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DNV

WHEN TRUST MATTERS

INDIAN COASTAL GREEN SHIPPING PROGRAMME

WHITE PAPER

Content

Disclaimer: This document is not meant to replace any rules, regulations or guidelines that are in existence. It is a compilation of experiences, practices, and information gathered from various sources in industry. It is expected that compliance with applicable class rules and statutory requirements will be ensured.

Preface

Maritime transportation is the cornerstone of global trade; 90% of international goods are carried by sea. However, the shipping industry accounts for about 3% of global greenhouse gas emissions. If we compare this figure with country emissions, global shipping ranks 6th, between Japan and Germany.

As a shipping nation, a green shift in the shipping industry is important to Norway and its government. The state is working with the industry to support the development of efficient technologies and low and zero-emission solutions to reduce global emissions.

Establishing several clusters and public-private partnerships has become drivers for the green shift in Norway's maritime and shipping industries. The Norwegian Green Shipping Programme (GSP) is a centrepiece in this approach. As a public-private partnership, it aims to advance the Norwegian government's maritime strategies and plans. The DNV-managed programme's vision is to develop and strengthen Norway's goal to establish the world's most efficient and environmentally friendly shipping methods.

As of spring 2022, the GSP included more than 103 private companies and organizations, research institutions, and 11 public observers. The GSP is financed partly by public allocations from the State budget of Norway and partly by its members. As part of this programme, studies, research, and pilot projects are undertaken.

Norway and India share a long maritime history, and maritime issues are central to the bilateral dialogue between our two countries. Green shipping is a key agenda point in our Joint Working Group Maritime.

On behalf of Team Norway in India, the Royal Norwegian Consulate General in Mumbai has commissioned this study and white paper. We hope that the white paper will be beneficial to building a green maritime and shipping industry in India and provide a useful framework for continued collaboration.

Consul General Arne Jan Flølo
Royal Norwegian Consulate General
Mumbai

Terminologies

AER	Annual Efficiency Ratio
AIS	Automatic Identification System
A*STAR	Agency of Science, Technology and Research
NH_3	Ammonia
CH_4	Methane
CII	Carbon Intensity Index
CNG	Compressed natural gas
CO_2	Carbon Dioxide
C-SAS	Cochin Shipyard Limited Strategic & Advanced Solutions
CICMT	Centre for Inland and Coastal Maritime Technology
DNV	DNV AS, headquartered in Norway
DWT	Deadweight Tonnage
EU	European Union
EEDI	Energy Efficiency Design Index
EEXI	Energy Efficiency Existing ship Index
EU ETS	EU Emissions Trading System
FOS	Fuel Optimization System
GHG	Greenhouse gas
GCMD	Global Centre for Maritime Decarbonisation
GRSE	Garden Reach Shipbuilders and Engineers
GWP	Global Warming Potential
GSP	Green Shipping Programme
GT	Gross Tonnage
HFC	Hydrofluorocarbons
H_2	Hydrogen
HFO	Heavy Fuel Oil
IACS	International Association of Classification Societies
IAPH	International Association of Ports and Harbours
IITM	Indian Institute of Technology Madras
IEC	International Electrotechnical Commission
IFO	Intermediate Fuel Oils
IHS	Information Handling Services
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
ISBT	The Institute of Ship Building Technology
IMS	Institute of Maritime Studies
IWAI	Inland Waterways Authority of India
KOM	Keppel Offshore and Marine
LNG	Liquified natural gas
LP	Low-pressure
LPG	Liquified petroleum gas
LSFO	Low Sulphur Fuel Oil
MARPOL	The International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee
MPSW	Ministry of Ports, Shipping and Waterways
MGO	Marine Gas Oil
METI	Marine Engineering Training Institute
MPA	Maritime and Port Authority

Terminologies

NTCPWC	The National Technology for Ports, Waterways & Coasts
NG	Natural gas
Ni	Nickel
N_2O	Nitrogen oxides
NTNU	Norwegian University of Science and Technology
NIC	Norway Innovation Cluster
NCE	Norwegian Centres of Expertise
PFC	Perfluorocarbons
PEMFC	Proton-exchange membrane fuel cell
SF_6	Sulphur hexafluoride
SEEMP	Ship Energy Efficiency Management Plan
SGMF	Society for Gas as a Marine Fuel
SOLAS	Safety of Life at Sea
SOX	Sulphur oxides
STCW	International Convention on Standards of Training, Certification and Watchkeeping
SMF	Singapore Maritime Foundation
TERI	The Energy and Resources Institute
TMMTDS	Tidal and Meteorological Monitoring, Telemetry and Display System
ULCV	Ultra large container vessel
ULS	Ultimate Limit State
ULSFO	Ultra Low Sulphur Fuel Oil
UNFCCC	United Nations Framework Convention on Climate Change
VLFSO	Very Low Sulphur Fuel Oil
VOC	Volatile Organic Components
WPCI	World Ports Climate Initiative

1. Executive summary

Just as many sectors of the global economy take their path towards green technology and sustainability, so must the shipping industry. The maritime sector will see a rapid energy and technological transformation that will greatly impact costs, asset values, and earning potential.

The GHG Challenge
Green House Gases (GHGs) are gaseous constituents of the atmosphere that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. To regulate the GHG emissions of the shipping industry, the IMO (International Maritime Organization) introduced the Initial GHG Strategy. This strategy currently guides the development of international shipping standards. As part of this initial strategy, SEEMP (Ship Energy Efficiency Management Plan) Part III, EEXI (Energy Efficiency of Existing Ships Index), and CII (Carbon Intensity Indicator) will take effect on January 1, 2023. They are expected to significantly impact the operations and design of all ships. The next set of regulations will include market-based measures that place a price on CO_2 with a need to consider the intensity of fuels' well-to-wake GHG emissions. The EU has also proposed to include shipping in the EU Emissions Trading System (EU ETS) and the FuelEU Maritime legislation. The public is under increasing pressure from customers, financial institutions, charterers, and consumers to increase sustainability.

Coastal Shipping in India
A significant channel to start reducing carbon emissions is by using coastal shipping, which is widely acknowledged as a viable and effective substitute for road transportation. Local trade will rise significantly if coastal transport grows and connects to important ports. Additionally, it will lessen highway congestion and traffic on the roads.

Although there are opportunities for coastal shipping to contribute to the Indian economy, it did not garner much attention due to the difficulties of operating at Indian coastal sites. Only recently has coastal shipping gained recognition as an affordable and environmentally friendly alternative to road and rail transportation. Both the Indian government and businesses have shown great interest in growing it. Chapter 4 analyzes the Indian coastal fleet, its traffic, fuel consumption, and emissions by segment.

Green Shipping Programmes

This switch to safer, more effective, and environmentally friendly shipping is a huge opportunity for India's development. The green transition has several benefits. This includes promoting industrial development and raising competitiveness. Energy use, transportation costs, local air and noise pollution, traffic congestion, and the consequences of climate change will also be reduced.

This transition is best driven through partnerships as part of forums, alliances, coalitions, and others. Collaborative projects can fast-track the industry’s uptake of greener and more innovative solutions. Such initiatives will identify great opportunities and find cutting-edge solutions to overcome the current ecosystem's barriers.

India can look to the unique Norwegian shipping ecosystem for inspiration. Its industry is characterized by a capacity for innovation and value creation, which has led to Norway becoming one of the most advanced maritime nations in the world today. The Norwegian maritime cluster is at the forefront of developing and using technology and concepts that help to reduce emissions and improve the environment. It serves as a showcase, an incubator, and a platform for exporting environmental technologies and green transport services from Norway to other countries.

The Norwegian Green Shipping Programme's success is a testament to the fact that active cooperation between public and commercial entities may promote wider use of ecologically friendly shipping alternatives. Chapter 5 explores the Norway Green Shipping Programme in-detail and other Green Shipping initiatives like the IMO-Norway GreenVoyage2050, Global Centre for Maritime Decarbonisation (GCMD), Mærsk Mc-Kinney Møller Centre for Zero Carbon Shipping.

Green Alternatives for Coastal Shipping

The green alternatives explored in Chapter 6 are classified as technological, operational, fuel, and other measures. Alternative shipping fuels are becoming more popular due to environmental and financial issues. However, there are few viable options. The most promising possibilities, according to DNV, are LNG, LPG, methanol, biofuel, and hydrogen. Methanol and biofuels will soon join LNG, having already surmounted the obstacles from international law. High fuel prices and lack of global bunkering infrastructure are significant obstacles to using low- or zero-carbon fuels. The lack of strict laws and regulations makes integrating necessary technologies on board difficult. The development of regulations lags behind technological developments in ammonia and hydrogen. As technological measures are more expensive, requiring a significant initial investment, operational measures and drop-in fuels like biofuels are preferred for the relatively old vessels in the coastal fleet. Technological and fuel measures can be adopted for newbuilds in the coastal shipping segment or be retrofitted to existing vessels.

Maritime Knowledge Cluster in India

Despite being one of the top countries globally in the number of maritime institutions, India lacks in the areas of technological advancements and development. India’s educational and research institutions currently operate independently, with few industry collaborations, which lowers the level of go-to expertise available in foreign educational institutions.

Knowledge clusters can be established in various maritime disciplines around India by replicating the Norwegian model of establishing maritime networks. For instance, Cochin has the elements to emerge as a cluster for SMART shipping technologies, given its track record of building technologically intensive vessels such as aircraft carriers and autonomous vessels. Kolkata can emerge as a green shipping cluster specializing in building electric ferries, given the current capabilities of yards in Kolkata. With Gujarat developing India’s first Maritime arbitration centre, the state has the elements to emerge as a cluster specializing in shipping law and finance. COEs can also be established in existing research institutions and maritime institutes such as NTCPWC and IMUs. Clusters can work closely with academic institutes, research organizations and COEs to transform India into a maritime knowledge hub.

Potential Opportunities and Challenges for the Indian Coastal GSP

This study identified opportunities and challenges and proposed the recommendations and their impact on India’s green coastal shipping.

TABLE 1.1

Key Opportunities for Indian coastal green shipping programme

Opportunities	Description
Growth of coastal shipping in India	India's coastal shipping cargo movement has increased for the past seven years.
India's increasing renewable electricity generation capacity	India has great potential to be a global supplier of green energy in the future.
Coordinating research activities of universities and other institutions.	Increasing research interest in maritime technologies and improving cooperation nationally and internationally.
Presence of initiatives and policies to promote greener technology	India has been stepping up initiatives and policies to promote greener technology in recent years, e.g., National Hydrogen Mission

TABLE 1.2

Challenges to the Indian coastal green shipping programme

Challenges	Description
Fuel Transition	Methanol and ammonia engines will be available in the next five years. Development of the regulations lags behind the technological developments in both ammonia and hydrogen.
Lack of infrastructure	India's port sector has been expanding. However, many ports lack the infrastructure to promote the uptake of greener technologies.
Lack of knowledge-sharing platforms between stakeholders	Lack of knowledge-sharing platforms and proper facilitation has been identified as a hindrance to India's green transition.
Skill shortage in handling alternative solutions	There is a need to adapt to new and evolving training requirements and provide graduates with skills to meet future requirement as decarbonization and digitalization in the marine industry progress rapidly.

To bring down barriers and speed up the progress of next-generation carbon-neutral ships will require accelerated technology development, large-scale piloting for deep-sea vessels, and ensuring the safe application of new fuels on board and onshore. Stronger emphasis is needed on system-level thinking and integration of all available technologies. This will require time, investment, and combining efforts from all stakeholders in the maritime supply chain.

Recommendations

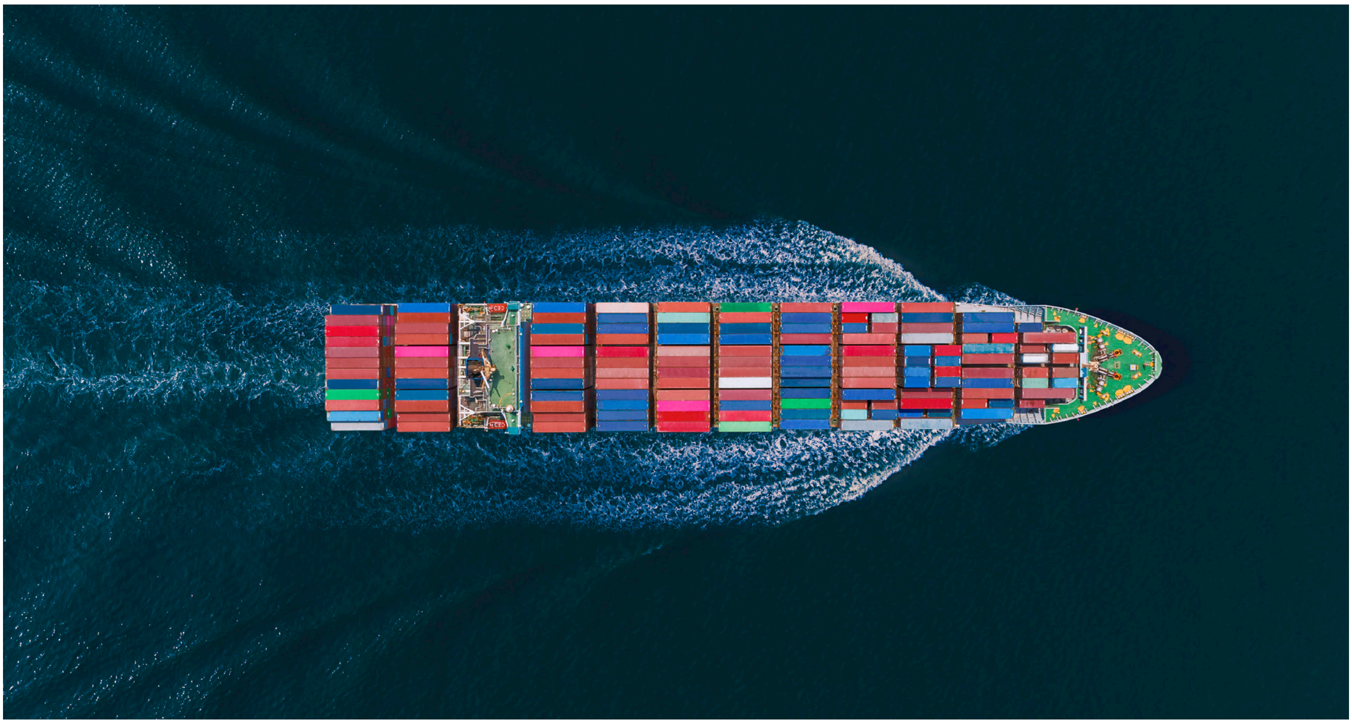
1. Set national climate targets and political ambitions for domestic shipping.
2. Establish maritime clusters and increase cooperation between industry actors throughout the value chain.
3. Developing short-term and long-term plans for green coastal shipping.
4. Create markets for green technology.
5. Reinforce shipowners' financial capacity and access to capital.
6. Establish infrastructure for green shipping.
7. Train the workforce to adapt to greener technologies.
8. Pilot green projects for short-sea shipping and inland waterways.
9. Inclusion of zero-emission transport requirements in public procurement processes.
10. Introduce CO_2 funds and support schemes.
11. Maximum utilisation of multi-modal transportation.
12. Continued investment into R&D and coordination of the activities of research institutes and maritime universities.
13. Create awareness of Green Corridors for Shipping.

Impact and benefits of the Indian coastal green shipping programme

1. Decrease in fuel usage, price, CO2 emissions, and air pollution for carriers and shippers.
2. Increase the use of cutting-edge techniques and technology throughout the supply chain.
3. Create more green employment opportunities.
4. Shippers and carriers who make specified advancements and use newer technologies will receive public recognition.
5. Promote the use of innovative solutions more rapidly.
6. Build consensus among the public, business, scientific, and other sectors.
7. Collect and distribute data and indicators on the effectiveness of shipping transport and logistics in reducing emissions and provide efficient and reliable techniques for measuring and reporting fuel use.
8. Present case studies of creative, repeatable solutions.
9. Encourage open peer-to-peer learning and exchange, as well as sharing and working together to establish standardized approaches, tools, and the provision of instruction and technical support.
10. Participate in the sustainable shipping movement, and enhance public awareness and consumer perception, which will help stakeholders publicly commit to sustainable logistics and shipping.

The Indian coastal green shipping programme will help India transition to green shipping and strengthen its institutional, economic, and human resources to achieve its regional and global carbon reduction goals.

2. Introduction



2.1 Background

The pressure is on the maritime industry to decarbonize. This pressure is exerted by three fundamental regulatory and commercial drivers: regulations and policies, access to investors and capital, and cargo owner and consumer expectations, shown in Figure 2.1.

The International shipping policy is now developed following the Initial IMO Greenhouse Gas Strategy, and the upcoming set of regulations will go into effect on January 1, 2023. They are the Ship Energy Efficiency Management Plan (SEEMP) Part III, the Energy Efficiency for Existing Ships Index (EEXI), and the Carbon Intensity Indicator (CII). They are anticipated to influence all ships' operations and design substantially. The next round of rules will be created, including market-based measures that put a price on CO_2 and a need to consider fuels' well-to-wake GHG emission intensity.

To boost the use of carbon-neutral fuels through a more onerous well-to-wake GHG intensity requirement, the EU has proposed inclusion of shipping in the EU Emissions Trading System (EU ETS) and the FuelEU Maritime legislation. These proposals may be adopted later in 2022. Supporting frameworks and standards enable the regulatory and commercial drivers, including ones setting science-based, net-zero GHG emission targets, taxonomies for sustainable activities, sustainability evaluation criteria, calculation methods for the well-to-wake GHG emissions of fuels, and supply-chain emission reporting requirements.

The public is under increasing pressure from customers, financial institutions, charterers, and consumers to increase sustainability. Shipowners are starting to future-proof their assets as the relevant practical concerns come into focus. Green shipping routes may act as launch pads, lowering the chance that port infrastructure will become dated when the fuel mix changes. The sector requires powerful alliances to drive the creation of supply networks that can guarantee the availability of fuel in the future. The whole marine value chain, including charterers, energy majors, fuel suppliers, governments, financiers, ports, and shipowners, should work together to provide enough funding and apply it to the appropriate projects. With increased knowledge and transparency about how banks, investors, insurers, and cargo owners will utilize the indicators presented to them and how they will act on initiatives that affect the climate alignments of their portfolios, stakeholders should be able to make the best decisions possible. Among Indian banks, there is no common shipping policy. The varying approaches to policy depend on each bank's approach, which mostly focuses on financing for corporations, their perspectives on trade restrictions and the future of shipping, and their total lending ceilings.

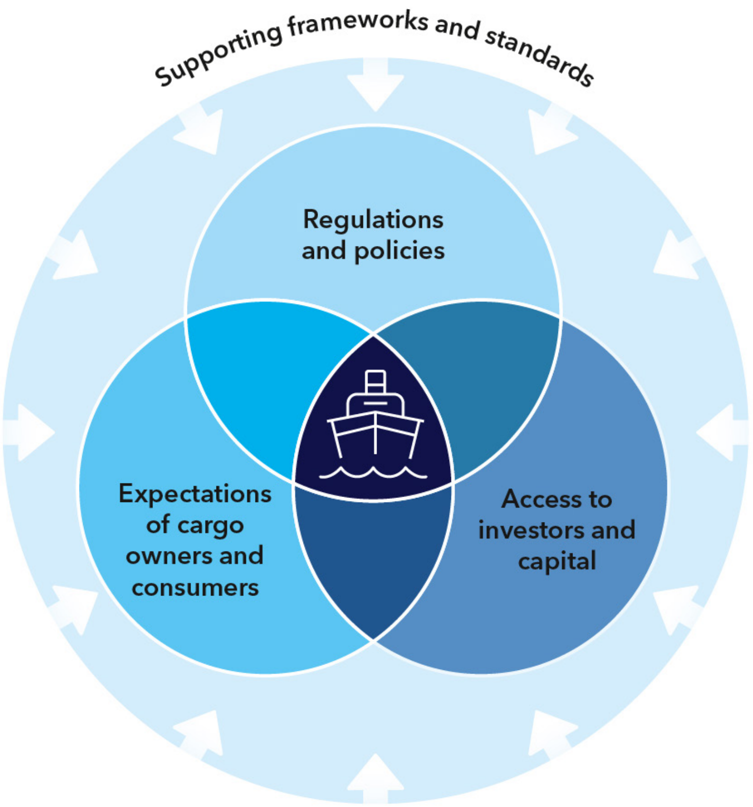
Decarbonization and digitalization are currently the most transformative forces in shipping. These two subjects are intertwined, with digitalization facilitating shipping's decarbonization in significant ways. These ambitions are beginning to change the shipping industry and will accelerate it in the coming years. To address future concerns, society and the shipping sector must undergo extensive and fundamental changes over the next few decades. This will be a challenge, but it will also provide the opportunity to innovate and develop new environmentally friendly technologies that can offer cost-effective emissions reductions in shipping while also having significant knock-on effects in the form of increased export opportunities, value creation, and jobs within the maritime industry. Such upheavals do not happen on their own. They demand further input from the industry itself; however, it is also a prerequisite that government authorities invest in and lay the groundwork for them.

On this, Norwegian shipping holds a unique position in the world. Its industry is characterized by a capacity for innovation and value creation, which has led to Norway becoming one of the most advanced maritime nations in the world today. The Norwegian maritime cluster is at the forefront of developing and using technology and concepts that help reduce emissions and improve the environment. It serves as a showcase, an incubator, and a platform for exporting environmental technologies and green transport services from Norway to other countries, significantly lowering emissions generated by shipping.

The success of the Norwegian Green Shipping Programme (GSP) is a proven testimony to the fact that active collaborations between government authorities and the private sector can encourage more widespread adoption of environmentally friendly solutions for shipping.

FIGURE 2.1

The three key fundamentals driving shipping decarbonization
Source: DNV 2022 Maritime Forecast to 2050



2.2 Aim and objectives of the whitepaper

Royal Norwegian Consulate General Mumbai has engaged DNV Maritime Advisory to study India’s green coasta shipping initiative. The project aims to create a white paper on greening Indian coastal shipping and to determine whether a scheme comparable to the Norwegian GSP may be adopted. The Indian coastal green shipping programme would help the marine sectors invest more quickly in environmentally friendly technologies. The initiative seeks to identify scalable solutions for effective and ecologically sustainable shipping. Cost-effective carbon reductions, economic expansion, improved competitiveness, and the creation of new employment will be the outcomes. The programme should include participation from government agencies, business leaders, and financial institutions with expertise in ship financing to accomplish these aims.

The switch to safer, more effective, and environmentally friendly shipping is a challenge but also a huge opportunity for India's development. Industrial growth, increased competitiveness, lower transportation costs, less energy consumption, lessening the effects of climate change, and the lowering of local air and noise pollution and traffic congestion are all advantages of the green transition. The Indian coastal green shipping programme helps India transition to green shipping and strengthens its institutional, economic, and human resources to achieve the associated regional and global carbon reduction goals. In this whitepaper, we explore the possibilities of initiating a programme like the Norway GSP in the Indian Subcontinent, the Indian Coastal Green Shipping Programme.

The white paper intends to:

1. Develop a prognosis and strategic direction for India’s potential green coastal shipping environment from the successful Norwegian GSP with required modifications. (Chapter 5).
2. Discuss India’s maritime knowledge cluster development (Chapter 7).
3. Identify the current status of coastal shipping in India, opportunities, and challenges in India’s maritime industry (Chapter 4,8).
4. Provide stakeholder composition and assess the roles of India’s government and its industry consortiums (Chapter 7).
5. Understand the alternative green technologies available to reduce emissions (Chapter 6).
6. Provide recommendations to the stakeholders to fast-track the green transition in its domestic shipping segment. (Chapter 9)

2.3 Research methodology and approach

The research for the whitepaper is performed according to the DNV's research methodology, as shown in Figure 2.2.

DNV has Identified stakeholders in the maritime and energy industry. Interviews were conducted with key personnel in private and government organizations in India for their perspective of the market, qualitative data, and industry surveys to capture cluster dynamics as primary external sources.

The list of companies/organizations interviewed include:

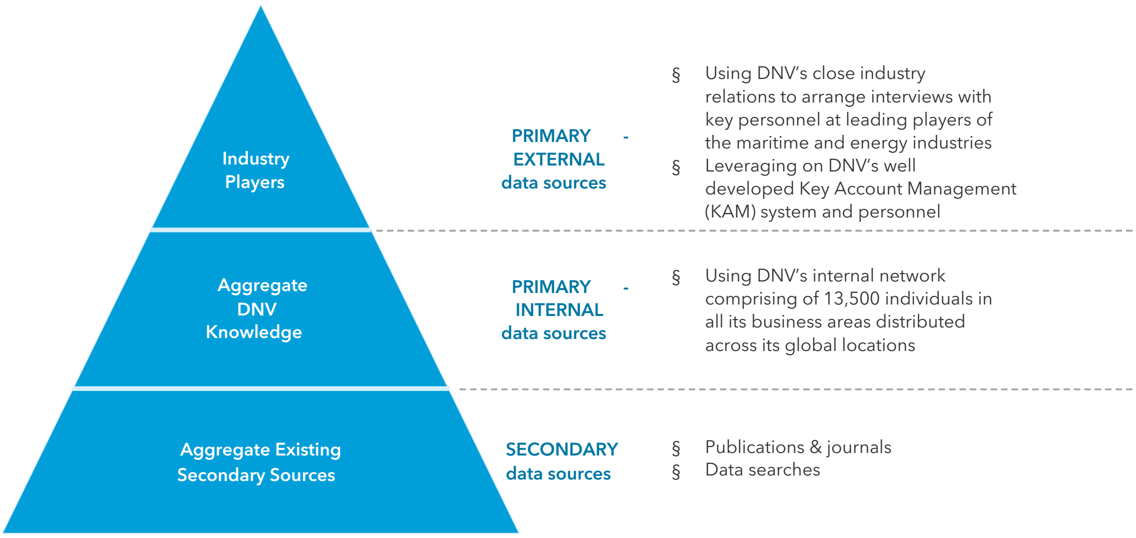
1. Cochin Shipyard Ltd.
2. Kochi Metro Rail Ltd.
3. Directorate General (DG) of Shipping
4. Oil & Natural Gas Corporation
5. World Bank
6. Shipping Corporation of India Ltd.
7. Ambuja Cements Ltd.
8. Cochin University of Science and Technology
9. Directorate of Marine Engineering Training (DMET) Calcutta
10. Indian Coastal Conference Shipping Association
11. The Energy and Resources Institute (TERI)
12. Mumbai Port Trust
13. Jawaharlal Nehru Port Trust
14. Gujarat Maritime Board
15. JSW Energy Ltd.
16. Seven Islands Shipping Limited
17. Norway Green Shipping Programme
18. NCE Maritime CleanTech Cluster

DNV has used internal global subject matter expertise, an internal database for analysis, and market scanning as primary internal sources. Required knowledge and data were taken from DNV internal sources, reports, and expert insights. An Automatic Identification System (AIS) was used to gather vessel traffic flow for data analysis. Also, this includes DNV's 2022 edition research publications such as Maritime Forecast to 2050 and Energy Transition Outlook.

External publications and materials were used as secondary data sources to supplement the article's contents, including data from DNV partners and maritime intelligence data publishers (e.g. Clarkson Research), scholarly articles, published research papers, published market reports, newspapers, the internet, and others.

FIGURE 2.2

Research Methodology



§ Using DNV's close industry relations to arrange interviews with key personnel at leading players of the maritime and energy industries
§ Leveraging on DNV's well developed Key Account Management (KAM) system and personnel

§ Using DNV's internal network comprising of 13,500 individuals in all its business areas distributed across its global locations

§ Publications & journals
§ Data searches

3. The Green House Gas Challenge

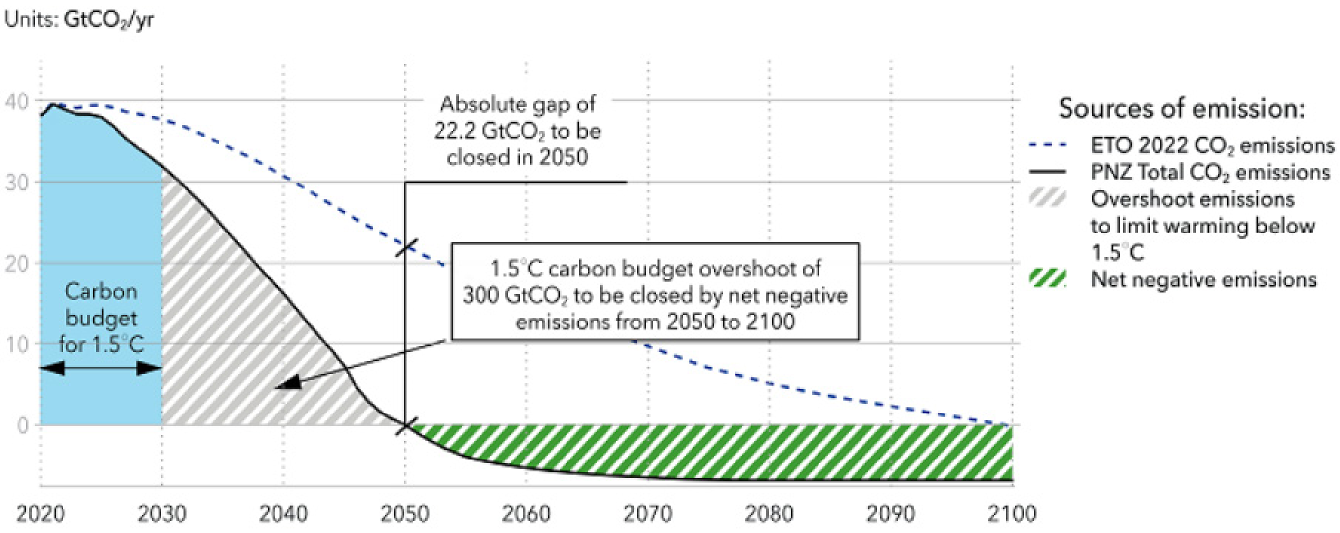
Green House Gases (GHGs) are gaseous constituents of the atmosphere that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. The major atmospheric gases responsible for causing global warming and climate change are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

The primary source of emissions from the transportation industry is the burning of fossil fuels. CO_2 makes up most of the emissions, but CH_4 is also a significant GHG when considering future climate effects. The increase in global temperature and atmospheric CO_2 concentration are strongly connected. The carbon budget for 1.5°C of global warming at the beginning of 2021 was 360 Gt of CO_2 , as illustrated in Figure 3.1 [1].

Regarding energy per tonne-kilometre, maritime transportation is the most energy-efficient mode. As a result, shipping accounts for more than 80% of all goods traded worldwide. [2]. Nearly 3% of global final energy demand, including 7% of the world's oil, is presently consumed by ships, mainly by international cargo shipping. When the Paris Agreement was adopted in 2015 in response to the increasing signs of global climate change, shipping was not included. Instead, the IMO was asked to develop their GHG emission reduction schemes [1].

