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Ministry of Ports,
Shipping & Waterways
Government of India

India's Maritime Green Shift: Pioneering Energy Transition and Pollution Control

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List of Abbreviations

MIV	Maritime India Vision
MAKV	Maritime Amrit Kal Vision
NAVIC	Neel Arth Vision Implementation Cells
IWAI	Inland Waterways Authority of India
NMPA	New Mangalore Port Authority
MbPA	Mumbai Port Authority
DPA	Deendayal Port Authority
KPL	Kamarajar Port Limited
VOCPA	V.O. Chidambaranar Port Authority
VPA	Visakhapatnam Port Authority
JNPA	Jawaharlal Nehru Port Authority
CoPA	Cochin Port Authority
PPA	Paradip Port Authority
SMPK	Syama Prasad Mookerjee Port Authority
ChPA	Chennai Port Authority
MgPA	Mormugao Port Authority
CTU	Central Transmission Utility

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Setting Sail Towards a Greener Horizon

1.1 The Urgent Need for Greening and Pollution Control in the Maritime Sector

India's maritime sector is one of the most critical pillars of its economic infrastructure. With a coastline spanning over 11,098 km and a network of 12 major ports and more than 217 non-major and intermediate ports, India's maritime reach is extensive and strategically positioned on key international shipping routes. Approximately 95% of India's trade by volume and 68% by value is conducted through maritime transport, underlining its pivotal role in facilitating both domestic logistics and global trade integration. This immense scale makes the sector not only a cornerstone of national economic growth but also a significant source of environmental impact.

The environmental cost of such a vast and active maritime footprint is considerable. Shipping accounts for around 3% of global greenhouse gas (GHG) emissions, and in 2022 alone, the global maritime industry emitted approximately 858 million tonnes of CO_2 India, as an emerging maritime hub with ambitious port modernization and inland waterway development plans, is expected to contribute a larger share unless immediate mitigation strategies are mainstreamed.

Inland Waterways Authority of India (IWAI) reports show a record rise in cargo movement, growing from 126.15 MMT in 2022–23 to 133.03 MMT in 2023–24, marking a 5.45% increase. Similarly, cargo traffic at Indian ports reached 1540.34 MMT in 2023–24, with a 7.5% growth compared to the previous year, showcasing a robust and expanding maritime ecosystem. This continuous upward trajectory—while vital for economic advancement—raises urgent concerns regarding energy consumption, emissions, waste discharge, and the overall ecological footprint of the sector.

Maritime emissions, if left unregulated, are projected to rise by 150–250% by 2050 under a business-as-usual scenario, as projected by the International Maritime Organization (IMO). These emissions aggravate climate change, contributing to sea level rise, ocean acidification, and biodiversity loss, disproportionately affecting vulnerable coastal communities and Small Island Developing States (SIDS). The pressing need to green this sector is not only an environmental mandate but also a socio-economic imperative for India.

This report, led by NAVIC Cell #3 under the Ministry of Ports, Shipping, and Waterways (MoPSW), is situated at the intersection of this dual challenge—sustaining high-growth maritime trade while aggressively reducing the sector's ecological burden. The following chapters will detail India's policy landscape, port and shipping-level green initiatives, transition strategies for inland waterways, and the enabling mechanisms of finance and skill-building, all aligned with the Government of India's commitment to a net-zero and resilient maritime sector.

1.2 India's Green Maritime Transition: Vision and Policy Landscape

India's maritime development is entering a decisive phase—one that embraces sustainability as a core principle rather than a peripheral goal. The Government of India, through the Ministry of Ports, Shipping, and Waterways (MoPSW), has initiated a robust set of programs and policies aimed at embedding environmental responsibility across the port, shipping, and inland water transport sectors. These initiatives are designed not just to comply with global mandates but to position India as a thought and action leader in sustainable maritime development.

Foundational policies such as the Maritime India Vision (MIV) 2030, the recently launched Maritime Amrit Kaal Vision (MAKV) 2047, and the Harit Sagar Green Port Guidelines have created a structured framework for action on port greening, renewable energy adoption, digitization, and pollution control. The National Green Hydrogen Mission, with dedicated projects at Paradip, Deendayal, and VOCPA, is catalyzing the creation of port-based green hydrogen hubs. Complementary schemes like the Jal Vahak Scheme, Hybrid and Hydrogen-powered Vessels, and the Green Tug Transition Programme (GTTP) further reinforce India's commitment to climate-aligned maritime growth.

Inland waterways too are undergoing a green transformation. Flagship efforts such as the Jal Marg Vikas Project (JMVP) and Arth Ganga integrate climate resilience, riverine pollution control, and last-mile multimodal connectivity, particularly in the Ganga and Brahmaputra river systems.

Additionally, institutional reforms such as the Merchant Shipping Bill 2024, Coastal Shipping Bill 2024, and digitization initiatives like the National Logistics Portal (Marine) and Enterprise Business System (EBS) are driving systemic efficiency while enabling better monitoring of environmental performance.

To further unify and scale these efforts, the National Green Shipping Policy (NGSP) 2025 is currently under formulation. The policy envisions India as a global leader in sustainable maritime development—one that harmonizes economic growth with environmental integrity, fosters climate-resilient infrastructure, promotes clean technology, and ensures equity in the green transition for all maritime stakeholders, including coastal communities.

Together, these policy instruments reflect a national resolve to not only reduce emissions but to embed sustainability into the DNA of maritime governance. The coming sections of this report will explore how NAVIC Cell #3 plays a central role in operationalizing these frameworks, addressing implementation gaps, and supporting ports, shipping lines, and allied stakeholders in navigating this green transition.

1.3 NAVIC Cell 3: Driving Green Maritime Policy and Action

The Ministry of Ports, Shipping, and Waterways (MoPSW) has operationalized 22 NAVIC Cells (Neel Arth Vision Implementation Cells) to institutionalize implementation under the Maritime India Vision and Amrit Kaal framework. NAVIC Cell #3, hosted under the VOCPA port is entrusted with spearheading India's green transition in ports and shipping. The Energy and Resources Institute (TERI) serves as the knowledge partner for this cell.

NAVIC Cell #3 serves as a technical and strategic node to:

- Design and monitor Green Port and Shipping Initiatives
- Drive Energy Transition, including shore power and electrification
- Guide Pollution Control and Waste Management protocols
- Enable Green Finance facilitation and inter-agency coordination
- Support Capacity Building and Skill Development

This collective expertise from the Ministry of Ports, Shipping, and Waterways (MoPSW), academic institutions, shipping corporations, and port authorities ensures a comprehensive strategy for sustainable development in the sector.

To enable focused action and technical depth, four specialized sub-groups have been constituted under NAVIC Cell 3:

- Renewable Energy: Focuses on challenges and solutions concerning the adoption of renewable energy at ports, within shipping, and across inland waterways. This subgroup is preparing a well-structured action plan identifying port-wise constraints and tailored solutions, complete with timelines for implementation.
- Shore-to-Ship Power Supply: Examines the phased rollout of shore power infrastructure, evaluates port readiness, and identifies practical and regulatory bottlenecks.
- Finance: Addresses the mobilization of capital through mechanisms such as the Maritime Development Fund, public-private partnerships, and international climate finance instruments.
- Capacity Building: Develops training modules, supports institutional partnerships, and strengthens technical and operational competencies across port and maritime personnel.

By integrating cross-sectoral insights and stakeholder coordination, NAVIC Cell 3 serves as a central implementation and advisory mechanism in India's maritime decarbonization journey, ensuring that sustainability is embedded into both operations and governance.

1.4 Strategic Relevance of NAVIC Cell 3 Within National Maritime Governance

NAVIC Cell #3's role is not limited to implementation oversight. It serves as a think-and-do tank, shaping green transition pathways that align national ambition with global standards, including the IMO Revised GHG Strategy 2023, which targets:

- At least 20% GHG reduction by 2030 (striving for 30%)
- At least 70% by 2040 (striving for 80%)
- Net- ZERO emission by on and around 2050

NAVIC Cell #3 also contributes to flagship programs such as the Green Tugs Transition Programme (GTTP), aiming for 100% green tug replacement by 2036. The Cell facilitates the shift from fossil fuels to clean energy—including hydrogen and electricity—while incorporating data-backed performance indicators and international collaboration frameworks.

By serving as an integrative platform between central authorities, port operators, academia, and financiers, NAVIC Cell #3 ensures that India's maritime decarbonization remains coordinated, accountable, and scalable.

1.5 Indicative Interventions for the Indian Context

To operationalize India's maritime decarbonization goals, NAVIC Cell 3 has identified a suite of indicative interventions that cut across ports, shipping, and inland waterways. These interventions are grounded in national policy targets—such as those outlined under the Maritime India Vision (MIV) 2030, Maritime Amrit Kaal Vision (MAKV) 2047, Harit Sagar Guidelines, and the National Green Hydrogen Mission—and are aligned with the core focus areas of NAVIC Cell 3's sub-groups.

These interventions address the interlinked challenges of energy transition, pollution control, waste minimization, ecosystem protection, and capacity enhancement. A thematic breakdown of these indicative areas of action is outlined below:

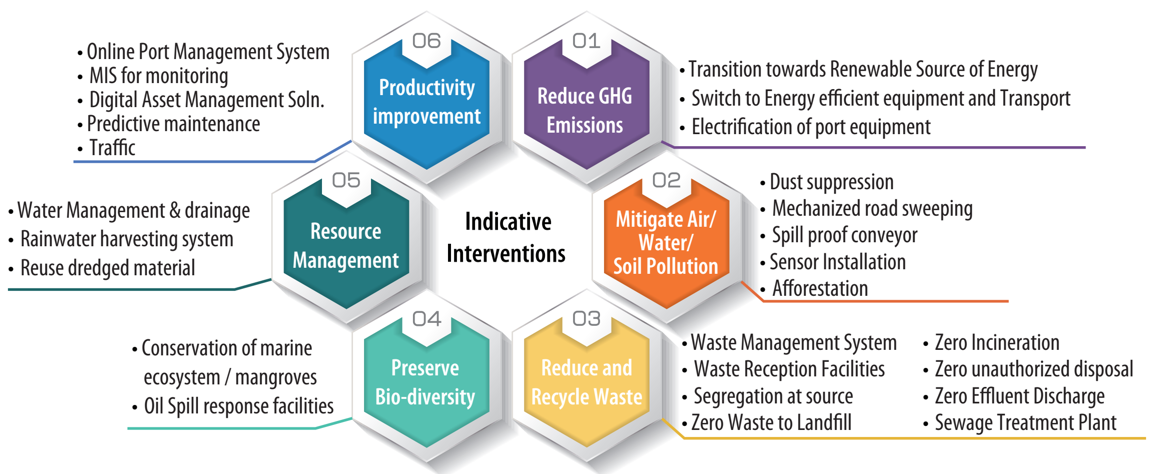

Figure 1.1.1: Indicative Interventions under NAVIC Cell 3

1.5.1 Reduce GHG Emissions

India's maritime decarbonisation strategy has evolved beyond aspirational targets into structured interventions. Under the Harit Sagar Green Port Guidelines, ports are now mandated to progressively increase the share of renewable energy, targeting over 60% by 2030 and 90% by 2047. This includes integration of solar, wind, and hybrid energy systems across port estates. Major ports such as VOC Port, Paradip, and Deendayal are already building renewable energy capacity, with dedicated areas allocated for green hydrogen production and bunkering.

Electrification is being pushed through phased plans to convert port handling equipment, harbour crafts, and vehicles to electric or alternative fuel-based propulsion. Shore-to-ship power infrastructure is being rolled out to reduce emissions from berthed vessels. These actions are supported by digital monitoring under platforms like SagarSetu (NLP-Marine) and Enterprise Business Systems (EBS), ensuring visibility and tracking of emissions per tonne of cargo handled.

- Transition towards renewable energy across port and vessel operations, with targets of >60% renewable share by 2030 and >90% by 2047.
- Electrification of port equipment and harbor crafts, with phased targets: 50% by 2030 and 90% by 2047.
- Switch to energy-efficient technologies including LED systems, smart building designs, and automation across maritime infrastructure.
- Deployment of green tugs under the Green Tug Transition Programme (GTTP), supported by the Maritime Development Fund (MDF) and phased procurement of over 50 vessels.

1.5.2 Mitigate Air, Water, and Soil Pollution

Pollution control in Indian ports is being advanced through dust suppression systems, covered conveyors, and cargo handling automation, especially in dry bulk terminals. Ports like Paradip and Mormugao are implementing these solutions to reduce particulate emissions.

To ensure air and water quality, the replacement of Heavy Fuel Oil (HFO) with cleaner alternatives like Marine Gas Oil (MGO) in port craft operations is gaining momentum. Sensor-based monitoring of ambient air and water quality is being piloted at select ports under Harit Sagar Guidelines, while afforestation programs aim to achieve 33% green cover in port estates by 2047.

Furthermore, stricter enforcement of Ballast Water Management (BWM) Convention compliance and emission norms under MARPOL Annex VI is being carried out by the Directorate General of Shipping.

- Dust suppression systems and spill-proof conveyors for handling dry bulk cargo.
- Sensor-based pollution monitoring systems at terminals.
- Complete replacement of heavy fuel oil (HFO) with cleaner fuels such as Marine Gas Oil (MGO) in selected port operations.
- Afforestation and green belt development, with a national target of achieving 33% green cover in port premises by 2047.
- Strict enforcement of ballast water management and emissions control protocols in compliance with IMO guidelines.

1.5.3 Reduce and Recycle Waste

Efforts to reduce waste and promote circularity include the integration of Solid Waste Management (SWM) and Sewage Treatment Plants (STPs) at major ports, with ports like Kamarajar and Chennai already achieving high waste segregation rates.

The vision for zero waste to landfill and effluent discharge by 2047 is being operationalized through Material Recovery Facilities (MRFs) and hazardous waste storage zones, supported by environmental management systems (EMS). Port-specific environmental action plans are under formulation to ensure regulatory compliance and community engagement.

- Full integration of waste recycling and management systems, including sewage treatment plants.
- Commitment to zero waste to landfill, zero incineration, zero unauthorized disposal, and zero effluent discharge by 2047.

- Port-specific action plans to implement material recovery facilities and hazardous waste compliance frameworks.

1.5.4. Preserve Biodiversity

Ports and inland water terminals are strengthening oil spill response mechanisms, installing oily waste reception facilities, and conducting Environmental Impact Assessments (EIAs) prior to expansion projects.

The development of coastal bio-shields, conservation of mangrove belts, and adherence to Coastal Regulation Zone (CRZ) norms are helping safeguard marine ecosystems. Projects are also aligning with Marine Spatial Planning (MSP) frameworks, being piloted in collaboration with NIOT and ICZM programs.

- Deployment of oil spill response systems and oily waste reception facilities.
- Promotion of zero marine biodiversity loss, through impact assessments and protection of coastal habitats.
- Alignment with Coastal Regulation Zone (CRZ) policies and Marine Spatial Planning (MSP) guidelines to minimize ecological disruptions.

