources such as wind, solar, etc?
- b. Does the country have any active programs or projects that support green shipbuilding?
- c. How can South Africa enhance its capacity for green shipbuilding through international partnerships?
- d. How can the government support green ship building?
- e. How can the private sector support green shipbuilding?

##### **4. Environmental impact assessment & URN**

- a. To what extent does South Africa's current shipbuilding methods contribute to Underwater Radiated Noise (URN)?
- b. What tools or techniques can be used to lower URN during shipbuilding processes?
- c. Do you believe regulators and shipbuilders in South Africa understand how URN affects the underwater life?
- d. How is URN pollution being handled currently in the South African shipbuilding industry?
- e. How can the South African maritime industry use MEM principles to reduce URN pollution?

##### **5. Implementation techniques & future prospects**

- a. What incentives or policy modifications would motivate more businesses to use green shipbuilding practices?
- b. How might education & training (capacity building) initiatives assist in developing competencies for South African green shipbuilding?
- c. What steps should be taken in developing a roadmap for green shipbuilding in South Africa?
- d. In terms of sustainability, how do you envision the shipbuilding industry in South Africa developing in the next 10-20 years?
- e. Would you like to add final comments or suggestions?

### Appendix 3: South African Shipbuilding Industry Stakeholders

| Serial Number | Stakeholder                                                                                             | Role in the South African Maritime Industry                                                                                                                                                          |
|---------------|---------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1             | Department of Transport (DoT)                                                                           | National policymaker and regulator for maritime transport under the National Transport Master Plan (NATMAP) and Comprehensive Maritime Transport Policy (CMTF).                                      |
| 2             | South African Maritime Safety Authority (SAMSA)                                                         | Ensures safety of life and property at sea; regulates maritime safety, security, marine pollution, and seafarer development. Also administers ship registration and maritime training accreditation. |
| 3             | Transnet National Ports Authority (TNPA)                                                                | Operates and manages South Africa's commercial ports. Provides port infrastructure, pilotage, dredging, and marine services. Plays a role in port decarbonisation and infrastructure upgrades.       |
| 4             | Transnet Port Terminals (TPT)                                                                           | Handles cargo operations at the ports including containers, bulk, and automotive. Key player in energy management at terminals and supporting logistics efficiency.                                  |
| 5             | National Department of Environment, Forestry and Fisheries (DFFE)                                       | Oversees marine environmental protection, ocean conservation, and implementation of the Ocean Economy Operation Phakisa goals.                                                                       |
| 6             | South African International Maritime Institute (SAIMI)                                                  | Coordinates maritime education, research, and skills development nationally. Supports green shipping and blue economy innovation.                                                                    |
| 7             | South African Navy (SAN)                                                                                | Responsible for maritime defense, patrols, and supporting marine sovereignty and anti-piracy efforts. Sometimes collaborates on training and maritime domain awareness.                              |
| 8             | National Ports Consultative Committee (NPCC)                                                            | Advises on port user needs and regulatory issues. Composed of port users, operators, and TNPA representatives.                                                                                       |
| 9             | South African Shipyards & Maritime Engineering Firms (e.g., Sandock Austral, Damen Shipyards Cape Town) | Design, build, and repair vessels. Vital for green shipbuilding, technology integration, and local manufacturing.                                                                                    |
| 10            | Maritime Unions & Labour Organizations (e.g., SA Transport and Allied Workers Union - SATAWU)           | Represent workers' rights in the maritime and port sectors, influence training standards and workplace safety.                                                                                       |

|    |                                                                                                       |                                                                                                                                            |
|----|-------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| 11 | Universities & Research Institutions (e.g., CPUT, Nelson Mandela University, Stellenbosch University) | Provide research, innovation, and capacity development in maritime studies, shipbuilding, marine engineering, and ocean sciences.          |
| 12 | Private Shipping Companies (e.g., Unicorn Shipping, Safmarine [Maersk])                               | Operate fleets in regional and international waters; influence demand for shipbuilding, crewing, and emissions compliance.                 |
| 13 | South African Revenue Service (SARS) – Customs                                                        | Regulates import/export through ports, plays a role in trade facilitation and port throughput efficiency.                                  |
| 14 | Department of Trade, Industry and Competition (DTIC)                                                  | Promotes industrial development, incentives for shipbuilding, marine manufacturing and innovation. Oversees Special Economic Zones (SEZs). |
| 15 | National Treasury                                                                                     | Finances public maritime infrastructure projects and administers incentives and green transition funding.                                  |
| 16 | South African Weather Service (SAWS)                                                                  | Provides marine weather forecasts and oceanographic data critical for safety, efficiency, and research.                                    |
| 17 | Environmental NGOs & Advocacy Groups (e.g., GreenCape, WWF-SA)                                        | Advocate for sustainable maritime practices, marine conservation, and decarbonisation policies.                                            |
| 18 | InvestSA / Industrial Development Corporation (IDC)                                                   | Support investment in maritime infrastructure, renewable energy integration in ports, and shipyard upgrades.                               |
| 19 | International Organizations (IMO, AU, IORA)                                                           | Influence regulatory compliance, technical cooperation, and alignment with international maritime standards.                               |