FIGURE 3.1

Pathway to net zero emissions
Source: DNV ETO 2022



3.1 IMO GHG Strategy 2050

Shipping is an international industry, and global environmental and safety standards for shipping are developed by the International Maritime Organization (IMO). The initial GHG strategy calls for at least a 40% reduction in CO_2 emissions per transport work by 2030, with efforts directed toward a 70% reduction by 2050, compared to 2008, and at least a 50% reduction in total yearly GHG emissions from international shipping by 2050. A "pathway of CO_2 emissions reduction consistent with the Paris Agreement temperature objectives" is part of the strategy. IMO continues to contribute to the worldwide effort to combat climate change by supporting the UN Sustainable Development Goal to take immediate action to address climate change and its effects. Following IMO's pollution prevention treaty, the International Convention for the Prevention of Pollution from Ships (MARPOL), mandatory measures have been established to limit greenhouse gas (GHG) emissions from international shipping.

The initial strategy serves as a framework for the Member States, outlining the long-term goals for international shipping, the levels of ambition to reduce GHG emissions, and guiding principles. It also includes potential short-, mid-, and long-term additional measures with future timelines and their effects on States. The plan also outlines obstacles to be overcome and helpful strategies, such as capacity building, technical collaboration, and research and development (R&D).

3.2 Upcoming IMO and European Union regulations

The next wave of IMO's GHG Strategy regulations will go into effect on 1 January, 2023. It will build upon its initial strategy, which presently guides policy development within the shipping sector. They are the Ship Energy Efficiency Management Plan (SEEMP) Part III, the Energy Efficiency for Existing Ships Index (EEXI), and the Carbon Intensity Indicator (CII). Final guidelines supporting these regulations, including instructions for creating SEEMP Part III and correction factors for the CII computations, were approved at MEPC 78 in June 2022.

Updating the IMO Strategy in 2023 may raise its targets for reducing emissions. Next, the development of market-based regulations putting a price on CO_2 and requiring that fuels be taken into account for their well-to-wake GHG emission intensity will be implemented [3].

Negotiations have started, and concrete suggestions supporting complete decarbonization by 2050 have been made. A decision is anticipated at MEPC 80 in July 2023. Laws implemented to ensure that shipping reaches the strategy's goals are also expected. One set of recommendations includes market-based measures (MBMs), which attempt to establish a price on CO_2 or GHG emissions, either well-to-wake or tank-to-wake, creating a financial incentive driving uptake of GHG emission reduction methods indirectly as opposed to through a technical necessity. The four MBM variations currently being considered are:

- A levy system based on the absolute well-to-wake emissions of GHG. The IMO would decide the cost of GHG.
- A levy system based on CII performance where ships with CII performance below a baseline would contribute per tonne CO_2 (tCO_2), while those performing above the benchmark and depending on the fleet's level of success, would be incentivized.
- A levy system based on actual CO_2 emissions from tank to wake, with some of the proceeds going toward direct rebates for zero-emission ships. The IMO would decide the CO_2 price and rebate.
- A cap-and-trade system for emissions in which the IMO sets the well-to-wake GHG emission limit and allowances are auctioned off, like the EU ETS. The market would then set the cost of carbon. In addition to the specific discounts and incentives mentioned above, the proceeds from market-based systems might be applied to outside and inside shipping to help mitigate and adapt to climate change. A future MBM measure may incorporate aspects from several of the concepts. The proposals will be further explored for MEPC 80 in July 2023.

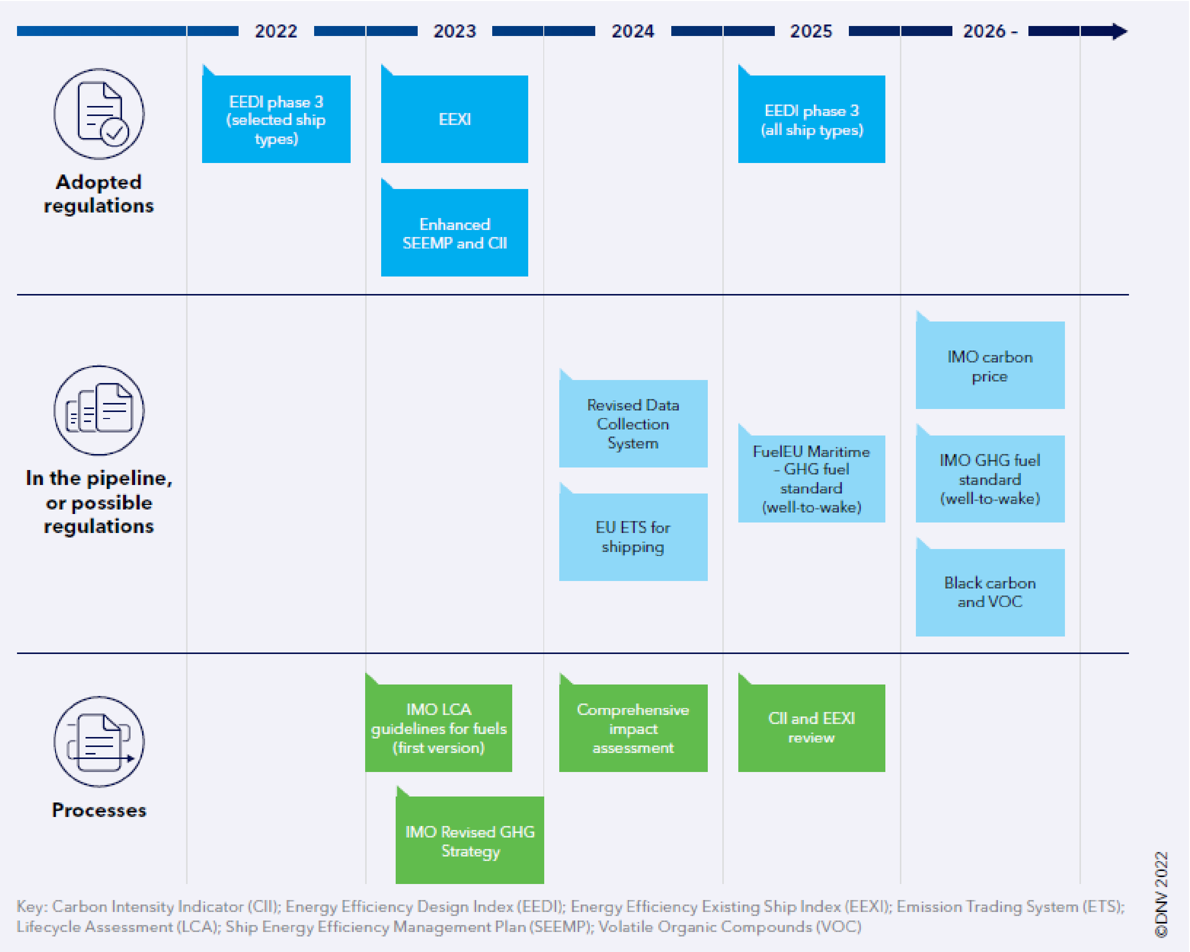
  When adopting a Decarbonization by 2050 pathway, the initial effects assessments of the MBM approach predict a CO_2 or GHG price between USD 50/tCO_2 and USD 300/tCO_2 towards 2050 and a transport cost rise of 50% to 90% [4]. This pricing, however, is based on the costs of mitigation, particularly the projected price differential between fossil and carbon-neutral fuels.

  The GHG Fuel Standard, which would establish requirements on the well-to-wake GHG emission per unit of energy given to the ship, whether as a fuel or as elec tricity, has also been submitted to the IMO in addition to the MBMs [5].

Beyond the IMO, the EU is among the most powerful and progressive organizations that regulate ships. Its goals include being carbon neutral by 2050 and cutting emissions by 55% (1990 vs. 2030). The EU put up its Fit-for-55 legislation packages and FuelEU Maritime regulation in July 2021 which intends to boost the use of carbon-neutral fuels by enforcing an ever-tougher well-to-wake GHG intensity requirement. The EU Emissions Trading System (EU ETS) is anticipated to cover shipping in Fit-for-55. Through a stricter lifecycle GHG intensity criterion, FuelEU Maritime seeks to encourage the usage of sustainable fuels. These ideas may be officially accepted later in 2022, with effects beginning in 2024 and 2025, respectively. Figures 3.2 and 3.3 shows the Timeline of key regulatory processes and decisions and the regulatory framework for GHG emissions reduction from international shipping in the IMO and the EU, respectively [6].

FIGURE 3.2

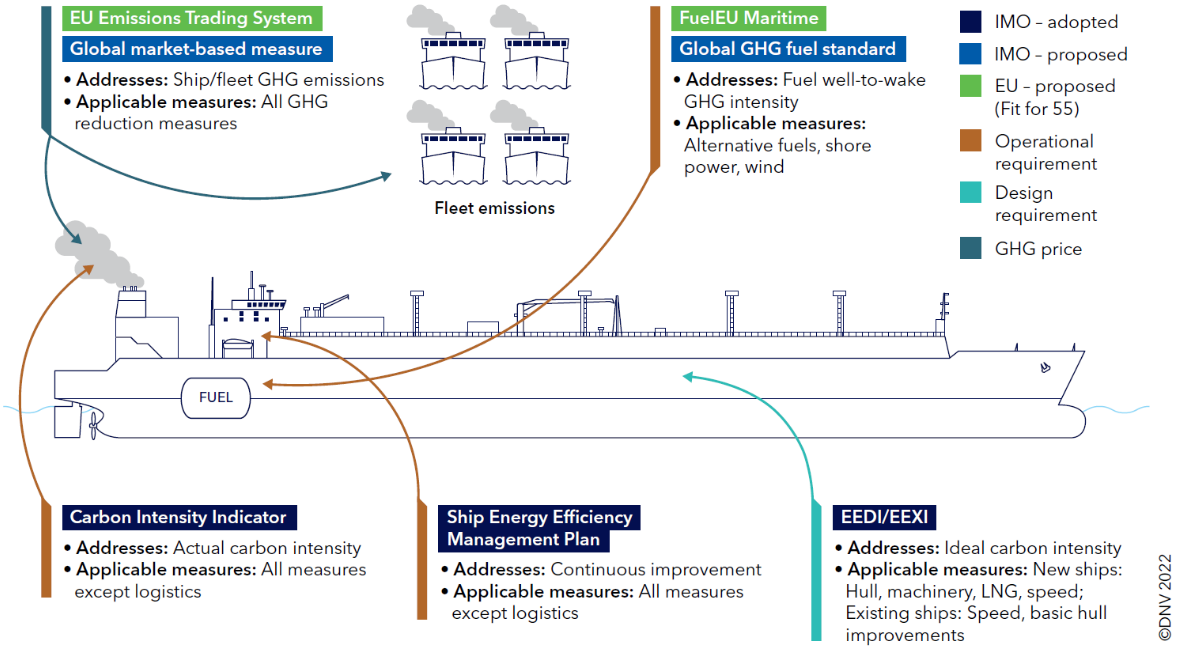
Timeline of key regulatory processes and decisions in the EU and the IMO
Source: DNV 2022 Maritime Forecast to 2050



Key: Carbon Intensity Indicator (CII); Energy Efficiency Design Index (EEDI); Energy Efficiency Existing Ship Index (EEXI); Emission Trading System (ETS); Lifecycle Assessment (LCA); Ship Energy Efficiency Management Plan (SEEMP); Volatile Organic Compounds (VOC)

FIGURE 3.3

IMO and EU regulatory framework for GHG emissions reduction from international shipping
Source: DNV 2022 Maritime Forecast to 2050



Regulatory policies and direct energy costs primarily influence the future fuel mix and the use of carbon-neutral fuel. To meet the current IMO aspirations and completely decarbonize shipping, the adoption of carbon-neutral fuel must accelerate in the mid-2030s, reaching 40% of the fuel mix in 2050. In the most ambitious decarbonization scenarios, fossil fuels like Very Low Sulphur Fuel Oil (VLSFO), Marine Gas Oil (MGO), and Liquefied Natural Gas (LNG) will be phased out by the middle of the century or will see a rapid decline.

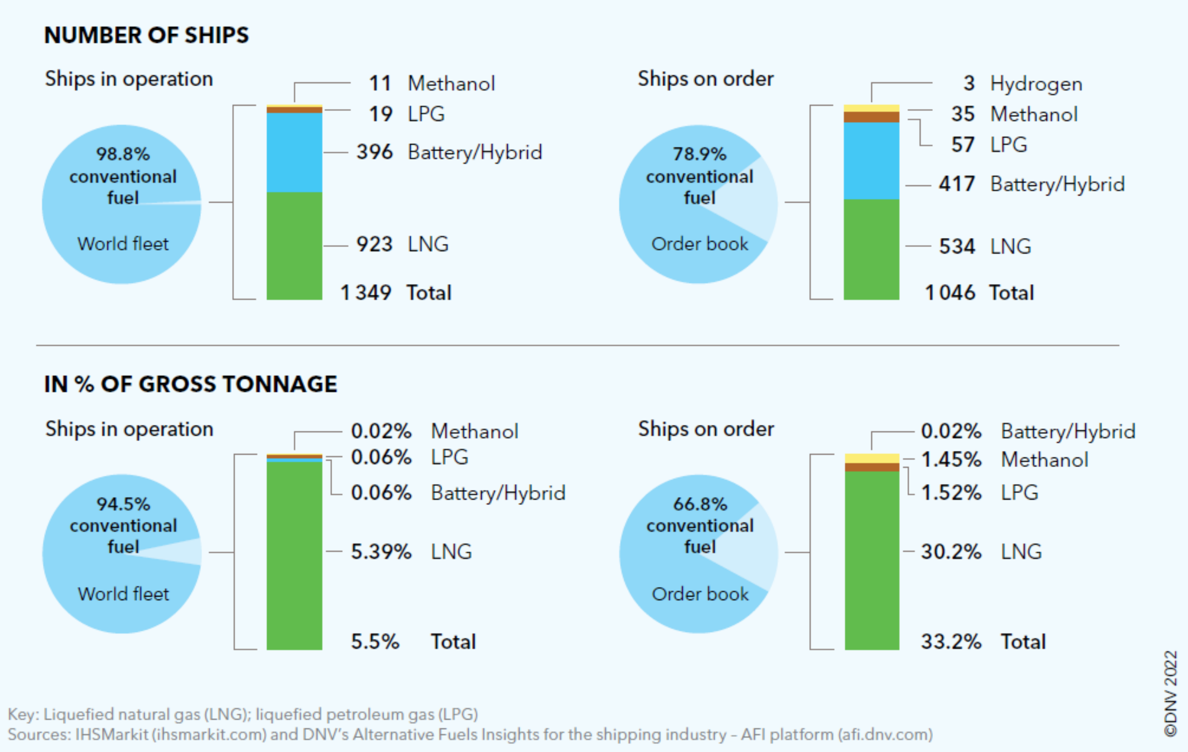
Supporting frameworks and standards that, among other things, create science-based net-zero GHG emission objectives, taxonomies for sustainable activities, sustainability evaluation criteria, calculation methodologies for the well-to-wake GHG emissions of fuels, and supply-chain emission reporting requirements. Shipowners will need to use new technology and fuels to cut emissions in response to the forces driving decarbonization.

The trend of ordering bigger ships with alternative fuel propulsion is still prevalent, with fossil LNG as the primary fuel. Figure 3.4 shows the alternative fuel uptake in the world fleet by the number of ships and gross tonnage [6]. A third (33%) of the gross tonnage of ships that are now on order and around 5.5% of the total gross tonnage of ships that are currently in service can or will be able to run on alternative fuels. LNG transporters are included in this. The adoption of methanol, liquefied petroleum gas (LPG), and the first newly constructed buildings powered by hydrogen are beginning to show in the statistics.

Concepts and pilot studies show considerable interest in using ammonia as fuel; however, at the moment, converter technologies are still in their infancy. To enable use in deep-sea and local short-sea transportation, there is concurrent development of 2-stroke and 4-stroke engine technologies for ammonia. The development of hydrogen technology is anticipated to benefit from short-sea transport. As a result, the development of fuel cells and 4-stroke engines have advanced beyond that of other hydrogen energy converters. Methanol fuel technologies are more advanced than ammonia and hydrogen fuel technologies now. All parties involved in the marine sector will need to emphasize safety more because of the use of new fuels and fuel technologies, including the creation and execution of safety regulations. The severe flammability of hydrogen and the toxicity of methanol and ammonia provide significant safety issues. Because there are considerable obstacles to adopting carbon-neutral fuels, there is a rising interest in using onboard CCS with conventional fossil fuels. Depending on regulatory changes and the development of land-based infrastructure, onboard CCS may be applicable for particular ship segments.

FIGURE 3.4

Alternative fuel uptake in the world fleet by number of ships and gross tonnage
Source: DNV 2022 Maritime Forecast to 2050



Key: Liquefied natural gas (LNG); liquefied petroleum gas (LPG)
Sources: IHSMarkit (ihsmarkit.com) and DNV's Alternative Fuels Insights for the shipping industry – AFI platform (afi.dnv.com)

3.3 Overcoming the GHG Challenge

With the help of a supportive framework and regulatory and economic motivations, the earliest decarbonization stages are underway. The complete fuel supply chain, including emissions from ships and fuel production and supply, is being scrutinized. The development of onboard fuel technology is advancing, and the fleet uses more alternative fuels. But many of the fuel technologies that would be required in 2050 are still in their infancy.

Further work is required to remove obstacles and hasten the development of next-generation carbon-neutral ships. Accelerated technological advancement, extensive deep-sea vessel piloting, and the safe use of new fuels on board and ashore are all necessary. System-level thinking and the integration of all available technologies require more focus. For this to be accomplished, all parties involved in the marine supply chain must put in the time, money, and combined effort. Green energy corridors, a concept now taking shape, might aid in this endeavour by coupling promises on fuel supply and demand and lowering the risk of being the first to market. By expanding the availability of alternative fuels in corresponding locations, the goal is to aid in the initiation of maritime decarbonization.

Several high-level statements made outside of COP26 highlighted the ongoing efforts of many stakeholders to decarbonize shipping by 2050, including creating green corridors to concentrate efforts and resources. As was already indicated, MEPC 77 also acknowledged the need to raise the bar for the IMO's GHG strategy when amended in 2023. Following these choices, the IMO and EU will be busy in 2022 defining frameworks and standards for the regulations that will govern shipping throughout the next decades.

The adoption of the EU's final, approved measures is anticipated for late 2022 or early 2023. The IMO will host its pivotal MEPC 80 conference in June 2023. At this meeting, the IMO will adopt an updated GHG policy and select regulatory measures that will place demands on specific ships to guarantee that the goals are reached. Technical specifications and market-based restrictions might both be part of them. The IMO's first set of rules for assessing the lifetime GHG emissions of marine fuels could be released in 2022.

Through tangible initiatives like the Nordic Roadmap for the Introduction of Sustainable Zero-Carbon Fuels in Shipping and the C40 Green Ports Forum, green corridors will be translated into practical activities [7][8]. The creation of several frameworks, norms, and regulations has made it possible for stakeholders, including cargo owners, financial institutions, and other parties, to exert more pressure and have higher expectations. In December 2021, the Poseidon Principles for Marine Insurance were developed [9]. The Net-Zero Standard was introduced in October 2021 by the Science Based Targets project (SBTi) [10]. The full value chain is covered by SBTi, which enables businesses to set net-zero ambitions following climate science. According to proposed regulations, enterprises must disclose direct and indirect GHG emissions and associated climate hazards in the US. Shipping companies will need to provide more thorough reporting on emissions and ensure that upcoming decarbonization requirements are met as a result of these requirements, as well as expectations on environmental, social, and corporate governance (ESG) reporting and disclosure of emissions in practice.

The decarbonization of shipping should not cause emissions to be transferred to other industries. Examples include employing non-sustainable biofuels that result in emissions from land-use change or creating ammonia or hydrogen from non-renewable power (from fossil sources without carbon capture and storage). A precise methodology and standards for estimating well-to-wake emissions and sustainability evaluation are required to ensure that using fuel does not have unexpected implications in other sectors.

Emissions from fuel manufacturing will also need to be calculated and reported at the corporate level. The GHG Protocol has reporting requirements that categorize emissions into categories, including direct emissions from burning non-biogenic fuels on owned or operated ships that fall under a shipping corporation and emissions from fuel manufacturing [11].

4. Coastal shipping in India

One of the major benefits of coastal shipping is that shippers get their goods in a reliable, consistent, and timely manner. Unlike road transport, which is more prone to delays and irregular logistics flow due to congestion, short sea shipping allows for scheduled departures and arrivals. This means the goods are received in time and can be efficiently distributed from the port terminals. Shippers do not have to worry about taking care of large goods volumes within short time frames or keeping inventory. Improving their water-based transport share would lower logistics costs for end-user industries as water-based transport is cheaper than rail and road modes. Also, other indirect benefits, such as reduced air and noise pollution and reduced accidents, would benefit the economy.

India has a long and contiguous coastline spanning 7,517 km, served by 12 major ports and 212 notified minor/intermediates ports, and extensive navigable inland waterways. Currently, coastal and inland waterways contribute ~6% of the country's freight modal mix. There is an excellent opportunity to tap an environmentally friendly water-based modal transport, which can complement rail and road-based cargo movement.

4.1 The Indian coastal fleet

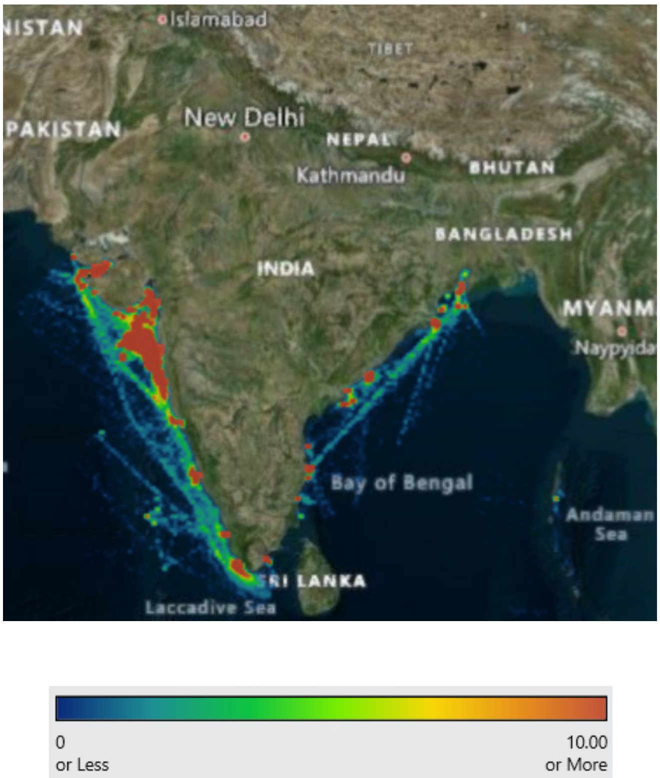
Coastal vessels in India

As per India's Merchant Shipping Act, an "Indian coastal vessel" is defined as any vessel exclusively employed in trading between any port or place in India with any other port or place in India having a valid coastal license issued by the Director General of Shipping or competent authority. This study has identified 816 self-propelled coastal vessels operating in India's Exclusive Economic Zone (EEZ), out of which 814 are active as of 1 November 2022. The vessels have been considered based on the vessel data provided by DG shipping and subsequent verification using the Automatic Identification System (AIS). Fuel consumption and emissions for these vessels from 1 January to 30 September 2022 were captured using AIS. Generic vessel data such as build year, ship owners, shipbuilders, GT, DWT etc., were extracted from IHS Markit's maritime portal. Figure 4.1 shows the heat map of vessel traffic captured using the AIS from 1 January to 30 September 2022. Layer 0 to 10 refers to the intensity of the number of vessels at points on the map. It can be observed that there is high coastal vessel traffic near the Mumbai region. This is because of a higher number of tugs and offshore vessels in the area.

FIGURE 4.1

Heat Map of Coastal Vessels in India

FIGURE 4.1 SHOWS THE HEAT MAP OF VESSEL TRAFFIC CAPTURED USING THE AIS FROM 1 JANUARY TO 30 SEPTEMBER 2022. LAYER 0 TO 10 REFERS TO THE INTENSITY OF THE NUMBER OF VESSELS AT POINTS ON THE MAP.

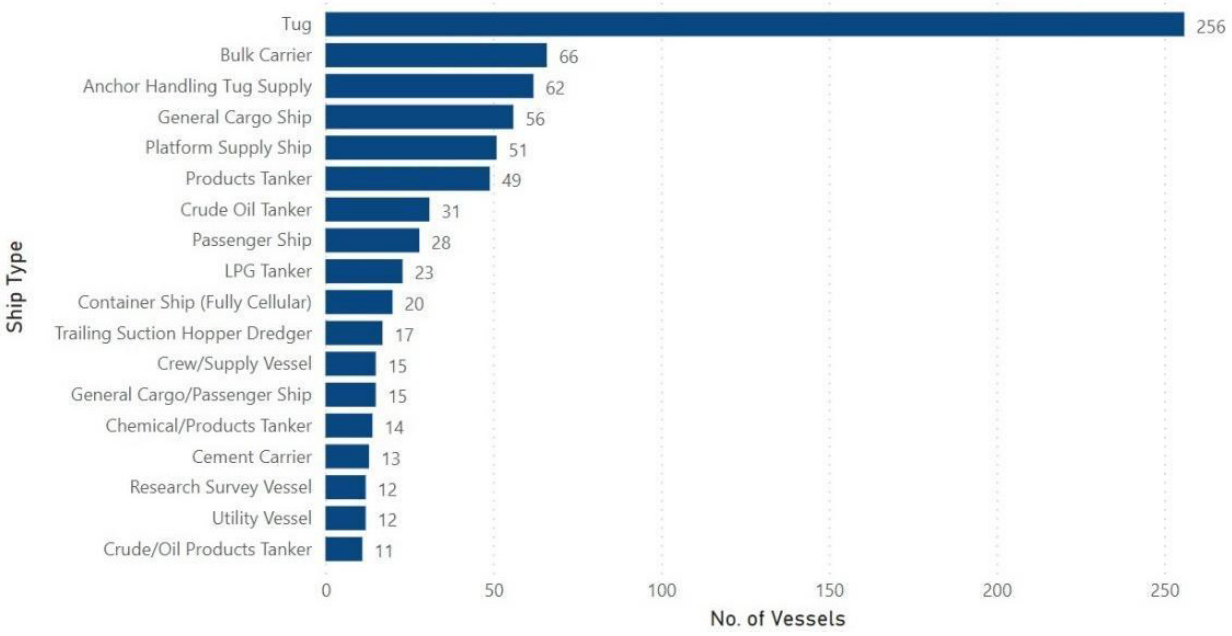


Major coastal vessel types

FIGURE 4.2

Major Coastal Vessel Types in India
Source: IHS Markit

TUGS ARE RECORDED AS ONE OF INDIA'S MAJOR COASTAL VESSEL TYPES, WITH THE HIGHEST NUMBER OF VESSELS AT 256, FOLLOWED BY BULK CARRIERS AT 66. FIGURE 4.2 SHOWS THE COASTAL VESSEL TYPES WITH A NUMBER GREATER THAN TEN.

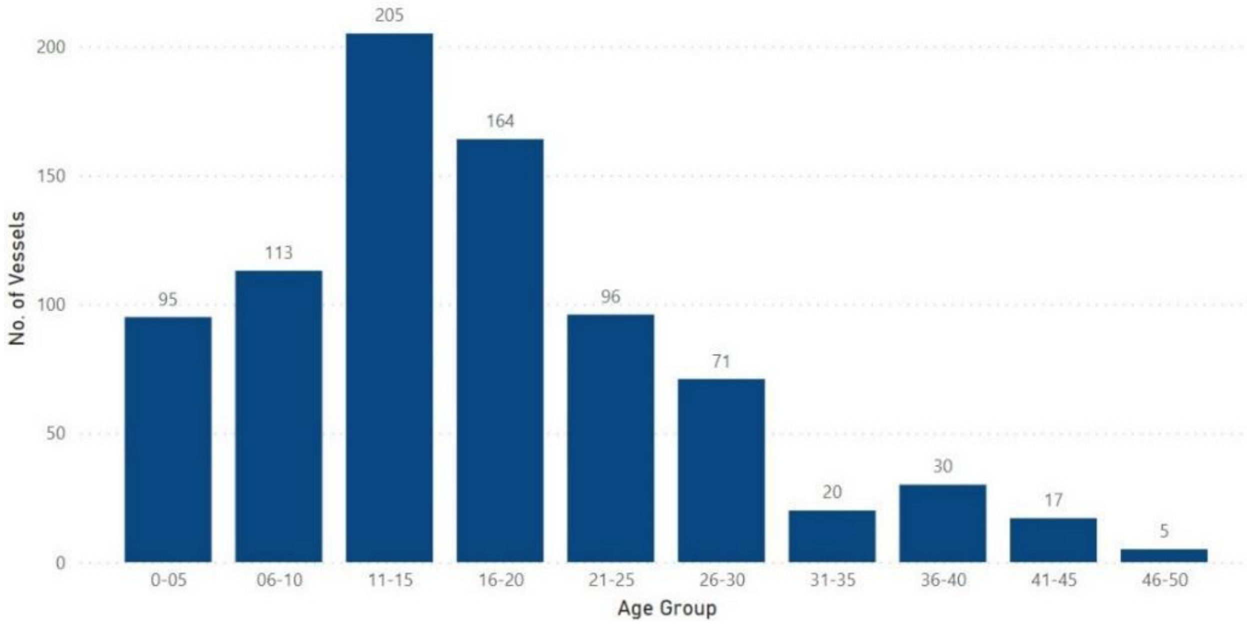


Vessel age distribution

FIGURE 4.3

Age Distribution of Coastal Vessels in India
Source: IHS Markit

FIGURE 4.3 SHOWS THAT 403 VESSELS, I.E., 50.61% OF THE INDIAN COASTAL FLEET, ARE OLDER THAN 15 YEARS. DETAILED AGE ANALYSIS FOUND THAT THE AVERAGE INDIAN COASTAL VESSEL IS 16.8 YEARS OLD.



Major builders

FIGURE 4.4

Major builders of Indian coastal vessels
Source: IHS Markit

FIGURE 4.4 SHOWS THE MAJOR BUILDERS OF INDIAN COASTAL VESSELS. HYUNDAI HEAVY INDUSTRIES CO., LTD., SOUTH KOREA AND KANAGAWA SHIPYARD, JAPAN, ARE THE TOP BUILDERS OF THE INDIAN COASTAL FLEET. COCHIN SHIPYARD LTD. IS THE LEADING ACTIVE INDIAN SHIPYARD THAT HAS BUILT THE MOST ACTIVE COASTAL VESSELS.