1.5.5 Resource Management

Indian ports are implementing rainwater harvesting, reuse of dredged materials, and energy-saving retrofits in buildings and utilities. For instance, dredged material from Haldia and Kolkata ports is being reused for land reclamation and port construction, reducing landfill pressure.

These initiatives are framed within a circular economy approach, integrating resource optimization in shipbuilding, maintenance, and port operations. Ports are also mandated to develop Water Management Plans as part of the Green Port Compliance Matrix.

- Implementation of water management plans, including rainwater harvesting and reuse of dredged material for construction and reclamation activities.
- Circular economy integration within port operations and shipyards to reduce resource consumption and material wastage.

1.5.6 Productivity Improvement Through Digitalization

Digitalization is a key enabler of green transformation. Systems such as the National Logistics Portal – Marine (NLP-Marine) and Port Community System (PCS 1x) are enhancing cargo visibility and operational efficiency. Several major ports have adopted Enterprise Business Systems (EBS) for real-time performance tracking.

Predictive maintenance using AI and sensor-based diagnostics is being explored for high-energy equipment like RTGCs and quay cranes. Simultaneously, capacity-building modules on green operations are being introduced at port training institutes and maritime academies, supported by NAVIC Cell 3's capacity-building subgroup.

- Establishment of Online Port Management Systems, Management Information Systems (MIS), and Digital Asset Management platforms.

- Use of predictive maintenance technologies for energy-intensive equipment.
- Capacity building and training modules to equip port and vessel operators with green operational protocols.

These interventions are not just thematic aspirations but are being translated into concrete projects with defined timelines, funding pathways, and implementation responsibilities. For instance, ports like JNPA and Paradip have begun transitioning their cargo handling equipment to electric models; IWAI is rolling out shore power in phased manner across inland terminals; and CSL is designing low-emission tug prototypes.

The following chapters will explore these interventions in greater depth, categorized by ports (Chapter 2), inland waterways (Chapter 3), low-carbon shipping (Chapter 4), financing (Chapter 5), and skill development (Chapter 6), providing a consolidated roadmap for India's maritime sustainability efforts.

2

Greening the Ports – Infrastructure, Energy, and Innovation

2.1 Background

As the Indian maritime sector expands to meet rising commercial demands, it also faces mounting pressure to reduce its environmental footprint in alignment with national and global sustainability commitments. In recent years, greening of Indian ports has emerged as a strategic priority, driven by the imperatives of decarbonization, resource efficiency, and environmental protection. Recognizing the environmental challenges posed by port operations such as Green House Gas (GHG) emissions, marine pollution, and energy inefficiency wherein the Ministry of Ports, Shipping and Waterways (MoPSW) has initiated policy and programmatic interventions to integrate sustainable infrastructure, clean energy solutions, and innovative technologies.

The key initiatives include the implementation of the Harit Sagar Guidelines, promotion of adoption of renewable energy sources, shore-to-ship power supply, electrification of port equipment and vehicles, development of green hydrogen, and ammonia bunkering facilities. These efforts are complemented by modernization of infrastructure through the 'Sagarmala Programme', enabling multimodal logistics and enhancing energy-efficient operations.

Furthermore, innovation in pollution control technologies such as ballast water treatment systems, dust suppression mechanisms, and real-time environmental monitoring is being integrated to minimize ecological impact. The initiatives pertaining to digitalization, smart port technologies, and public-private partnerships are also playing a vital role in accelerating the energy transition and environmental stewardship of Indian ports.

Collectively, these initiatives position Indian ports to become global exemplars of green maritime infrastructure, contributing significantly to India's broader net-zero ambitions and blue economy growth.

2.2 Guidelines and Policies

The Indian maritime sector is undergoing a structured green transition guided by progressive policies and frameworks focused on sustainable infrastructure, clean energy adoption, and environmental innovation. The 'Harit Sagar Green Port Guidelines' 2023, issued by MoPSW, serve as a cornerstone for environmentally responsible port operations. These guidelines emphasize key measures such as mentioned above such as shore power provisioning, electrification of port equipment, use of renewable energy sources, implementation of waste and water management systems, and promotion of cleaner fuels like LNG, hydrogen, and green ammonia. Aligned with Maritime India Vision 2030, these initiatives aim to reduce carbon intensity, modernize port infrastructure, and improve resilience to climate impacts through green and smart port development.

Moreover, complementary to these efforts include national missions such as the 'National Hydrogen Mission', which promotes green fuel infrastructure at ports, and compliance with international standards including IMO MARPOL regulations on emissions, ballast water, and ship recycling and also 'Green Tug Transition Programmes' which promotes the adoption of low-emission and electric/hybrid tugs at Indian ports to reduce carbon emissions, improve fuel efficiency, and support the maritime sector's shift towards cleaner propulsion technologies. To take these ambitions forward, Public–private partnerships are being actively promoted to accelerate innovation in pollution control technologies and green logistics. Incentive mechanisms, environmental performance benchmarks, and digital monitoring systems are also being deployed to encourage and track sustainable practices. Together, these policy instruments are shaping a future-ready maritime ecosystem that supports India's broader goals of energy transition, environmental stewardship, and net-zero emissions. The overall existing programs in Indian maritime sector are noted as follows

- Harit Sagar Guidelines (2023): Establish a three-phase transition plan with clearly defined targets for renewable energy use, waste minimization, and port equipment electrification by 2030 and 2047.
- Maritime India Vision (MIV) 2030: Focuses on converting 50% of cargo handling equipment to electric by 2030 and achieving 60% renewable energy penetration at ports.
- Maritime Amrit Kaal Vision (MAKV) 2047: Envisions net-zero ports with 90% RE adoption, 100% electric port operations, and full integration of digital port systems by 2047.
- National Green Hydrogen Mission: Supports the development of hydrogen-ready port infrastructure, with Paradip, Deendayal, and VOCPA identified as early hubs.
- Proposed National Green Shipping Policy (NGSP) 2025: Envisions India as a global leader in sustainable maritime development, aligning green shipping, port decarbonization, and coastal community inclusion into one integrated policy.

These frameworks are not standalone—they are converging through coordinated action plans facilitated by NAVIC Cell 3 and supported by enabling instruments such as the financial support, PPP concessions, and port performance evaluation through green metrics. The policy landscape also includes evolving regulatory mandates like the DGS Circular 09/2025 on shore power standards and amendments to the Major Ports Authorities Act that enable sustainable procurement and project planning.

2.3 A Review of Key Performance Indicators

The Key Performance Indicators (KPIs) are essential tools for evaluating and accelerating the green transition in India's port ecosystem. They serve as quantifiable benchmarks that allow policymakers, port authorities, and technical institutions to assess progress, identify gaps, and refine implementation strategies in real time.

In the context of the Harit Sagar Guidelines and the wider Maritime Amrit Kaal Vision (MAKV) 2047, KPIs have been framed to capture performance across multiple dimensions—renewable energy integration, electrification of equipment, shore power adoption, waste and water management, and emission intensity per unit cargo handled. These indicators help in tracking alignment with national targets and in facilitating transparent, data-driven governance.

The establishment of these KPIs also enables inter-port comparison and performance grading. They support the identification of high-performing ports that can serve as replicable models, while also pinpointing where focused interventions or additional support may be required.

As India's ports move toward full digitization under systems like NLP-Marine and Enterprise Business Systems (EBS), these platforms are increasingly being leveraged to automate the tracking and reporting of green performance. The KPIs also guide investment decisions, procurement planning, and capacity-building needs under both national and port-level green transition plans. The following Table 2.3.1 shows overall KPIs and what each of them entails.

Table 2.3.1: A review of Key Performance Indicators

KPI	Includes
Renewable Energy	Solar/wind energy consumption, on-site/off-site usage
Shore Power	Shore power supply systems, capacity, connected berths, usage details
Electrification of Port Equipment	Electrified cranes, vehicles, and auxiliary equipment; percentage converted
Energy Efficient Equipment	Use of LED lighting, energy-saving drives and equipment
Green Belt Development	Plantation details, area covered
Marine Ecosystem Support	Marine habitat restoration, biodiversity initiatives, mangrove plantations
Reduction in Freshwater Consumption	Freshwater usage trends, efficiency measures
Water Reuse & Rainwater Harvesting	RWH structures, treated wastewater reuse, desalination capacity
Effluent Discharge Measures	STP capacity, effluent standards compliance, monitoring mechanisms
Waste Management (Ships & Ports)	Collection, segregation, disposal of ship waste, port waste handling
Additional Waste Management	Hazardous waste handling, oil spill preparedness, biomedical waste systems
Environmental Management Plan	EMP actions, implementation status, monitoring framework
Green Incentives	Incentives for eco-friendly ships, equipment conversion, energy savings

A detailed, port-wise review of these indicators—along with progress status and targets—is provided in the following sections of this chapter.

2.4 Adoption of Renewable Energy

Major Indian ports are increasingly adopting renewable energy, particularly solar and wind, to meet their electricity needs. This move is part of the broader Green Ports Initiative, which aims to reduce the carbon footprint of the maritime sector. By shifting to cleaner energy sources, the ports seek to lower greenhouse gas emissions, improve energy efficiency, and achieve long-term sustainability and cost savings. Ambitious targets for incorporating solar and wind energy into operations are being set, with renewable energy now contributing a larger share of their total electricity consumption.

In this section, we are discussing about the current status as per targets mentioned in key national frameworks including MIV 2030, HARIT SAGAR guideline and MAKV 2047 along with challenges faced by ports and action plan with timelines for adoption of renewable energy.

2.4.1 Targets

The targets lay out as per MIV 2030, Harit Sagar guidelines, and MAKV 2047 are shown in Table 2.4.1.

As per the MAKV 2047, the status as of 2021 is <10% with reference to share of renewable energy which is targeted against 60% share of renewable energy adoption by 2030 and 90% by 2047.

Table 2.4.1: Renewable Energy Targets

MIV 2030	Harit Sagar Guidelines	MAKV 2047
1. >60% of total energy by 2030 across Indian ports with primary focus on solar and wind 2. Phase 1- Increase share of renewable energy at ports to 30% by 2024 3. Phase 2- Increase share of renewable energy at ports to 50% by 2027 4. Phase 3- Increase share of renewable energy at ports to >60% by 2030	1. Share of renewable energy at Ports should exceed 60 percent by the Year 2030 and 90 percent by year 2047	1. Target (2030) : >60% 2. Target (2047) : >90%

2.4.2 Current Status and Projections for 2030 for Share of Renewable Energy at Indian Major Ports

The major ports are currently at varying levels of renewable energy (RE) adoption, as detailed in Table 2.4.2. The data captures the RE consumption across all 12 major ports. In addition, Table 2.4.2 presents the projected RE share for each port up to 2030, highlighting their planned transition pathways and the anticipated pace of clean energy integration across the port sector.

Table 2.4.2: Current Status and Projections for 2030

Ports	% RE Power (2023-24)	Projected % RE Power (2030)
New Mangalore Port Authority* (NMPA)	100	100
Mumbai Port Authority (MbPA)	87	84
Deendayal Port Authority (DPA)	69	87
Kamarajar Port Limited (KPL)	45	60
V. O. Chidambaranar Port Authority (VOCPA)	41	80
Visakhapatnam Port Authority (VPA)	12	77
Jawaharlal Nehru Port Authority (JNPA)	8.5	68
Mormugao Port Authority* (MgPA)	6.46	100
Cochin Port Authority (ChPA)	5	64
Paradip Port Authority (PPA)	<1	60
Syama Prasad Mookerjee Port Authority (SMPK)	4	43
Chennai Port Authority (ChPA)	4	7

*Data shown for NMPA and MgPA is port consumption only.

As per the baseline year 2023-24, renewable energy accounted for 15.48% of the total electricity consumption across Indian major ports. During this period, the total electricity consumption was 488.24 GWh, of which 75.60 GWh was sourced from renewable energy. By 2029-30, the total electricity demand is projected to increase to 777.76 GWh, with 512.09 GWh expected to be met through renewable sources—representing 65.84% of the projected consumption.

Following are some of the key observations as per the consumption data for the major ports:

- New Mangalore Port Authority has already achieved 100% RE power consumption for the ports consumption and aims to maintain it through 2030. However, data for NMPA is under assessment pertaining to PPP Operators.
- Mumbai Port Authority and Deendayal Port Authority have already achieved the renewable energy (RE) target of 60% in 2023-24, with RE shares of 87.22% and 69.41%, respectively. Both ports are projected to maintain RE shares above 60% through 2030, with estimated shares of 84.21% and 87.48% in 2029-30, thereby reflecting consistent compliance with the target.
- Seven Major Ports — Kamarajar Port Limited, V.O. Chidambaranar Port Authority, Visakhapatnam Port Authority, Jawaharlal Nehru Port Authority, Cochin Port Authority, and Paradip Port Authority and Mormugao Port Authority — are on track to achieve the target of over 60% renewable energy (RE) share by 2030, as per their respective action plans. These projections indicate significant commitment towards clean energy transition in alignment with national sustainability goals.
- Two major ports — Syama Prasad Mookerjee Port Authority and Chennai Port Authority— are currently not projected to meet the 60% renewable energy (RE) target by 2030 due to land availability and cost constraints.

The NAVIC Cell 3 has reviewed these challenges and provided suitable recommendations tailored to each port's specific context.

The projected RE share transitions for these ports from 2023–24 to 2029–30 are as follows:

» Syama Prasad Mookerjee Port Authority: from 3.97% to 42.98%, reflecting a steady shift towards RE adoption.

» Chennai Port Authority: from 3.69% to 7.19%, indicating limited progress in RE integration.

2.4.3 Challenges and Gaps Identified

All 12 major ports have identified their respective challenges as shown in Table 2.4.3 and formulated detailed action plans, including timelines, for the transition to clean energy. This includes both the ports that are on track to achieve the 60% renewable energy (RE) target by 2030, as well as those that are currently unable to meet the target due to specific constraints.

The key challenges — such as land availability, regulatory hurdles, and infrastructure limitations — are outlined in Table 3. These plans form the basis for targeted interventions and support required to ensure a collective shift towards sustainable port operations.

The key impediments include limited availability of land for RE infrastructure development and certain state-specific regulatory constraints. These issues have significantly affected the pace of RE adoption at these ports.

Table 2.4.3: Challenges and Gaps Identified for Renewable Energy Adoption at the ports

Ports	Challenges Identified
New Mangalore Port Authority* (NMPA)	• No RE mandate for PPP operators. • No power distribution license to Port.
Mumbai Port Authority (MbPA)	• NA
Deendayal Port Authority (DPA)	• NA
Kamarajar Port Limited (KPL)	• Limited land availability
V. O. Chidambaranar Port Authority (VOCPA)	• NA
Visakhapatnam Port Authority (VPA)	• Land allotted for 14MW ground mounted Solar Power with hilly terrain. • Changing policies by the State Electricity Board. • Withdrawal of exemptions on electricity duty, transmission charges, and distribution losses
Jawaharlal Nehru Port Authority (JNPA)	• MERC's New MYT orders may have major impact on consumption of RE through Open Access. • Solar Open Access PPA treats behind-the-meter generation as gross metering, discouraging installation.