## Appendix 4: Mapping of Research Instruments to Analytical Themes

Mapping of research instruments to analytical themes.

| Chapter 4 Topic                                                                                    | Source    | Question Numbers           |
|----------------------------------------------------------------------------------------------------|-----------|----------------------------|
| Barriers to Implementing Green Shipbuilding Practices in SA                                        | Survey    | Q6, Q18, Q17, Q19, Q20     |
|                                                                                                    | Interview | Q2(a-e)                    |
| Opportunities for Green Shipbuilding Practices in the SA Shipbuilding Industry                     | Survey    | Q7, Q8, Q11, Q12, Q13, Q16 |
|                                                                                                    | Interview | Q3(a-e), Q5d               |
| Environmental Impacts of Traditional Shipbuilding and the Role of MEM Principles in URN Mitigation | Survey    | Q2, Q3, Q4, Q5             |
|                                                                                                    | Interview | Q4(a-e)                    |
| Proposed Strategy for Promoting Green Shipbuilding and URN Reduction in SA                         | Survey    | Q8, Q9, Q20                |
|                                                                                                    | Interview | Q5(a-c), Q5e               |

## Appendix 5: Maritime Institutions in South Africa

| <b>Institution Name</b>                               | <b>Type</b>           | <b>Description</b>                                                      |
|-------------------------------------------------------|-----------------------|-------------------------------------------------------------------------|
| <b>Cape Peninsula University of Technology (CPUT)</b> | Technical University  | Academic maritime programs                                              |
| <b>Cape Town Maritime College</b>                     | Training College      | SAMSA-accredited training from Able Seafarer to Chief Engineer.         |
| <b>SA Maritime School &amp; Transport College</b>     | Private College       | Offers diplomas and certificates in shipping, logistics, and transport. |
| <b>Sea Safety Training Group (SSTG)</b>               | Training Provider     | STCW and STCW-F maritime training (deck & engine).                      |
| <b>Seatrain</b>                                       | Training Centre       | Offers STCW-compliant short courses; based in Simon's Town.             |
| <b>Southern Seas Institute (SSI)</b>                  | Training Institute    | Vocational and seafarer training; Durban-based.                         |
| <b>False Bay TVET College</b>                         | TVET College          | Offers boat-building and marine-related courses.                        |
| <b>Transnet Maritime School of Excellence</b>         | Corporate Training    | Maritime and rail technical training; owned by Transnet.                |
| <b>SA Maritime Training Academy (SAMTRA)</b>          | Private Training      | Offers STCW and simulator-based maritime training.                      |
| <b>SA International Maritime Institute (SAIMI)</b>    | National Coordinator  | Coordinates maritime skills development and research nationally.        |
| <b>Maritime Centre of Excellence</b>                  | Training/Coordination | TVET-based maritime skills training.                                    |
| <b>College for Business &amp; Maritime Studies</b>    | Private College       | Combines maritime, logistics, and business education.                   |

## Appendix 6: Maritime Institutions in Türkiye

| Institution Name                            | Type                   | Description                                                                                            |
|---------------------------------------------|------------------------|--------------------------------------------------------------------------------------------------------|
| Istanbul Technical University (ITU)         | University             | Faculty of Naval Architecture and Ocean Engineering; includes model testing lab.                       |
| Piri Reis University                        | Specialized University | Maritime-focused university offering marine engineering, naval architecture, and IMO-aligned programs. |
| Dokuz Eylül University (DEÜ)                | University             | Faculty of Maritime Business & Management and Institute of Marine Sciences (Izmir).                    |
| İskenderun Technical University             | University             | Offers maritime-focused programs across engineering, sciences, and vocational training.                |
| Middle East Technical University (METU-IMS) | Research Institute     | Institute of Marine Sciences; specializes in oceanography and marine environmental science (Mersin).   |
| Turkish Naval Academy                       | Military Academy       | Offers BSc degrees in naval engineering, ship systems, and navigation for naval officers.              |
| Yaşar University                            | University             | Provides programs in maritime business and port management.                                            |
| Atilim University                           | University             | Offers courses in naval architecture and marine systems engineering.                                   |
| Maritime Trainer (MTR)                      | Private Training       | Delivers e-learning and simulator-based maritime training.                                             |
| Delmar Academy                              | Private Training       | Offers advanced ship handling, bridge resource management, and safety courses.                         |
| Poseidon Maritime Academy                   | Private Training       | STCW-certified training and hands-on courses for seafarers.                                            |
| Xone Superyacht Academy                     | Private Training       | Specializes in superyacht crew training and luxury vessel operations.                                  |