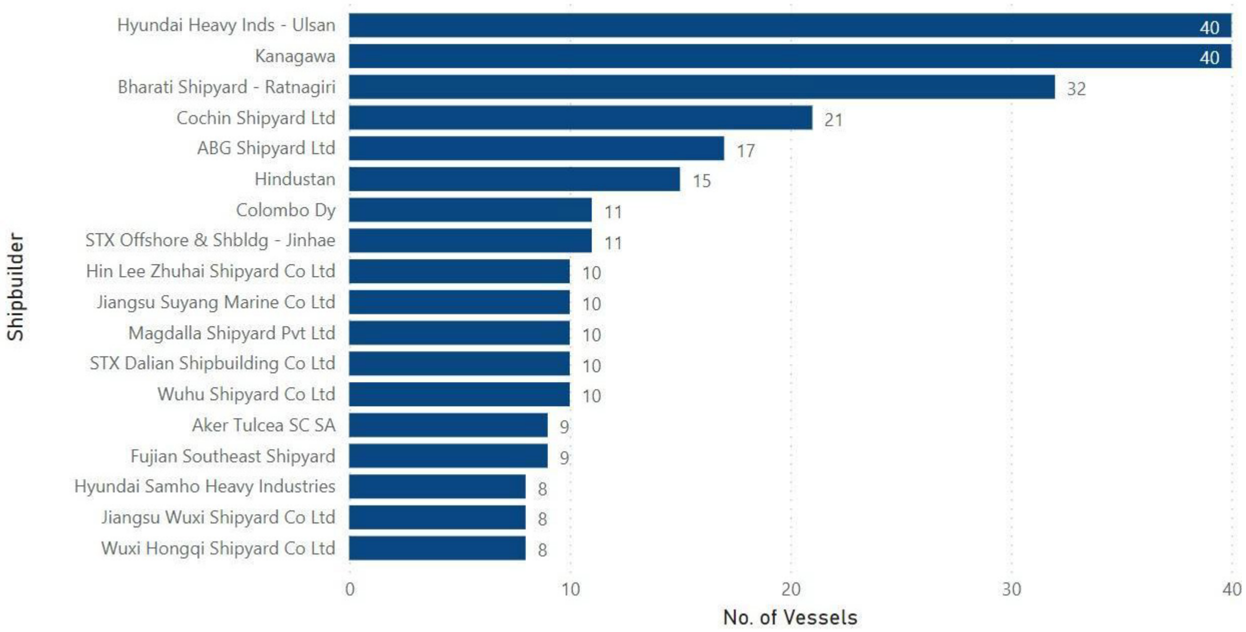
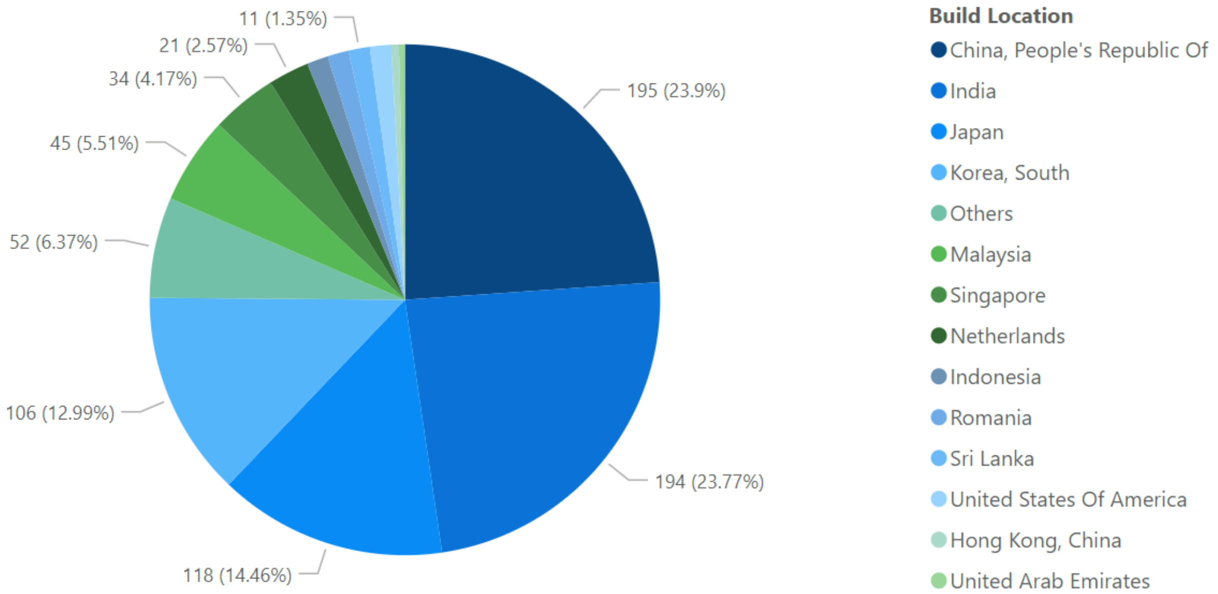


FIGURE 4.5

Build locations of Indian coastal vessels
Source: IHS Markit

FIGURE 4.5 SUGGESTS THAT 23.9% (195 VESSELS) OF THE INDIAN COASTAL FLEET WAS CHINA-BUILT VERSUS INDIA-BUILT AT 23.77% (194 VESSELS).



Fleet fuel consumptions and emissions

Emissions based on ship-types

FIGURE 4.6

Total Fuel Consumption (MT) of Major Coastal Vessels in India by Vessel Type

FUEL CONSUMPTION AND RELATED EMISSIONS OF 816 COASTAL VESSELS IN INDIA'S EEZ ZONE WERE EXTRACTED FROM 1 JANUARY TO 30 SEPTEMBER 2022 USING THE AIS. FIGURE 4.6 SHOWS THE TOTAL FUEL CONSUMPTION IN METRIC TONNES (MT) BY VESSEL TYPE. THE ANALYSIS FOUND THAT TANKERS HAVE THE HIGHEST FUEL CONSUMPTION (MT) WITH 166.47 K MT, FOLLOWED BY CONTAINER SHIPS AND BULK CARRIERS WITH 65.01 K MT AND 53.83 K MT, RESPECTIVELY.

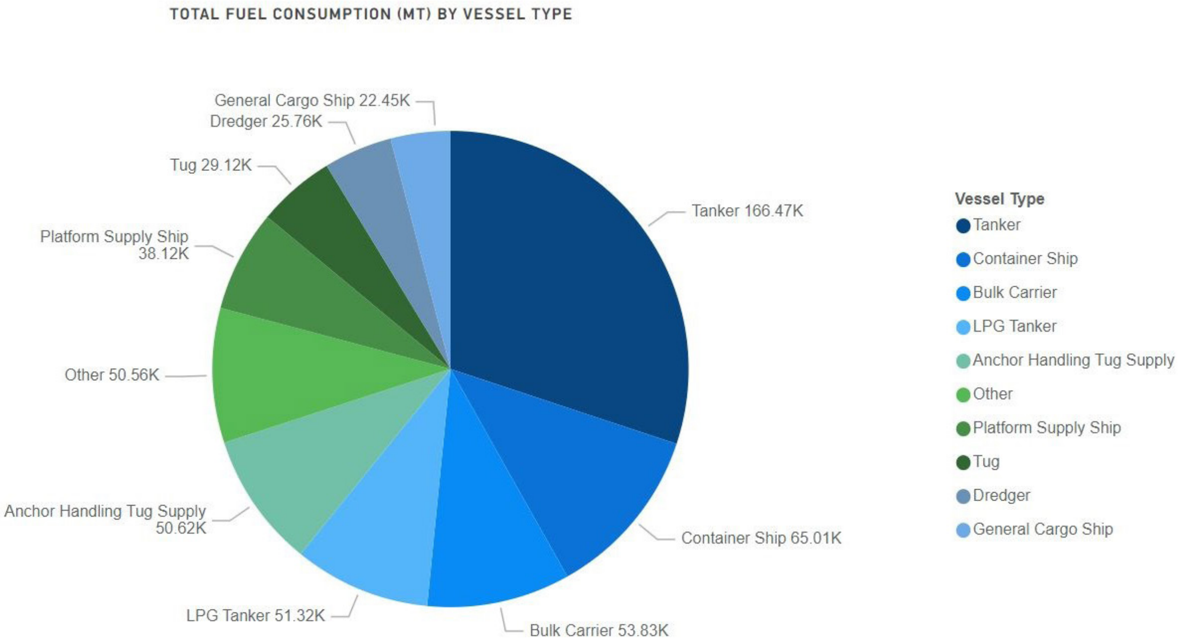


FIGURE 4.7

Heat Map of CO_2 emissions produced by Indian Coastal Vessels

FIGURE 4.7 SHOWS THE HEAT MAP OF CO_2 EMISSIONS PRODUCED BY INDIAN COASTAL VESSELS DURING THE CONSIDERED TIMEFRAME. RELATIVELY HIGHER CO_2 EMISSIONS CAN BE OBSERVED IN MUMBAI AND GUJARAT REGIONS. THIS IS DUE TO THE HIGH TRAFFIC OF TANKERS, CONTAINERS AND TUGS IN MUMBAI PORT, JAWAHARLAL NEHRU PORT AND KANDLA PORT.

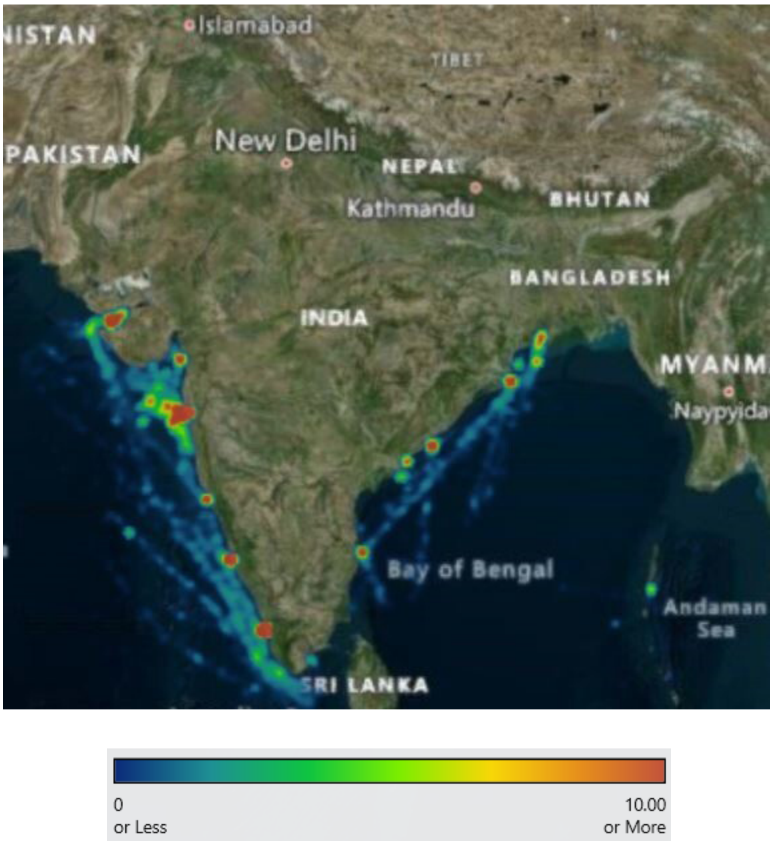


TABLE 4.1

Total Emissions of Major Coastal Vessels in India by Vessel Type

Vessel Type	No. of. Vessels	BC Emissions (t)	CH4 Emission (t)	CO2 Emission (t)	CO Emission (t)	N2O Emission (t)	NMVOC Emission (t)	NOX Emission (t)	OC Emission (t)	PM Emission (t)	SO2 Emission (t)
Tanker	106	29.12	40.82	514758.95	1030.93	17.18	340.09	9216.49	82.08	829.42	1318.89
Container Ship	20	11.54	17.96	204354.40	446.88	5.82	145.88	4236.93	36.29	377.23	551.07
Bulk Carrier	66	9.42	14.80	166920.22	367.81	4.68	119.96	3500.41	29.91	309.58	450.79
LPG Tanker	23	9.24	14.02	163401.70	350.10	4.86	114.57	3134.16	28.30	270.46	416.93
Anchor Handling Tug Supply	62	8.95	14.92	158885.95	367.99	3.98	119.35	2202.93	30.23	59.67	89.51
Platform Supply Ship	51	6.75	11.10	119797.08	274.23	3.09	89.06	1643.82	22.48	45.33	67.52
Tug	269	5.22	8.71	92509.90	214.79	2.32	69.66	1277.16	17.65	34.83	52.25
Dredger	20	4.64	6.63	81970.89	167.11	2.68	55.02	1087.75	13.35	33.19	51.11
General Cargo Ship	56	4.03	5.95	70924.57	149.11	2.23	48.95	1029.11	11.98	28.49	93.25
Other	143	8.89	11.78	157105.61	300.25	5.66	99.67	1886.13	23.62	85.73	175.06
Total	816	97.81	146.68	1730629.27	3368.94	52.50	1202.21	29214.90	295.90	2073.95	3266.37

Table 4.1 shows the total emissions of major coastal vessels in India by vessel type. The main objective of this analysis is to find the vessel type with the most emissions, thus mainly focusing on reducing emissions for these vessel types. Based on the emission analysis, tankers have the highest emissions, followed by container ships and bulk carriers.

In Figure 4.6 and Table 4.1, the other vessel category includes Anchor Handling Vessels, Cement Carriers, Supply Vessels, Deck Cargo Ships, Support Vessels, Research Vessels, FPSOs, Passenger Ships, Heavy Load Carriers, Pilot Vessels, Standby Safety Vessels, Trans Shipment Vessels, Utility Vessels, Water Injection Dredgers, Well Stimulation Vessels, and Yachts.

Ship types like Asphalt/Bitumen Tankers, Chemical/Products Tankers, Crude Oil Tankers, Crude/Oil Products Tankers, and Product Tankers have been included under the tanker segment and Articulated pusher tugs, offshore tug/supply ships, pusher tugs, and tugs are grouped under Tug segment.

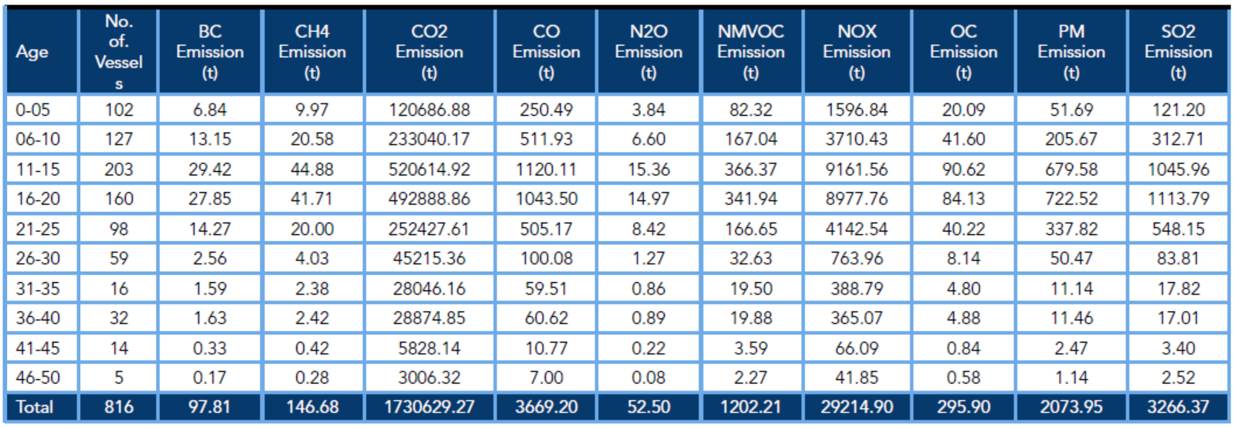
Based on the emission study, the top three vessel types, tankers, container ships and bulk carriers, constituted 51.2% of the total CO_2 emissions during the considered time-frame.

Emissions based on vessel age group

TABLE 4.2

Total Emissions of Major Coastal Vessels in India by Age

TABLE 4.2 SHOWS THE TOTAL EMISSIONS OF MAJOR COASTAL VESSELS IN INDIA BY AGE. THE TOTAL EMISSIONS OF A VESSEL TYPE WERE ANALYZED BASED ON THE AGE GROUP AND THE NUMBER OF VESSELS. BASED ON THE TOTAL EMISSIONS AND THE NUMBER OF VESSELS, THE AGE GROUP 11-15 HAS THE HIGHEST TOTAL EMISSIONS OF 533168.79 T WITH 203 VESSELS, FOLLOWED BY THE AGE GROUP 16-20 OF 505,257.04 T WITH 160 VESSELS.



Age	No. of. Vessels	BC Emission (t)	CH4 Emission (t)	CO2 Emission (t)	CO Emission (t)	N2O Emission (t)	NMVOC Emission (t)	NOX Emission (t)	OC Emission (t)	PM Emission (t)	SO2 Emission (t)
0-05	102	6.84	9.97	120686.88	250.49	3.84	82.32	1596.84	20.09	51.69	121.20
06-10	127	13.15	20.58	233040.17	511.93	6.60	167.04	3710.43	41.60	205.67	312.71
11-15	203	29.42	44.88	520614.92	1120.11	15.36	366.37	9161.56	90.62	679.58	1045.96
16-20	160	27.85	41.71	492888.86	1043.50	14.97	341.94	8977.76	84.13	722.52	1113.79
21-25	98	14.27	20.00	252427.61	505.17	8.42	166.65	4142.54	40.22	337.82	548.15
26-30	59	2.56	4.03	45215.36	100.08	1.27	32.63	763.96	8.14	50.47	83.81
31-35	16	1.59	2.38	28046.16	59.51	0.86	19.50	388.79	4.80	11.14	17.82
36-40	32	1.63	2.42	28874.85	60.62	0.89	19.88	365.07	4.88	11.46	17.01
41-45	14	0.33	0.42	5828.14	10.77	0.22	3.59	66.09	0.84	2.47	3.40
46-50	5	0.17	0.28	3006.32	7.00	0.08	2.27	41.85	0.58	1.14	2.52
Total	816	97.81	146.68	1730629.27	3669.20	52.50	1202.21	29214.90	295.90	2073.95	3266.37

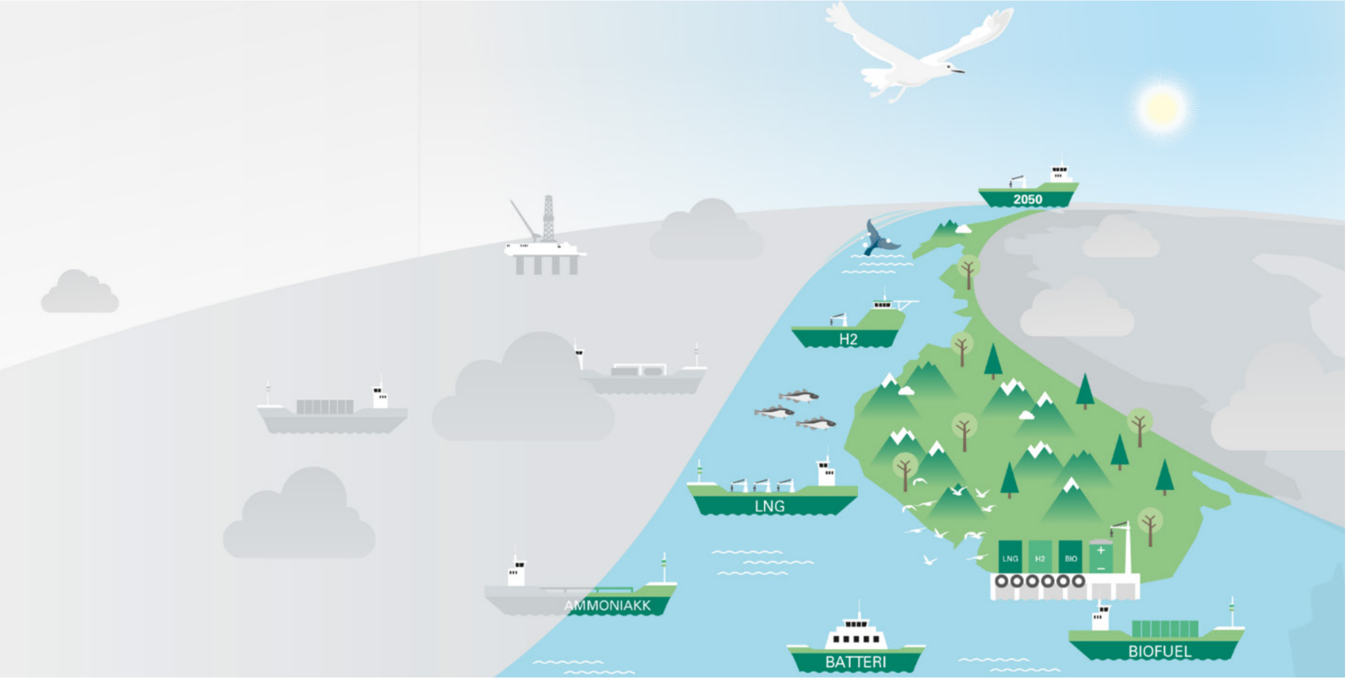
5. Green Shipping Programmes

5.1 Norway Green Shipping Programme (GSP)

There is a strong focus on reducing shipping emissions within the industry and by the authorities at all levels. It is vital to utilize the full potential of the maritime cluster and collaborate to realize great ideas. By sharing knowledge and experience, it is proven that new technology and solutions can be scaled, give the industry an international advantage, and be more competitive. Due to fast development, the industry also needs to adapt rapidly to this change.

Norwegian authorities have set ambitious goals. The authorities aim to reduce GHG emissions by 50% by 2030 for domestic shipping and fishing. To reach the goal, Norway must have approximately 700 low-emission ships and 400 zero-emission ships in 2030, distributed over all ship categories.

The Norwegian GSP is a collaborative project between government authorities and the private sector that was established in 2015 on DNV's initiative to encourage more widespread adoption of environmentally friendly solutions for shipping. The programme's vision is to offer significant reductions in GHG emissions, lead to sustainable growth, and strengthen Norway's goal to establish the world's most efficient and environmentally friendly shipping.



Key stakeholders and pilot projects

The GSP, established in January 2015, consisting of 16 organizations and two government ministries, now includes more than 103 private organizations and ten governmental entities.

Key stakeholders include shipowners and ship operators, shipyards and equipment suppliers, fuel suppliers, ports, and service providers of many kinds, including financial, insurance, classification and consultancy services and research and educational institutions, cargo owners, logistics companies, and government authorities. Together, these comprise a complete cluster with significant value creation and employment.

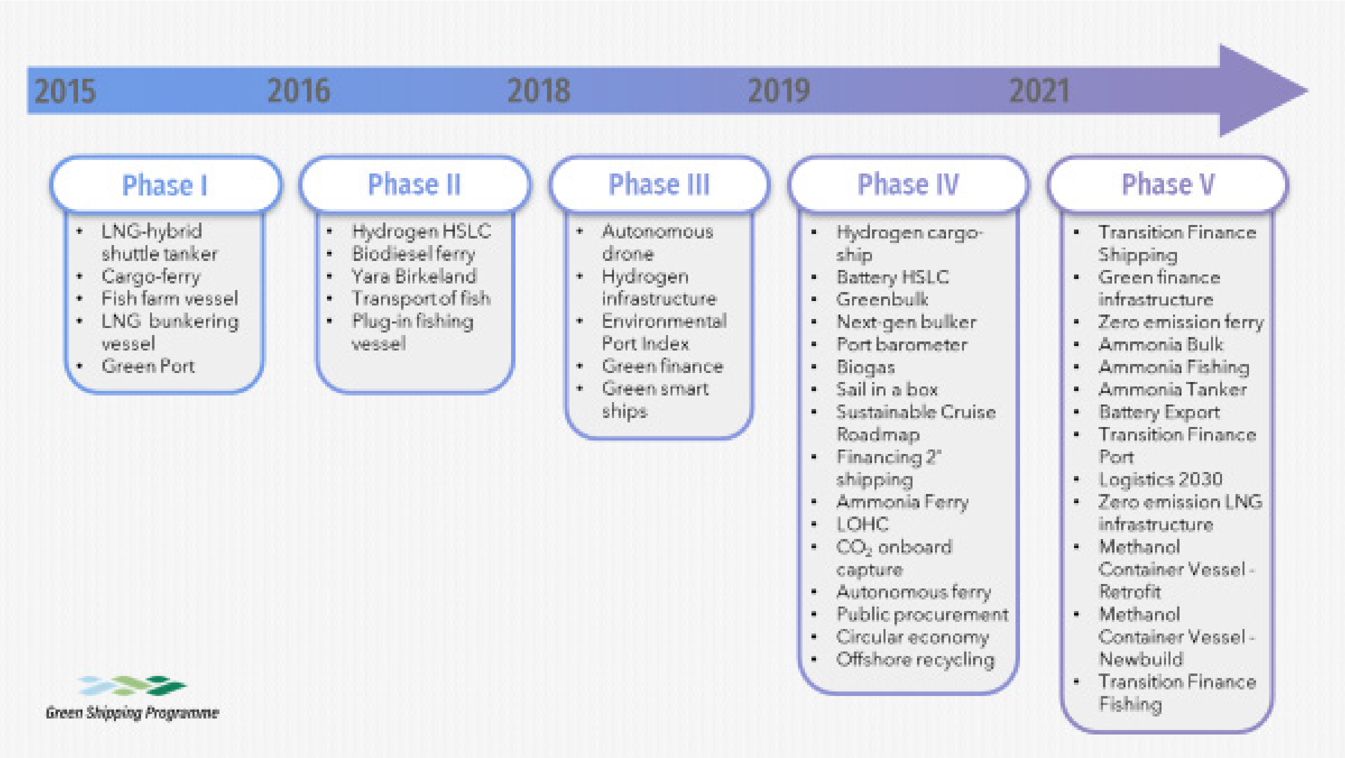
The GSP is financed by public allocations from the State budget of Norway and partly by the members themselves. The Norway government allocates seven MNOK for the programme annually. The member companies provide an annual participation fee of 100,000 NOK, whereas small companies (less than ten employees) and academic institutions have a yearly fee of 50,000 NOK.

FIGURE 5.1

Stakeholders involved in Norway GSP

FIGURE 5.2

Green pilot projects initiated in the Norway GSP



The programme has initiated over 44 green pilot projects, of which 15 have been released or are under development.[1] Initially, all pilots were owned by ship owners and were mainly focused on energy efficiency, LNG, and battery technologies. Further, the focus area expanded to port infrastructure, green market, and green financing. The cargo owners are the main drivers of the green market, and the finance sector should aid the market by providing green financing.

Goals set and results achieved in the Norway GSP

thSince its start-up in 2015, the Norway GSP has been developed through five defined phases.

First phase (2015-2016):
The first phase assessed Norway's potential for battery and gas-powered maritime transport. Its goal was to identify emissions, the potential for emission reductions, and the effect on industry and exports.

Two studies and five pilot projects were identified and started up in the first phase of this programme. Also, a barrier study for green ferry tenders (for county municipals) was carried out, which contributed greatly to the ferry revolution in Norway and the electrification of international shipping. Electrification has grown from 15 to 450 battery ships in five years, with a 40% Norwegian market share and Norway in the lead on the supplier side.

The GSP was awarded the Lloyd's List Global Environmental Prize in 2015. The initiative created a platform to spread knowledge through discussions and debates to help stakeholders make informed decisions.

Second phase (2016-2017):
The second phase evaluated business cases in the industry. Its goal was to define the way forward, analyze the business and economic consequences of the measures, and raise concrete challenges and opportunities for the Norwegian parliament and government.

A roadmap for green coastal shipping was prepared and handed over to the government's expert committee for green competitiveness. An open debate with Norway's top business, government and political leaders was organized.

The programme promoted the need for a national plan for green fuels. Furthermore, five new pilot projects were kickstarted, and a monthly newsletter was established during this phase.

Third phase (2018-2019):
The third phase focused on removing barriers to green solutions. Its goal was to answer important analytical questions related to the green transition through studies of barriers, opportunities, and policy instruments related to cargo ships, speedboats, ferries, fishing vessels, aquaculture, and oil companies' services and ports.

The government's strategy for green competitiveness focused on green framework conditions and early markets for green technologies was implemented. Also, the second edition of the debate with top leaders from business, government, and politics in Norway was conducted, and five new pilot projects were started in this phase of the programme.

Fourth phase (2019-2020):
The fourth phase was to develop and scale green solutions in Norway. Its goal was to increase the programme's scope by piloting greener technologies, fuels, logistical and financial solutions, and providing evidence-based input to the government's planning work.

An environmental policy debate and a round table conference were held with the Norwegian Prime Minister and some 20 top leaders.

Thirteen pilot projects were kickstarted, and the involvement in the IMO GreenVoyage2050 was initiated during the fourth phase.

Fifth phase (2021-Present):
The fifth phase is ongoing. The goal is to develop and scale green solutions in Norway and beyond by piloting greener technologies, fuels , logistical and financial solutions, and focus on cargo ships, offshore wind, autonomous ferries, aquaculture and oil companies' services, green public and private procurement, and moving cargo from road to sea. This phase also aims to increase export competitiveness and further develop the GSP's role in developing international green markets.

Summary of the Norway GSP Learnings from Domestic Shipping

The Norway GSP created an ecosystem for stakeholders to collaborate with initiatives for a greener way to work, including encouraging green procurement practices in the public sector, increasing carbon tax, subsidizing green alternatives for competitiveness and introducing smart regulations in the private sector. Furthermore, it identified the potential opportunities and barriers to finding solutions together and influencing future requirements and policies.

5.2 IMO-Norway GreenVoyage2050

The IMO-Norway GreenVoyage2050 Project was established to support the effective implementation of the Initial Strategy and the IMO resolution on ports. Recognizing that developing countries, Least Developing Countries (LDC) and Small Islands Developing States (SIDS) have special needs regarding capacity-building and technical cooperation, the project aims to work with selected developing countries. [62]

The project plans to utilize existing capabilities to expand government and port management capacities to undertake legal and policy reforms and develop national action plans. Additionally, it intends to catalyze private-sector partnerships, promote innovation, enable technology transfer and deliver pilot demonstration projects to facilitate technology uptake. The approach is through a broad range of coordinated actions by some Pioneer Pilot Countries (PPC), New Pilot Countries (NPC), and industry and strategic partners at national, regional, and global levels.

The countries participating in the GreenVoyage2050 project include Azerbaijan, Belize, China, the Cook Islands, Ecuador, Georgia, India, Kenya, Malaysia, Solomon Islands, South Africa, and Sri Lanka. These countries are participating as either a PPC or NPC.

GreenVoyage2050 is currently supporting the government of India in identifying solutions for green shipping through the provision of technical advisory support to the Assam Inland Water Transport Project, which has obtained financing from the World Bank for the procurement of three new green ferries.

5.3 Global Centre for Maritime Decarbonisation (GCMD)

The GCMD was formed on 1 August 2021 with funding from the Maritime and Port Authority of Singapore (MPA) and six founding partners, namely BHP, BW, DNV Foundation, Eastern Pacific Shipping, Ocean Network Express and Sembcorp Marine.

Located in Singapore, the GCMD was set up as a non-profit organization to support the decarbonization of the maritime industry to meet or exceed the IMO's goals for 2030 and 2050.

The GCMD operates to accelerate the deployment of scalable low-carbon technologies across the maritime ecosystem by validating technical and commercial feasibility and lowering the adoption barriers for low to zero-carbon fuels and technologies by closing the gaps in infrastructure, safety, operations, and financing.

The GCMD has initiated an ammonia bunkering safety study carried out by DNV, in partnership with Surbana Jurong and Singapore Maritime Academy, and a pilot project to establish an assurance framework for ensuring the supply chain integrity of current and future green marine fuels.