Ports	Challenges Identified
Cochin Port Authority (ChPA)	• Approval for banking of RE power from Kerala State Electricity Board. • Approval for tariffs from Electricity Regulatory Commission
Paradip Port Authority (PPA)	• Land Scarcity for further solar power. • Scarcity of data on wind energy potential.
Chennai Port Authority (ChPA)	• Land availability
Syama Prasad Mookerjee (SMPK)	• Land Availability at KDS • High-cost of solar power generation in KDS, as no common intake point for power supply is available.
Mormugao Port Authority (MoPA)	**PPP Operator 1:** • Land availability • Longer Payback period **PPP Operator 2:** • Clause on battery backup by Goa Electricity department for Intra state open access of solar power.

*NA – Not Applicable

2.4.4 Action Plan Along with Timelines Identified by Ports

All major ports have formulated detailed action plans, including specific timelines, for the transition to clean energy. These plans outline key interventions, and implementation strategies tailored to each port's context as shown in table 2.4.4. The action plans reflect a sector-wide commitment to decarbonization and align with national sustainability goals.

Table 2.4.4: Action Plan Along with Timelines

Ports	Action Plan till 2030
New Mangalore Port Authority* (NMPA)	• Pursuing PPP operators to follow Harit Sagar guidelines.
Mumbai Port Authority (MbPA)	• Installing 3MWp solar rooftop by December 2025.
Deendayal Port Authority (DPA)	• Adding 30MW RE capacity through Hybrid RE Park by 2030.
Kamarajar Port Limited (KPL)	• To augment installed RE capacity through BOT terminal operators. • Purchase RE from green grid/ RE DISCOM.
V. O. Chidambaranar Port Authority (VOCPA)	• Adding 1MW ground-based solar & 400kW rooftop capacity by 2025. • Further addition of 6MW wind power capacity by 2026.

Ports	Action Plan till 2030
Visakhapatnam Port Authority (VPA)	• Repairing and updating existing 10 MW solar plant will be completed by February 2025. • A combined total of 14 MW (12MW + 2MW) solar power to be generated under Group Capital with the existing two PPP operators for which appointment of PMC is under process.
Jawaharlal Nehru Port Authority (JNPA)	• JNPA is in process of installing 1.5 MWp (approx.) Roof Top Solar panels at their own selected buildings by the end of 2026. It will increase the existing capacity of RE to 47.35 MWp (Roof Top Solar + Open Access).
Cochin Port Authority (ChPA)	• Green Power Open Access approved for 2 MWp only by KSERC as per the petition filed by the ICTT operator. • 461 kW under implementation by Prosumers and expected to be commissioned within 1-2 months • Re-tender for 1.5 MW floating solar plant : Technical evaluation of bids are being carried out. • 350 kW roof top solar : Re-tender will be invited shortly. • 3.5MW floating solar by 2028 and 2 MW ground mounted by 2029 • 43 lakhs units through short term green power open access for providing supply to proposed Cruise vessel project. • Port will be exploring the RESCO model for renewable energy projects.
Paradip Port Authority (PPA)	• 700 kWp of roof mounted solar power by 2025. • 10 MW ground mounted solar plant by 2026. • Balance requirement of RE will be sourced from the State Grid. • DISCOM license to be obtained by March 2025 (process under way)
Chennai Port Authority (ChPA)	• RE power to be purchased via DISCOM
Syama Prasad Mookerjee (SMPK)	• 2.3 MW Roof top solar power plant to be commissioned by 2025. • 2MW Solar power plant to be installed. • Installations of 5 MW & 1 MW solar power plants are under planning stage. • Balance RE power to be purchased through local DISCOM.
Mormugao Port Authority (MgPA)	PPP Operator 1: • Plan A: Solar power plants are being setup by Tersus Energy at Verna • Plan B: Another solar power plant being set up at Cuncolim. PPP Operator 2: • RE power to be procured from Khawda, Gujrat hybrid RE plant.

2.4.5 NAVIC Cell 3 Recommendations

Ports are encountering a range of challenges in adopting renewable energy (RE), including those that are currently on track to meet the 60% RE target by 2030.

In particular, Syama Prasad Mookerjee Port Authority, Chennai Port Authority, are not expected to achieve the 60% RE target by 2030 due to specific issues such as land availability and cost related constraints.

To address these challenges, NAVIC Cell 3 has proposed the following recommendations:

- MoPSW may liaise with Ministry of Power to facilitate availing distribution licenses to the ports concerned.
- Chennai Port Authority and Syama Prasad Mookerjee Port Authority may purchase RE power from respective DISCOM to meet the renewable energy targets.

2.5 Shore to Ship Power Supply

Shore to Ship Power supply (Cold Ironing) enables ships to connect to shore-based power systems while docked, allowing them to turn off their onboard generators, thereby reducing emissions, fuel consumption, and noise pollution in port areas. This technology follows International Maritime Organization (IMO) standards and can be implemented across all types of vessels in Indian ports.

Shore power offers significant environmental and operational benefits for ports as well as shipping companies. By allowing vessels to shut down their auxiliary engines while dock can significantly reduce SO_2, NO_x, and Particulate matter at berth by up to 90%. This reduction is particularly important for improving air quality in India's densely populated port cities, where pollution levels are already high. In addition to environmental benefits, shipping companies can achieve substantial fuel savings, as they no longer need to run onboard generators while in port, thereby lowering their operational costs. Furthermore, the elimination of engine use during berthing reduces noise and vibrations in and around port areas, creating a quieter and healthier environment for both port workers and nearby communities.

2.5.1 Targets

The Maritime Vision 2030 is the flagship policy framework guiding the development of India's ports and shipping sector, providing a clear roadmap is established for the implementation of SPS systems across Indian ports in a phased manner. Key Targets for shore to ship power supply under Maritime Vision 2030 and MKV 2047 are as below:

- Phase 1 (2023): Shore power for port crafts and small vessels.
- Phase 2 (2026): Extension of shore power to Indian-flag vessels involved in coastal operations.
- Phase 3 (2030): Full implementation for foreign-flag vessels and international cargo ships, making shore power mandatory in all Indian ports by 2030.
- 2030–2035: Complete use of shore power on all vessels in all Indian ports

2.5.2 Status of Implementation of Shore to Ship Power Supply

2.5.2.1 Current Status

This status was the derived outcome of the data collected form the Major ports:

Table 2.5.1: Current Status mapping

S. No.	Port	Current Status		
		Phase 1 – Port stationed Vessels by 2023	Phase 2 – Coastal Vessels by 2026	Phase 3 – EXIM Vessels by 2030
1	NMPA	Completed	To be initiated	To be initiated
2	DPA	Completed	To be initiated	To be initiated
3	MbPA	Completed	In Process (2 berths planned by 2029)	To be initiated
4	KPL	Completed	In Process (2 berths initiated)	To be initiated (1 berth planned by 2030)
5	VOCPA	Completed	To be initiated (3 berths planned by 2030)	To be initiated (12 berths planned by 2030)
6	VPA	Completed	In Process (3 berths initiated)	To be initiated (DPR under process.)
7	JNPA	Completed	In Process (1 berth initiated)	PMC work awarded & EPC tender to be floated for one PPP Terminal (APMT). Project planned to complete by Dec 2026. Necessary action will be taken regarding the remaining terminals after approvals.
8	CoPA	Completed	· Shore power facility already implemented in 6 berths for coastal vessels. CoPA is providing shore power to the vessels of Indian Navy, NTRO etc. · CoPA had supplied 42,73,986 kWh shore power supply for the FY 2024-25. Shore power facility already available in 6 berths	To be initiated (5 berths planned by 2029)

S. No.	Port	Current Status		
		Phase 1 – Port stationed Vessels by 2023	Phase 2 – Coastal Vessels by 2026	Phase 3 – EXIM Vessels by 2030
9	ChPA	Completed	To be initiated (2 berths planned by 2026) *Note*: The Project is in conceptual stage. Since the Cost / unit of Shore power is more than In-built Diesel power, the project is economically not viable. Hence, the project of 15 MVA is kept on hold.	To be initiated
10	SMPK	Completed	To be initiated (4 berths planned by 2029)	To be initiated (2 berths planned by 2030)
11	MgPA	Completed	Completed (1 berth)	To be initiated (1 berths planned by 2027)
12	PPA	Completed	In Process (2 berths initiated)	To be initiated

The Table 2.5.1 above presents the status and phased implementation of shore to ship power supply across major Indian ports. Phase I, targeting port-stationed vessels, has been successfully completed at all 12 listed ports, indicating strong foundational progress. Phase II, aimed at coastal vessels by 2026, is in varying stages of development. While MoPA has already completed Phase II for one berth, several ports such as VPA, JNPA, KPL, MbPA and PPA have initiated works for select berths. Others, including VOCPA, CoPA (Phase –II at CoPA is completed for 6 berths), and SMPK, have outlined future with targeted completion by 2029–2030. Phase III, which focuses on EXIM vessels by 2029, is generally in its early stages, with most ports either planning or awaiting DPRs. Notably, JNPA and VOCPA have laid out detailed berth-wise targets, reflecting strategic foresight. Overall, the data reflects a committed, phased approach across Indian major ports, though the pace of progress in Phases II and III varies and will depend on financial viability, regulatory clarity, and technological readiness.

As part of the planned course of action, a detailed study has been recommended based on the outcomes of the NAVIC Cell 3 assessment. Four ports VPA, VOCPA, PPA and DPA have been selected to conduct pilot vessel studies. The data collected from these pilot studies will be used by the National Centre of Excellence for Green Ports and Shipping (NCoEGPS) to develop a robust and practical business model for shore-to-ship power implementation. A detailed analysis of the same is presented in the later section of the report.

2.5.2.2 Current Accomplishments

i. Foundational regulatory support for shore to ship power implementation (by DGS):

DGS was tasked with developing the regulatory and technical framework for shore to ship power implementation. It has successfully completed the preparation of draft technical standards for port-side infrastructure and guidelines for Indian coastal vessels. This process included stakeholder consultations, internal reviews, and amendments. The final circular consolidating all these guidelines under Circular No. 09 of 2025 was issued on 12 March 2025. With all milestones completed on schedule, DGS has laid the foundational regulatory support for shore to ship power implementation across Indian major ports.

ii. Implementation status from other Major Ports:

PPA and VPA were designated as pilot ports for Shore to ship power implementation. Both authorities awarded their respective shore to ship power projects by 31 March 2025, marking a critical first step in operationalizing shore power infrastructure. The experience of these two ports is intended to serve as a reference model for replication by other major ports.

Following the pilots, other major ports have begun initiating their STS power implementation efforts based on the experiences of PPA and VPA. These ports are at different stages of readiness. For instance, JNPA has completed its feasibility and DPR and is proceeding with implementation in a phased manner, starting with a PPP terminal. KPL has already installed OPS at two coal berths. MbPA is assessing a feasibility report for shore power at its cruise terminal. SMPK's KDS division is finalizing the DPR, while the HDC division is preparing to issue an NIT. NMPA's feasibility study, conducted by NITK, is under review and undergoing modifications. ChPA is reviewing its DPR and planning STS power deployment on two berths. VOCPA is awaiting final decision-making based on the business model prepared by NCoEGPS. This staggered yet active engagement indicates a growing momentum among ports toward OPS readiness.

iii. Business model for shore to ship power supply implementation at major ports:

Four ports (VOCPA, VPA, PPA, DPA) were selected for conducting vessel studies to assess STS power feasibility from both EXIM and coastal shipping perspectives. As of the reporting period, VOCPA, VPA, and PPA have completed their vessel studies. DPA study is still underway. Based on the collected vessel data, NCoEGPS has prepared a draft business model, with scenario-based assessments currently in progress. The model addresses technical, financial, and operational considerations from both the port and shipowner standpoints and will guide structured implementation of Shore to ship power across major ports.

2.5.3 Challenges in Shore-to-Ship Power

The implementation of shore-to-ship power at Indian ports faces several common challenges. Key issues include the absence of mandatory international and national regulations for shore power use, especially for EXIM vessels, and the lack of standardization in electrical parameters and shore reception facilities across different vessel types and flags. Ports also face technical hurdles such as voltage and frequency incompatibility, space constraints for Cable Management Systems (CMS), and the need for flameproof installations at certain berths. Financially, high capital expenditure (capex), lack of viable business models, and the absence of clear incentives discourage investment. Additionally, many ports do not possess electricity distribution licenses and face limitations under existing PPP concession agreements, which do not cover shore power installation. Uniform policy guidelines and regulatory mandates from the Directorate General of Shipping (DGS) and Ministry of Ports, Shipping and Waterways (MoPSW) are essential to address these challenges and drive wider adoption. To address those constraints the port wise challenges while implementing shore to ship power are listed below in Table 2.5.2.

Table 2.5.2: Port Wise Challenges in adoption of Shore to Ship Power supply at the major ports of India

Name of the Port	Challenges
NMPA	Under Assessment
VPA	· Standardization is required for shore reception facilities on vessels. For cruise ships, ferries, RO/RO vessels, and container vessels, such facilities are not mandatory under international norms. · Standardization is needed due to differing electrical parameters of equipment on vessels for different flags. · Electricity distribution license from the State Electricity Board is required. · Informed by PPP operators that as per the concession agreement, providing Shore Power System is not in their scope.
SMPK	· IMO guidelines have yet to mandate shore power use for EXIM vessels at ports. · Mandatory STS power use by EXIM vessels at designated berths is crucial for the scheme's economic viability.
MoPA	· High capex for STS power. · Mormugao Port has no Power Distribution License. · IMO has not issued guidelines for shore supply to EXIM vessels.
KPL	· No mandate for PPP operators to install shore power at their terminals. · No uniform policy and mandate for STS power implementation for coastal and EXIM vessels
MbPA	· Unavailability of a business plan to incentivize vessels to use the STS power, as required tariff for a reasonable payback period may exceed fuel costs. · Need for flameproof shore-to-ship power supply arrangements at liquid cargo berths. · Port is not having electricity distribution license.
PPA	· A uniform policy for STS power and mandate through DGS and MoPSW for shore power reception facility for Coastal and EXIM vessels. · Cable Management System is an issue at loading berths due to ship loader movement.
JNPA	· Implementation of STS at higher voltage i.e., 6.6 kV at 60 Hz required for EXIM vessels (Voltage incompatibility issue) · High Project Cost (INR 629 Cr.). STS in Liquid Terminal is not feasible. · A uniform policy for STS power and mandate through DGS/MoPSW for shore reception facility for Coastal / EXIM vessels. · Separate tariff category required for STS for effective utilization.
VOCPA	· Reluctance of OEMs to implement STS at the port. · Mandatory or incentive-based system is needed to encourage STS power use, but current PPP agreements lack provisions for concessionaires to establish the facility.