5.4 The Mærsk Mc-Kinney Møller Centre for Zero Carbon Shipping

The Mærsk Mc-Kinney Møller Centre for Zero Carbon Shipping is a non-profit, independent R&D centre tasked to accelerate the transition towards a net-zero future for the maritime industry. The programme, founded in October 2020, currently involves 53 partner organizations and 18 countries. With partners, the centre facilitates developing and implementing new energy and maritime technologies.

The centre accelerates zero carbon shipping transition by offering a safe space for collaborative research, development and innovation that unites players across the maritime value chain behind a shared mission and by influencing global, regional, and national decarbonization strategies to push for the needed policies and regulations.

6. Green alternatives for coastal shipping

The environmental impact of marine freight is known to be smaller than that of road freight. CO_2 emissions may be significantly reduced through a major shift in cargo transportation from land to short marine routes.

Shipowners will be compelled by policy developments and stakeholder involvement over the coming decades to find, assess, and employ technology, fuels, and solutions that aid in decarbonizing ships, reducing energy consumption, and meeting other environmental requirements. This chapter presents an updated assessment of the technological readiness levels of future ship technologies and fuels.

6.1 Alternative options and measures

An enormous opportunity for affordable emission reductions exists across the board for domestic shipping. Short-sea boats have various decarbonization choices, including more alternative power sources and driveline layouts. For these ships, electric or hybrid-electric power and propulsion systems (including diesel/gas-electric) are frequently more effective than conventional mechanical drives because of the shorter distances and extremely variable power demands. The most recent DNV Maritime Forecast to 2050 shows that the electrification of ferries is still clearly on the rise in the short-sea sector, with several ferries considering fuel-cell and hydrogen technologies to extend their range [16]. Ships' GHG emissions can be decreased in a variety of ways.. We can categorize these actions under technological, operational and fuel measure.

Technological measures

Technological measures should be used on newly constructed ships. Optimizing hull design, propellers, propulsion engines, hybridization of batteries, onshore power, and charging are a few examples. Frequently though, more expensive procedures that are best suited to newly built ships may also be applied to ones already in operation. These may include a Fuel Saving Propeller Attachment, a ship propeller energy-saving device placed at the hub that creates counterrotating swirls to balance the propeller's swirls, increase propulsion effectiveness, and modify the ship’s bulbous bow to reduce fuel consumption [13].

These technologies will be more expensive, requiring a large initial investment. However, to a certain extent, we have seen that once the technologies take root, they may result in considerable cost reductions.

Operational measures

Operational measures include methods for lowering emissions from ships without requiring physical modifications to the vessel. Optimized draught, better and more regular hull cleaning, and speed modifications are a few examples. Most operating procedures may be applied to new and old ships.

A wide range of actions is required to successfully and sustainably reduce the quantity of fuel consumed per tonne of commodities transported between ports of origin and destination. For better port call efficiency and improved behaviour, such as updated incentive structures inside and across companies, communication techniques for slow-speed operations, increased capacity utilization, and route planning are crucial. For any measure to be implemented successfully, particularly during operations, behavioural and communication factors must be considered.

Slow steaming

Slow steaming is the operational measure with the highest potential [3]. Fuel consumption may be significantly affected by even a small speed reduction. Although slow steaming is a desirable choice when ships are overcapacity, its impacts cannot be anticipated to be as large when maritime services are more in demand [15]. Fuel fees and controlled speed limits for ships are suggestions for sustaining slow-speed operations in the international fleet to lower CO_2 emissions from ships [16] [17].

Trim optimization

Ship trim optimization has gained enormous momentum in recent years, being an effective operational measure for better energy efficiency to reduce emissions. Ship trim optimization analysis has traditionally been done through tow-tank testing for a specific hull form. Computational techniques are increasingly popular in ship hydrodynamics applications.

It is pertinent to highlight that optimum trim be achieved by shifting weights while avoiding taking ballast water since increased displacement due to ballast water can cause higher resistance and, thus, higher fuel consumption. Ship trim optimization has enormous potential in liquid cargo carriers where it is easy to manipulate trim by shifting liquid weight.

Efficient machinery operation

Regular monitoring and maintenance of onboard machinery are necessary for good performance and to save fuel. For example, fuel oil injection pumps and injectors are subject to wear and tear, and turbochargers and scavenge air coolers to fouling and deposition.

The efficiency of auxiliary engines is maximum at a specific load range. Consideration should be given to the number of parallel-running engines. It is always more efficient to run one engine in its optimal load range than two or three engines at a low load.

Hull cleaning

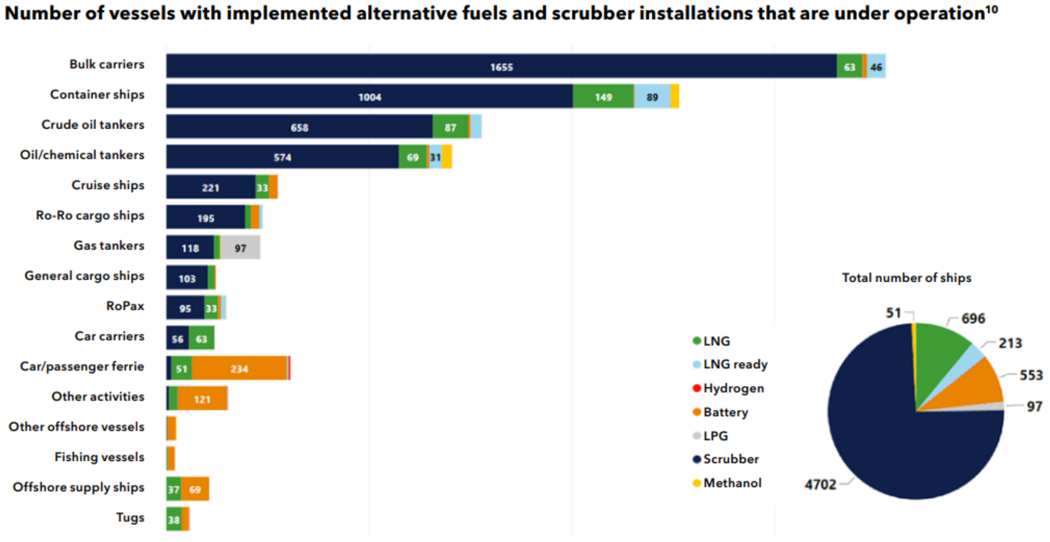
The purpose of underwater hull cleaning is to remove biological roughness or fouling. The build-up of marine fouling can lead to increased drag, negatively impacting a vessel’s hydrodynamic performance, including its speed, power and fuel consumption. Therefore, regular hull cleaning, if carried out correctly, will reduce fuel consumption, CO_2 emissions and voyage cost.

Fuel measures

Fuel measures include all substitutes for the currently preferred options, which are variations of fossil diesel. Natural gas (LNG), biogas, biofuels, and hydrogen, are examples of alternative fuels. While ICEs are anticipated to continue to dominate the fleet's energy conversion, marine fuel cells may possibly be integrated into power systems to increase efficiency and reduce fuel consumption. When used with alternative fuels like hydrogen, fuel cells may effectively reduce pollutants and noise while improving energy efficiency compared to traditional internal combustion engines. In addition to electric motors for propulsion, batteries for energy storage, and generators, hybrid systems will take advantage of fuel cells' modularity and electric efficiency.

FIGURE 6.1

Number of ships with alternative fuels (In Operation and On Order)
Source: DNV 2022 Maritime Forecast to 2050



Source: https://afi.dnv.com

Liquefied Natural Gas (LNG)

Natural gas used in industry, homes, and power plants has a chemical composition similar to liquefied natural gas (LNG). Methane (CH_4), which is the primary component of LNG, is the hydrocarbon fuel with the lowest carbon content and hence the one with the greatest potential to lower CO_2 emissions (maximum reduction: roughly 26% compared to HFO). LNG is produced using a method that virtually eliminates sulphur. So, there are no SO_x emissions while using LNG as fuel.

LNG must be kept in insulated tanks since its boiling point is -163°C at 1 bar of absolute pressure. Although the volumetric density of LHV (kg/m^3) is only around 43% of that of HFO (MJ/kg), the energy density per mass is about 18% greater than that of HFO. As a result, the volume is nearly double that of the amount of energy stored in HFO. Cylindrical LNG tanks generally occupy three to four times the volume of an equivalent quantity of energy stored in the form of fuel oil when shape-related space needs are considered.

LNG is considered a transitional fuel, as it offers cleaner combustion and reduces the vessel's CO_2 emissions compared to HFO.

Liquefied Petroleum Gas (LPG)

A liquid combination of propane and butane is referred to as liquefied petroleum gas (LPG). Propane is often thought of when someone uses the phrase LPG in the USA. Specific butane and propane mixes are employed to get the desired saturation, pressure, and temperature properties. Propane is gaseous in normal circumstances with a boiling point of -42°C. Applying a moderate pressure (8.4 bar at 20°C) will allow it to be handled like a liquid. For storage on land, propane tanks include safety valves that limit the pressure to 25 bar. Because LPG is less dense than oil, LPG fuel tanks are bigger than oil tanks. LPG comes from two primary sources: oil and gas production by-products and oil refineries. LPG may also be produced from renewable sources, for instance, as a by-product of renewable diesel production.

Liquefied Petroleum Gas (LPG)

Hydrogen (H_2) is a colourless, odourless, and non-toxic gas. It can be chemically bonded, stored as compressed gas, or kept as a cryogenic liquid for usage aboard ships. The LHV of 120 MJ/kg has an energy density per mass almost three times that of HFO. Liquid H_2's (LH_2) (71 kg/m^3) volumetric density is just 7% of that of HFO. As a result, its volume is around five times larger than when the same energy was stored as HFO. The volume of the same amount of energy when stored as a compressed gas is approximately ten to 15 times larger (depending on pressure [700 to 300 bar]) than the volume when stored as HFO [14].

H_2 is an energy source and a common chemical component. It may be created using various energy sources, such as natural gas reforming or the electrolysis of renewable energy sources. Reforming natural gas is now the most used technique of production in the transportation industry. A zero-emission value chain for transportation may arise if the generated CO_2 is collected.

In combination with CO_2, H_2 may be used to create methane, which can be utilized similarly to LNG or as a component of synthetic liquid fuels as a substitute for diesel or gasoline. The ability to store and transmit excess renewable energy through hydrogen electrolysis is seen as a way to stabilize the energy output of solar or wind power facilities. The emissions caused by alternative marine fuels might be reduced or eliminated when combined with marine fuel cells. Zero-emission ships are achievable if H_2 is produced using renewable energy, nuclear power, or natural gas with carbon capture and storage.

Major engine producers are experimenting with blend-in technology combining H_2 with different fuels in the short-sea market to enhance the performance of 4-stroke engines. Within the next two years, the world's first 4-stroke hydrogen-powered tugboat (Hydrotug) and cargo ship (with Orca) are expected to be serviced.

The proton-exchange membrane fuel cell (PEMFC) technology used to convert H_2 to electricity is relatively mature. Norled, a Norwegian ferry operator, has received two fuel cell modules from Ballard Power Systems with a combined 400 kW of power. Later this year, the MF Hydra, the first liquid hydrogen-powered ferry in the world, will run on DNV-approved fuel cell modules [16].

Hydrocarbons may be transformed into H_2 via a process known as steam reforming. As a result, H_2 will need to be generated and stored close to or at ports, which calls for significant infrastructure expenditure.

Currently, the cost of using H_2 as a fuel is considerably higher than for conventional solutions, and this is the main barrier to implementing hydrogen as a shipping fuel. However, this cannot be done without financial assistance from industrialized countries and international organizations like the EBRD, EIB, and World Bank.

Biofuels

Primary biomass or biomass leftovers are transformed into liquid or gaseous fuels, which are the source of biofuels. Conventional (first-generation) and advanced (second and third-generation) biofuels may be manufactured using a wide range of conversions and feedstocks. In principle, using biofuels is justified as this should result in a limited or zero increase in atmospheric CO_2 levels, considering the life cycle.

The carbon source used in biofuel production is a typical way to group it:

- First-generation biofuels: made from plant sources such as sugar, starch, or lipid

- Woody crops, intentionally cultivated non-food feed stock, and wastes/residue are the sources of second-generation biofuels.
- Biofuels of the third generation made from aquatic autotrophic organisms (e.g. algae)

Biofuels are commonly noted as having a rivalry with food production. This is only a problem with first-generation fuels. Since they do not compete with food crops, advanced biofuels are regarded as being more sustainable.

Conventional biofuels usually contain less energy and emit less GHGs than traditional marine fuels. However, there might be more NOx emissions. Biodiesel (such as hydrotreated vegetable oil [HVO], biomass-to-liquids [BTL], and fatty acid methyl ester [FAME]) and liquefied biogas are the most promising biofuels for ships (LBG). Straight vegetable oil (SVO) may replace HFO, whereas biodiesel is better for replacing MDO/MGO and fossil LNG.

Renewable HVO biodiesel is a quality fuel with oxygen removed using hydrogen, giving it long-term stability. It may be utilized in existing engines with the manufacturer's permission and is compatible with the current infrastructure. From a life-cycle viewpoint, the GHG emissions are around 50% lower than diesel, and the NOx and particulate matter (PM) emissions are also lower. No sulphur emissions are produced.

Methanol

The simplest alcohol, methanol, has the highest hydrogen concentration and lowest carbon percentage of any liquid fuel. Its chemical formula is CH_3OH. At atmospheric pressure, methanol is a liquid with a temperature between -93°C and +65°C (176–338 Kelvin).

Methanol may be created using various feedstock materials, primarily natural gas or coal, but also from renewable sources like black liquor from pulp and paper mills, forest thinning, agricultural waste, or even CO_2 directly absorbed from power plants. Natural gas is commonly generated using a steam reforming and partial oxidation combination, with an energy efficiency of up to roughly 70%. Gasifying coal yields methanol at a low cost with a vast supply. However, the process produces nearly twice as much GHGs as burning natural gas.

Methanol fuel tanks are around 2.5 times bigger than oil tanks for the same amount of energy due to their density and lower heating value (19.5 MJ/kg). Methanol is a fuel with a low flashpoint, with a flashpoint between 11 and 12 degrees Celsius. Dimethyl ether (DME), which may be used as a fuel for diesel engines, can also be produced from it.

Tankers carrying methanol as cargo have successfully been using dual-fuel 2-stroke methanol engines for propulsion since 2017. With increased interest in methanol as a fuel, the commercially available product range is expected to grow, and we also foresee other makers entering this market. Retrofit options for a range of 2-stroke engines are also available.

Ammonia

Ammonia (NH_3) is a colourless gas with a lower density than air. It may be handled as a liquid at room temperature with a reasonable amount of pressure and a boiling point of -33.3 °C. Ammonia is a liquid with a density of 0.61 t/m^3 at pressures greater than 8.6 bar and 20°C. The density is 0.68 t/m3 at the boiling point. A lower heating value base gives ammonia a heating value of 18.6 MJ/kg. As a result, the energy content of MGO in its liquid state is less than half on a mass basis and around 30% on a volume basis.

Compared with methanol, engine technologies for ammonia are less mature. Neither 2- nor 4-stroke engines using ammonia as fuel are currently commercially available.

Battery-electric operation

In terms of performance, safety, and fuel efficiency, electric power systems utilizing batteries are more manageable and simpler to optimize. New opportunities arise as battery technology advances and costs reduce with more electric ship power systems. With current battery technology, all-electric solutions are suitable for relatively short routes where frequent recharging is possible.

Fully electric ships are an advancement in power system design, although they are currently only practical for a few uses, such as ferries and short-sea transport. Other boats' ability to operate entirely on electricity is often constrained by the size or price of the necessary battery pack. Naturally, many other applications of battery systems also have the same restrictions.

Batteries as a source of electrical energy for propulsion widen the range of choices for improving the power system. Recent advancements in battery technology and the decline in battery prices due to increased worldwide demand make this technology appealing to shipping. The Yara Birkeland project shows that full electrification may be possible in the cargo vessel segment on certain short, regular routes.

Fuel cell systems

Compared to traditional engines, fuel cells have a high electrical efficiency of up to 60% and emit less noise and vibration. The major parts of a fuel cell power system are the fuel cells, which use electrochemical oxidation to directly transform the chemical energy held in the fuel into electrical and heat energy. Depending on the fuel cell type and fuel utilized, this direct conversion provides up to 60% electrical efficiency. Alkaline fuel cells (AFC), proton exchange membrane fuel cells (PEMFC), high-temperature PEMFCs (HT-PEMFC), direct methanol fuel cells (DMFC), phosphoric acid fuel cells (PAFC), molten carbonate fuel cells (MCFC), and solid oxide fuel cells are some of the several fuel cell technologies (SOFC). The SOFC, PEMFC, and HT-PEMFC fuel cell technologies are the most promising for ship usage.

Fuel reformers transform the original fuel into hydrogen-rich fuel for use in fuel cells. Fuel reformers permit using natural gas, methanol, low-flashpoint diesel, and pure hydrogen.
An electrochemical process rather than burning is how the fuel cell operates. The only process that could include any fuel burning is Reforming. Cell technology can, therefore, significantly lower emissions into the air.

Electrochemical oxidation is a process fuel cells employ to convert a fuel's chemical energy directly into electrical and thermal energy. This direct conversion method offers up to 60% electrical efficiency, depending on the fuel cell design and the fuel used. It also lessens vibration and noise emissions, another important flaw with combustion engines.

Other measures
In addition to the actions above, GHG emissions could be significantly reduced through sea instead of road cargo transportation. According to a DNV analysis for the Norwegian Shipowners' Association, multimodal transport systems could use less energy and generate significantly less GHG than car-based systems. In the analysis of domestic and inter-European transportation scenarios, it was determined that CO_2 emissions could decrease by 54–80%. This translates to a national reduction in CO_2 emissions of 300,000 tonnes per year, or the environmental impact of 150,000 electric vehicles when converted to an assessed transfer potential of five million tonnes of cargo from road to sea.

Improvements in design, more energy-efficient operation, and increased fleet utilization are just a few of the significant ways digitalization may help shipping reduce its carbon footprint. Many digital technologies that may be employed in the shipping business have recently been developed. These tools, either alone or in combination with other digital technologies, can offer digitally enabled optimization and decreased emissions in shipping. However, it should be acknowledged that the onboard technologies required to assist the marine energy transition are still mostly under development.

It is also possible to install a Fuel Optimization System (FOS) on ships that sends and gathers data using equipment and software installed aboard the vessel. It also evaluates the external aspects of the route and the state of the vessel. The ML software allows an FOS to process data on shipping conditions and external parameters affecting projected paths. Continuous voyage-impacting data collection and predictive analysis will forecast the most fuel-efficient path, guaranteeing ships always sail at the right speed and avoid port delays and adverse weather[20].

Much of the fuel used by ships at berth is used to generate electricity, which powers facilities such as air conditioning, cooking, lighting, and pumps required to load and unload cargo on tanker ships, as well as facilities for crew and passenger usage. This indicates that compared to other ship types, ferries, cruise ships, and tankers use comparatively more fuel while berthed. A different option is for ships to berth electricity connected to the land. This technology has not yet made much of an impact, although it is available in a few ports, where ships engaged in the liner trade may link to shoreside energy. Development has been slowed by various real-world problems, including fluctuations in electrical current voltage and frequency, the expense of investments, and the availability of crews to construct the actual connection.

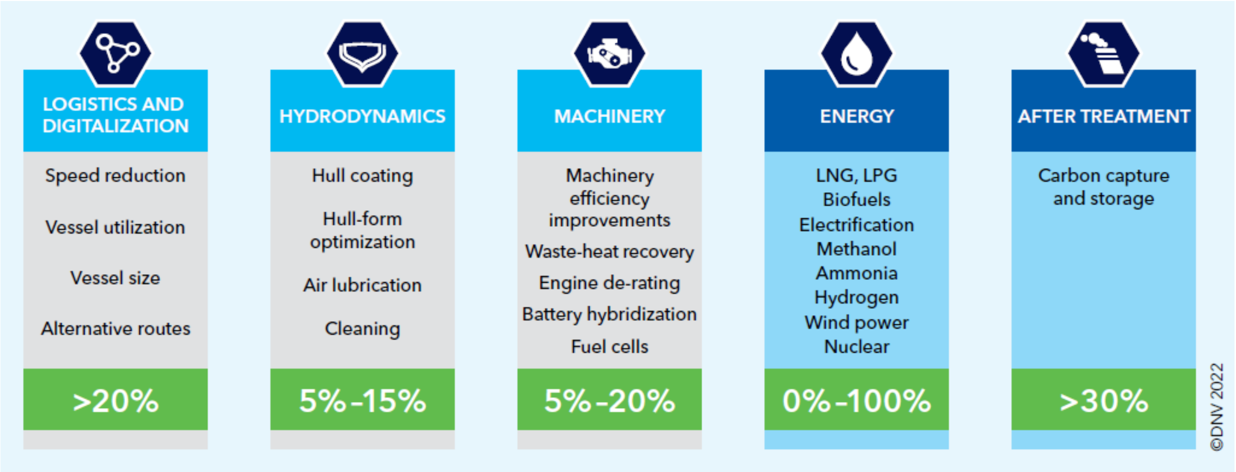
Whether or not shoreside energy is a suitable alternative for lowering CO_2 emissions depends on how the electricity is generated: coal-powered electricity may increase CO_2 emissions, but it will be greatly decreased by using renewable sources. However, the major benefit of shoreside energy is that it lessens the discharge of pollutants like NO_X and particulates in inhabited areas.

6.2 Comparison of green alternatives

New fuels, increased energy efficiency, and better logistics will be necessary to decarbonize shipping. Regardless of efficiency improvements, switching to carbon-neutral fuels will be necessary to achieve aggressive decarbonization objectives. Unfortunately, new fuels are not yet readily available in significant quantities, and they are also frequently more expensive and space intensive. These elements strengthen the business case for energy efficiency (and harvesting) solutions. The current scenario with high LNG and fuel oil costs will likely further increase the focus on fuel savings. When energy-efficiency techniques and wind-assisted propulsion are used, ship ideas now under development have a substantial potential to reduce fuel consumption.

FIGURE 6.2

GHG emission reduction potential of technologies that can contribute to shipping decarbonization
Source: DNV 2022 Maritime Forecast to 2050



Comparison of alternative fuels

CO_2 emissions

CO_2-equivalent emissions are used to assess GHG emissions. LNG has the lowest CO_2 emissions of all relevant fossil fuels. The advantage over HFO and MGO, however, might be diminished by the emission of unburned CH_4 (so-called methane slip), as CH_4 has a 25 to 30 times greater GHG effect than CO_2.

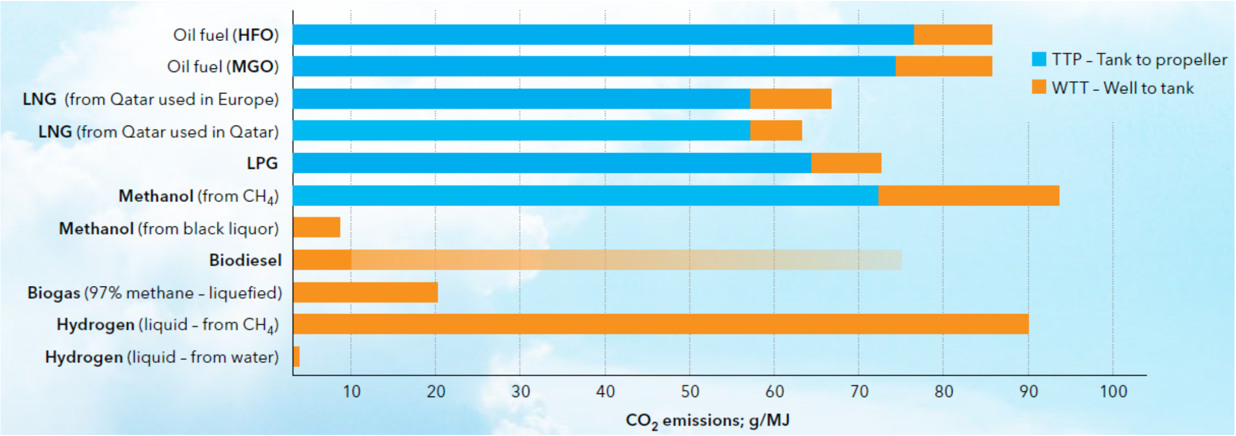
Methanol and hydrogen from natural gas have a more significant carbon footprint than HFO and MGO. A low carbon footprint is the main advantage of renewable energy fuels.

First-generation biodiesel has one of the weakest potentials to reduce CO_2 among these fuels. The potential to reduce CO_2 is particularly great in biogas, which is liquefied methane produced from biomass. It should be emphasized that CH_4 is also the primary ingredient of LNG, making the two liquefied gases equivalent.

Hydrogen created using renewable energy is the cleanest fuel. In the future, liquefied hydrogen could be employed in ships. Since hydrogen has a big storage volume and a low energy density, it might not be possible to utilize it in international deep-sea transport.

FIGURE 6.3

CO_2 Emissions of Fuel Alternatives in Shipping
Source: DNV AFI



Fuel prices

The engine technology investment is typically not the key component of the business case. The most important aspect is frequently the fuel cost during the ship's lifetime or the anticipated rate of return on investment. The fuel cost is affected by several variables, including market circumstances, which are difficult or impossible to forecast. Figure 6.4 shows the current prices of fuels, with LPG and methanol having the lowest price per MMBtu.

FIGURE 6.4

Fuel Price Statistics
Source: DNV AFI

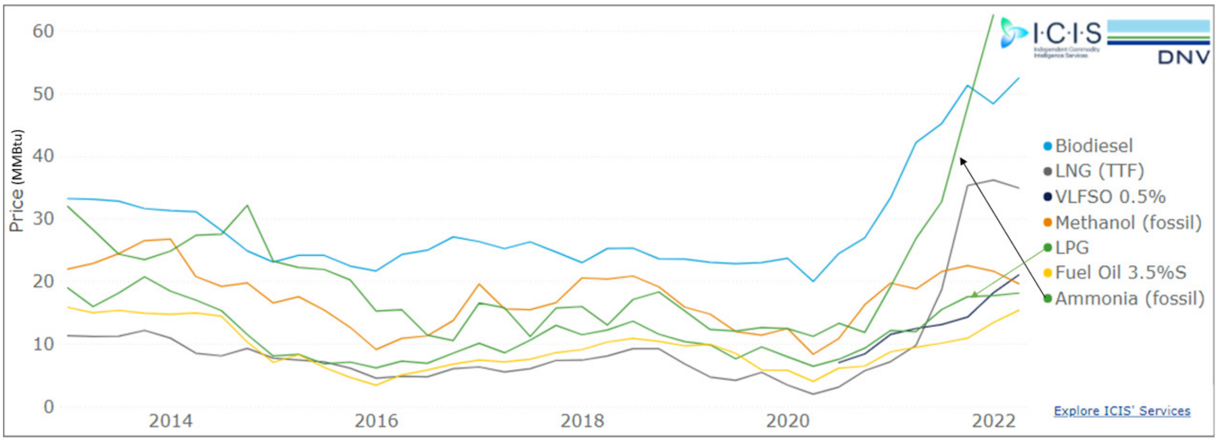


FIGURE 6.5

Qualitative price range of possible ship fuels by 2050
Source: DNV 2022 Maritime Forecast to 2050

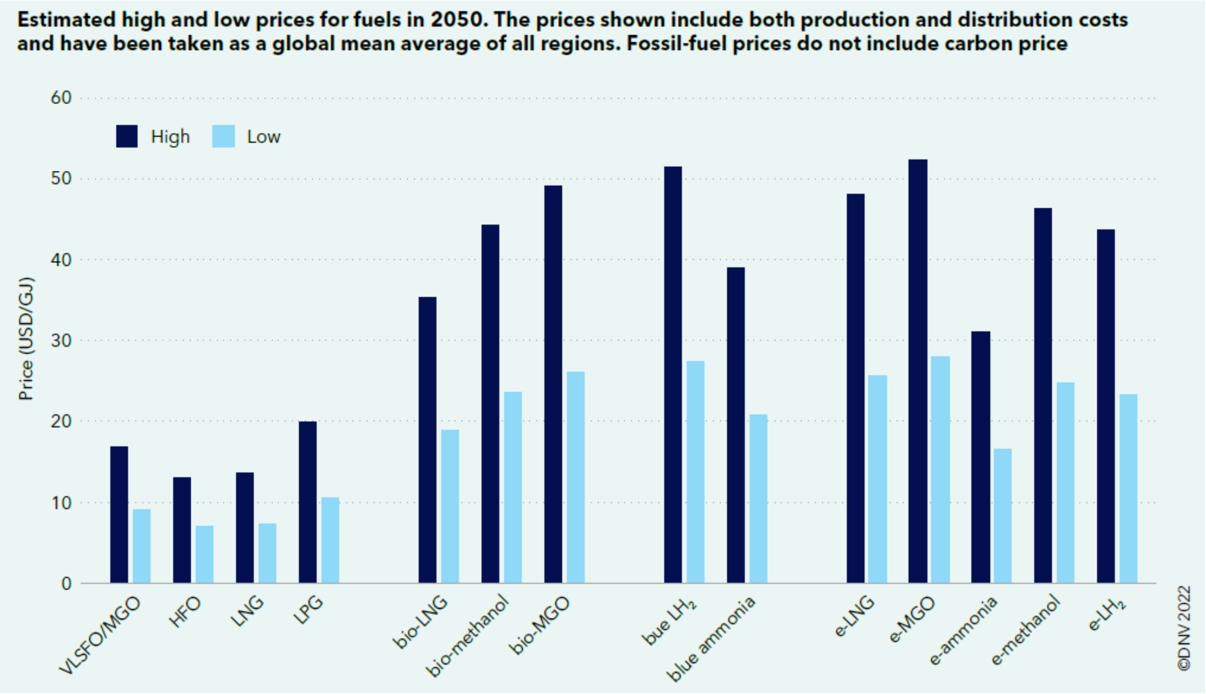


Figure 6.5 estimates the highs and lows of mid-century fuel prices, calculated as a global mean average of all ten regions as defined in DNV's Energy Transition Outlook model of the worldwide energy system to 2050 [1].

Hydrogen is expected to cost more to produce with renewable energy compared to Brent crude oil. It would only be competitive for use with significant subsidies or if conventional fuels were subject to high levies. Nearly all hydrogen generated today comes from natural gas, making its production more costly than natural gas.

Today, natural gas is the major source of methanol production. The cost of methanol often exceeds that of gasoline for this reason. From the diagram, methanol made from gas (e-methanol) is cheaper than methanol produced from biomass (bio-methanol). Biomass is used to make biofuels. The cost is often higher than that of Brent crude oil; however, it varies depending on the kind of biofuel and the cost of the biomass.

Fuel availability

Apart from its price, future fuels must be available to the market in sufficient quantity. In the next ten years, assuming a relatively modest increase in transportation applications, all fuel choices considered here might satisfy the needs of the shipping sector. Except for LNG, a sharp increase in demand would necessitate significant expenditures in production capacity for all alternative fuels. Theoretically, given that the present LNG output exceeds the energy needs of the shipping sector and LNG only accounts for 10% of the overall gas market, converting the whole world's fleet to LNG is now feasible.

FIGURE 6.6

Traditional fuel supply chain
Source: DNV 2022 Maritime Forecast to 2050

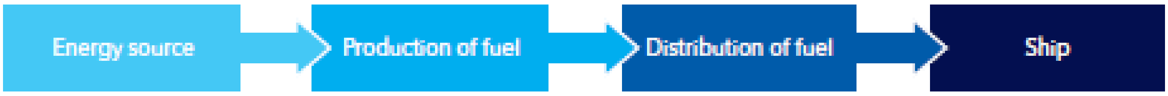
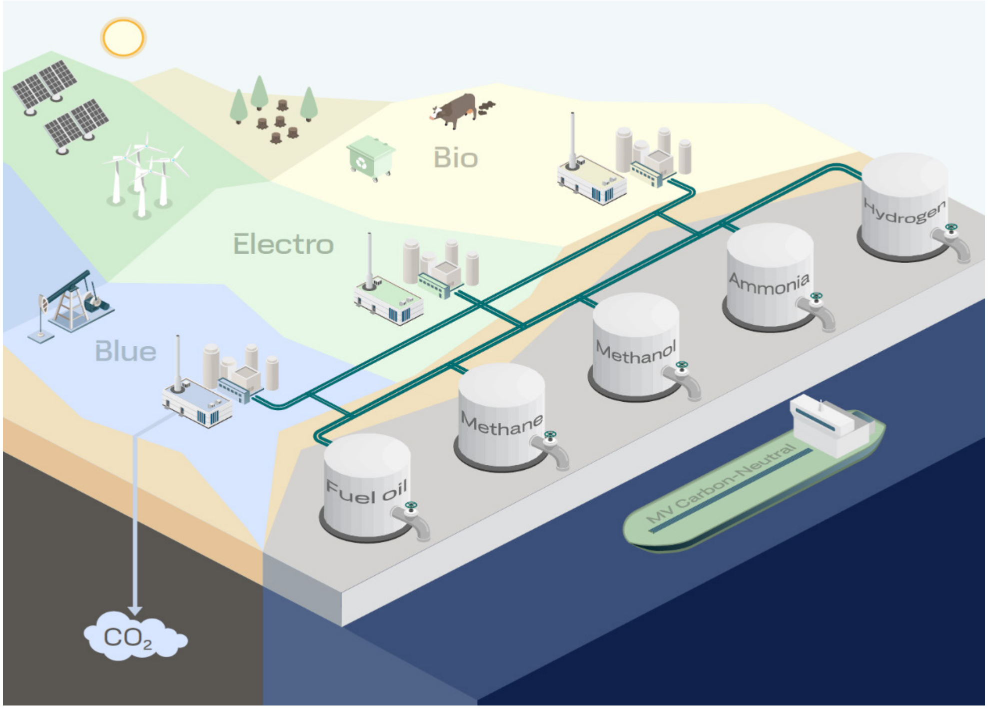


FIGURE 6.7

Future fuel supply chain
Source: DNV 2022 Maritime Forecast to 2050



Concluding remarks

Alternative shipping fuels are becoming more popular due to environmental and financial issues; however, there are few viable options. The most promising possibilities, according to DNV, are LNG, LPG, methanol, biofuel, and hydrogen. Methanol and biofuels will soon join LNG, having already surmounted the obstacles from international law. It will take some time before the relevant new laws under the IMO IGF Code apply to LPG and hydrogen.

All alternative fuels may be used in today's technology to comply with the current and prospective environmental constraints. However, the IMO's ambitious goal of reducing GHG emissions by 50% by 2050 would necessitate the widespread use of zero-carbon fuels and other energy-saving initiatives.

The sole exception is LNG, which is now available in sufficient quantities to match the projected demand of the shipping sector for many years. A significant rise in consumption would necessitate a commensurate increase in production capacity. Renewable fuel prices will struggle to keep up with those of traditional fossil fuels in the absence of taxes or subsidies.

As the Indian coastal fleet is relatively old, as observed in Chapter 4, operational measures and drop-in fuels are preferred for the relatively old vessels over technological measures as it’s fairly economical. Technological and fuel measures can be adopted for newbuilds in the coastal shipping segment.

7. Maritime knowledge cluster in India

7.1 Overview of the Indian maritime knowledge cluster

India has made significant progress in the past ten years as a maritime nation. Major ports in India have made significant improvements in port efficiency, inland waterways have been developed to facilitate the movement of logistics, shipbuilding sector has expanded through various government policies. Looking at the area of maritime education, India is one of the top countries in the world when it comes to the number of maritime institutions. India's maritime education and training are led by the Directorate General of Shipping, and significant efforts have been made to establish a network of maritime institutions in it. Locations such as Cochin, Chennai and Mumbai are regions with strong presences of maritime institutes. Research intuitions such as the National Technology for Ports, Waterways & Coasts (NTPWC) and Indian Maritime University (IMU) have been key players in maritime research in India.

Cochin

Cochin is home to several maritime training institutes, including Marine Engineering Training Institute (METI), which was set up to cater for developing digital and technological advancements in the maritime field. METI is located and operated by Cochin Shipyard. Cochin has been dubbed the technological hub of the Indian Maritime Industry, where numerous highly specialized vessels have been delivered by Cochin Shipyard, the largest public sector shipyard in India. Cochin Shipyard built India's first indigenous aircraft carrier, INS Vikrant. INS Vikrant is the first aircraft carrier of the Indian Navy that was designed and built in India. The aircraft carrier was designed with a high degree of automation for machinery operations, ship navigation and survivability and is equipped with the latest state-of-the-art equipment and systems [21]. The shipyard also recently delivered two 67m-long autonomous barges, each including a battery with a capacity of 1,846kWh, to ASKO Maritime and received orders for technological advancement vessels such as a dredging vessel. Cochin shipyards boast its in-house R&D division, Cochin Shipyard Limited Strategic & Advanced Solutions (C-SAS), formed to allow the shipyard to venture into future technologies. The shipyard is building India's first type of hydrogen-fuelled electric vessels, a pilot project partly funded by the Ministry of Ports, Shipping and Waterways (MoPSW) [22].

FIGURE 7.1

INS Vikrant
Source: Press Trust of India

Mumbai

Mumbai is ranked 6th in the world regarding the number of maritime education institutions, behind leading maritime knowledge hubs such as Singapore and London. It is also one of the top 50 cities in the world in the 2022 publication of Leading Maritime Capitals of the World studies. Home to maritime institutes and universities, with varying specializations from seafarer training to business or technology-related courses, Mumbai houses several shipyards in the city, such as Mazagon Dock Shipbuilders and Bombay Dockyard. Mazagon Dock Shipbuilders is a state-owned shipyard capable of building Indian Naval warships, coastal merchant vessels, and offshore support vessels. Bombay Dockyard is a state-owned primarily focused on building vessels for the Indian Navy.

Chennai

Located on the East Coast of India, Chennai houses 11 maritime institutions and one of the biggest shipyards in India, L&T Shipbuilding. Collaborations with Japanese shipbuilder Mitsubishi Heavy Industries have allowed the shipyard to design and construct various commercial ships, such as offshore support vessels and chemical tankers [23]. Chennai is also home to the National Technology Centre for Ports, Waterways and Coasts (NTCPWC), which the Ministry of Ports, Shipping and Waterways (MPSW) set up to provide and develop technological innovations and solutions for the port and maritime sector. Established in the Indian Institute of Technology Madras (IITM), the centre provides education, applied research and technology transfer in maritime transportation. In recent years, the centre has developed effective solutions for major Indian ports and waterways, which led to significant cost savings [24]. These solutions include software systems such as Tidal and Meteorological Monitoring, Telemetry and Display System (TMMTDS) to provide reliable and easily accessible environmental and operational data critical to port operations [24].

Kolkata

Kolkata is home to several maritime colleges, including the prestigious Indian Maritime University Kolkata Campus, which comprises two premier institutions, the Marine Engineering & Research Institute (MERI, Kolkata) and the Indian Institute of Port Management (IIPM, Kolkata). Garden Reach Shipbuilders and Engineers (GSRE) is a premier defence shipyard in India that has played a crucial role in building up the defence capabilities of the Indian Navy. The shipyard has delivered over 100 warships since the 1960s, and the yard can build frigates and missile corvettes [25]. The yard also has the capability of building cargo and passenger ferries and received orders to build next-generation electric ferries to replace the current diesel ferries operating in the Hooghly River [25]. The 24-meter-long electric ferries will have a maximum speed of 8 knots and a carrying capacity of 145 passengers. The in-house design team of GRSE will fully design the ferries. [25]

Kolkata will be home to the Centre for Inland and Coastal Maritime Technology (CICMT), a maritime research intuition set up under the Sagarmala programme. The CICMT will be set up at the Indian Institute of Technology Kharagpur (IITK), known for its Ocean Engineering and Naval Architecture programmes [26]. The centre will provide applied research in ship design, shipbuilding, green energy harvesting and automation and artificial intelligence for inland and coastal waterways in India. The research centre is also the first in India to develop testing facilities for shallow water, a necessity for inland vessels. The centre will also provide relevant Master and PhD programmes [26].

Goa

Goa houses several maritime institutions, including the Institute of Ship Building Technology (ISBT) and the Institute of Maritime Studies (IMS) and is also home to commercial and defence shipyards. The ISBT provides diploma programmes in shipbuilding, and the institute extends its facilities to the industry to train workers in shipbuilding [27]. Chowgule Shipyard Ltd is a state-owned shipyard that builds vessels for the defence industry and merchant vessels. The yard can build hybrid electric coastal vessels and defence patrol vessels. Goa Shipyard Limited is another defence shipyard contributing significantly to the Indian Navy and Indian Coast Guard. The yard can build high-speed crafts up to 40 knots and Naval Offshore Patrol Vessels with state-of-the-art navigation and communication equipment and electronic warfare equipment [27].

Visakhapatnam

Located on the East Coast of the Indian peninsula, Vishakhapatnam houses maritime institutions such as the Indian Maritime institute, which comprises India's premier ship design and maritime research institution, the National Ship Design and Research Centre. Also located in Visakhapatnam is one of India’s largest defence shipyards, Hindustan Shipyard. The yard can refit submarines for the Indian Navy and offshore platforms. Sagar Bhushan is a highly sophisticated and complex drillship built in India for the first time by Hindustan Shipyard [28]. The Hindustan shipyard is the only shipyard in India capable of submarine refits [28].

Gujarat

Located along the west coast of India, Gujarat is an emerging maritime cluster. In 2015, the state received approval to establish India’s very dedicated maritime cluster. The cluster aims to bring together various stakeholders of India's maritime industry, including the establishment of Gujarat Maritime University (GMU). GMU will address the need for an industry-ready workforce and open doors for industry-academia R&D collaboration [29]. GMU will also be the first maritime institution in India to cater for all disciplines in the maritime sector, including maritime law, shipping finance and economics [29]. India’s first maritime arbitration centre will also be set up in the cluster. The cluster will be located in Gujarat International Finance Tec-City, one of India’s top financial centres.

FIGURE 7.2

Concept Design of Hybrid Electric Ferry
Source: Garden Reach Shipbuilders and Engineers Ltd

7.2 Assessment of India's maritime technology

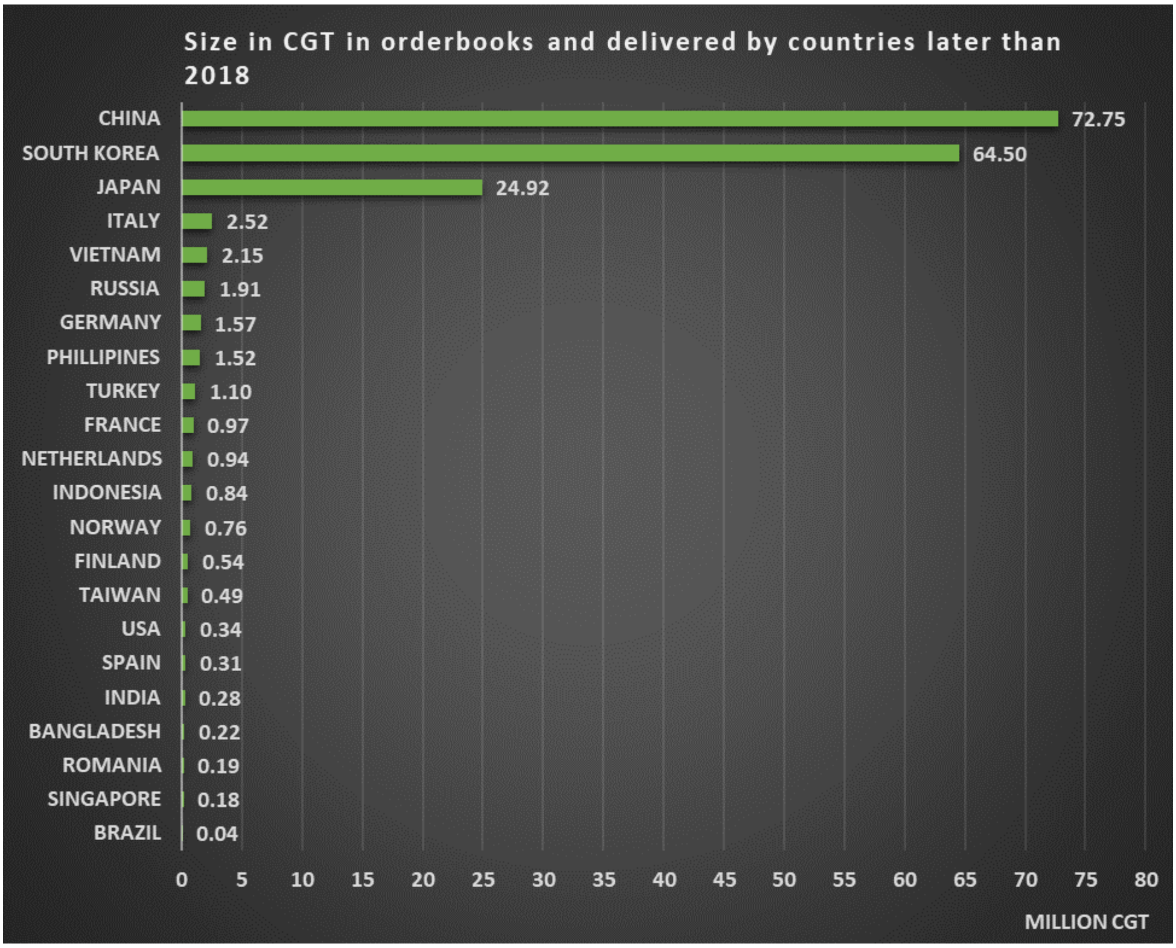
Maritime technology is a good metric to assess a country's existing maritime knowledge capabilities. Shipyard delivery by size, including low or zero-carbon fuel vessels, the share of world fleet by classification societies, the market value of ships built at shipyards, and the number of maritime education institutions are some indicators used in the Leading Maritime cities report 2022 to assess a city's maritime technology capability. In this subsection, these objective indicators will be utilized to compare India's maritime technological capabilities against top maritime nations worldwide, including Singapore and Norway.

Shipyard deliveries by size of fleet

Shipbuilding is an activity where shipyards must adhere to design and industry standards. Assembling ships is a technologically and logistically demanding operation. Some shipyards can assemble in one location, but for advanced ships, it is common for hull construction to occur in low-cost countries before outfitting is done in countries with more highly skilled and costly labour [31].

FIGURE 7.3

Size in CGT in orderbooks and delivered by countries later than 2018
Source: Clarkson Research 2022

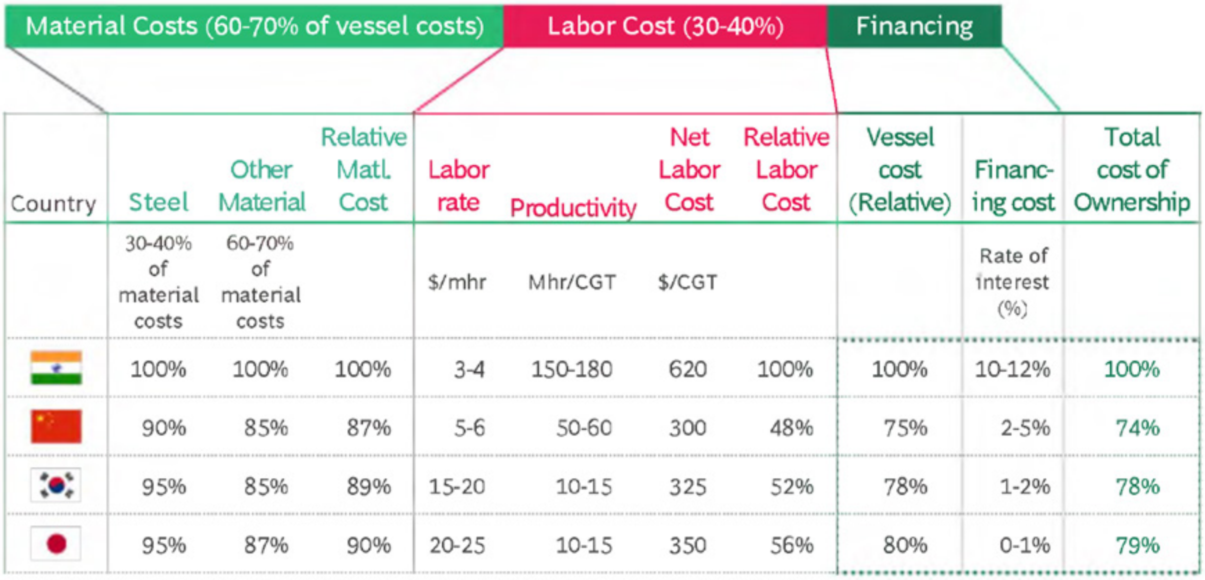


In terms of vessels delivered and on order, China, South Korea and Japan dominate the world shipbuilding industry, taking up the lion's share of 90%. India accounts for 280,000 CGT, only capturing 0.5% of the world market share and ranked 19th in the world. Norwegian yards account for 758,000 CGT and rank 13th globally, while Singapore accounts for 180,000 CGT and is ranked 15th.

India has lagged behind top competitors in the world of shipbuilding. Although India has demonstrated strong shipbuilding capabilities with deliveries such as aircraft carriers and sophisticated offshore and naval vessels, they have struggled globally against vessel sizes delivered from regional players like China, Korea, and Japan. The reasons include higher material costs, low productivity, and high financing rates in India, as shown in Figure 7.4.

FIGURE 7.4

Overview of Cost to Build Vessel in India compared to global leaders
Source: MIV 2030 Report



	Material Costs (60-70% of vessel costs)			Labor Cost (30-40%)				Financing		
Country	Steel	Other Material	Relative Matl. Cost	Labor rate	Productivity	Net Labor Cost	Relative Labor Cost	Vessel cost (Relative)	Financing cost	Total cost of Ownership
	30-40% of material costs	60-70% of material costs		$/mhr	Mhr/CGT	$/CGT			Rate of interest (%)	
🇮🇳	100%	100%	100%	3-4	150-180	620	100%	100%	10-12%	100%
🇨🇳	90%	85%	87%	5-6	50-60	300	48%	75%	2-5%	74%
🇰🇷	95%	85%	89%	15-20	10-15	325	52%	78%	1-2%	78%
🇯🇵	95%	87%	90%	20-25	10-15	350	56%	80%	0-1%	79%

Shipyard deliveries by size of eco-friendly ships

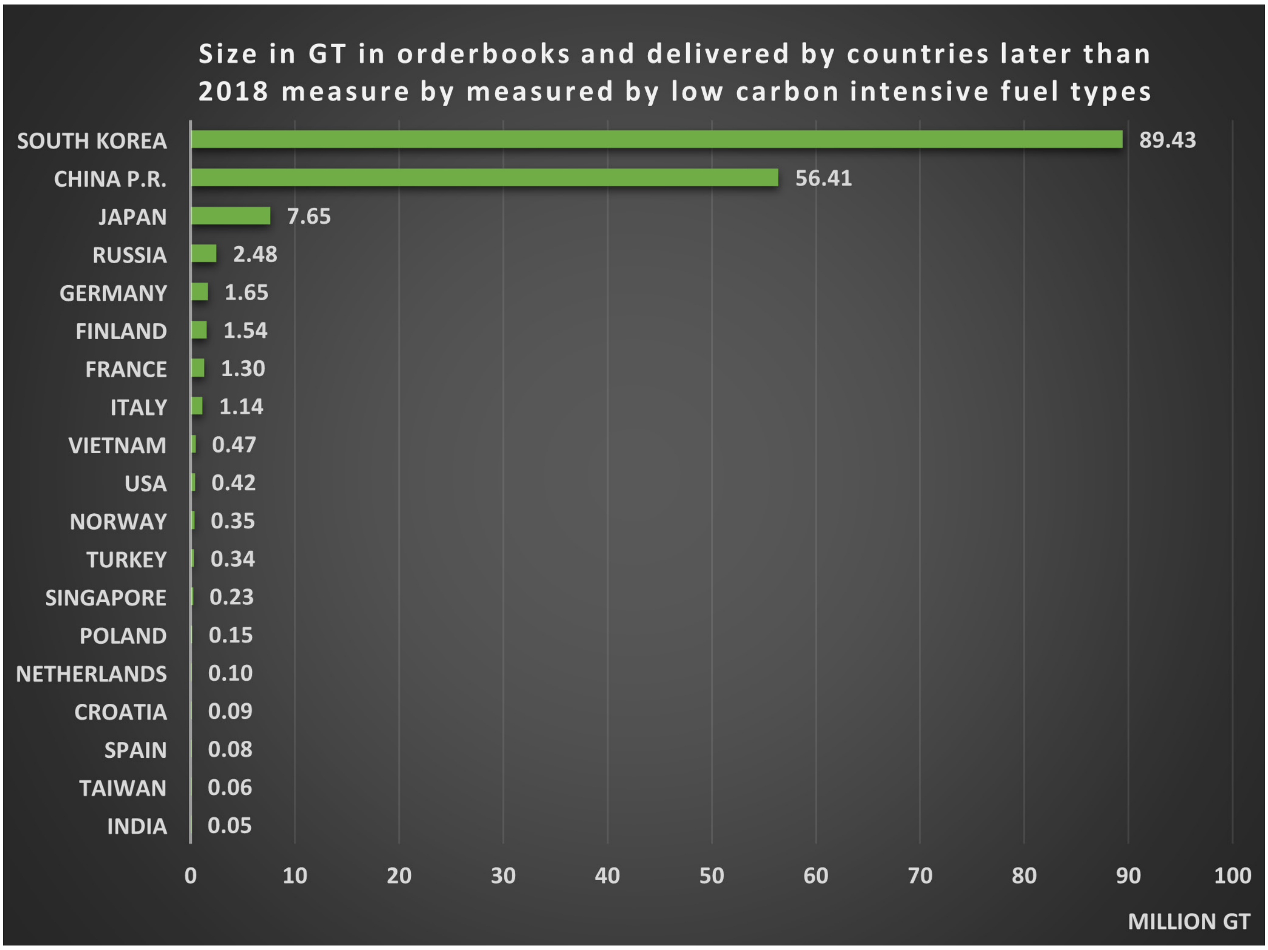
Building eco-friendly vessels are technologically intensive and require an innovative design and manufacturing approach compared to traditional ones. New strategies will have to be derived through innovative solutions which can put the shipyard in a strong position compared to its competitors. Building an eco-friendly ship is not just about a change of an engine; smart ship technologies also play a crucial part. In this aspect, shipyard deliveries of eco-friendly ships are a good indicator of how technologically advanced a shipyard is [31].

South Korea, China, and Japan capture most of the global market of eco-friendly ships built in terms of GT, with South Korea leading at 86% of alternative-fuelled vessels built being LNG-capable and LNG-ready. In the past three years, 50% of all vessels built in the top three countries were eco-friendly. India ranks 19th in the world, accounting for only 46,500 GT of eco-friendly vessels built. Norway accounts for 350,000 GT, dominating the area of batteries and fuel cells. Singapore is ranked 15th, accounting for 230,000 GT.

Although small in scale, Indian shipyards have already made initiatives to venture into alternative-fuelled vessels. Cochin shipyard has been involved with numerous projects related to greener fuels, including the delivery of two battery-powered barges. The shipyard has also received an order to build 23 hybrid electric aluminium catamaran hull vessels, of which five have been delivered to the Kochi Water Metro Project [32]. The shipyard has also engaged in a pilot project involving hydrogen fuel cells in collaboration with local partners. Chowgule Shipyard in Goa is another yard involved in building alternative-fuelled vessels. The yard has won contracts to build six highly energy-efficient electric hybrid vessels with a DWT of 5350 T with a length of 90 meters, a breadth of 16 meters, and a draft of 6 meters each. The vessel's battery packs, shore-side electricity solution and electric hybrid use, will enable emission-free and noise-free port calls [33].

FIGURE 7.5

Size in GT in orderbooks and delivered by top shipbuilding countries later than 2018 measured by low carbon-intensive fuel types
Source: Clarkson Research 2022



Case Study On Kochi Water Metro Project

The Kochi Water Metro project is an initiative by Kochi Metro Rail and the Government of Kerela to create an inland water transport network that connects ten islands through 15 identified routes in Kochi spanning 78 Km. The project's primary objective is tointegrate rail and water transport and enhance connectivity for the residents of Kochi, thereby improving the standard of living. The vessel traffic will be monitored from an operating control centre at the central hub [34]. When completed, the water transport system will be the second largest in the world, behind Venice [35].

The project will utilize a fleet of 78 hybrid electric ferries to transport people around Kochi. The vessel's hull is a twin-screw aluminium catamaran designed for better stability and safety and caters to low drafts in inland waterways. Numerous fast charging stations were also constructed, capable of charging batteries within 15 minutes. The battery technology used for the vessel's electric propulsion is a Lithium Titanium Oxide (LTO) supplied by Echandia, a leading maritime energy storage solutions provider. Echandia also partnered with Siemens to create electric propulsion systems for the ferries [36]. Trials are underway, and the services will likely commence late 2022.

The total investment of the project is Rs 819 crore (USD 100 Million), of which Rs 579 crore (85 million Euros) is funded through a long-term loan agreement by the German financial organization Kreditanstalt für Wiederaufbau (KfW). The arrangement falls under the Indo-German financial cooperation, a strategic partnership tackling global climate and environmental challenges [34] [37]. The project is expected to achieve an estimated internal rate of return of 1.42% and is deemed sustainable by the local authorities [38].

Given the profitability and feasibility of the project, pilot projects like the Kochi Water Metro project serve as an opportunity for other potential cities in India. The project model can be replicated in Mumbai, Goa, Kolkata, and many other Indian cities with inland canals and waterways.

FIGURE 7.6

Kochi Water Metro Ferry
Source: Indian Register of Shipping

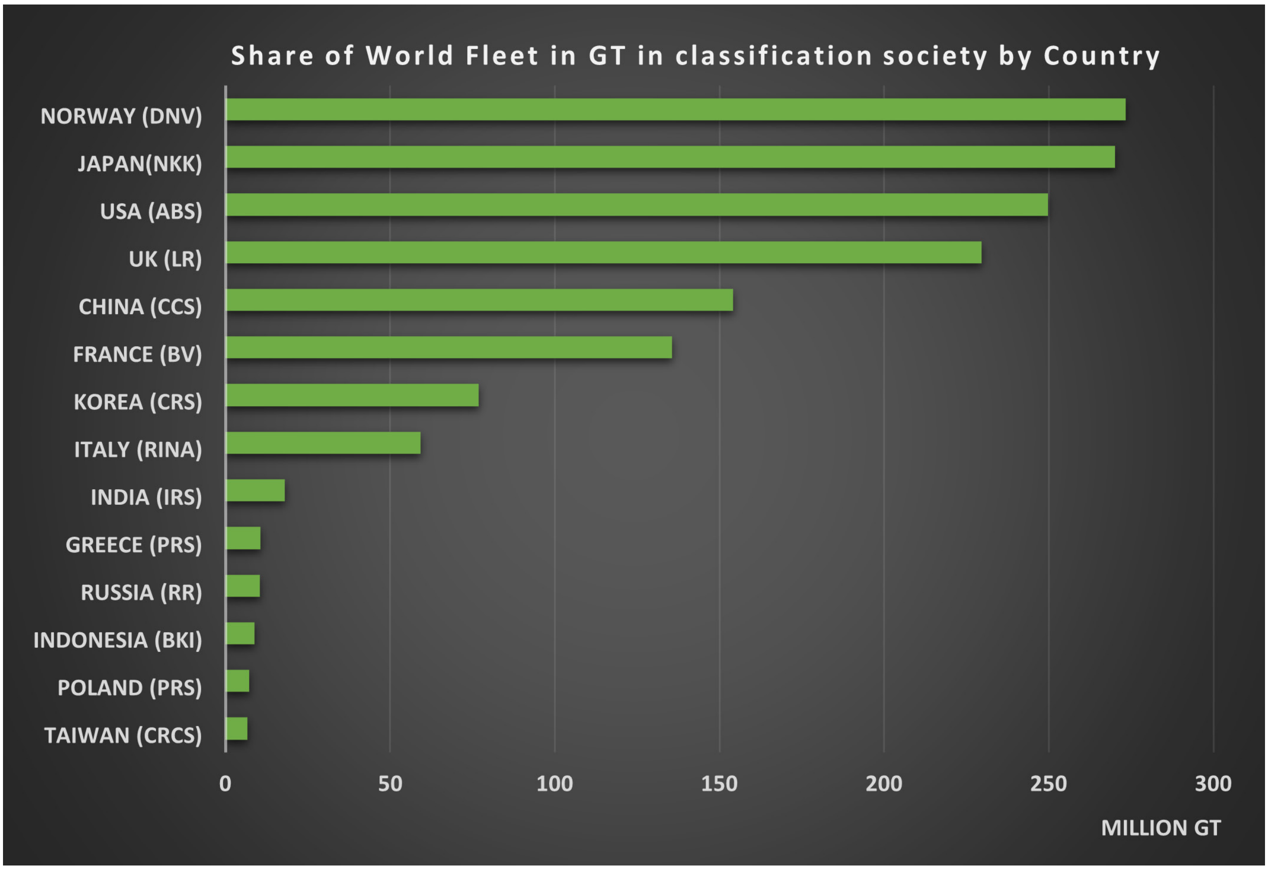
Classified fleet

Technical specifications for ships and offshore buildings are established and upheld by classification societies. All classification societies, especially the International Association of Classification Societies (IACS) members, place a significant emphasis on R&D in protecting the environment and enhancing maritime safety. Class certifies technological changes in construction and plays a key role in quality assurance in the maritime industry [31].

When ranking classification societies in terms of the size of their classed fleets, DNV leads at 17% of the world market share in terms of GT. NKK of Japan classifies 15% of the world's fleet. The Indian Register of Shipping, a classification society based in India, is ranked 9th.

FIGURE 7.7

Share of World Fleet in GT in classification society by Country
Source: Clarkson Research 2022



Maritime education institutions

The number of maritime education institutions in a country, including dedicated universities and training academies catering to the maritime sector, is a good indicator for assessing the competency of a country's graduates. Maritime players in the country stand to gain by sourcing talent within it [31].

With 108 dedicated maritime institutions, the UK leads all other nations. India takes third place with 51, while Norway and Singapore house 21 and 9 maritime institutions, respectively.