Name of the Port	Challenges
DPA	· Vessels at DPA are mostly bulk carriers and lack provisions for shore power and also lack sufficient deck space for a Cable Management System (CMS). · Standards are required for retrofitting with in-built Cable Management System (CMS) as per international standards (IEC/IEEE 80005-1:2019 or IEC/PAS 80005-3: 2014). · No uniform policy and mandate for STS power implementation for coastal and EXIM vessels
CoPA	· Cruise Vessels: DPR prepared and sent to MoPSW with an estimated cost of Rs56.73/- Cr., seeking grant. A response to the same is awaited. · After receiving financial support from MoPSW, shore power supply for cruise vessels (6 MVA) will be implemented at the port. · Shore Power supply facility to Coastal vessels is available in 6 berths
ChPA	· Shore power and power reception at vessels differ in voltage and frequency and most ships requires retrofitting, which is expensive. Hence Regulatory mechanism by DGS is mandatary. Otherwise the facility could not be marketed. · As per the feasibility report, the project cost for 2 berths is INR 146 Cr for 15 MVA capacity. Hence due to huge financial implications, the Project could not be implemented at present. · TNERC is not willing to entertain ChPA's claim for special Tariff & DISCOM status. · Mandating vessels to have shore reception facility is required.

2.5.4 Action Plan with Timelines Identified by Ports

All the Indian ports are in varying stages of planning and execution for STS power supply systems. Ports like NMPA, MgPA, and ChPA are currently conducting feasibility studies and preparing DPRs, with implementation decisions expected by mid-2025. VPA, PPA and VOCPA have identified specific berths and are progressing with tenders and phased installations, targeting completion between 2025 and 2030. MbPA and CoPA are seeking regulatory approvals and financial support to proceed with proposed projects. JNPA has planned a pilot project at one terminal, with future expansion based on its success. KPL is planning phased implementation with shared investments from terminal operators. Meanwhile, DPA Port is still reviewing feasibility due to technical constraints for the bulk berths. Overall, the ports are adopting a phased and cautious approach, with most targeting full implementation for coastal and EXIM vessels by 2030, subject to regulatory clarity and financial viability. The detailed port wise action plan is listed below in Table 2.5.3

Table 2.5.3: Action plan with timelines for adopting shore to ship power

Name of the Port	Action Plan with Timelines by the ports
NMPA	· Port conducting a comprehensive feasibility study with NIT Karnataka as consultant. · Preliminary study report and findings submitted. · Based on the study report, the decision will be taken to implement Shore to Ship (STS) facility and an estimate will be prepared.

Name of the Port	Action Plan with Timelines by the ports
VPA	· Planned 1000 KVA STS power facility at EQ1 (berth), and extended it to EQ1A and EQ2, which is under financial vetting. · The work is expected to be completed by December 2025. · The appointment of PMC for "preparation of DPR" is under process for providing STS power at new international cruise terminal and expected by December 2025. · All 7 PPP operators are directed to explore to provide suitable STS facility at their berths (7 nos.) before 2030.
SMPK	· At Port, one berth at KDS and one berth at HDC have been earmarked for providing STS power to EXIM/Coastal vessels in phase 2 & 3 (phased manner approach). · Further shore power facility will be taken up in other berths subsequently. · For EXIM vessels/Coastal vessels, a draft feasibility report for STS Power supply has been submitted by the consultant in KDS. · TEFR and DPR have been submitted by the consultant at HDC.
MoPA	· NITK, Surathkal has been appointed as a Consultant for Comprehensive Feasibility Assessment for shore power supply. · DPR to be submitted by 2025.
KPL	· Port plans to explore STS power at BOT operated terminals in a phased manner to achieve the goal. · For BOT terminals, the terminal operator and port will share the cost of installing shore power, with the port's contribution being 65 Cr.
MbPA	· The Port is currently reviewing the Detailed Project Report (DPR) prepared for 10 MVA STS facility for cruise vessels at MICT. · Port has applied for a Distribution License.
PPA	· Work orders issued for STS power provision at two coastal berths with 1000 kVA capacity per berth, was expected to be commissioned by March 2025. · Additional berths will be equipped with STS power in phases following the successful operation of the current facility. · CMS at the loading berth is an issue due to ship loader movement but will be addressed for each berth, based on the guidelines from DG Shipping and a TEFR study.
JNPA	· Action taken for implementation of SPS in one terminal. (PMC onboard, EPC contract to be finalized.) · Necessary action will be initiated for remaining terminals after necessary approvals.

Name of the Port	Action Plan with Timelines by the ports
VoCPA	· Port completed the augmentation of STS power to Port stationed vessels in the year 2024–25. · Port to provide shore power to coastal vessels for 3 Berths and planning in the year 2026–27, expected to be completed by 2029–30. · Port / PPP operator planning to provide STS power to EXIM vessels in 2025–26 and expected to be completed by 2029–30.
DPA	· Due to technical issues and utilization constraints being faced by other ports, feasibility is under review for such infrastructure development.
CoPA	· DPR prepared and sent to MoPSW with an estimated cost of Rs 75/- Cr., seeking grant. A response to the same is awaited. · After receiving financial support from MoPSW, shore power supply will be implemented at the port
ChPA	· Feasibility study for pilot projects is under progress. Site inspection made and DPR finalizing is under progress (for phase 2) · On completion of the pilot project, action will be initiated suitably. · Since the project is economically not viable, it is kept on hold.

2.5.5 Good Practices in the Field of STS Adoption

Ensuring the successful adoption of shore-to-ship power supply at major Indian ports requires alignment with current international standards and best practices. An international good practice is provided that outline the shore to ship implementation.

A. Shore Power at the Port of Los Angeles

The Port of Los Angeles has emerged as a global leader in implementing shore power technology (also refer as Alternative Maritime Power (AMP)) allowing vessels to plug into the local electrical grid while at berth, shutting off their auxiliary diesel engines.

i. Investment

The total port-wide investment required for implementing shore power infrastructure including retrofitting the terminal facilities and establishing ship-to-shore connection systems and Cable management systems, has been estimated at approximately ₹1,500 crore (USD 180 million).

ii. Ship Retro fitment cost

To utilize shore power, individual ships must be equipped with compatible onboard systems. The cost for retrofitting a single vessel typically ranges between ₹8 crore to ₹16 crore (USD 1–2 million). This investment is primarily borne by shipowners, including major operators such as Maersk, Carnival, and other leading carriers calling at the port.

iii. Environmental benefit

By 2020, the Port of Los Angeles recorded significant environmental gains due to widespread shore power adoption, according to the study done by port the GHG emissions were reduced by approximately 35,000 metric tons of CO_2 equivalent and also the pollutants levels are significantly reduced as listed below:

- PM: Reduced by 95%
- NOx: Reduced by 95%
- SOx: Reduced by 100% during periods of shore power connection

iv. Utilization

By 2022, more than 80% of eligible vessels were consistently connecting to shore power during their calls at the port. Cruise and container terminal of the port which contribute a large share of port emission has been achieved near-total compliance with shore power regulations.

v. Success Factors

- Regulatory Enforcement: California's CARB mandates require 80% of fleet calls to use shore power.
- Early Investment & Partnerships: Collaborated with shipping lines (e.g., Maersk, Carnival) to retrofit vessels.
- Standardization: Adopted international HVSC standards, enabling interoperability across global ports.
- Incentives & Grants: Used public funds to reduce capital risk for operators and terminal owners.

Salient features

- 6.6 to 11 kV, 60 Hz (US standard), 7.5–10 MVA per connection
- Container ships, cruise ships, and refrigerated cargo vessels
- Automated cable management system on quay
- Real-time power monitoring, metering, and safety

2.5.6 Shore Power Supply (SPS) Business Model for Major Ports in India

Based on the current scenarios, Shore power requires substantial capital investment in both ports and ships. To make investment most optimal, NCoEGPS is currently developing a shore power business model which can be implemented in the major ports. As observed, vessels continue to rely on diesel auxiliary engines, resulting in high emissions and health impacts. The root causes are not just technological barriers, but lack of strict regulations and policies framed in support of implementation is a serious concern.

Despite developing a shore power facility at a few ports, they are facing problems with respect to gaps related to implementation and revenue generation from shore to ship power supply.

Some of the gaps are listed below

i. Tariff Structures

Current port tariffs are largely based on deadweight tonnage (DWT) rather than actual electricity usage. This distorts cost comparisons, making SPS appear more expensive than diesel, even when accounting for environmental and health benefits.

ii. Coordination

Effective SPS implementation requires seamless collaboration among ports, electricity utilities, and shipping companies. Existing coordination mechanisms are fragmented, leading to delays, technical mismatches, and underutilization of green infrastructure.

iii. Capital Expenditure Constraints

SPS systems require upfront investment in onshore infrastructure, transformers, and cabling, which can be significant for ports with limited financial resources. Financial instruments such as public-private partnerships (PPPs), green bonds, and carbon credit monetization are critical to bridging this gap.

iv. Awareness and Adoption

Shipping lines may be hesitant to adopt SPS due to perceived operational complexity, lack of incentives, or uncertainty around pricing mechanisms.

Bridging these gaps is essential to convert India's strategic vision into actionable reality, ensuring both environmental sustainability and maritime competitiveness.

2.5.6.1 Objectives of the STS Business Model

SPS can be financially viable in India if supported by the right business models and tariff reforms. Mechanized cargo berths already demonstrate parity, while general cargo and container terminals can achieve competitiveness with kWh-based tariffs, subsidies covering part of CAPEX, and monetization of emission reductions through carbon markets.

Several global case studies highlight the transformative potential of SPS:

- **California, USA:** Under regulations from the California Air Resources Board (CARB), ports such as Los Angeles and Long Beach have achieved SPS compliance rates of over ninety percent for container and cruise ships. Over USD 200 million has been invested, yielding substantial reductions in port-side emissions.
- **Port of Rotterdam, Netherlands:** Europe's largest port began with pilot projects for ferries and offshore service vessels, progressively scaling up toward container terminals. Rotterdam's collaborative governance — involving the municipality, utilities, and shipping lines — ensures phased but steady adoption.
- **Port of Oslo, Norway:** Oslo leverages a hydroelectric-dominated grid to electrify ferries and cruise ships, reducing over 70,000 tonnes of CO_2 annually while improving local air quality.
- **China's Coastal Ports:** Driven by subsidies, ports like Shanghai and Shenzhen have rapidly deployed mobile SPS units across container and bulk terminals. By 2022, over six hundred vessels were SPS-enabled.

These examples demonstrate that SPS is not a theoretical option but a proven solution. Success, however, depends on robust business models, regulatory frameworks, and financial incentives — themes that are central to India's journey.

2.5.6.2 Problem Statement, Hypothesis, and Pathway

A. Problem Statement

Despite international momentum and India's policy direction, SPS adoption in Indian ports is lagging. Vessels continue to rely on diesel auxiliary engines, resulting in high emissions and health impacts. The root causes are not technological barriers — SPS systems are mature and globally available — but rather financial disincentives and institutional fragmentation.

B. Hypothesis

The central hypothesis is that SPS can be financially viable in India if supported by the right business models and tariff reforms. Mechanized cargo berths already demonstrate parity, while general cargo and container terminals can achieve competitiveness with kWh-based tariffs, subsidies covering part of CAPEX, and monetization of emission reductions through carbon markets.

C. Importance of this hypothesis

This hypothesis is critical for both environmental and strategic reasons:

- Environmental/Public Health: SPS adoption would reduce SO_x emissions by 98%, NO_x by 85%, and PM by 100%, directly improving the health of millions in port cities.
- Competitiveness: Ports with SPS will attract global shipping lines aiming to comply with emission regulations.
- Policy Alignment: SPS supports India's commitments under the IMO, MIV 2030, MAKV 2047, and Harit Sagar Guidelines.

2.5.6.3 Global Port Business Model Studies

Table 2.5.4: Analysis of the Global Business models

Model Type	Description & Global Examples	Pros	Cons	Key Takeaways for India
1. Port Authority-Led	Port authority finances, builds & operates SPS (e.g., *Rotterdam, Oslo*)	• Strong control & policy alignment • Easier standardization	• High CAPEX burden • Slower rollout if funds limited	Best for **major ports (JNPA, VOCPA)** with strong central funding
2. Utility-Led	Utility owns/ operates SPS; port provides space (e.g., *Seattle, Vancouver*)	• Utility expertise in tariffs & grid • Enables renewable integration • Reduces port financial burden	• Ports lose control • Needs tight coordination	Ideal for **states with strong DISCOMs** (Tamil Nadu, Gujarat)
3. Public-Private Partnership (PPP)	Shared investment among port, utility, private operators (e.g., *LA & Long Beach, Shanghai*)	• Risk sharing • Encourages innovation • Faster scaling	• Complex contracts • Tariff disputes possible	Fits **PPP-heavy ports** (JNPA, Mundra, Ennore) for rapid adoption
4. Cluster/ Consortium	Regional cooperation among ports (e.g., *Swedish & Baltic port clusters*)	• Economies of scale Standardization across ports	• Coordination challenges • Slower decisions	Suitable for **Sagarmala-linked small/regional ports**

Model Type	Description & Global Examples	Pros	Cons	Key Takeaways for India
5. User-Investment / Co-Financing	Shipping lines co-invest (e.g., *Stena Line, CMA CGM*)	• High utilization by committed users • Low risk for ports	• Depends on user interest • Limited for diverse traffic	Suited for **dedicated terminals** (coal, LNG) with long-term contracts
6. Mobile / Shared Infrastructure	Movable SPS units (e.g., *Rotterdam barges, Shenzhen trucks*)	• Low CAPEX & flexible. • Scalable pilot model	• Limited capacity for large ships • Higher O&M costs	Best for **pilot projects** at mid-sized ports (e.g., VOCPA)
7. Regulatory & Incentive-Based	Mandated SPS adoption with subsidies (e.g., *California CARB, EU Fit for 55*)	• Rapid compliance • Level playing field	• Needs strong legal framework • Risk of resistance	Long-term goal: **mandatory adoption post-2035** after infra readiness

Proposed Pathways

For the successful implementation of STS several proposed pathways are being studied.

i. Immediate Action: Deploy fixed, mobile/shared SPS units at mechanized cargo berths based on the financial assessment and breakeven analysis.

ii. Tariff Reform: The Tariff structure under implementation shall be reviewed suitably to enable kWh-based billing with a fixed connection fee for Shore power supply in line with the report findings, inferences and recommendations.

iii. Financial Levers: Introduce subsidies covering 30–50% of CAPEX; monetize emission reductions through carbon credits.

iv. Renewable Integration: Pair SPS with port-based solar, wind, and storage to ensure long-term decarbonization.

v. Institutional Mechanism: Establish a National SPS Task Force including ports, utilities, shipping lines, and regulators to coordinate rollout.

For dedicated cargo terminals, user-investment or co-financing models can leverage private participation and ensure steady utilization. Looking ahead, India should move toward a regulatory and incentive-based framework by 2035, mandating SPS readiness across major ports, while offering financial levers such as 30–50% CAPEX subsidies and carbon credit monetization to bridge the early-stage viability gap. This balanced approach aligns with India's maritime decarbonization goals and promotes sustainable port development.