FIGURE 7.8

Number of Maritime Institutions in Country
Source: World Shipping Register & MIV 2030 Report

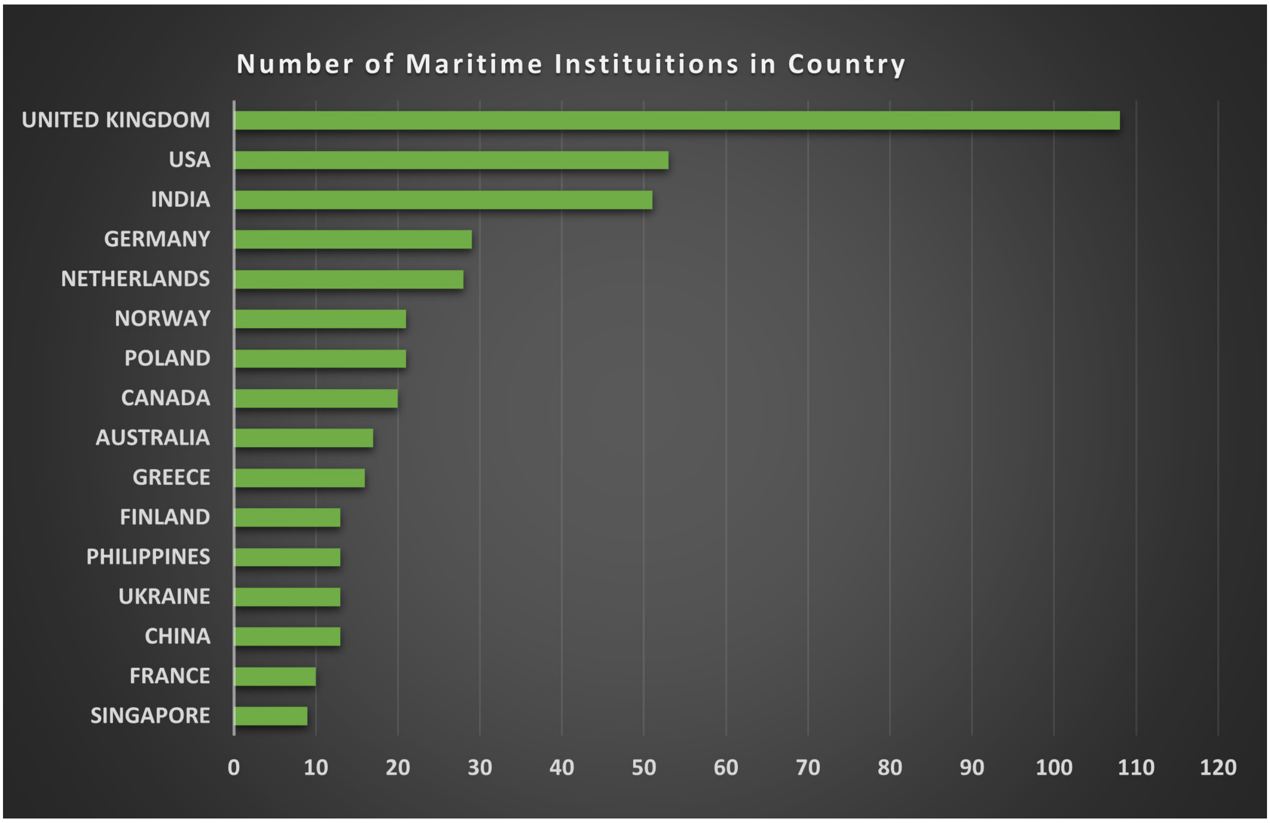
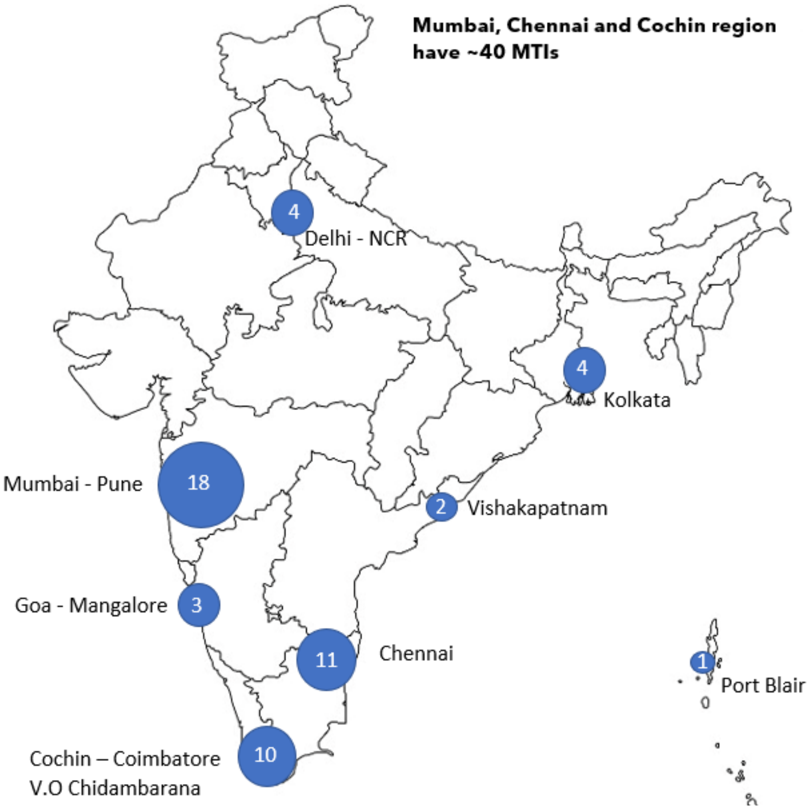


FIGURE 7.9

Overview of Maritime Training Institutes in India
Source: Adapted from MIV 2030 Report



The Indian Maritime University is a leading maritime institute in India that promotes maritime studies, training, and R&D . Leading universities such as IIT Bombay, IIT Kharagpur and IIT Madras offer ocean and marine engineering courses. Another key educational institution recently inaugurated in February 2022 is the Centre of Excellence in Maritime & Shipbuilding (CEMS). The COE is an initiative by the government of India to upskill and reskill the workforce in the maritime sector.

The Union and State government of India have invested heavily in maritime legal education and established several universities and maritime centres. Gujarat Maritime University (GMU), the Centre for Maritime Law and Research at Maharashtra National Law University (MNLU), Mumbai and Gujarat National Law University (GNLU), Gandhinagar and School of Integrated Coastal, Maritime Security Studies at Rashtriya Raksha University (RRU) are some examples [39]. The Centre of Excellence in Maritime Studies (CEMS) at the University of Mumbai was recently established in 2021, covering a broad range of maritime disciplines, including Maritime Laws, Trade, Commerce, Logistics, and Science and Technology.

7.3 Maritime cluster composition in India

Under Maritime India Vision 2030, key cluster compositions have been identified to spur domestic demand for Indian shipbuilding, ship repair, and ship recycling. Clusters focussing on these motives will have players from a few relevant segments of the maritime ecosystem.

Key players in the Indian coastal shipping ecosystem are shipowners, ship operators, cargo owners, shipyards, and equipment suppliers. Other industry players include fuel suppliers, ports, and service providers like financial institutions, insurance companies, classification societies, consultancy services, and research and educational institutions. Industry players such as cargo owners, logistics companies, buyers of transport services, and government authorities are premise providers to the industry.

A green shipping cluster for coastal shipping will have stakeholder participation from the following segments of the maritime ecosystem:

Regulators and Policy Makers

Maritime policies in India are governed by the Ministry of Ports, Shipping and Waterways, along with the 16 autonomous bodies acting in different ports across India. The Ministry of New and Renewable Energy, Ministry of Power, Ministry of Petroleum & Natural Gas, Ministry of Environment, Forest & Climate Change, State Maritime Boards, and other regulators come under this segment.

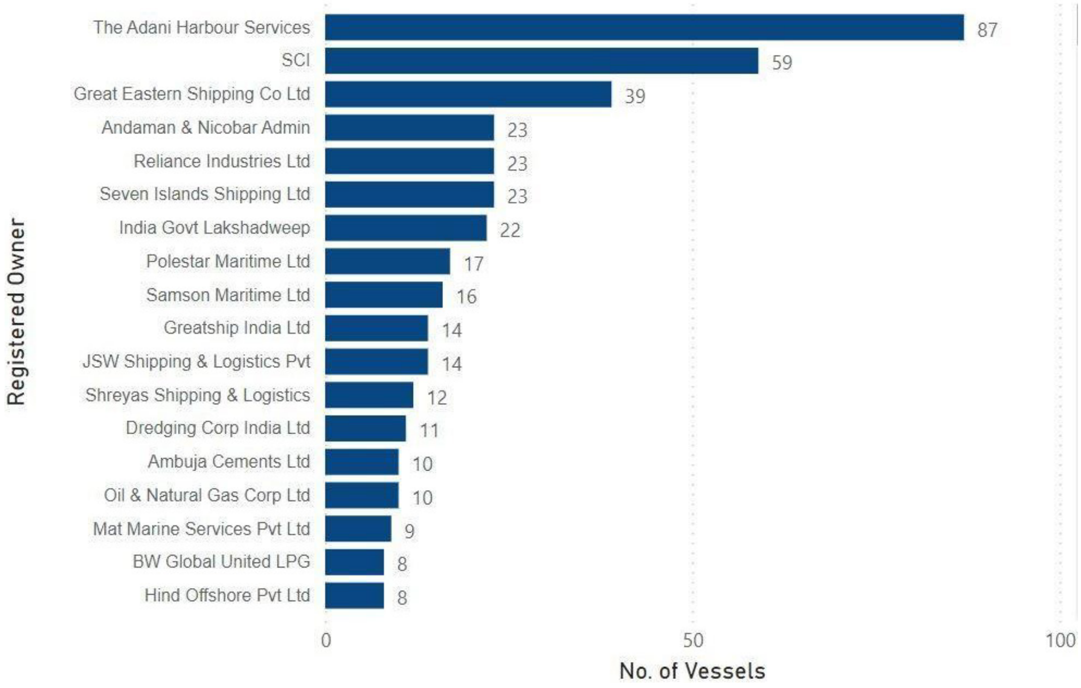
Shipping Services and Related Associations

Ship owners, ship management companies, charterers, and operators fall under the shipping services segment. Figure 7.10 shows the leading ship owners of the Indian coastal fleet. Adani Harbour Services Ltd. is the leading shipowner after recently acquiring Ocean Sparkle Ltd, followed by the Shipping Corporation of India.

The Indian Coastal Conference Shipping Association (ICCSA), formed in 1951, is the representative body of coastal operators in India. With 63 member companies, the association represents the interest of the coastal shipping players at various forums, including the government ministries. [68]

FIGURE 7.10

Major Coastal Vessel Owners in India
Source: IHS Markit



Yards and Technologies

Shipyards, other equipment manufacturers (OEMs) and suppliers comprise the yards and technologies segment. Figure 7.11 shows the major Indian shipbuilders who built the active Indian coastal fleet. Cochin Shipyard Ltd. and Hindustan Shipyard Ltd. are the leading active Indian shipyards with the highest number of Indian coastal vessels.

Knowledge providers

Universities and Research institutes play the role of knowledge providers to the industry. Institutions that promote and have the potential to perform domestic research on strategic topics such as green shipping, like the IITs, IMUs/MTIs and research institutions like TERI, come under the knowledge provider segment.

Ports and related services

Cargo and passenger terminals, ship bunkering, and other transport and freight forwarding companies come under the ports and related services segment. Figure 7.12 ranks the major Indian ports based on the volume of coastal cargo handled during 2021. Table 7.1 ranks the major Indian ports based on the total cargo handled, both overseas and coastal, from April to September 2022.

FIGURE 7.11

Major builders of active Indian coastal vessels
Source: IHS Markit

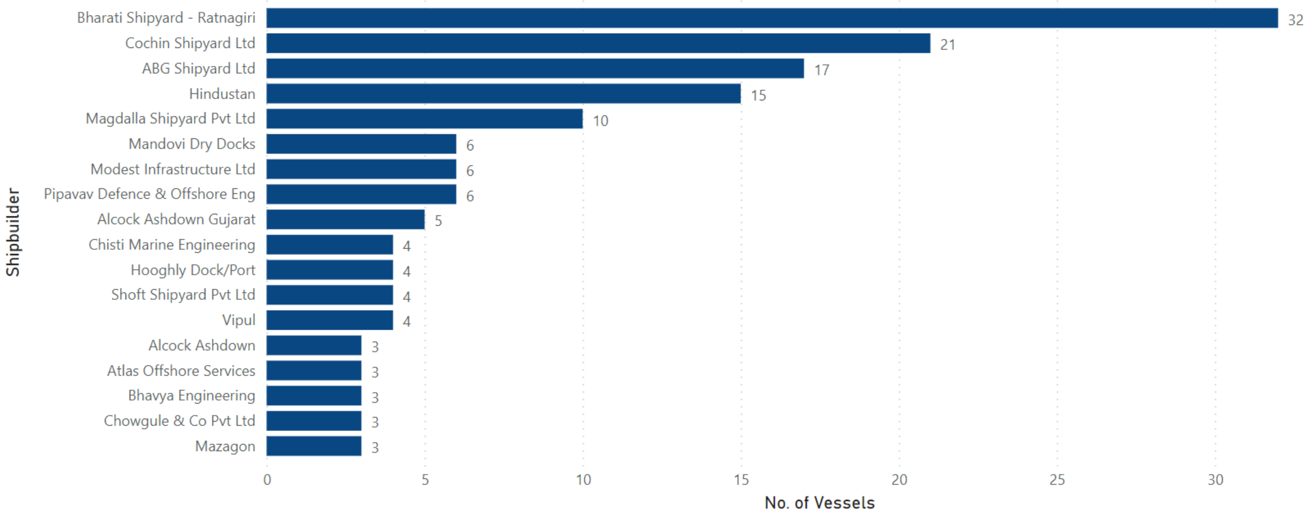


FIGURE 7.12

Volume of coastal cargo handled across India by major ports during the FY2021 (in million metric tonnes)
Source: Indian Ports Association

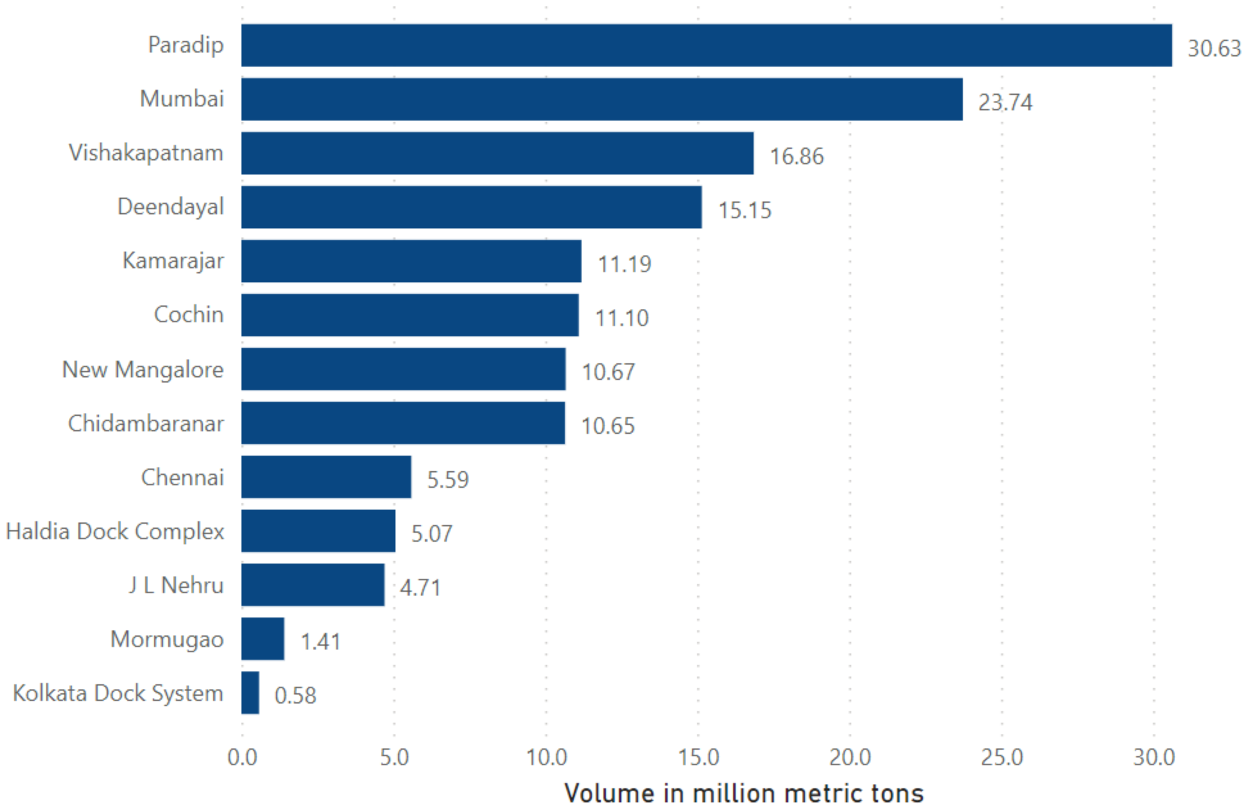
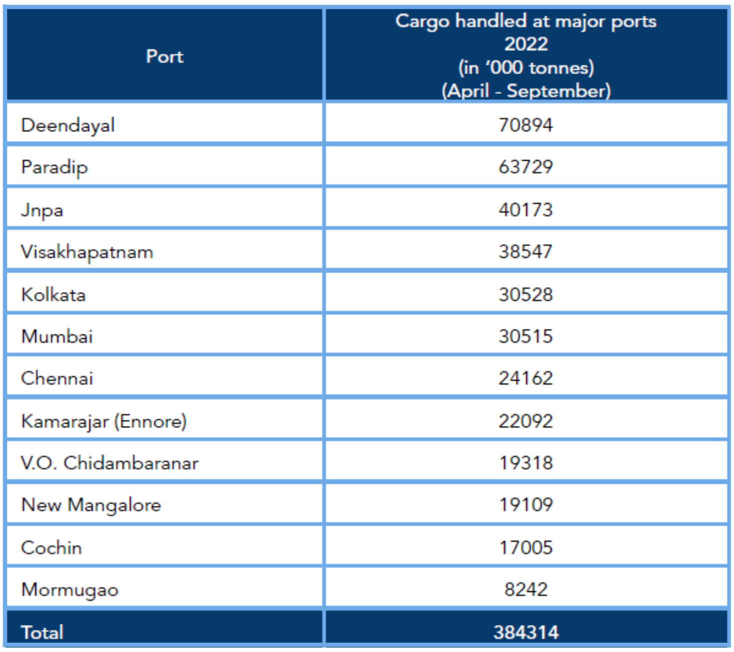


TABLE 7.1

Traffic Handled at Major Ports in India
Source: Indian Ports Association



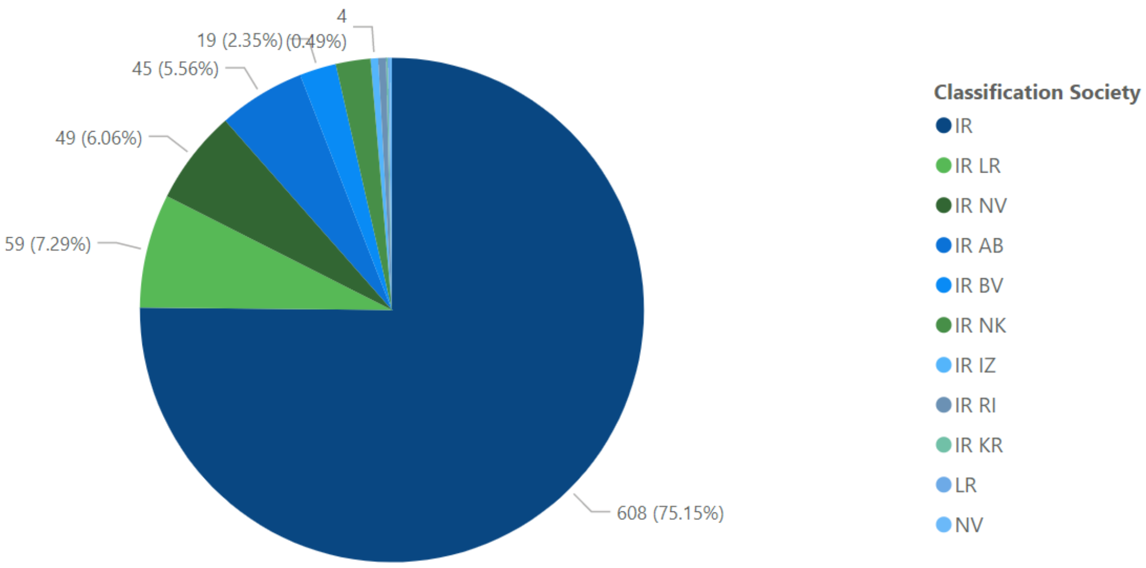
Port	Cargo handled at major ports 2022 (in '000 tonnes) (April - September)
Deendayal	70894
Paradip	63729
Jnpa	40173
Visakhapatnam	38547
Kolkata	30528
Mumbai	30515
Chennai	24162
Kamarajar (Ennore)	22092
V.O. Chidambaranar	19318
New Mangalore	19109
Cochin	17005
Mormugao	8242
Total	384314

Other maritime services

Maritime finance, class societies and other support services comprise the other maritime services segment. Banks and financial institutions have been shipping companies' main source of ship debt financing.

FIGURE 7.13

Classification societies of the Indian Coastal Fleet
Source: IHS Markit



7.4 Gaps in India's maritime knowledge cluster

Despite being one of the top countries in the world in the number of maritime institutions, India lags in technological advancements and developments. India's share of shipbuilding is less than 1% globally, significantly below the 5% aim outlined in the Maritime Agenda 2010-2020 [53]. India's educational and research institutions operate independently, with few industry collaborations, which lowers the level of go-to expertise available in rival international educational institutions [54]. The existing institutions also provide few course alternatives and have minimal affiliations with businesses and universities worldwide, which limits student exposure to new technology and developments in the marine industry. Knowledge sharing between industrial and research and educational institutes is low, and a limited number of research institutions in the field of Maritime Technology also hinders India's progress towards developing new technologies such as alternative fuels.

From interviews conducted with various stakeholders from research and educational institutions, it is evident that universities and research institutions are willing to collaborate with the industry. However, there is a lack of enthusiasm from the industrial stakeholders to take the lead in driving university-industry collaborations. The government plays an important role by creating a system to define policies and provide funding to support R&D activities. The Maritime Vision 2030 blueprint recognizes the issue of the lack of collaboration and has identified initiatives to bolster linkages and knowledge transfer between R&D institutes and industry.

Clusters can be established in various maritime disciplines around India by replicating the Norwegian model of establishing maritime networks. For instance, Cochin has the elements to emerge as a cluster for SMART shipping technologies, given its track record of building technologically intensive vessels such as aircraft carriers and autonomous vessels. Kolkata can emerge as a green shipping cluster specializing in building electric ferries. Given the current capabilities of yards in Kolkata and Gujarat, developing India's first Maritime arbitration centre, the state has the elements to emerge as a cluster specializing in shipping law and finance.

COEs can also be established in existing research institutions and maritime institutes such as NTCPWC and IMUs. Clusters can work closely with academic institutes, research organizations and COEs to transform India into a maritime knowledge hub.

7.5 Case study: Norway maritime knowledge cluster

The Norwegian maritime cluster is one of the world's top maritime clusters and is known for having a complete maritime cluster. According to Leading Maritime Cities, Norway led maritime technology from 2017 to 2019, but came in second to Singapore in 2022. Norway boasts a sizable maritime industry, consisting of many shipyards, suppliers of ship equipment, and a variety of other businesses and organizations engaged in marine-oriented activities, such as educational and research institutions and political bodies. All these players make up the essential components of the Norwegian maritime cluster. Strong interdependence between the sectors' diverse participants and focus on innovation and entrepreneurship created a robust marine industrial cluster and a global maritime knowledge hub for Norway.

The maritime knowledge cluster in Norway is concentrated in different regions. The region of Bergen specializes in industrial shipping, and the knowledge hub of Norway is located in Central Norway, where leading universities and research institutions are located. Oslo is Norway's financial, legal and technological hub, and the Kongsberg cluster produces a wide range of advanced products and systems for the offshore and maritime industry. The Haugalandet/ Hordaland cluster revolves around the installing, running and maintaining sub-sea systems. Finally, the south of Norway is where the drilling equipment and production cluster is situated.

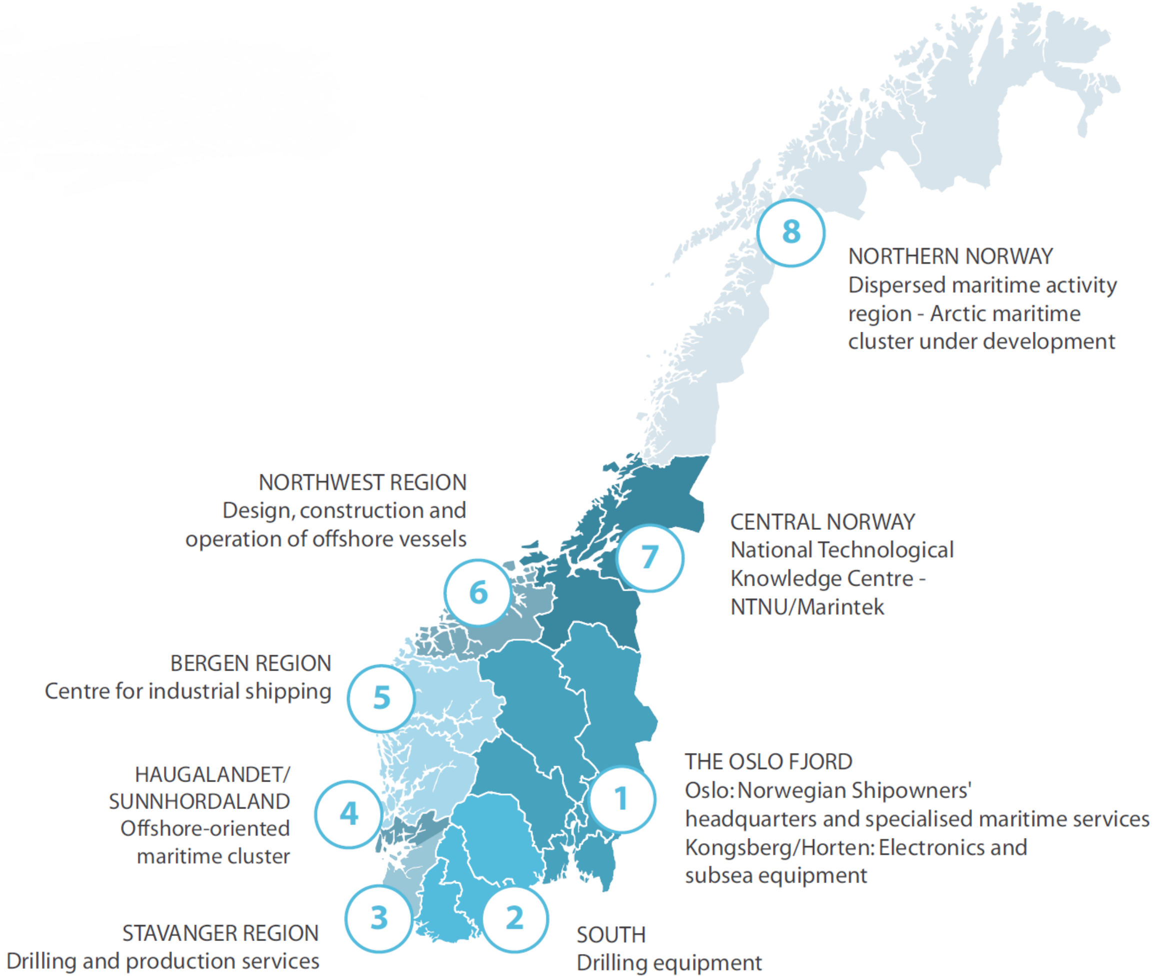
Knowledge clusters in Norway were created through various forms of interactions. Collaboration among ship owners, equipment suppliers, system integrators, ship designers and educational and research institutions has allowed for innovation and knowledge growth in clusters. Additionally, fierce competition among stakeholders contributed to creating knowledge clusters. Due to rising rivalry, cluster businesses are forced to innovate to stay ahead of competition. The proximity of firms also enabled knowledge spill over in the cluster, which resulted in technological breakthroughs. [40]

Through successful collaborations with various industry players, Norway has built competency in ship design, specialized shipbuilding, maritime equipment, services, operations, and research. When Asian nations started to dominate the shipbuilding sector, Norwegian maritime companies did not shut down their yards. Instead, Norwegian yards specialized in the more advanced segments of shipbuilding, embracing the offshore sector, which demanded specialized supply ships, anchor handling vessels and advanced drilling and production rigs. A good example would be Ulstein yard which became well-known for its innovative X-bow design in supply vessels [41]. The strong collaboration between ship owners, shipyards, designers, manufacturers, and maritime services has contributed to innovation and technological breakthroughs.

Also contributing to the success of Norway's technological and maritime innovation is the involvement of research and educational institutes in Norway. The Norwegian University of Science and Technology (NTNU) is Norway's leading university focusing on Science and Technology, with its main campus in Trondheim and smaller campuses in Aalesund and Gjovik. NTNU in Trondheim hosts the Centre for Ships and Ocean Structures (CeSOS), the world's leading research institute in hydro dynamics and maritime technology, and a dedicated Centre of Research Excellence, attracting numerous researchers and PhD candidates from around the world. Other leading research organizations include the Norwegian Marine Technology Research Institute (MARINTEK) and SINTEF, located in Trondheim and Det Norske Veritas (DNV), located at Høvik just outside Oslo. Universities and research institutions take an active role in making themselves relevant for the industries in Norway. Their activities benefit the maritime cluster in Norway as they produce highly educated and qualified graduates for the maritime industry, and the research conducted strengthens Norway's maritime technology position globally [41].