From the above study, the pathway to Shore Power Supply (SPS) adoption should be phased, collaborative, and strategically diversified. The country should start with mobile or shared PPP-based pilots at mechanized berths to minimize financial risks while demonstrating feasibility. In the medium term, utility-led models involving strong state DISCOMs such as TANGEDCO and GUVNL can help stabilize tariffs, ensure reliable power integration, and link SPS systems with renewable energy sources. Regional cluster or consortium approaches under the Sagarmala initiative can enable smaller ports to share costs and standardize technologies.

2.5.6.4 Structuring Shore Power Supply (SPS) Business Models at V.O. Chidambaranar Port Authority (VOCPA), Tuticorin

A. Need Assessment and Traffic Analysis Report

The period under analysis spans 2009–10 through 2023–24, utilizing comprehensive operational data derived primarily from VOCPA annual reports. VOCPA, a major multipurpose port, efficiently handles an extensive range of cargo including dry bulk, break bulk, mechanized coal, and containerized shipments. The purpose of this report is to evaluate berth utilization, vessel traffic patterns, cargo throughput, and operational efficiency, with the forward-looking objective of guiding effective Shore Power Supply (SPS) adoption to curtail emissions, boost sustainability, and elevate port operations.

VOCPA's multi-berth configuration includes general cargo berths (Berth II and III with 8 berths total), mechanized coal jetty (CJ-I with 3 berths), and container berths (Berth VII with 2 berths). Historical berth occupancy analyses from 2009 to 2024 show variable utilization: Berth III sustains higher occupancy compared to Berth II, maintaining occupancy rates near 73%, while Berth II's occupancy has dropped to recent averages around 46%. Container (Berth VII) and mechanized coal berths (CJ-I) depict declining occupancy trends with recent averages below 40% and 33% respectively, signaling underutilization. Peak utilization across cargo berths was observed in 2011–12 exceeding 90%, suggesting available capacity for expanded operations without immediate capital outlay.

B. Vessel Traffic Analysis

Over the last five years on average, the port has received approximately 183 conventional dry bulk vessels, 381 break bulk vessels, 166 mechanized dry bulk carriers, and 490 container vessels annually. Geared vessels represent 68% of bulk carriers, while ungeared vessels account for 32%, with most bulk carriers converging on general cargo berths and a smaller portion accessing mechanized coal facilities. Container vessels primarily berth at Berth VII, with a nearly balanced split between geared and ungeared vessels. Vessel turnaround times reflect operational characteristics: general cargo and coal berths experience longer stays averaging near 3 days, constrained by mechanization capacities; container berths benefit from efficient cargo handling and achieve rapid turnaround with average stays below a day.

C. Cargo Handling Analysis

The bulk of cargo throughput remains dominated by dry bulk commodities such as coal and minerals, moving between 5.6 and 12.3 million DWT annually, averaging 7.95 million DWT. Break bulk and containerized shipments also contribute significant tonnage, with container volumes steadily increasing and averaging near 9.93 million DWT. Cargo distribution reflects berth specialization, with general cargo berths handling upwards of 900,000 tons annually, container berths close to the same magnitude, and coal jetty throughput limited by berth occupancy and turnaround dynamics.

D. Vessel Type and Gear Distribution

The port's infrastructure supports a versatile mix of vessel types. General cargo berths accommodate a significant population of geared vessels, optimizing loading and unloading operations on board. Mechanized coal facilities, by contrast, cater to fewer but more specialized ships. Container terminals maintain balanced mixes of geared and ungeared vessels, lending operational flexibility that supports efficient cargo operations and berth utilization.

The analysis reveals that general cargo berths approach high operational occupancy during peak demand, while coal and container berths demonstrate underutilization, pointing to scope for throughput enhancement without immediate infrastructure expansion. The port's traffic remains relayed predominantly by dry bulk and break-bulk vessels, with container vessel volumes showing consistent growth. Efficient container handling is underscored by short berth stays, contrasting with slower coal handling reflective of mechanization constraints. The port's mix of geared and ungeared vessels effectively supports operational diversity and flexibility.

E. Feasibility of Shore Power Supply (SPS)

Shore Power Supply holds notable promise as a sustainable intervention, given that berthed vessels conventionally operate auxiliary diesel engines contributing NO_x, SO_x, and CO_2 emissions within the port vicinity. VOCPA's 490 annual container vessel calls and approximately 166 mechanized bulk vessels, with average berth durations up to three days, present a strong case for electrification through SPS. Suitable berths prioritized for SPS deployment include container berths (Berth VII) and mechanized coal berths (CJ-I), attributed to their relatively longer stays and concentrated vessel traffic. The power demand for effective SPS operation is estimated to be between 2 to 6 MW per berth, corresponding to typical auxiliary load consumption by vessel types.

Operational benefits include substantial emission reductions improving the port's sustainability index, alongside potential carbon credit earnings. Enhanced health and environmental conditions for port workers further augment the value proposition. The implementation challenges encompass capital expenditures for onshore infrastructure and vessel retrofitting, alongside the necessity of shipping line coordination to ensure compatibility and uptake. A phased implementation commencing with container berths, and subsequently expanding to coal facilities, coupled with innovative tariff designs, including subscription or pay-per-use models, is recommended to optimize operational and financial sustainability.

SPS deployment at VOCPA aligns with international maritime environmental standards and India's National Green Port strategy, exemplifying the port's commitment to sustainable development.

From the above study we concluded, VOCPA's cargo handling efficiency and vessel traffic profile confirm the port's capability to support current trade volumes with minor operational and infrastructural adjustments. Containers and mechanized coal berths possess unexploited capacity, offering flexibility for traffic growth. Structured SPS adoption is feasible and desirable, promising environmental benefits and enhanced operational performance.

Takeaways from the Traffic data studies are discussed below:

To capitalize on SPS potential and overall operational efficiency, VOCPA should deploy advanced scheduling mechanisms to reduce vessel dwell times at mechanized coal berths and optimize berth allocation between general cargo and container vessels. Infrastructure upgrades focusing on additional mechanized equipment and selective berth expansions or dredging initiatives will mitigate future capacity constraints. Maritime stakeholders should be encouraged to deploy higher-capacity container vessels, maintaining operational flexibility via a balanced geared/ungeared mix.

SPS strategies must adopt phased rollout plans, incorporating flexible tariff arrangements and proactive collaboration with shipping companies ensuring vessel compliance with shore power readiness. Integrating SPS-specific performance indicators into port sustainability metrics is critical for ongoing monitoring and adaptive management. Long-term planning ought to emphasize monitoring cargo and vessel trends, berth utilization, and power demand metrics. High-impact shipping segments, such as container vessels and cruise liners, should be prioritized for SPS technology adoption, utilizing port-specific data like mechanized berth breakeven points to identify pilot projects.

2.5.6.5 Business Model for Shore-to-Ship Power (SPS) for Coastal Bulk Carriers

The proposed business model has been developed to facilitate the implementation of shore-to-ship power (SPS) infrastructure at Indian ports, with exclusive applicability to coastal bulk carriers engaged in regular domestic trade. Preliminary assessments revealed that while the same model was tested for foreign-going vessels, inconsistent voyage patterns, variable berthing frequencies, and lack of inter-port coordination rendered it financially unviable in the present conditions. Hence, the model has been refined for coastal operations, where predictable routing and frequent port calls make both cost recovery and infrastructure sharing feasible.

The framework adopts a subscription-based approach that combines fixed and variable cost components. It ensures that ports can recover the cost of SPS investment over a defined capital recovery period while enabling vessel operators to realize direct fuel cost savings. Furthermore, a shared retrofitting cost mechanism between two ports on the same coastal circuit reduces upfront investment burden and encourages early adoption.

A. Structure of the Business Model

The total cost levied on a vessel consists of two principal components:

i. Subscription Fee:

The subscription fee is a fixed annual payment determined by the expected number of feasible vessel visits. Feasibility is estimated using two critical operational parameters—average berth occupancy rate and vessel age.

- The berth occupancy rate defines the operational availability of the berth for SPS-connected calls, ensuring that power-supplied berthing does not exceed the berth's practical capacity.

- The vessel age determines its specific fuel oil consumption (SFOC), influencing the achievable savings through SPS substitution. Data from multiple engine manufacturing companies were used to establish SFOC benchmarks across vessel age profiles.

The subscription model follows a five-year capital recovery structure, aligned with the Los Angeles Port model, and includes a shared retrofit cost component between two ports forming the vessel's circuit.

ii. Power Consumption Charge:

The variable cost component is based on the electricity consumed by the vessel during its SPS connection. It is levied at a uniform green tariff, proposed to be benchmarked to the lowest rate currently available at Paradip Port, Odisha. Each port computes its own cost independently while maintaining tariff uniformity for fairness.

Since ports are not licensed as DISCOMs, they facilitate power supply through the respective state utilities while ensuring metered delivery to vessels at berth.

B. Data Sources and Analytical Basis

The model integrates data and insights from a combination of verified institutional and technical sources:

- TANGEDCO vessel data provided inputs on annual visit frequency, berth duration, and MGO fuel consumption. The data was taken from secondary literature sources.
- VOC Port Authority (VOCPA) supplied berth occupancy data and coastal traffic statistics.
- Chennai Port Authority (ChPA) data were used to estimate the per-MVA cost of fixed SPS infrastructure.
- BIMCO and international maritime databases provided bunker price information for Marine Gas Oil (MGO).
- OEM specifications from major engine manufacturers informed the SFOC differentiation by vessel age.
- DG set operational cost references were compiled from multiple technical publications and case studies.

C. Application to TANGEDCO Coastal Vessels

A consortium-based implementation framework has been adopted in this business model to ensure coordinated investment and operational efficiency. Under this arrangement, participating ports and ship-owning entities, such as the Shipping Corporation of India (SCI) and other coastal operators, form a joint consortium wherein the ports undertake the complete turnkey retrofitting of eligible vessels to make them compatible with shore-to-ship power connectivity. This arrangement allows the vessels to access SPS facilities without bearing immediate capital costs, thereby accelerating the transition to cleaner berthing operations. Beyond the environmental benefits of emission reduction and noise abatement, the consortium model also ensures shared profitability and feasibility, with both port and vessel stakeholders realizing measurable returns through optimized energy usage and reduced operating expenditure.

Table 2.5.5: Inputs for the Business Model

Parameters	Fixed
Type of Vessel	Dry Bulk
No. of Vessel	1
Berth Time	3.00
Max BOR	72%
Ports involved	2
Avg. Annual Berthing days/vessel per berth	107
Recovery Period	10
Avg. GT	44,000
Size of the Vessel	Panamax
PF	0.90
VGF	0%
Age of the Vessel	5
Fuel	MGO
Bunk Price	₹ 56.80
CCP	₹ 0.00
CCP in Tariff/Conn.	
State of Port	Odisha

Table 2.5.6: Outputs

SPS Capacity (MVA)	0.78
No. of Visits Required for Break-even	15
Max. Visits Possible	88
Average Visits	36
Visits Required	33
	[SPS Tariff = Fuel Tariff
/GT	₹ 32.46
Annual GT Demand	₹ 14,52,000
Green Tariff	₹ 6.05
Annual Energy Demand	11,88, 000
Power Cost	₹ 71,87,400.00
[Subscription Cost %	₹ 3,06,00,877.87
Pay Back Period (years)	5.07
Total SPS Cost	₹ 3,77,88,277.87
Total Diesel Cost	₹ 4,71,31, 1.87
Profit	₹ 93,43,620.00

The model was tested for a TANGEDCO-operated Panamax bulk carrier ranging between 38,000 GT and 44,000 GT, typically calling at ports about 36 times annually.

For a 44,000 GT vessel, the findings are as follows:

- The vessel reaches break-even with MGO-based DG operation after 15 annual visits under SPS connection.
- The port achieves payback within five years if the vessel completes at least 33 annual visits, as per the capital recovery framework.

Under DG operation, the annual cost of onboard generation (using MGO) was estimated at ₹4.71 crore, while the SPS operation cost amounted to ₹3.77 crore, resulting in annual savings of approximately ₹0.94 crore. These savings accrue without any direct investment burden on the vessel operator.

D. Operational and Environmental Advantages and Way Forward

The adoption of Shore Power Supply (SPS) delivers significant environmental, operational, and financial advantages for ports and vessels alike. By enabling ships to shut down auxiliary engines while berthed, SPS reduces engine wear, maintenance costs, and fuel consumption, while also cutting berth-level emissions, vibration, and noise, thereby improving air quality and port-side working conditions. Moreover, it supports compliance with the IMO's Carbon Intensity Indicator (CII) and global emission reduction targets, positioning ports and operators for future regulatory alignment. The evolving SPS framework further strengthens its appeal by integrating carbon credit valuation, allowing emission reductions to be quantified and monetized. This innovative feature enables participating vessels to generate revenue from verified carbon savings, enhancing return on investment and providing a strong financial incentive for widespread SPS adoption across the maritime sector. To further optimize costs and enhance deployment flexibility, two parallel SPS infrastructure concepts are being developed:

i. Mobile Containerized SPS Units:

These modular systems can be relocated between berths or ports as required, reducing idle time and deferring high capital expenditure associated with fixed installations. Their deployment allows phased implementation in smaller ports or trial operations before permanent systems are commissioned.

ii. Infrastructure in Mechanized Cargo Berths:

In mechanized bulk berths, the existing conveyor systems and trenching layouts are being evaluated for integration with SPS cable routers. This shared-use approach minimizes civil work, reduces trenching costs, and allows the same service corridor to support both cargo handling and power supply infrastructure.

These innovations aim to significantly reduce the overall cost per MVA of SPS infrastructure, thereby improving affordability and scalability across diverse port types.

The evolving business model is being aligned with policy instruments such as carbon credit mechanisms, priority berthing incentives, and green corridor frameworks. Ports may introduce berth allocation preferences for vessels equipped with SPS reception systems, encouraging other operators to retrofit or procure compliant vessels.

The proposed subscription-based SPS business model thus represents a financially viable, operationally flexible, and environmentally progressive pathway for India's coastal shipping sector. Continued refinement through multi-port collaboration, shared cost modeling, and dynamic tariff structures will further strengthen its applicability and pave the way for nationwide SPS integration under India's green port transition agenda.

2.6 Electrification of Port Equipment and Harbor Crafts/Tugs

Modern ports are rapidly evolving with the integration of advanced equipment and emerging technologies to enhance operational efficiency, safety, and sustainability. A wide range of specialized machinery supports diverse cargo handling operations—Ship-to-Shore (STS) cranes and quarry cranes are essential for vessel loading and unloading, while Rubber-Tired Gantry (RTG) and Rail-Mounted Gantry (RMG) cranes facilitate container stacking. Yard Tractors (YTs) and Automated Guided Vehicles (AGVs) manage horizontal container transport, alongside straddle carriers and reach stackers, which offer both stacking and movement functions within terminals.