FIGURE 7.14

Location of Norwegian Clusters
Source: Menon Economics

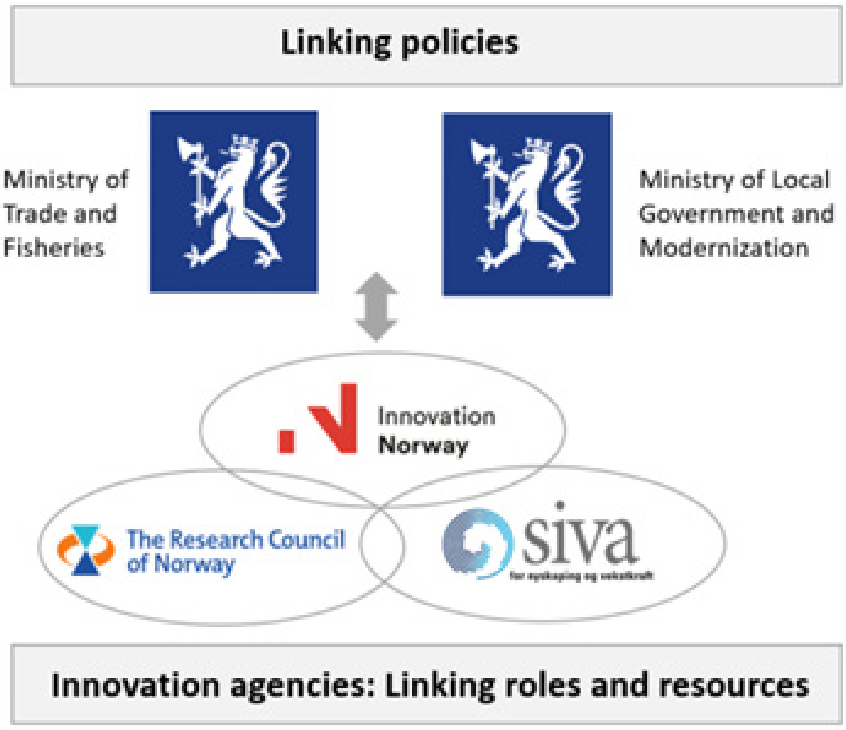


Norway Innovation Cluster

The Norway Innovation Cluster (NIC) is an initiative by the Norwegian government to increase the ability of businesses to innovate and compete through long-term internal and external collaboration between companies, R&D and educational institutions. Established in 2014, the NIC is a cooperation between several government organizations, such as Innovation Norway, SIVA, and the Norwegian Research Council. Innovation Norway is part of Norway's Ministry of Trade and Industry, and it is the government's most important instrument for the innovation and development of Norwegian enterprises. SIVA is the Industrial Development Corporation of Norway - owned by the Norwegian Ministry of Trade and Fisheries, set up to improve national infrastructure for innovation. The Norwegian Research Council takes on the role of the chief advisory body for the government authorities on research policy issues. It allocates 30% of all public spending on research every year. Under the NIC, the Research Council of Norway develops the programme and cluster project's engagement in R&D initiatives. SIVA is responsible for developing the programme and cluster project's engagement in enhanced innovation efforts, especially through incubation. Innovation Norway has the primary operational responsibility, including managing grants and contracts with the cluster organizations (beneficiaries) and formal decisions regarding financing and contractual terms [42]. and formal decisions regarding financing and contractual terms [42].

FIGURE 7.15

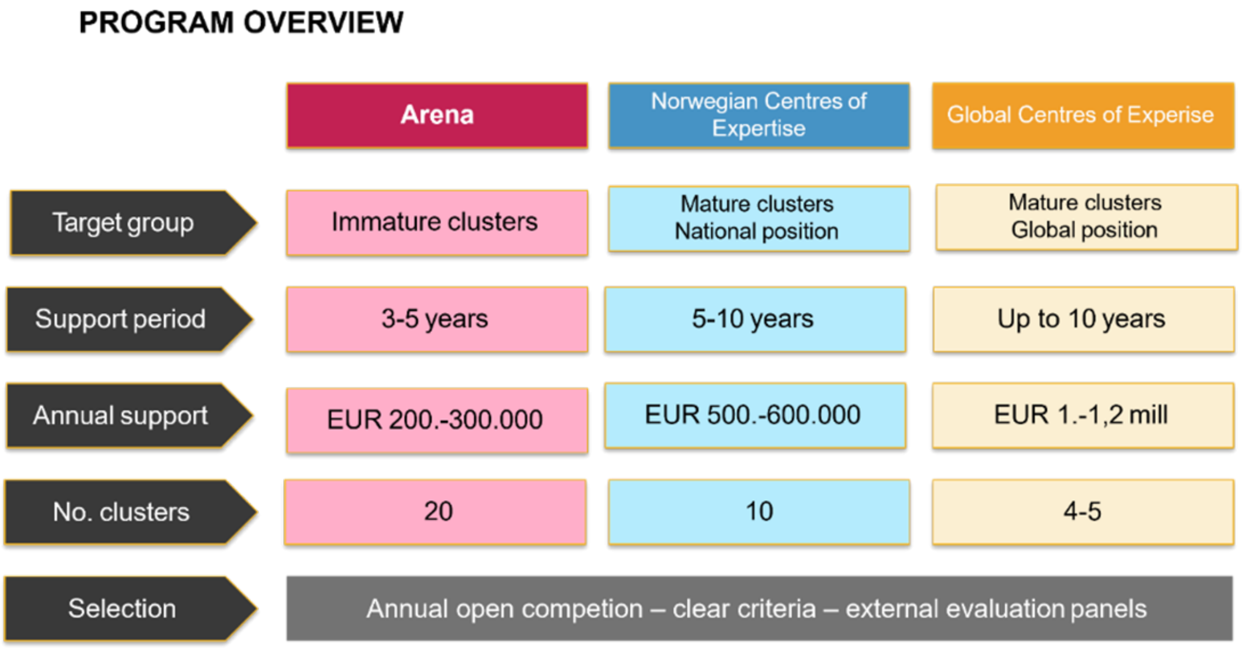
Illustration of the Norwegian Innovation Cluster Governmental Stakeholders
Source: TCI Network



Since the early 2000s, Norway has had a strategy to strengthen business clusters. The Arena Programme was established in 2002, the Norwegian Centres of Expertise (NCE) in 2006 and the Global Centre of Expertise (GCE) in 2014. In 2019, Arena Pro was introduced to address the need for changes in the programme and recommendations for enhancements that surfaced during an evaluation carried out in 2017 [43]. The NIC was developed at three levels: the Arena was programmed for smaller and emerging local clusters. The Norwegian Centre of Expertise (NCE), launched in 2006, was for the more mature and large regional clusters, and the Global Centre of Expertise (GCE) was for the top global clusters in Norway. NCE is no longer a programme but a brand name that clusters can qualify. Each sub-cluster establishes projects with specific objectives from its starting point and the qualification criteria for further development according to the objectives for each level. Clusters receive funding through annual grants for activities organized by the cluster management.

FIGURE 7.16

Norwegian Innovation Cluster Development Programme in 2016
Source: TCI Network

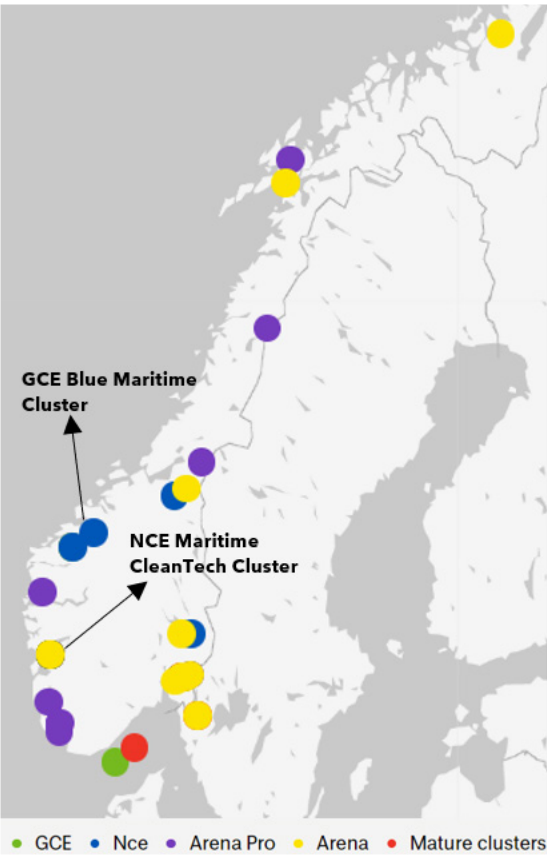


PROGRAM OVERVIEW

	Arena	Norwegian Centres of Expertise	Global Centres of Experise
Target group	Immature clusters	Mature clusters National position	Mature clusters Global position
Support period	3-5 years	5-10 years	Up to 10 years
Annual support	EUR 200.-300.000	EUR 500.-600.000	EUR 1.-1,2 mill
No. clusters	20	10	4-5
Selection	Annual open competion – clear criteria – external evaluation panels		

FIGURE 7.17

Overview of Cluster Organizations
Source: Innovasjonnorge



Maritime cluster organizations

GCE Blue Maritime Cluster

Located in Møre, the GCE Blue Maritime Cluster is one of the world's most complete maritime clusters and a competitive hub in advanced offshore vessels for the global oil and gas industry. The cluster was awarded the status of a worldwide centre of expertise due to its unique market position and contribution to Norwegian value creation. The cluster comprises over 200 maritime companies, including 19 shipping companies, ten shipyards, six ship designers, 131 equipment suppliers and several education and research institutions. In 2021, the cluster achieved a combined revenue of NOK 50 billion (EUR 5 billion) [44].

The cluster in Møre consists of several innovative SMEs supplying Norway and the overseas maritime industry with specialized products and services. These SMEs exhibit innovation capabilities, making it attractive for large international corporations to acquire and set up businesses in Norway. The GCE Blue Maritime cluster contains some big national corporations, including Ulstein Group, Vard, Kongsberg, Bourbon offshore, Havila Shipping, Brunvoll, and medium-sized enterprises including, Jets Vacuum, Island Offshore, and Sperre.

Research and educational institutes collaborate closely with industrial participants to develop pilot projects in the cluster. The NTNU, MARINTEK and SINTEF are key R&D partners with active research projects in the cluster. Such collaboration is the main driving force for rapid innovation in the cluster. Much of the cluster's success can be attributed to the innovative dynamics between cluster players based on geographical proximity, good cooperation, informal communication, a pioneering prototype-oriented spirit, and tough competition between all links in the value chain [41].

The collaboration between the various stakeholders has brought about innovations for the cluster. For example, in 2012, Far Solitaire, a platform support vessel owned by Farstad shipping, won the ship of the year award. It was the first PSV to be built fit to carry dangerous chemicals. The vessel was also designed to focus on reduced fuel consumption, efficient and safe operations and decreased emissions [45].

FIGURE 7.18

Key Participants in GCE Blue Maritime Cluster
Source: Menon Economics

FIGURE 7.19

Far Solitaire
Source: VARD

NCE Maritime Cleantech
The NCE CleanTech cluster is renowned as one of the world's most comprehensive maritime commercial centres and is well known for its green shipping technology. Extending from Karmøy in the south to Stord in the north, the cluster has over 150 participants covering every segment of the maritime value chain, including shipyards, shipping, shipping consultants, shipbrokers, subsea companies, and equipment suppliers. The cluster aims to strengthen the cluster partners' competitiveness by developing and launching innovative solutions for energy-efficient and clean maritime activities.

Established in 2011, the cluster consisted of 11 companies and one research institution partnered to promote maritime technology. By 2018, the cluster grew to 122 members, of which 80% are private companies, 10% are research and education institutions, and 9% are public organizations [46]. The cluster has successfully demonstrated multiple electric and hybrid solutions since its inception. In 2015, the cluster delivered the world's first fully electric ferry, with a capacity of 360 passengers and 120 vehicles. The project's success has opened a new market in Norway, which has driven all future ferry contracts to have low or zero-emissions technology. Another project in the cluster which has gained international attention is the Urban Water Shuttle (electric fast ferry concept). The project is now being developed for the river Thames in London, Zenne Canal in Belgium, and Stavanger in Norway [46]. The cluster has also advocated for the public sector to actively demand cleaner technology in public tenders within shipping services [46]. Through collaborations with the Norwegian government, the cluster has successfully pushed for a greener shipping industry in Norway. An example would be the parliament's success in adopting zero-emissions regulations in World Heritage fjords by 2026 [46].

FIGURE 7.20

Concept Design of the Urban Water Shuttle
Source: Maritime CleanTech

7.6 Case study: Singapore maritime cluster

Singapore was ranked the top city in the 2022 edition of the Leading Maritime Cities report. The Singapore maritime cluster has achieved tremendous success through connectivity, collaborative R&D, practical knowledge, and talent management. Excellent public policy measures and governance have also allowed Singapore to be an attractive location as a maritime city. The Maritime and Port Authority (MPA), Economic Development Board, and Agency of Science, Technology and Research (A*Star) are some institutions that have played a key role in Singapore's development as a maritime hub. A pro-business regulatory framework and public policies such as attractive tax regimes have been a factor that facilitated the development of a strong maritime cluster. Such policies allowed foreign shipping enterprises in various disciplines to establish their business in Singapore.

Another factor of Singapore being a top maritime cluster is the facilitation of knowledge flows and network links between key actors of the cluster. One such key actor is Keppel Offshore and Marine (KOM) group. KOM is known for their innovative solutions for ultra-Deepwater offshore rigs, such as semisubmersibles, drilling tenders, or compact drill ships. Despite being in a tropical region, it also built icebreakers for customers in the west and fabricates jack-ups for the artic region [47]. Keppel has developed its competence for innovative solutions through strong R&D collaborations with local research and educational institutions such as A*Star, Ngee Ann Polytechnic (NP), Nanyang Technological University (NTU), and the National University of Singapore (NUS). In 2003, NUS established the Centre for Offshore Research and Engineering (CORE) with numerous professorships, including the Keppel Professorship in Ocean, Offshore and Marine Technology [47]. The centre's goal was to be a leading centre in R&D, education, and manpower training to advance the offshore and maritime industry. Strong collaborations between local and overseas industry partners and research institutions have made Singapore a leading player in offshore oil and gas (Drilling units, Offshore Support Vessels).

Cluster organizations

Maritime Port Authority (MPA)

The MPA is unique for a maritime administration/regulator and not seen in any other maritime administration/regulator in terms of allocated resources. The MPA's primary role is to regulate the maritime sector, including taking up the role of maritime administrator. Thus, it is responsible for enforcing the regulations agreed upon by the IMO. Other countries have similar organizations, such as the Maritime & Coastguard Authority (MCA) for the United Kingdom, the Norwegian Maritime Authority (NMA) for Norway, and the United States Coast Guard (USCG) for the United States of America (USA) [48]. In Singapore, the MPA also takes on another key role as a lead agency for developing Singapore into an International Maritime Centre. The MPA works with other government organizations and maritime industry partners, such as the SMF and SSA, to attract international ship owners, ship managers, and operators to set up their operations in Singapore, and improve the overall business environment for the maritime industry.

The MPA has the budget and authority to establish policies, measures, and initiatives for the maritime sector. To allow Singapore to be an attractive location for shipping and maritime business, the MPA has introduced several fiscal and non-monetary incentives such as:

1. The Maritime Innovation and Technology (MINT) Fund
   Since the fund's launch in 2003, the MPA has injected $265 million to grow Singapore's maritime innovation and technology ecosystem. The scheme promotes R&D by providing financial aid to universities, and research firms, providing grants of up to $100,000 to start-up pilot projects [49].

2. The Maritime Cluster Fund (MCF)
   The scheme aims to spur growth in the Singapore maritime cluster by providing financial aid in manpow er development, such as training and courses, financial support to companies that set up or expand operations in Singapore, and grants to companies that develop or adopt technology solutions. [49]

3. The Maritime Sector Incentive (MSS) – Approved International Shipping (AIS) Enterprise Award and Singapore Registry of Ships (SRS) Award
   The scheme encourages foreign ship operators and owners to operate their commercial shipping businesses in Singapore. Companies eligible will enjoy tax exemption benefits derived from activities such as ship operations, carriage of passengers, mail, livestock or goods by foreign ships, risk management and foreign exchange activities related to shipping operations, provision of ship management services and capital gains from the sale of ships, ships under construction, and sales of ordinary shares [42].

4. The Maritime Sector Incentive (MSI) – Maritime Leasing Award (MSI-ML)
   The award provides tax exemptions when using Singapore as a base for capital and funding for chartering, leasing of seagoing ships to specified persons outside the port limits of Singapore, foreign exchange and risk management activities related to ship leasing and gains from selling seagoing ships, ships under construction, and ordinary shares in a qualifying special purpose company [42].

5. The Singapore Maritime Institute Fund
   In collaboration with Agency for Science, Technology and Research (A*STAR) and the Economic Development Board (EDB), launched the Singapore Maritime Institute (SMI) in September 2010 to align education and research with Singapore's maritime interests [50]. The scheme encourages collaboration between industry and research, and educational institutes by providing funding to R&D programmes and projects and setting up of Centres of Excellence which is crucial to Singapore becoming a leading global maritime hub. Centres of Excellence such as the Centre of Excellence in Modelling and Simulation for Next Generation Ports (C4NGP), the Centre of Excellence in Maritime Energy and Sustainable Development (MESD), the Centre of Excellence in Maritime Safety (CEMS), and the Centre of Excellence for Autonomous & Remotely Operated Vessels (CEAOPS) have been set up to bolster Singapore's R&D capabilities in strategic areas [51]. The C4NGP is a collaboration with NUS to develop innovative solutions and studies to develop the next-generation port and maritime systems. The MESD COE was set up with a focus on green ports and shipping by working closely with key industry stakeholders to develop innovative solutions. The CEMS was set up with Singapore Polytechnic to research communities to develop new technological solutions and training systems that reduce or mitigate maritime incidents. The CEAOPS is a COE focused on R&D in maritime autonomous surface ships [51].

6. In 2013, MPA introduced MGIA, an award that provides local ungraduated with the opportunity of a 12-week internship programme to immerse in experiential learning with international maritime companies in Singapore and around the world.

Singapore Maritime Foundation (SMF)
The SMF, established as a private sector-led body, has been considered a clear voice representing the maritime industry in Singapore, both locally and internationally. Its members cover the different spectrums of the maritime industry [48]. The SMF Board sets the direction for the industry's promotion and initiatives. It also taps the experience of members of the SMF Advisory Panel, consisting of seasoned professionals and practitioners in the local and global maritime industry. One of SMF's focus areas is a public outreach programme in collaboration with the government and private sector to promote Singapore as an IMC. The special focus is on longer-term manpower development for the maritime sector, including student outreach, maritime education, and training. The SMF facilitates and administers the establishment of scholarships sponsored by various maritime industry partners to attract some of the best minds. An example of attracting talent to the industry is the launch of the MaritimeOne Scholarship, where the foundation and its partners offer funding and job opportunities for students enrolled in maritime-specific courses and pursuing a maritime career [48].

Singapore Shipping Association (SSA)
The SSA represents a wide spectrum of shipping companies and other business entities closely related in their activities to the shipping sector [52]. It is considered a national trade association formed to serve and promote the interest of its members. It has an additional role to enhance the competitiveness of Singapore as an International Maritime Centre. The association consists of ship owners and operators, ship managers, ship agents and other ancillary companies organized into eight operational committees.

They discuss issues and provide feedback to MPA and other governmental bodies, including challenges its members raise and ideas to make Singapore competitive. One key achievement of the SSA is having developed the Singapore War Risk mutual, a marine insurance product for a young maritime nation for the benefit of ships operating under the Singapore flag [48]. The SSA works closely with MPA to increase Singapore's attractiveness and competitiveness as a maritime nation. SSA represents all members of the shipping community of Singapore, and their feedback provides valuable input to MPA, which allows them to carve out policy measures and initiatives to increase Singapore's competitiveness.

7.7 Best practices from case studies

The Norway Innovation cluster and the Singapore Maritime cluster are good examples of well-rounded clusters that can be considered relevant in developing a maritime knowledge cluster in India. In both case studies, several common elements were observed in strategies for developing maritime clusters. The elements include significant involvement from the state, where multiple agencies were involved in developing measures for promoting R&D through developing public R&D institutes and providing incentives for the private sector, R&D, infrastructure, and talent development.

Since its inception, the Norway innovation cluster has seen a significant increase in R&D activities between industry firms and research and educational institutions and, subsequently, an increase in innovation within the clusters. The NIC followed a bottom-up approach to cluster development and activities, led by the cluster organization, where they encouraged innovation and knowledge creation through strong collaborations. The dedicated cluster organizations facilitated joint industry projects with the involvement of universities and research institutions. A critical success of the cluster organizations was the funding provided by the Norwegian government agencies in the form of annual grants, up to 50% co-funding to support activities in the cluster. This was done through a transparent process laid out by government agencies.

The Singapore maritime cluster followed a government-led approach where government and industry entities came together to improve Singapore's competitiveness to develop Singapore's position as an International Maritime Centre and a global maritime knowledge hub. Pro-business policies set by cluster facilitators (MPA, SMF, SSA) have contributed to many MNEs setting up business in Singapore, transforming Singapore's maritime cluster into a world-leading international maritime cluster. Strong emphasis on R&D has also led Singapore to be a maritime knowledge hub. The MPA's close collaboration with SMI has allowed for establishing several COEs in collaboration with educational institutions to strengthen R&D capabilities in the cluster.

8. Potential opportunities and challenges for the Indian coastal GSP

8.1 Opportunities

Growth of coastal shipping in India

According to the Ministry of Shipping, coastal cargo in India (excluding overseas cargo) amounted to over 147.35 million tonnes at major ports and 80.76 million tonnes at minor ports in 2021. When the Sagarmala Programme began in 2015, the proportion of coastal freight in all cargo handled was about 16.34% (2014–15) [51]. According to the most recent forecasts, the percentage of coastal freight was around 22% from 2020–2021. Since 2014, non–major ports have accounted for a growing portion of the overall coastal traffic handled by Indian ports.

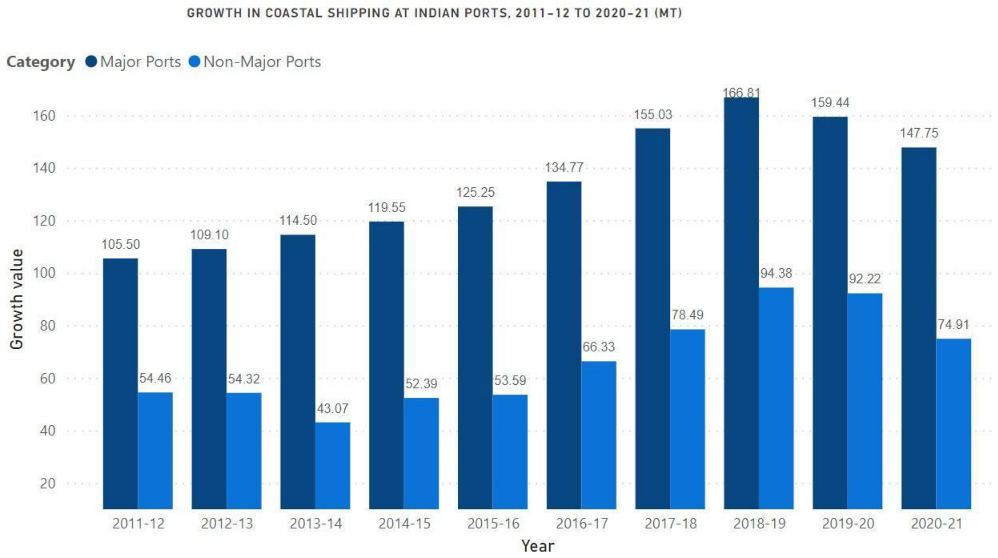
The Ministry of Ports, Shipping and Waterways has undertaken several initiatives in the last four years to facilitate coastal shipping, such as incentivizing the creation of coastal berths, reducing port tariffs for coastal cargo, provisioning green-channel clearance of coastal cargo, prioritizing berthing of coastal vessels and relaxing cabotage rules to increase vessel availability. Approved initiatives have led to a 13% growth rate in coastal shipping movement during the last two years compared to 4% in the preceding years. Iron ore, coal, fertilizer, petroleum, oil, and container cargo are a few products transported by coastal shipping. Recently, Ro-Ro vessels have caught the eye of automobile companies like Renault, Ford, Hyundai, Toyota, and Honda, expanding their supply chain network by transporting via coastal shipping. This shift is a reaction to the government's decision to increase the discount on Ro-Ro vessels to 80% for two years at all major ports.

The Indian coastal cargo comprises POL (petroleum, oil, and lubricants), iron ore, pellets, coal, and fertilizers for PSUs. POL and thermal coal combined made up around 60% of the coastal traffic handled by important ports in 2019. It is possible to investigate the feasibility of transportation of goods like cotton, tiles, sugar, cement, and vehicles using this route. Figure 8.1 shows the growth of coastal shipping at Indian ports from 2011 to 2020. It shows increasing growth in all years, especially in major ports, except in 2020 due to the global pandemic.

Cargo shipped by road or rail can also be carried by coastal ships. Local trade will significantly rise if inland water transport grows and connects to important ports. Additionally, it will lessen highway congestion and traffic on roads. Encouraging inland waterways for commercial transportation will expand shipyards and the ship equipment industry because of the coastal commerce, which will spur coastal development and employment.

FIGURE 8.1

Growth of Coastal Shipping in India
Source: Indian Ports Association



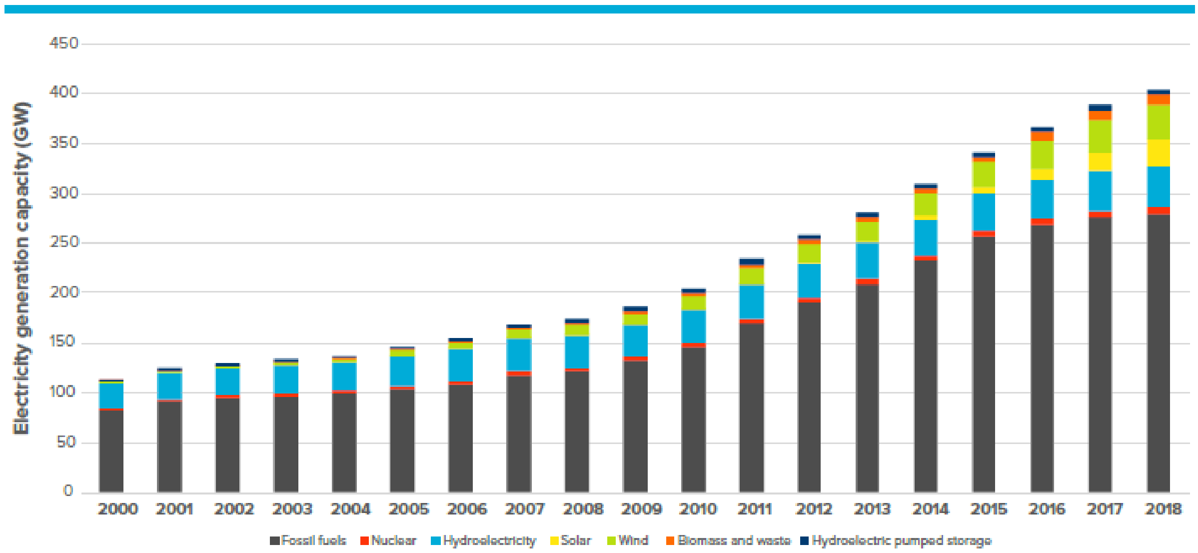
India’s increasing renewable electricity generation capacity

India's capacity to produce renewable energy has sharply expanded since 2010. In 2018, electricity production was 69% and derived from fossil fuels. In recent years, the growth of renewable energy sources has outpaced conventional ones. Compared to fossil fuel-powered electricity generation during the same period, renewable energy sources (hydro, solar, wind, biomass, and waste) have expanded by 131% between 2010 and 2018. Consequently, renewable energy sources already accounted for 28% of electricity-producing capacity in 2018. Figure 8.2 shows the electricity generation capacity in India from 2000 to 2018, highlighting an increasing capacity growth in hydroelectric pumped storage.

Recently, Keppel Infrastructure Holdings Pte Ltd and Greenko Group (Greenko), through their subsidiaries, signed a Memorandum of Understanding (MOU). The MOU seeks to jointly explore green ammonia and renewable energy opportunities to meet the growing demand for low-carbon energy in India, Singapore, and the rest of the world. This initiative explores the feasibility of jointly developing a production facility to produce at least 250,000 tonnes of green ammonia annually. Additionally, it seeks to identify further and evaluate a portfolio of solar and wind energy projects with an installed capacity of up to 1.3 GW, complemented by pumped hydro-storage to power the green ammonia production facility.[67] This highlights the potential of India to be a global supplier of green energy in the coming years.

FIGURE 8.2

Electricity Generation Capacity in India, 2000-2018
Source: World Bank



Coordinating research activities of universities and other institutions

Research activities on green shipping are gaining traction in India. For example, Denmark and India plan to establish a Centre of Excellence on Green Shipping [58]. The Green Strategic Partnership has acted as a catalyst for further collaboration between India and Denmark. It was founded during a virtual summit between the Prime Ministers of Denmark and the Republic of India in September 2020. The decision of the two Prime Ministers to issue a joint request for R&D initiatives in the fields of green fuels and green hydrogen was welcomed. They took notice of the areas that the joint call specifically referred to, especially green hydrogen and other green fuels for transportation and industries where no affordable alternatives to fossil fuels exist.

Another case in point is illustrated by the two twin-screw coastal research vessels purchased by the National Institute of Ocean Technology in Chennai. These vessels are equipped with the most cutting-edge scientific and operational equipment, such as bow thrusters, flap rudders, and drop keels. The concept design for this ship was created by the Indian Maritime University, Visakhapatnam Campus, and the full tank testing was carried out at the test facility at IIT Madras [59].

Presence of initiatives and policies to promote greener technology

Some measures have been implemented in India to promote a green ecosystem following the IMO's 2030 and 2050 GHG Strategy. Maritime India’s Vision 2030 was formulated by the Ministry of Ports, Shipping & Waterways to propel India to the forefront of the global maritime sector in the next decade.

The Government of India launched the National Action Plan for Climate Change (NAPCC) back in 2008 to adapt to the adverse impact of climate change [60]. This action plan, launched with eight sub-missions, aims at fulfilling India’s developmental objectives with a focus on reducing the emission intensity of its economy. The National Hydrogen Mission was launched by the Government of India on 15 August 2021 with a mission to aid the government in meeting its climate targets and making Indian a green hydrogen hub.