In line with global trends, Indian ports are embracing automation and electrification to reduce environmental impact and improve throughput. Automated equipment such as QCs, RMGs, AGVs, Automated Lift Vehicles (ALVs), and Automated Stacking Cranes (ASCs) are increasingly deployed, integrated with intelligent systems for real-time monitoring, remote operation, and collision avoidance.

Moreover, there is a significant interest towards electrification of tugs highlighted by the 'Green Tug Transition Programme', which aims to replace conventional diesel-powered tugs with electric, hybrid, or alternative fuel-based tugs. This initiative is a critical component of India's broader strategy to decarbonize port operations, reduce maritime emissions, and enhance energy efficiency. Coupled with the use of AI, robotics, and predictive maintenance, these developments are transforming Indian ports into cleaner, smarter, and more resilient hubs for maritime logistics.

2.6.1 Targets

The targets laid out as per Harit Sagar guidelines, MIV 2030, and MAKV 2047 are shown in Table 2.6.1.

Table 2.6.1: Electrification of Cargo Handling Equipments

MIV 2030	Harit Sagar guidelines
1. Convert cargo handling equipment (e.g. ship to/from shore cargo movers and within-port cargo movers) to electricity driven – 50% by 2030 2. Mandate purchase of electrical equipment's as replacement for all further purchase to achieve full electrification over the next 10 years-90% by 2047	1. Ports shall make efforts to achieve the target for Electrification of Vehicles/Ports equipment as envisaged in MIV 2030 / Blue Economy 2047 and accordingly, should target more than 50 percent electrification by the Year 2030 which is to be further increased to more than 90 percent by the year 2047. 2. Ports should target retro fitment / conversion of Diesel-powered equipment / cranes / forklift / pay loader / vehicles etc. to electrically powered in a phased manner by making suitable plans. 3. All future procurements of Port vehicles and cargo handling & other equipment shall preferably be electrically driven / electrically powered or should be compatible with low carbon greener fuels viz., CNG, Methanol, Ethanol, Ammonia, Hydrogen Fuel Cell etc.

2.6.2 Current Status: Green Tug Transition Programme (GTTP)

The GTTP is an initiative by the Indian Ministry of Ports, Shipping and Waterways (MoPSW) aimed at decarbonizing the maritime sector by promoting the adoption of low-emission and zero-emission tugboats. The programme targets the deployment of at least 30% green tugs at all major ports by 2030, with a phased transition to alternative propulsion systems such as electric, hybrid, hydrogen, and methanol-based technologies. GTTP supports India's broader commitments to sustainability and net-zero goals, fostering innovation, reducing carbon footprint, and enhancing environmental compliance across port operations.

This electrification of tugboats represents a critical shift toward sustainable and environmentally responsible maritime operations in India. The tugboats are essential assets in port logistics, responsible for manoeuvring large vessels during berthing, unberthing, towing, and rescue operations. Traditionally reliant on diesel engines, these tugs contribute significantly to GHG emissions and local air pollution in port environments.

The transition to electric or hybrid-electric propulsion systems offers a cleaner and more energy-efficient alternative which aligns with India's broader decarbonization goals and supports international commitments to reduce maritime emissions. The electrified tugs not only minimize environmental impact but also deliver operational advantages, including reduced fuel consumption and lower maintenance costs.

The feasibility of tugboat electrification is further strengthened by advancements in battery technologies, the increasing integration of renewable energy sources, and policy support through national green port initiatives. Together, these developments present a strong opportunity to modernize port infrastructure, enhance operational sustainability, and drive long-term environmental and economic benefits across India's maritime sector.

The status of the implementation of GTTP as of July 2025 is as follows in Table 2.6.2.

Table 2.6.2: Status of implementation of GTTP

Track	Milestone	TDC	Action By	Status
Track 1	Floating of Tender by DPA	10.11.2024	DPA	Completed
	Award of Green tug by DPA	31.03.2025	DPA	Completed
Track 2	Releasing of bid documents by IPA	31.01.2025	IPA	Completed
	Issuance of NIT for green tug by Major Ports (except CoPA & MgPA)	31.03.2025	All Major Ports except CoPA & MgPA	NIT Issued by · VOCPA · JNPA · PPA · NMPA · VPA · SMPK: Under budgetary stage, and currently meeting ongoing with GRSE and CSL on green tugs · KPL: Already hired diesel powered tug in Aug 2025. After the contract expires in Aug 2027, a green tug is planned for purchase. · CoPA: Under discussion stage in the project (Status: Estimate for hiring GT for 15 years sent to Competent Authority for approval) · MoPA: Funds are required through support from MoPSW
	Green tug award by PPA, VOCPA & JNPA	31.03.2025	PPA, VOCPA, JNPA	Ongoing

The Green Tug Transition Plan (GTTP) is progressing across two strategic tracks with defined milestones. Deendayal Port Authority (DPA) has successfully completed both key actions—floating the tender and awarding the green tug contract. The IPA has released the bid documents as scheduled. The issuance of NIT by major ports—excluding CoPA and MgPA—is underway. Notably, VOCPA, NMPA, JNPA, VPA and PPA have already issued their NITs, while SMPK is in the budgetary planning stage and engaged in discussions with GRSE and CSL. KPL has indicated plans to procure a green tug after its current diesel tug contract ends in August 2027. CoPA is in the discussion phase (Estimate for hiring green Tug for 15 years sent to Competent Authority for approval), and MoPA requires funding support from the MoPSW. The award of green tugs by PPA, VOCPA, and JNPA is currently ongoing, indicating forward momentum in implementing Phase I of the GTTP.

2.6.2.1 Phase-wise Plan prescribed under GTTP

The Green Tug Transition Programme outlines a phase-wise implementation plan to facilitate a structured and scalable shift to low-emission and zero-emission tugboats in India's maritime sector. The phased approach includes initial pilot deployments, followed by gradual retrofitting of existing fleets and procurement of green tugs across major ports. Each phase is aligned with technical readiness, infrastructure availability, and regulatory support, ensuring a balanced transition without disrupting port operations. This step-by-step roadmap enables capacity building, encourages industry participation, and ensures steady progress toward long-term decarbonization targets.

The action plan for transition to green tugs is noted in Table 2.6.3.

Table 2.6.3: Action Plan for Green Tug Transition Program

GTTP Phase	Duration	Remarks	GTTP Requirement (on current fleet)	Replacement requirements – As per demand side assessment
Phase I	1-Oct-2024 to 31-Dec-2027	Procurement/ Chartering of atleast 2 green tugs each by JNPA, DPA, VoCPA & PPA Atleast 1 green tug by other major ports	16 (19%)	☑ – 57 tugs proposed to be replaced (67%)
Phase II	1-Jan-2028 to 31-Dec-2030	Atleast 30% of operational tug fleet (owned and chartered) at all major ports to be GTTP complaint subject to completion of life/ charter period of existing tugs	26 (16 + 10)	☑ – 74 tugs proposed to be replaced (87%)
Phase III	1-Jan-2031 to 31-Dec-2033	Atleast 60% of operational tug fleet (owned and chartered) at all major ports to be GTTP complaint subject to completion of life/ charter period of existing tugs	51 (26+25)	☑ – 83 tugs proposed to be replaced (97%)
Phase IV	1-Jan-2034 to 31-Dec-2036	100% of operational tug fleet (owned and chartered) at all major ports to be GTTP complaint subject to completion of life/ charter period of existing tugs	85 (51+34)	☑ Almost compliant – 100% by 2038 due to completion of life span
Phase V	1-Jan-2037 to 15-Aug-2040	All non –major ports to finalise action for 100% transition to FTTP compliant tugs		NA

2.6.2.2 Inventory of Tugs in India

The Green Tug Transition Programme aims to decarbonize the Indian maritime sector by progressively replacing conventional tugboats with green alternatives. A comprehensive inventory of tugs operating across Indian ports provides the foundation for assessing transition needs. The programme envisions a phased approach, focusing on retrofitting existing tugs and procuring new energy-efficient units powered by cleaner fuels such as electricity, LNG, hydrogen, or methanol. The requirement is driven by national sustainability goals, with targets set to progressively increase the share of green tugs, ensuring alignment with global emission reduction commitments and future-ready port operations.

The Table 2.6.4 provides an overview of the total tug inventory across major Indian ports, categorizing the tugs into port-owned and hired.

Table 2.6.4: Number of tugs at the ports

Name of the Port	Hired Tugs	Port Owned Tugs	Total No. of Tugs at the port
DPA	14	2	16
SMPK	9	5	14
MbPA	4	7	11
JNPA	9	0	9
PPA	5	1	6
VPA	3	3	6
CoPA	3	2	5
NMPA	4	1	5
KPL	4	0	4
MoPA	3	1	4
ChPA	3	0	3
VoCPA	2	1	3

The Table 2.6.4 presents a comprehensive inventory of tugboats deployed across twelve major ports in India, distinguishing between port-owned and hired assets. A total of 86 tugs are currently in operation, comprising 62 hired and 23 port-owned units as reported in 2023–2024. DPA has the highest number of tugs at 16, predominantly hired 14, followed by SMPK with 14 tugs, including a relatively higher number of port-owned units 5. MbPA maintains 11 tugs, the majority being port-owned (7), while JNPA operates entirely with 8 hired tugs. Ports such as PPA and Visakhapatnam VPA each manage 6 tugs with mixed ownership. Smaller fleets are observed at ChPA, VoCPA, and other ports, with fleet sizes ranging from 3 to 5 tugs. This data provides a valuable snapshot of tug deployment patterns, highlighting operational dependencies on hired services and informing strategic planning for future upgrades, including the potential transition to electric or hybrid tug technologies.

2.6.2.3 Tug Replacement requirement in existing fleet: Demand Mapping of Tugs

Based on current fleet data, in Table 2.6.5 approximately 65% of the tugs operating at major Indian ports are projected to reach their economic age limit or complete their contractual hire period within the next three years. To ensure uninterrupted port operations and meet future demand, it is estimated that 57 new tugs must be commissioned immediately. The development timeline for each new tug is estimated at 30 months, which includes 24 months for construction and an additional 6 months for the tendering and bid evaluation process. Although construction timelines may shorten with subsequent orders, a maximum period of 30 months is being considered for planning purposes. Notably, retrofit solutions have been evaluated but are not recommended by shipyards and port authorities due to technical and operational limitations. Consequently, the strategy moving forward is focused solely on the procurement of new tugs to ensure fleet modernization and operational readiness.

Table 2.6.5: Demand mapping of the Tugs

Year	Tugs required	Tugs ordered/ replacement
2024	17	57
2025	21	5
2026	12	6
2027	7	6
2028	5	2
2029	6	3
2030	6	4
2031	2	0
2032	3	0
2033	4	0
2034	0	1
2035	0	1
2036	0	0
2037	1	0
2038	1	0

2.6.2.4. Replacement and Compliance Goals

It is estimated over the full timeline, the GTTP will replace 100% of the current tug fleet with green technologies. The compliance milestones will progressively increase from 19% in phase I to 100 % in phase IV and V. The phased approach considers fleet lifespans, charter durations and technological readiness, ensuring balance between environmental goals and operational feasibility. The Non major ports are included in phase V, promoting holistic and inclusive transition to sustainability across maritime sector. To support the transition to a sustainable tug fleet, a comprehensive strategy has been outlined focusing on phased replacement and capacity building. Conventional tug hire contracts will be capped at three years to align with green tug development timelines, while owned tugs over

20 years old and those with high emissions or low fuel efficiency will be prioritized for replacement. A rolling green tug development pipeline will be established at major ports, targeting a 40:60 owned-to-hired ratio and synchronized with contract expirations and decommissioning schedules. The plan emphasizes domestic manufacturing under the "Make in India" initiative, mandating at least 50% local value addition and encouraging procurement from MSME shipyards. It also includes the implementation of a structured training program for personnel and mandates adherence to Standard Bidding Documents (SBDs) to ensure transparency and uniformity in procurement processes.

2.6.3 Current Status on Electrification of Port Equipment

The current status of electrification across major Indian ports shows varied progress in transitioning to cleaner cargo handling operations. Ports such as PPA, MoPA, and NMPA have achieved 100% electrification of cargo handling equipment (CHE), with several also reporting full or targeted adoption of electric or low-carbon vehicles by 2030. Other ports like VPA, CoPA, KPL, and DPA have made substantial progress, with CHE electrification rates ranging between 76% and 89%. However, adoption of green vehicles remains limited at many ports, with only a few achieving more than 40%. Ports such as MbPA currently have no CHE in operation. Across most ports, retrofitment of equipment is either in progress or deemed less feasible, with a preference for complete replacement to ensure compatibility with green technologies and higher operational efficiency. The current status mapping for electrification of port equipment is given below in Table 2.6.6.

Table 2.6.6: Current status mapping for electrification of port equipment

S. No.	Port	Electrification of cargo handling equipment*	Electric/ Low carbon Greener fuel Vehicles**	Retro fitment of other cargo handling equipment#
1	DPA	89% (33/37)	14% (16/114)	Replacement Preferred
2	SMPA	35% (34/97)	0% (To be initiated)^	Replacement Preferred
3	MbPA	No CHE	0% (No Electric/ Low carbon Greener fuel Vehicles)	No CHE
4	JNPA	51% (107/210)	25% (60/239)	In process/ Initiated
5	PPA	100% (14/14)	1.5% (2/131)	100% replacement achieved
6	VPA	78% (42/54)	52% (46/88)	Replacement Preferred
7	CoPA	79% (26/33)	13% (5/38)	In process/ Initiated
8	NMPA	100% (2/2)	40% (23/58)	Replacement Preferred
9	KPL	79% (30/38)	33% (32/97)	Replacement Preferred

S. No.	Port	Electrification of cargo handling equipment*	Electric/ Low carbon Greener fuel Vehicles**	Retro fitment of other cargo handling equipment#
10	MgPA	100% (4/4)	0% (No Electric/ Low carbon Greener fuel Vehicles)^	Replacement Preferred
11	ChPA	11.5%(18/157)	0%^	0%
12	VoCPA	76% (34/45)	51% (24/47)	Replacement Preferred
	Overall Status	50% On Track to achieve 100% by 2030	25% (Except^ ports) On Track to achieve 50% by 2030	

Note: **Cargo handling equipment refers to Stackers, Reclaimer, Stacker cum Reclaimer, Ship loaders and unloaders, Wharf cranes, Reach stackers, Harbor Mobile Cranes, Rail mounted Quay Cranes, Rubber tired Gantry Cranes etc., whether owned or rented/ licensed by Port/ PPP operators.*

***Vehicles refer to cars, buses, utility vehicles, and similar types, whether owned or rented by port/PPP operators. Low-carbon, greener fuels include options such as CNG, methanol, ethanol, ammonia, and green methanol.*

#Other Cargo handling equipment refers to Diesel powered cranes/ forklift/ vehicles etc., whether owned or rented by Port/ PPP operator and outside agencies/ others

2.6.4 Action Plan & Key Challenges Faced by the Ports for Electrification

An action plan for each major port is essential under the Green Tug Transition Programme to ensure a targeted, efficient, and context-specific shift toward sustainable tug operations. Given the diversity in operational scale, fleet composition, and infrastructure readiness across ports, individualized plans enable accurate assessment of retrofit potential, procurement needs, fuel availability, and supporting infrastructure. Such port-specific roadmaps facilitate phased implementation aligned with national decarbonization goals while ensuring minimal operational disruption. They also promote accountability, enable performance tracking, and support timely interventions to achieve green tug deployment targets.

A port-specific action plan enables targeted assessment of these barriers, prioritization of equipment for electrification, and alignment with power supply planning and financial models—ultimately supporting a smooth transition to cleaner, energy-efficient port operations. The port specific action plans can be noted as follows in Table 2.6.7.

Table 2.6.7: Port wise action plans for electrification of port equipment (with timelines)

Name of the Port	Action plans till 2030
DPA	All future procurements are ensured for compliance with electric/ low-carbon fuel vehicles.
PPA	· 4 berths to be mechanized by 2030 for 100% compliance. · Proposal for electric hybrid vehicles to be finalized by March 2025. · Transition to all-green fuel vehicles will be achieved in phases by 2030.
VOCPA	· All other port vehicles and CHEs will be converted upon completion of their life period. · Port will conduct stakeholder meeting for retrofitment of equipment.
SMPK	· 64% existing CHEs to be replaced by electric CHEs by 2030. · 50% vehicles to be replaced by electric/ low carbon green fuel vehicles by 2030.
VPA	· 46 CNG Vehicles have been hired. · 2 EV charging stations have been installed and commissioned. · Remaining Vehicles (42) to be converted to either CNG or EV by 2030.
KPL	Port is in transition towards cleaner technologies and alternate fuels. The proposed actions will be taken in a phased manner complying with the timelines set in the Harit Sagar guidelines for Green Port.
JNPA	As pilot project six Battery Swapping Trucks are being used for internal container handling and for them one Battery Swapping Station is also installed. Approximately, 632 diesel Trucks can be replaced with battery swapping trucks in phased manner by PPP terminal operators by 2029.
MgPA	· NITK Surathkal is engaged for preparing a draft report. Feasibility report submitted by May, 2025. The NITK draft report is enclosed herewith and MoPA commitment to shore supply has been appraised to Ministry vide letter dtd.07.07.2025. Copy of report and letter is attached herewith. · Internal resources to be utilized for hiring EV after contracts expire in 2029. · Mandated purchase of electrical equipment will be done as per the port requirements.
NMPA	Two duel powered MHCs proposed to procure/ Hired.
MbPA	Port doesn't have cargo handling equipment i.e. STS, SUL, Wharf cranes, Reach stacker, HMC, RTG, RMTG, etc.
ChPA	30/157 viz., 20% cargo handling equipment will be electrified.
CoPA	Electric FLTs and reach stackers will be purchased after 2030 since existing equipment shall complete their life span.

There is a need to address the challenges faced in electrifying cargo handling equipment and port vehicles requiring a focused action plan at the individual port level to ensure effective and scalable implementation. There are variations in equipment types, usage patterns, grid capacity, and infrastructure readiness necessitate tailored solutions for each port. There are certain key challenges which include high capital costs, limited availability of electric alternatives, charging infrastructure gaps, and operational integration.

A port-specific challenges enables targeted addressal of key barriers in implementation, prioritization of equipment for electrification, and alignment with power supply planning and financial models—ultimately supporting a smooth transition to cleaner, energy-efficient port operations. The port specific challenges are shown in the Table 2.6.8.

Table 2.6.8: Port specific challenges for Indian major ports

Name of the Port	Key Challenges
DPA	NA
PPA	NA
VOCPA	· Retrofitting of other CHEs is not viable due to considerable lifetime. · No financial incentive mechanisms for retrofitment.
SMPK	NA
VPA	NA
KPL	NA
JNPA	· No mandate for purchase of Electric/ clean fuels based CHEs in existing concessionaire agreements. · Lack of financial incentives for retrofitment of other cargo handling equipment.
MgPA	NA
NMPA	NA
MbPA	Feasibility issue in purchasing an EV with ceiling price at Rs. 6 Lakhs. High hiring costs have also stalled the proposal.
ChPA	The PPP operators will take decision based on the cost of replacement Vs Revenue generated.
CoPA	Finance

2.6.5 Good Practices in Electrification

Green Tug Transition at the Port of Auckland

The Port of Auckland marked a significant milestone in maritime decarbonization by launching the world's first full-electric harbour tug in June 2022. With a bollard pull of 70 tonnes and powered by a 1.5 MW shore-based charging system, the electric tug is capable of performing 2–3 operations per day on a single charge. Despite having nearly twice the capital cost of a conventional tug, it delivers substantial benefits, including 50% lower operating costs, 30–40% reduction in fleet fuel consumption, zero local emissions, and minimal noise pollution. The project highlights the value of early investment, robust crew training, and seamless shore-side integration, establishing Auckland as a global leader in green port innovation.

Salient Features

- 50% Lower Operating Expenses (OPEX)
  - » Due to savings on fuel, maintenance, and simpler mechanical systems
- 30–40% Reduction in Fleet Fuel Use
  - » Significantly lowers fossil fuel dependency across port operations
- Zero Local Emissions
  - » No CO_2, NO_2, or particulate matter emissions during operation
- Noise Reduction:
  - » Provides a quieter working environment for crew and nearby communities

2.6.6 NAVIC Cell 3 Recommendations

The NAVIC Cell recommendations for electrification are noted as follows

1. As a part of NCoEGPS, TERI is undertaking a comprehensive assessment of electrification of port and other cargo handling equipment, and it would produce a roadmap for their implementation for the 4 participating ports by 2026 in consideration of the master plan.
2. Recently TERI has been appointed as the nodal agency for PM-E Drive Initiative in deploying Electric trucks in ports. TERI would leverage this to engage with various ports to make a roadmap for the purpose based on the master plan.

2.7 Scaling of Energy Efficient Equipment

The adoption of energy-efficient equipment is a crucial step for green ports in creating more sustainable and environmentally friendly maritime infrastructure. Green ports, committed to reducing carbon emissions and minimizing environmental impact, have spearheaded this movement. They actively invest in advanced technologies and innovative solutions to optimize energy usage. This could involve high-efficiency lighting, smart grid management, or on-site renewable energy generation. Beyond just equipment, green ports are also exploring ways to make cargo handling more energy-efficient, such as using electric or hybrid-powered cranes and vehicles. The benefits are substantial – lowering energy consumption, operating costs, and the carbon footprint of port activities.

2.7.1 Targets for Energy Efficient Equipment

The targets laid out as per MIV 2030, Harit Sagar guidelines, and MAKV 2047 are shown in Table 2.7.1 below.

Table 2.7.1: Targets for Scaling of Energy Efficient Equipment

MIV 2030	Harit Sagar guidelines
1. Ports shall use energy-efficient equipment / material viz. LED smart lighting system, highest energy rating equipment such as AC, Fans, Electronic devices etc. to reduce the energy consumption demand.	1. Reduction of Energy consumption per ton of cargo more than 20% by 2030 2. All new buildings shall comply with Green Building concept 3. Ports shall use energy efficient equipment/ material viz. LED smart lighting system, highest energy rating equipment such as AC, Fans, Electronic devices etc. to reduce the energy consumption demand

2.7.2 Current Status for Energy Efficient Equipment

The status mapping in terms of percentage progress with respect to Indian ports in Table 2.7.2 below. Currently for all ports, the 100% replacement for energy efficient equipment is completed barring few ports where process is ongoing such as PPA, CoPA & SMPK (expected to be completed by Dec 2025).

Table 2.7.2: Current Status for Energy Efficient Equipment

Ports	Current status
DPA	Completed except PPA, CoPA & SMPK (expected to be completed by Dec 2025)
PPA	
VOCPA	
VPA	
KPL	
MoPA	
CoPA	
SMPA	
CPA	
NMPA	
ChPA	

2.7.2.1 Total Energy Savings by the ports (in 2023)

The energy saving through usage of energy efficient appliances are noted as follows in Table 2.7.3.

Table 2.7.3: Port wise energy savings due to scaling of energy efficient equipment

Name of the Port	Energy Saving (Lakh KWh) in 2023
ChPA	13.2
VoCPA	12.64
KPL	9.14
MPA	8.3
CoPA	6.08
MbPA	6.6
VPA	5.3

The cumulative savings reported by 7 ports was 61 lakh units for the year 2023 due to adoption of energy efficient technologies. The corresponding monetary savings are INR 5.614 crore.

In addition to energy efficient appliances, measuring energy consumption per ton of cargo is a critical performance indicator for individual major ports in India's maritime sector, enabling the assessment of energy efficiency and environmental impact at the operational level. This metric helps identify energy-intensive processes, supports benchmarking across ports, and informs strategic interventions for optimizing equipment usage, reducing fuel dependency, and integrating renewable energy solutions. Regular monitoring also enhances compliance with national sustainability mandates, such as the Harit Sagar Guidelines, and aligns with global best practices in port decarbonization. Establishing energy baselines per ton of cargo handled is fundamental to setting realistic targets, tracking improvements, and demonstrating progress toward green port objectives.

Moreover, the need of adopting the "Green Building" concept for all new constructions at individual major ports is crucial to promote sustainable infrastructure, reduce environmental impact, and enhance energy and water efficiency from the design stage. The green buildings incorporate eco-friendly materials, renewable energy systems, and smart resource management, aligning port infrastructure with national climate goals and global green standards. Implementing this approach at the port level ensures long-term operational savings, improved occupant well-being, and compliance with sustainability mandates such as the Harit Sagar Guidelines, positioning ports as responsible and future-ready hubs of maritime activity. The status of energy consumption per ton cargo handled and compliance to "Green Building" concept is given below in Table 2.7.4.

Table 2.7.4: Status of Energy Consumption per ton cargo handled and compliance of Indian major ports to "Green Building" concept

S. No.	Port	Current Status of Energy Consumption per ton cargo handled (kWh/MT)	All new buildings shall be built by adopting "Green Building" concept (Compliance based)
1	NMPA	0.115	Yes
2	DPA	0.27	Yes
3	MbPA	0.12	Yes
4	KPL	0.77	Yes
5	VOCPA	Data under Assessment	Yes
6	VPA	0.72	Yes
7	JNPA	1.03	Yes
8	CoPA	1.06	Yes
9	ChPA	0.47	Yes
10	SMPK	0.53	Yes
11	MoPA	0.47	Yes
12	PPA	0.6	Yes

2.8 Pollution Control Measures

Recognizing the diverse geographical, ecological, and operational realities of India's twelve major ports, a port-wise assessment framework was developed under the supervision of the NAVIC Cell #3 (MoPSW). This approach allows for the contextualization of pollution control strategies, ensuring flexibility in execution while maintaining standardization in monitoring. Accordingly, ports have been instructed to develop data-backed action plans for wastewater reuse, installation of energy-efficient systems, minimization of marine and port waste, and green incentivization of ports and shipping sector.

The role of digital technologies, particularly in environmental monitoring and reporting, is being increasingly recognized. Initiatives such as real-time effluent tracking, GIS-based green belt monitoring, and automated water quality sensors are being piloted in select ports. These measures are expected to strengthen compliance with national regulations such as the Environmental Protection Act, 1986, and international sustainability disclosure frameworks such as ISO 14001.

NAVIC Cell's recommendation to institutionalize third-party audits through NABET-accredited agencies, along with the integration of results into port-level dashboards, is expected to improve transparency, standardization, and comparability. In the long term, the success of pollution control measures will depend not only on infrastructural investments but also on capacity building, cross-agency coordination, and public accountability.

2.8.1 Current Status of Pollution Control Measures

An evaluation of pollution control measures across India's twelve major ports for the year 2023–24 reveals a landscape of asymmetrical progress, with high-performing ports advancing key environmental targets and others lagging due to systemic, financial, or logistical constraints. The implementation of the Harit Sagar Guidelines has provided a clear thematic structure, but execution remains contingent on each port's institutional capacity, geographic characteristics, and regulatory context. Here in this section, we will be discussing the status of the different Key progressive indicators under pollution control.

2.8.1.1 Green Belt:

The green belt development status across major Indian ports indicates varied progress toward the targets set under Maritime India Vision (MIV) 2030 and Maritime Amrit Kaal Vision (MAKV) 2047 is provided in Table 2.8.1

Table 2.8.1: Green Belt development status across major Indian ports

Green Belt Cover: MIV 2030 Target is 20% & MAKV 2047 target is 33%

Ports	% Complete		Will it meet 2030?	Will it meet 2047?
NMPA	33		Already met	Already met
VPA	17.53		In process	In process
SMPK	HDC	>33	Already met	Already met
	KDS	>30.36	Already met	In process
MoPA	33		Already met	Already met
KPL	22.82		Already met	In process
MoPA	27		Already met	In process
PPA	>20		Already met	In process
JNPA	>33		Already met	Already met
VoCPA	8.77		In process	In process
DPA	>33		Already met	Already met
CPA	6.36		In process	In process
ChPA	12		Can't meet due to lack of land availability	Can't meet due to lack of land availability

Ports such as JNPA, NMPA, DPA, MgPA, and the HDC of SMPK have already exceeded the 33% green cover target, aligning with both 2030 and 2047 goals. Presently, KDS of SMPK has 30.36 % green cover, SMPK has taken target to fulfil the requirements of 33% of green cover within 2047. Several other ports, including KPL, MbPA, PPA, and KDS of SMPK, have surpassed the 20% target, positioning them well to meet the 2047 objective with continued efforts. Ports like VPA, VOCPA, and CoPA remain in progress toward both milestones, indicating the need for sustained green development initiatives. Notably, ChPA Port faces a unique constraint due to limited land availability, making it unlikely to meet either the 2030 or 2047 green cover targets. Overall, while many ports demonstrate strong alignment with the MIV and MAKV goals, a few require focused strategies and land-use planning to bridge the gap.