8.2 Challenges

Fuel transition

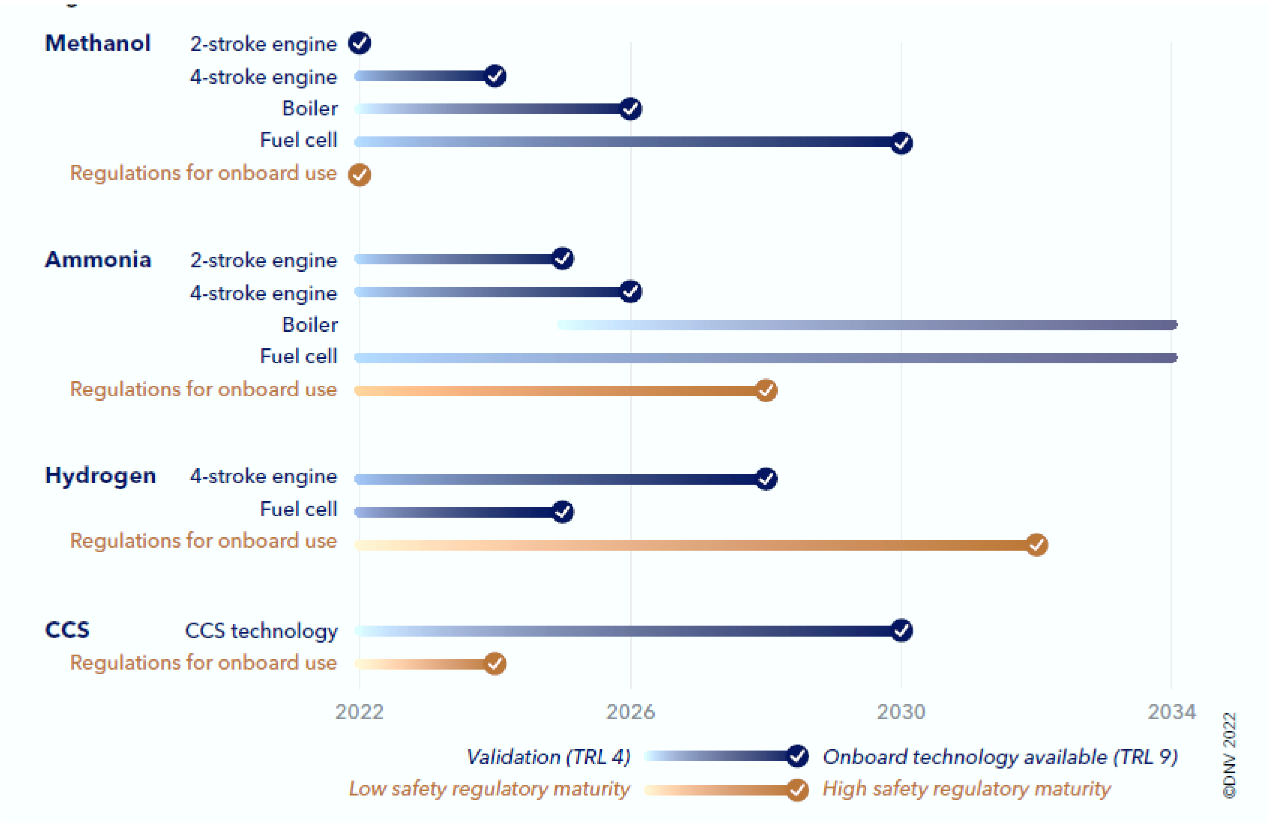
Increased capital expenditure, restricted fuel supply, a lack of global bunkering infrastructure, high fuel prices, and the increased need for onboard storage capacity are major obstacles to using low or zero-carbon fuels. The intensity of such restrictions will differ amongst fuels. Safety is also a top priority, and the lack of strict laws and regulations makes it difficult to integrate the necessary technologies on board. Figure 8.3 shows the estimated maturation timelines for energy converters, onboard CCS technologies, and corresponding safety regulations for onboard use. It also shows that regulation needs to catch up to technological developments in both ammonia and hydrogen.

Figure 8.3 applies a colour scale to indicate the maturation of energy converters, CCS technologies, and corresponding safety regulations for the onboard use of relevant fuels. The technology maturation scale ranges from validated technologies (TRL 4) to technologies available from one or more manufacturers (TRL 9). It may be expected that technologies and power ranges serving the core markets will be available first, followed by an expansion in product range depending on demand.

The resulting timeline is our best estimate of the maturation for energy converters using methanol, ammonia, or hydrogen as energy carriers and for onboard CCS technology. We have categorized the energy converters into 2-stroke engines, 4-stroke engines, auxiliary boilers, and fuel cells. 2-stroke engines are typically used for propulsion by larger cargo ships, having the largest share of total installed power in the world fleet and accounting for most maritime fuel consumption and emissions.

FIGURE 8.3

Estimated maturation timelines for energy converters, onboard CCS technologies, and corresponding safety regulations for onboard use



Lack of infrastructure

Rebuilding the fleet of ships requires time. As the transition needs to happen quickly, a wait-and-see approach to determine which technologies and solutions will succeed in the market may not be possible.

The infrastructure and procedures of many Indian ports are trailing behind the world's top ports in constructing the infrastructure that would enable them to handle a wide range of goods. Most Indian ports lack the infrastructure for high port productivity, such as modern handling equipment and advanced telecommunication systems. Compared to developed ports, port-centric logistics, which combines a variety of services, is still in its early stages. The underdevelopment of smaller ports forces shippers and customers to rely significantly on major ports, driving up the cost of port handling and land-based transportation. Most of today's smaller ports can only handle small barges and lack the infrastructure to accommodate those transporting a lot of twenty-foot equivalent units (TEUs). Although India's shipbuilding sector has been expanding, many necessary spare parts still need to be imported at high duty rates which slows the industry's expansion.

Lack of knowledge sharing platforms between stakeholders

Collaboration between traditional industry leaders and start-ups is rising, and maritime testbeds and accelerators have emerged. Feedback from interviews conducted with various stakeholders in the Indian maritime ecosystem expressed a willingness by organizations to collaborate and adopt newer technologies. However, a lack of knowledge-sharing platforms and proper facilitation hindered successful collaboration. Such platforms must be established for the public and private sectors as they can be effective policy instruments for initiating and implementing the government’s maritime strategy.

Skill shortage in handling alternative solutions

Training seafarers to support shipping’s decarbonization is already subject to several constraints. These include a low pace of regulatory development and a lack of clarity surrounding the viability and uptake of alternative fuel options and decarbonization trajectories, which makes investment in seafarer training challenging.

The decarbonization and digitalization of the global economy's production models and work organization systems directly impact labour, employment, and tasks. There are many safety challenges related to alternative fuels in shipping. These include pressurized storage, low flashpoint, and toxicity. Hydrogen, for example, is substantially more flammable than diesel, and ammonia is toxic to humans and the marine environment.

The potential change in the work and employment patterns will produce two big challenges in the maritime industry. The first will be a shortage in the supply of skilled personnel worldwide, and the second will be the prediction of the future skills needs for technological developments. These challenges pull policymakers into a gruelling race to spend continued efforts to invest in the skills required for the changing needs of the ships in the future and to build a workforce with future-proof skills. For maritime education and training institutes, special efforts must be made to respond to new and changing training needs and educate graduates with the appropriate skills required for the future.

9. Recommendations, Impact, and Conclusion

9.1 Recommendations

The recommendations are developed based on our analysis of the Indian coastal fleet, stakeholder interview feedback, and literature survey for the Indian shipping ecosystem and other successful global cluster models.

Set national climate targets and political ambitions for domestic shipping

Adopting the Paris Agreement was a turning point in international climate cooperation. Through the agreement, the world's countries aim to limit global warming to well below 2 °C and are pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels.

At COP26, India promised to cut its overall emissions to net zero by 2070, reduce the carbon intensity of the economy by 45% by 2030 (over 2005 levels), reduce total projected carbon emissions by one billion tonnes from 2022 to 2030, produce 50% of its energy requirements from renewable energy by 2030 and reach 500 GW of non-fossil energy capacity by 2030.

As regulations will be one of the key drivers for implementing greener technologies, setting ambitious national climate targets for domestic shipping and specific vessel types that are in operation can fast-track the adoption of greener technologies.

Establish maritime clusters and increase cooperation between industry actors throughout the value chain

Considering India's scale, national working groups and regional clusters for green shipping should be established. Regional maritime clusters can be set up in locations identified in Chapter 7. Key enablers and industry actors throughout the shipping value chain, nationally and locally in maritime clusters, must be identified and encouraged by the facilitator to be part of the systematic collaboration programme. Cargo owners and purchasers of transport services must be involved in all interactions as these parties, together with government authorities, can make the decisions that will have the greatest impact and trigger the green shift.

To capitalize on the global expertise, initiatives can also be organized with successful global programmes, like the Norway GSP, NCE Maritime CleanTech and others, to identify potential areas for collaboration, identification and development of pilot projects, and technology transfer.

Developing short-term and long-term plans for green coastal shipping

Establishing national short-term and long-term sustainable shipping strategies is important to achieve global and national climate targets. While setting up infrastructure for greener alternatives is important, existing infrastructure still needs to be optimized. As the infrastructure for greener alternatives is still developing, green transition in the short term can be enabled using drop-in fuels with relatively lesser emissions. Vessel segment emission reduction strategies can be developed from the emission insights shared in Chapter 4.

Green shipping strategies for the long term should be aligned with national renewable energy policies announced by the governments, such as the National Hydrogen Mission.

Besides the national strategies, National Working Groups and Maritime Clusters related to green shipping should have well-defined phase-wise targets similar to Norway GSP mentioned in Chapter 5.

Create markets for green technology

Cargo owners, shipping agents, shipowners, port authorities, shipyards and suppliers of equipment, gas, power, and services, as well as other actors within the field of safety and environmental approvals, must invest in training and promotion of new technologies. The market's willingness to pay for environmentally-friendly ships and services must be guaranteed before shipowners invest in novel solutions. Among purchasers of transport services, there is a reluctance to pay, and shipowners, therefore, feel that not investing presents the least risk to them. As heavy investment into new, green ships does not increase income compared to older, conventional ships, one cannot expect investments to be made. This would require concrete, effective steps that will make the market for green solutions work.

An important prerequisite is that cargo owners, shipping agents and end users of transport services show a greater willingness to pay for green maritime services. At the same time, government authorities can also go a long way to creating a market for green shipping through incentives and regulations and as a purchaser of maritime services.

Reinforce shipowners' financial capacity and access to capital

Access to capital is limited, hindering the necessary financing from accelerating the green transition. Many shipowners struggle financially and cannot invest in expensive fleet renewal programmes. Green financing schemes should be encouraged to increase cash flow from the public, private and non-profit sectors. State guarantee schemes and favourable loan schemes can be established to fund the development of more environmentally-friendly ships.

Establish infrastructure for green shipping

It is vital to develop a green shipping sector where ports provide onshore power, charging facilities and adequate bunkering services for sustainable fuels. There is a need for capacity building in the public, corporate, and urban sectors.

The national infrastructure for producing, distributing, and bunkering sustainable fuels like bio-LNG, liquid biofuels, ammonia, and hydrogen is required. Technology transfer can be encouraged to capitalize on existing innovative solutions, and further R&D can be performed to make the systems more efficient.

Electricity will be one of the important energy carriers. Today, fully electric and chargeable battery hybrid solutions are limited by the infrastructure available and the large degree of special adaptations for the operational profile. To accommodate the use of onshore power, rechargeable hybrids, and fully electric ships, it should be made a requirement to use onshore power for all relevant ship types in all ports with substantial emissions. Gradually this can be expanded and stepped up for rechargeable hybrids and fully electric ships.

These infrastructures can be set up in ports based on the number of port calls and the amount of cargo handled by overseas and coastal vessels, as shown in Chapter 6. It is found that Deendayal, Paradip and JNPT are the busiest ports in India in terms of cargo handling from April to September 2022, and these top three busiest ports should look for establishing greener infrastructure for shipping.

The pricing of tariffs for onshore power and charging should be adapted so that the power supply is competitive. Through this competitive power pricing, we expect an explosive market penetration for this ship type, which will give shipowners operational savings together with reduced emissions of gases harmful to health and the environment.

A sustainable shipping observatory can be established to gather and disseminate data on logistics and shipping, create techniques and indicators, harmonize terminology, process gathered data and calculate results, and enhance stakeholders' ability.

Train the workforce to adapt to greener technologies

The role of the maritime workforce is expected to shift dramatically as decarbonization, sustainability, and digital technology advance. The workforce will be exposed to the challenges mentioned in Chapter 8. Therefore, the maritime workforce will need to be upskilled, and training standards will need to be strengthened to have a smooth green shipping transition. Per the interview feedback from maritime universities, the current curriculum lacks additional training concerning digitalization and the risks associated with alternative propulsion fuel.

With the third largest number of maritime education institutes and as the third largest seafarer-supplying nation to the global maritime industry, India must take the initiative to update the training curriculums of universities and training institutes. Required skills and competencies are analyzed in detail in the DNV white paper 'Insights into the seafarer training and skills needed to support a decarbonized shipping industry'.[69]

Pilot green projects for short-sea shipping and inland waterways

Pilot projects with new technologies are hypothesized as an essential phase between R&D and market diffusion. Pilot projects impact both mindset and market when they demonstrate a climate-neutral alternative that is operationally feasible. They can build trust in the new technologies and inspire others to contribute to the green transition. The knowledge development and spreading of this knowledge can thus enable follow-up projects or spin-offs and make scale-ups manageable. As investing in pilot projects are generally far from profitable, the support of subsidies is important. The regulators must support the creation of pilot projects, which can include elements incorporating innovative business ideas, creative logistics ideas, new logistics planning software, widely accessible finance choices, relevant policy tools etc.

The Kochi Water Metro project launched by Kochi Metro Rail Limited (KMRL) is a model that can be implemented in other parts of the country where passenger ferries still use conventional fuel sources.

Inclusion of zero-emission transport requirements in public procurement processes

Green public procurement (GPP) is an instrument public actors use to purchase goods and services with a lower environmental impact in their lifetime. Regulators of all levels must set requirements for environmental friendliness to be a characteristic of transportation in all public procurements.

The rapid phase-in of ferries with electric propulsion systems in Norway has been driven by requirements included in public procurement processes combined with grants, for example, from Enova and the NOx fund, for technology development and building charging infrastructure.

Introduce CO_2 fund and support schemes

Emissions pricing is one of the main instruments that can provide incentives to achieve emission cuts at the lowest possible cost to society. The Government can increase the standard carbon tax rate per year, and the revenue can be used to reduce taxation of groups affected by the increases to ease the transition. Predictable stepwise increases in the carbon tax will make it easier for shipowners to consider future carbon prices when making investment decisions.

Carbon pricing will often not be sufficient to justify the costs of developing new environmental technology. Well-designed support schemes may be necessary to compensate for high costs and risk levels during a transitional period. Schemes to support the development of environmental technology must be limited to projects where there is a prospect that zero- and low-emission solutions will, in time, become competitive without support.

Enova, Innovation Norway, the Research Council of Norway, and the NOx Fund all support the development of new technology and the necessary infrastructure. Instruments like the carbon tax, a lower electricity tax rate for commercial vessels and differential rates for port fees based on environmental grounds can make green solutions more competitive.

Maximum utilization of multi-modal transportation

According to estimates, the coastal vessels in India spend about 70% of their time in ports and only 30% in transit. Also, the 12 major ports handle 75% of the total cargo leading to problems of congestion and excessive delays. This is a major cause of shipment delays and slow growth in the shipping sector. The average turn-around time of vessels in India's major ports is nearly four days.

There is a need to develop a multi-modal solution with coastal linkages, as coastal shipping cannot stand alone. There is a need to integrate coastal shipping into the transport network in a way where inland waterways supplement road and rail transport, making it an easier and cost-effective solution for both companies and end-users.

Together with other industry actors, cargo owners must find out how the transportation of goods can be differentiated between what must be conveyed rapidly and what can take slightly longer so that the advantages of the different forms of transport can be leveraged to the greatest extent possible. The combination of different means of transport can be optimized by identifying this. Proper optimization can reduce road congestion, emissions, cost, and transportation time.

Continued investment in R&D and coordination of the activities of research institutes and maritime universities

Maritime research should be promoted by identifying key institutes and their area of research. A centralized research organization should be established to coordinate the research activities of identified institutions. Key and potential research areas of various institutions must be identified and supported with adequate funding. A centralized research institution can monitor, coordinate, and fund the activities of various institutions involved. To increase awareness among stakeholders about newer technologies and solutions, fact sheets, newsletters, and annual knowledge reports on sustainable shipping can be published.

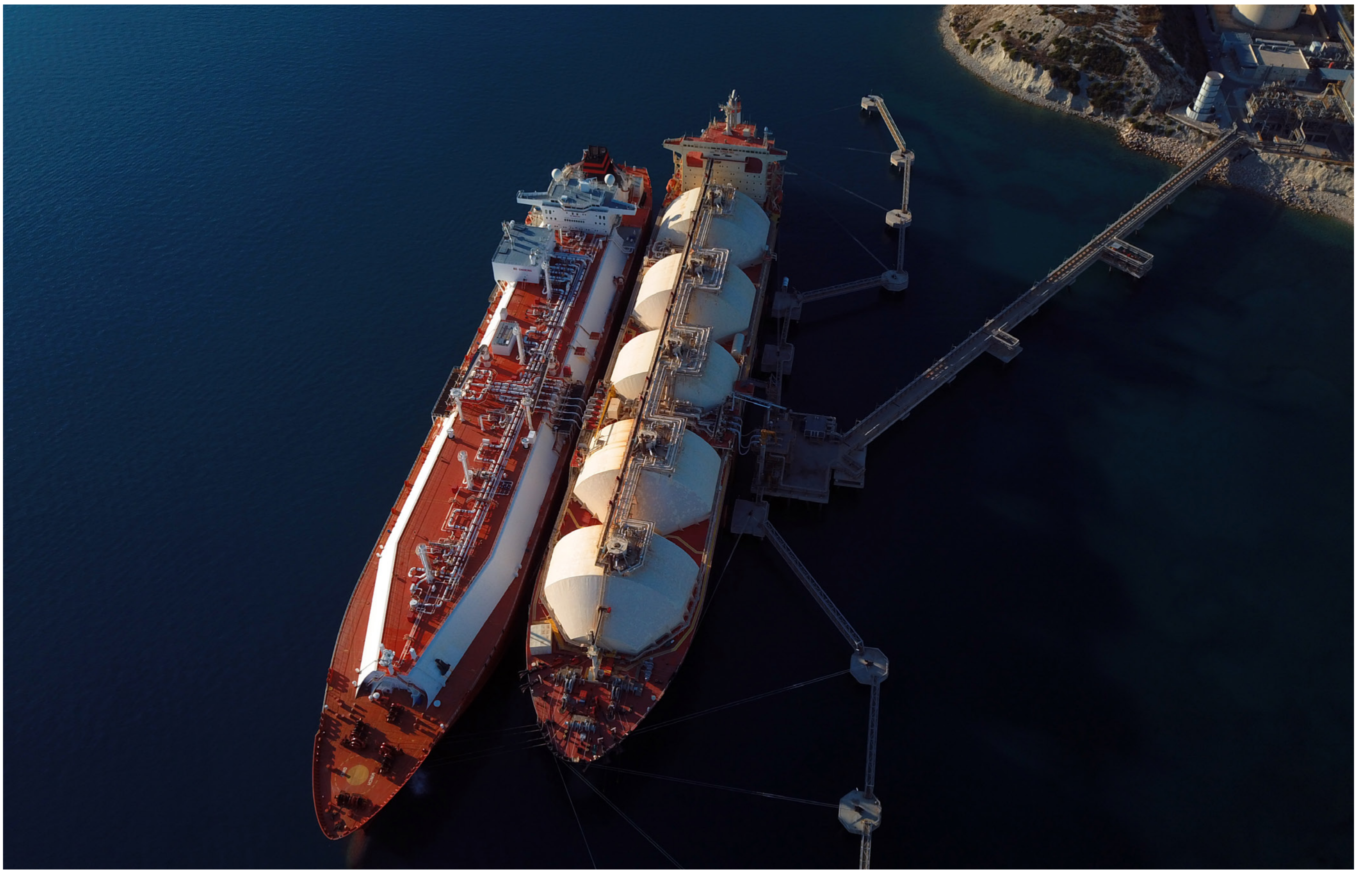
A database of all feasible green shipping technologies and their associated parameters, such as CapEx, OpEx, lifespan, and fuel/cost-saving potential, should be maintained for awareness and to aid the stakeholders in decision-making.

Create awareness of green corridors for shipping

Awareness of green shipping corridors can be created by establishing more forums on national and international levels. Some examples would be organizing annual forums on sustainable shipping and logistics and developing and managing urban shipping partnerships, establishing a Centre of Excellence in Logistics, and creating sustainable shipping campaigns by creating a communication plan that integrates social media campaigns and conventional media to mainstream sustainable shipping and logistics practices. On the public level, social media could be used to create skill awareness and attract talent into the workforce.

Standards can be raised by recognizing and rewarding shippers and operators that set an excellent example of best practices in their business. For example, depending on how well they meet the predefined criteria, bronze/silver/gold ratings could be awarded as part of certification. This will help to create, spread, and improve the use of best practices and innovations in shipping logistics that help India achieve its goals and policy in terms of impact on the economy, society, and environment.

9.2 Conclusion



Economic growth is made possible by shipping and logistics operations, which boost industrial competitiveness, link producers and consumers, facilitate the integration of local shipping and logistics activities with global supply chains, and promote inclusive development and social advancement. Coastal shipping is increasingly becoming a viable and effective substitute for road transportation. It produces much less GHG emissions, cuts freight costs across medium to long transit distances, and eases traffic congestion and noise pollution in large cities. India's coastal shipping and logistics business must be sustainable to achieve economically effective, socially viable, and ecologically friendly transportation and logistics services.

As in other sectors of the global economy, the shipping industry also must take its path towards green technology and sustainability. This transition is best driven through partnerships, as part of forums, alliances, and coalitions.

The Indian Coastal Green Shipping Programme will create the following benefits:

1. Decrease fuel usage, price, CO2 emissions, and air pollution for carriers and shippers.
2. Increase the use of cutting-edge techniques and technology throughout the supply chain.
3. Create more green employment opportunities.
4. Give public recognition to shippers and carriers who make specified advancements and use newer technologies.
5. Promote the use of innovative solutions rapidly.
6. Build consensus among the public, business, scientific, and other sectors.
7. Collect and distribute data and indicators on the effectiveness of shipping transport and logistics in reducing emissions and provide efficient and reliable techniques for measuring and reporting fuel use.
8. Present case studies of innovative and repeatable solutions.
9. Encourage open peer-to-peer learning and exchange, as well as sharing and working together to establish standardized approaches, tools, and the provision of instruction and technical support.
10. Enhance public awareness and consumer perception by participation in the sustainable shipping movement, thereby helping stakeholders publicly commit to sustainable logistics and shipping.

Collaboration models like the Indian Coastal Green Shipping Programme will fast-track the industry's uptake of greener, innovative solutions. They will identify great opportunities, find cutting-edge solutions to overcome the current ecosystem’s barriers, and ensure that the wheel is not reinvented.

References

[1] DNV 2022 Energy Transition Outlook.
Source: http://bit.ly/3EoSglA

[2] UNCTAD – United Nations Conference on Trade and Development (2021) State of Commodity Dependence 2021.
Source: http://bit.ly/3tmEFoM

[3] IMO's work to cut GHG emissions from ships.
Source: http://bit.ly/3UM4Ws3

[4] ISWG-GHG 12/3/14, ISWG-GHG 12/3/17.
Source: http://bit.ly/3tnllYe

[5] ISWG-GHG 12/3/3.
Source: https://bit.ly/3tnllYe

[6] DNV Maritime Forecast to 2050.
Source: http://bit.ly/3GbJEA2

[7] DNV to lead Nordic Roadmap partnership for zero-carbon ship fuels (2022).
Source: http://bit.ly/3G8cWQi

[8] C40 Cities. (n.d.). Port of Los Angeles, Port of Shanghai, and C40 Cities announce partnership to create world's first transpacific green shipping corridor between ports in the United States and China.
Source: http://bit.ly/3E0n7U1

[9] Poseidon Principles for Marine Insurance.
Source: http://bit.ly/3WUhSxN

[10] Science Based Targets. Net-Zero.
Source: http://bit.ly/3E2uNVM

[11] Greenhouse Gas Protocol.
Source: http://bit.ly/3DYSJto

[12] India GHG Programme.
Sources: http://bit.ly/3hrKNsR

[13] Network, M.N. HHI's New Fuel Saving Propeller Attachment Can Save Up To 2.5 % of Fuel.(2015).
Source: http://bit.ly/3E2IjJn

[14] ML/AI based Fuel Optimization System.
Source: http://bit.ly/3TrbStB

[15] Lindstad, H., B. E. Asbjörnslett and A. H. Strömman (2011), Reductions in greenhouse gas emissions and cost by shipping at lower speeds. Energy Policy, 39, 3456-3464.
Source: http://bit.ly/3A9CtVo

[16] Cariou, P. (2011), Is slow steaming a sustainable means of reducing CO2 emissions from container shipping? Transportation Research Part D: Transport and Environment, 16, 260-264.
Source: http://bit.ly/3Epusyb

[17] Faber, J. (2012), Regulated slow steaming in maritime transport an assessment of options, costs and benefits. CE Delft. Delft, Netherlands.
Source: http://bit.ly/3NYKLFc

[18] DNV Veracity
Source: http://bit.ly/3hBm1qf

[19] International Energy Agency, Ministry of Petroleum & Natural Gas, Petroleum Planning and Analysis Cell (PPAC),TRW-MoPSW.
Source: http://bit.ly/3UKJZOj

[20] Assessment of selected alternative fuels and technologies in shipping - DNV. (2021)
Source: http://bit.ly/3TuNxmy

[21] The Indian Express. (2022). INS Vikrant: All about India's first indigenous aircraft carrier.
Source: http://bit.ly/3A8mfeW

[22] Looking beyond the horizon Innovating ideas for sustainable future Annual Report.
Source: http://bit.ly/3WLyR5s

[23] Shipbuilding | L&T India.
Source: http://bit.ly/3hARysE

[24] NTCPWC - National Technology Centre for Ports, Waterways and Coasts | Home. Source: http://bit.ly/3DZLoK1

[25] Official website of Garden Reach Shipbuilders and Engineers Limited – A Government of India under taking, Ministry of Defence.
Source: http://bit.ly/3UwSYCY

[26] CICMT
Source: http://bit.ly/3DQVKfe

[27] IMS GOA. No.1 personalized Marine Engineering Courses in India | Maritime Study.
Source: http://bit.ly/3UJ6OT3

[28] HSL (Hindustan Shipyard Limited), A Government of India Undertaking, Department of Defence Pro duction (DDP), Ministry of Defence (MoD), India.
Source: http://bit.ly/3DZMk0Z

References

[29] About GMC - Gujarat Maritime Cluster.
Source: http://bit.ly/3TrdWSw

[30] Reliance Naval and Engineering Ltd. (2016)
Source: http://bit.ly/3hyiol7

[31] Holmen, L. and Barradas, D. THE LEADING MARITIME CITIES OF THE WORLD 2O22
Source: http://bit.ly/3tr0F1q

[32] Much-delayed water metro ferries likely to roll out by mid-October, The New Indian Express. The New Indian Express. (2022)
Source: http://bit.ly/3Tn6YOp

[33] Chowgule.
Source: http://bit.ly/3fXaeCk

[34] Kochi Metro Rail Ltd. (2022, October 13). Water Metro. Source: http://bit.ly/3O54lj5

[35] Kochi Water Metro. (2022, September 20)
Source: http://bit.ly/3NYMbj0

[36] Kochi Water Metro (2021) Echandia.
Source: http://bit.ly/3Enl5Pd

[37] Amt, A. Indo-German economic cooperation at a glance, Indo-German Economic Cooperation at a glance - Federal Foreign Office.
Source: http://bit.ly/3Epy17a

[38] KOCHI WATER METRO PROJECT REPORT (2018) Ministry of Environment, Forest and Climate Change Government of India.
Source: http://bit.ly/3fWVVO9

[39] Ruhal, S. (2022). Indian Maritime Legal Education: A Critical Analysis. Asian Journal of Legal Education, 9(2), 156-184.
Source: http://bit.ly/3WXMsaa

[40] Gunther, M. (2014). The Dynamics of the Norwegian Maritime Industry.
Source: http://bit.ly/3hrMG8V

[41] Reve, Torger. "Norway – a global maritime knowledge hub." (2009).
Source: http://bit.ly/3Tttjd7

[42] Osman, S., Sundarakani, B., & Reve, T. (2021). Benchmarking of Singapore maritime cluster: the role of cluster facilitators. Benchmarking: An International Journal, ahead-of-printSource: http://bit.ly/3A929RT

[43] Norwegian Innovation Clusters.
Source: http://bit.ly/3EnAQ8R

[44] Basso, M., Abrahamoglu, S., Haug, K., Aslesen, S. and Jakobsen, E.
Source: http://bit.ly/3NVRD6a

[45] PROGRAM LEVEL Global Centre of Expertise (GCE) 2. THE CLUSTER PROJECT'S OBJECTIVE AND JUSTIFICATION 2.1 The maritime cluster in Møre -today's recipe for success. (n.d.).
Source: http://bit.ly/3hAZc6l

[46] Hessevik, A. (2021). Network‐led advocacy for a green shipping transformation: A case study of governance networks in the Norwegian maritime sector. Regulation & Governance. doi:10.1111/rego.12386.
Source: http://bit.ly/3NUIMBO

[47] Development through knowledge.
Source: http://bit.ly/3NZw1pn

[48] Osman, Shahrin, Balan Sundarakani, and Torger Reve. "Benchmarking of Singapore maritime cluster: the role of cluster facilitators." Benchmarking: An International Journal 29.5 (2022): 1452-1483.
Source: http://bit.ly/3TInqsN

[49] MPA. Grants and Funding.
Source: http://bit.ly/3hzMapF

[50] MPA. Singapore Maritime Institute Fund.
Source: http://bit.ly/3fTLbQK

[51] MPA. Maritime Centres of Excellence.
Source: http://bit.ly/3hAsXUL

[52] Singapore Shipping Association. (n.d.). Homepage.
Source: http://bit.ly/3EoyXJi

[53] India Foundation. (2021). A TECHNOLOGY DRIVEN MARITIME VISION FOR INDIA.
Source: http://bit.ly/3NWzPYy

[54] MARITIME INDIA VISION 2030 Ministry of Ports, Shipping and Waterways Government of India.
Source: http://bit.ly/3EpyCWP

[55] TCI Network Introduction to Norwegian innovation clusters programme, Share and Discover Knowledge on SlideShare.
Source: http://bit.ly/3htsEel

References

[56] Overview over the Norwegian Innovation Cluster.
Source: http://bit.ly/3fUexhG

[57] Introduction to Norwegian Innovation Clusters.
Source: https://bit.ly/3htsEel

[58] SagarMala - Background Ministry of Shipping, GOI, Government of India.
Source: http://bit.ly/3TInB7r

[59] Efforts to Expand: Opportunities abound in the coastal shipping space. (2021)
Source: http://bit.ly/3TpdCDD

[60] SAFETY4SEA. (2022). Denmark and India to establish a Centre of Excellence on Green Shipping.
Source: http://bit.ly/3tkkuHJ /

[61] The potential for Indian inland waterway and coastal transport.
Source: http://bit.ly/3UQ8MR9

[62] National Action Plan for Climate Change – Wikipedia.
Source: http://bit.ly/3WR3vdQ

[63] Green Shipping Programme Efficient and environmentally friendly shipping.
Source: http://bit.ly/3tog2Yw

[64] GreenVoyage2050
Source: http://bit.ly/3DWnPlf

[65] GCMD - Global Centre for Maritime Decarbonisa tion | Singapore.
Source: http://bit.ly/3NWD6ae

[66] Home | Mærsk Mc-Kinney Møller Centre for Zero Carbon Shipping.
Source: http://bit.ly/3UwXcdO

[67] Norwegian Government, 'The Government's action plan for green shipping', 2019
Source: http://bit.ly/3hzMDYX

[68] Green Shipping Programme, 'Charting a course for Green Coastal Shipping', 2016
Source: http://bit.ly/3G9A7tu

[69] Keppel Corporation: Keppel Infrastructure partners Greenko to explore green ammonia and renewable energy opportunities.
Source: http://bit.ly/3Trbmf1

[68] ICCSA
Source: http://bit.ly/3WS9GhA

[69] DNV Seafarer training and skills for decarbonized shipping.
Source: http://bit.ly/3NVTWGg

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