2.8.1.2 Marine Ecosystem Conservation Compliance

The status of marine ecosystem conservation across Indian major ports reveals a mixed level of compliance as follows in table 2.8.2

Table 2.8.2: Conservation of Marine Ecosystem

Conservation of Marine Ecosystem

Ports		Develop programs to protect and conserve the shore, mangrove forest and habitats	Emergency oil pollution response management as per NOS-DCP to combat oil pollution within Port limits	Implementation of Ballast water management by all ships as per IMO/DG Shipping guidelines
NMPA		In Compliance (Continuous Process)	In Compliance (Continuous Process)	In Compliance (Continuous Process)
VPA		In Compliance (Continuous Process)	In Compliance (Continuous Process)	In Compliance (Continuous Process)
SMPK	HDC	More than 9.5 lakhs Mangrove plantation has been developed at Nayachar Island Jointly as per the advice of HSD & Env. Cell of KDS. The plantation area has turned into a dense forest of Managrove & its associate vegetation.	SMPK (KDS & HDC) has Oil Pollution Response Plan approved by Coast Guard	In process/Initiated
	KDS	More than 9.5 lakhs Mangrove plantation has been developed at Nayachar Island Jointly as per the advice of HSD & Env. Cell of KDS. The plantation area has turned into a dense forest of Mangrove & its associate vegetation. KDS has recently planted 5000 mangrove vegetation at Nischintopur river Bank.	DO	In process/Initiated
MoPA		Can't Achieve under current circumstances/infrastructure	In Compliance (Continuous Process)	In Compliance (Continuous Process)
KPL		In Compliance (Continuous Process)	In Compliance (Continuous Process)	In Compliance (Continuous Process)
MbPA		In Compliance (Continuous Process)	In Compliance (Continuous Process)	Can't Achieve under current circumstances/ infrastructure
PPA		In Compliance (Continuous Process)	In process/Initiated	In Compliance (Continuous Process)
JNPA		In process/Initiated	In process/Initiated	In Compliance (Continuous Process)
VOCPA		In process/Initiated	In process/Initiated	In Compliance (Continuous Process)

Ports	Develop programs to protect and conserve the shore, mangrove forest and habitats	Emergency oil pollution response management as per NOS-DCP to combat oil pollution within Port limits	Implementation of Ballast water management by all ships as per IMO/DG Shipping guidelines
DPA	In Compliance (Continuous Process)	In Compliance (Continuous Process)	In Compliance (Continuous Process)
CoPA	In process/Initiated	In process/Initiated. Work awarded to IRS	In Compliance (Continuous Process)
ChPA	Can't Achieve under current circumstances/infrastructure	In process/Initiated	In process/Initiated

Ports such as NMPA, VPA, KPL, and DPA have fully implemented all three key components: shoreline and habitat conservation, emergency oil spill response per NOS-DCP, and ballast water management, with efforts categorized as ongoing continuous processes. MoPA and MbPA show partial compliance—MoPA has not yet developed ecosystem conservation programs due to infrastructural constraints, while MbPA is unable to implement ballast water management under current conditions. JNPA, VOC, and CoPA have initiated actions wherein work awarded to IRS all areas but are still in the implementation phase for shoreline conservation and oil spill response, while PPA has fully complied with two of the three criteria. SMPK (both HDC and KDS) and ChPA are still in the early stages or have infrastructural limitations, particularly in shoreline protection and oil spill preparedness. SMPK (both HDC and KDS) has prepared Oil Spill Contingency Plan (OSCP) by engaging IRS. Mumbai. The plan has been vetted by Indian Coast Guard Head Quarters, New Delhi on 13.3.2025. The OSCP to be revalidated by Indian coast Guard by January 2030. Overall, while ballast water management is widely in compliance across most ports, greater attention is required for shore and habitat conservation and oil spill response preparedness, particularly in SMPK, JNPA, VOC, CoPA, and ChPA, to ensure comprehensive marine ecosystem protection.

2.8.1.3 Water and Wastewater Management Plan

Efficient management of water resources and wastewater recycling has become a central tenet of pollution control planning across Indian ports. In line with the Harit Sagar Guidelines, ports are mandated to reduce freshwater consumption, promote closed-loop water systems, and implement rainwater harvesting and wastewater reuse strategies.

Table 2.8.3: Reduction in fresh Water Consumption

Reduction in Freshwater Consumption, and Recycle & Reuse of Wastewater

Ports		20% reduction in freshwater consumption per ton cargo handled as compared to the base year for Port		20% reduction in freshwater consumption per ton cargo handled as compared to the base year for PPP Operator		100% use of recycled and reuse of wastewater in total for Port	100% use of recycled and reuse of wastewater in total for PPP operator
		Current Consumption	Quantity to be Reduced	Current Consumption	Quantity to be Reduced		
		(L/tonne)	(L/ tonne)	(L/tonne)	(L/ tonne)	(%)	(%)
NMPA		14.4	2.88	Data under assessment		100	Data under assessment
VPA		18.08	3.61	Data under assessment		100	Data under assessment
SMPK	HDC	25	5	Data under assessment		In process/ Initiated	To be initiated
	KDS	4040 (This water usage is for both residential & Office areas as well as dock areas)	8	Data under assessment		7.63	To be initiated
MoPA		6.34	1.27	17.4	3.48	80	50
KPL		2.59	0.52	1.35	0.27	26	44
MbPA		3.55	0.71	No PPP operators.		Can't Achieve under current circumstances/ infrastructure	No PPP operators.
PPA		PPA is using recycled and reused water instead of fresh water				100	
Jawaharlal Nehru Port Authority		This is a landlord port.		18.41	3.68	25	30

Ports	20% reduction in freshwater consumption per ton cargo handled as compared to the base year for Port		20% reduction in freshwater consumption per ton cargo handled as compared to the base year for PPP Operator		100% use of recycled and reuse of wastewater in total for Port	100% use of recycled and reuse of wastewater in total for PPP operator
	Current Consumption	Quantity to be Reduced	Current Consumption	Quantity to be Reduced		
	(L/tonne)	(L/ tonne)	(L/tonne)	(L/ tonne)	(%)	(%)
VOCPA					Recycled Sewage water is utilized for dust suppression system & green belt development.	
DPA	Current Consumption: 4.34. Optimum reduction reached; no further reduction is currently possible		Data under assessment		100	Data under assessment
CoPA	22	4.4	9.4	1.88	In process	
ChPA	12.9	2.58	Data under assessment		Data under assessment	

VPA has operationalized a 10 MLD Sewage Treatment Plant (STP), with proposals to refurbish and expand its capacity to 15 MLD. Additionally, a new 5 MLD STP has been proposed to meet future dust suppression and green belt maintenance requirements. Similarly, VOCPA and JNPA have repurposed treated effluents from coal yards and administrative buildings for green cover development.

Other ports are in earlier stages of implementation SMPK is undertaking water audits at both the Haldia Dock Complex and Kolkata Dock System, in partnership with NPC & FICCI respectively, to assess consumption and identify areas for conservation. KDS of SMPK is maintaining one 150 KLD STP at Taratolla colony. The treated waste water is used for gardening. MgPA, with Sagarmala support, is laying a dedicated pipeline from a government-run STP in Baina to the port and planning a 150 KLD STP for its cruise terminal. These initiatives are also aligned with India's broader National Water Mission, which encourages wastewater reuse in industrial and port areas.

Rainwater harvesting efforts vary considerably. JNPA, for instance, has rejuvenated lakes to enable seasonal groundwater recharge, while others like KPL and CoPA are relying on sedimentation-based infiltration to reduce runoff. However, a lack of filtration and treatment mechanisms at several ports limits the reuse potential of harvested rainwater.

NAVIC Cell #3 has advised ports to integrate water budgeting and real-time tracking tools into their environmental dashboards. Future compliance will also require the use of volumetric benchmarks

— such as freshwater consumed per tonne of cargo handled — to assess performance across ports on a standardized basis

2.8.1.4 Sewage Treatment, Desalination, & Rainwater Harvesting

Data gathered through NAVIC Cell's port-specific assessments indicates that several pollution control components—such as the installation of Sewage Treatment Plants (STPs), rainwater harvesting structures, and effluent monitoring.

Table 2.8.4: Sewage Treatment, Desalination, & Rainwater Harvesting

Sewage Treatment, Desalination, & Rainwater Harvesting

<table>
<tr><th rowspan="2" colspan="2">Port</th><th>Sewage Treatment plant – Port status</th><th>Sewage Treatment plant – PPP Operator status</th><th>Desalination plant – Port status</th><th>Desalination plant – PPP operator status</th><th>Rainwater harvesting – Port status</th><th>Rainwater harvesting - PPP operator status</th></tr>
<tr><th>(MLD)</th><th>(MLD)</th><th>(MLD)</th><th>(MLD)</th><th>(KL)</th><th>(KL)</th></tr>
<tr><td colspan="2">NMPA</td><td>1.2</td><td>Data under assessment</td><td>NA</td><td>40 MLD Capacity installed by MRPL (Major port users)</td><td>1,06,512</td><td>Data under assessment</td></tr>
<tr><td colspan="2">VPA</td><td>10</td><td>Data under assessment</td><td>Currently no desalination plants.</td><td>Data under assessment</td><td>190</td><td>Data under assessment</td></tr>
<tr><td rowspan="2">SMPK</td><td>HDC</td><td>2.06</td><td>Data under assessment</td><td rowspan="2" colspan="2">Desalination plant is not required at KDS. However, on the basis of NPC report on water Audit, final decision on installation of Desalination plant will be taken up..</td><td colspan="2">As per study, water level is high at HDC, therefore, rainwater harvesting may not be so much effective.</td></tr>
<tr><td>KDS</td><td>0.15</td><td>150 KLSTP in operation.
Data under assessment</td><td>Current capacity is 0 and plans are there to increase it to 15kL by 2030.</td><td>Final Decision on Water Harvesting system will be taken up after obtaining report on Water Audit</td></tr>
</table>

Port	Sewage Treatment plant – Port status	Sewage Treatment plant – PPP Operator status	Desalination plant – Port status	Desalination plant – PPP operator status	Rainwater harvesting – Port status	Rainwater harvesting - PPP operator status
	(MLD)	(MLD)	(MLD)	(MLD)	(KL)	(KL)
MgPA	1.31	MgPA currently has 1.31 MLD capacity STP facility but lack this facility in PPP operated berths.	Currently no desalination plants.		90	MgPA has limited rainwater harvesting facilities but lack this facility in PPP operated Berths due to space constraint.
KPL	0.06	0.053	Plan to install a 1 MLD plant by 2025-26.	Currently no desalination plants.	18	24
MbPA	0.25	No PPP operators.	Currently no desalination plants.	No PPP operators.	Currently there are no rainwater harvesting facilities.	No PPP operators.
PPA	6	Data under assessment			2	Data under assessment
JNPA	4.1	0.65	Currently no desalination plants.	Currently no desalination plants.	1,000	15
VOCPA	1	Currently there are no STPs.	3	Currently no desalination plants.	3,000	Data under assessment

Port	Sewage Treatment plant – Port status	Sewage Treatment plant – PPP Operator status	Desalination plant – Port status	Desalination plant – PPP operator status	Rainwater harvesting – Port status	Rainwater harvesting - PPP operator status
	(MLD)	(MLD)	(MLD)	(MLD)	(KL)	(KL)
DPA	2.5	Currently PPP operator is using the port facilities.	0.6	Currently PPP operator is using the port facilities.	Under conceptualization stage	Data under assessment
CoPA	Currently there is no STP but the port plans to install a capacity of 0.05 MLD by 2025-26 and increase the capacity to 0.1 MLD by 2030.	0.009	Currently no desalination plants.	Currently no desalination plants.	12	Currently there are no rainwater harvesting facilities.
ChPA	0.13	0.07			121 number of Rainwater Harvesting pits in Port Area	

The status of sewage treatment, desalination, and rainwater harvesting across Indian major ports in Table 2.8.4 reveals varied levels of infrastructure development and planning. Ports such as VPA and PPA have relatively higher sewage treatment capacities at 10 MLD and 6 MLD respectively, while JNPA (4.1 MLD), DPA (2.5 MLD), and KDS-SMPK (150 KLD capacity) also demonstrate significant installations. Several ports, including KPL, ChPA, and CoPA, have low-capacity or planned STPs, while ports like MbPA and MgPA currently has 1.31 MLD capacity STP facility but lack this facility in PPP operated berths. On desalination, most ports—including VPA, JNPA, CoPA, and ChPA—do not yet have operational facilities, though VOC (3 MLD), PPA (2 MLD), and DPA (0.6 MLD) have installed or shared infrastructure. 40 MLD Capacity desalination plant installed at NMPA by MRPL (Major port user). In terms of rainwater harvesting, NMPA and JNPA lead with capacities of over 1 lakh KL and 1,000 KL respectively, followed by VOC (3,000 KL). ChPA has 121 rainwater harvesting pits, and KPL has implemented both port and PPP-level harvesting systems. However, MbPA, MgPA, despite limited space and ecological constraints, has effectively reused STP-treated water for dust mitigation measures at Operational areas and maintaining gardens and green areas, and CoPA currently lack rainwater harvesting facilities. Several ports, including SMPK and DPA, are still in planning or water audit stages for deciding future actions. KDS & HDC has completed study on Water audit by FICCI & NPC respectively. Draft report has been submitted. Presently the report is under examination. Overall, while select ports show robust initiatives in water management, there remains a need for systematic upgrades and uniform implementation across sewage, desalination, and rainwater harvesting systems, particularly through strengthened PPP collaboration.

2.8.1.5 Effluent Discharge Monitoring Systems

From the table 2.8.5 current status of effluent discharge monitoring across Indian major ports reflects a significant data gap and inconsistent reporting of the key initiatives.

Table 2.8.5: Monitoring of Effluent Discharge

Ports		Monitoring of Effluent discharge from all the ships as per IMO/DG shipping rules	Discharge of any wastewater/bilge water/ oily bilge/waste water generated from ships shall be prohibited in Port waters	Declaration of type (as per MARPOL) & approx quantity of waste on board
NMPA		In Compliance (Continuous Process)		
VPA				
SMPK	HDC			
	KDS			
MoPA				
KPL				
MoPA				
PPA				
JNPA				
VOCPA				
DPA				
CoPA				
ChPA		Data under assessment		

As per the available information, only NMPA is in full compliance with IMO and DG Shipping regulations, enforcing continuous monitoring of ship-generated effluents, prohibiting discharges into port waters, and ensuring declaration of waste types and quantities in line with MARPOL norms. ChPA has indicated that data is still under assessment. For all other ports—VPA, SMPK (HDC & KDS), MoPA, KPL, MbPA, PPA, JNPA, VOC, DPA, and CoPA is monitoring as per MARPOL norms, indicating a need for urgent attention to ensure compliance with international maritime pollution control standards. Strengthening port-level monitoring frameworks and standardizing reporting mechanisms will be critical to ensure effective environmental oversight of shipborne waste management in Indian port waters.

2.8.1.6 Management of Waste from Ships

The status of waste management from ships at Indian major ports highlights uneven implementation and limited reporting.

Table 2.8.6: Management of Waste from Ships

<table>
<tr><th colspan="2">Ports</th><th>Shore reception facility for collection and discharging the waste of ships as per the Indian rules</th><th>Waste management (other than waste from ships & waste water)</th></tr>
<tr><td colspan="2">NMPA</td><td rowspan="13">In Compliance (continuous process)</td><td rowspan="13"></td></tr>
<tr><td colspan="2">VPA</td></tr>
<tr><td rowspan="2">SMPK</td><td>SMPK</td></tr>
<tr><td>KDS</td></tr>
<tr><td colspan="2">MoPA</td></tr>
<tr><td colspan="2">KPL</td></tr>
<tr><td colspan="2">MoPA</td></tr>
<tr><td colspan="2">PPA</td></tr>
<tr><td colspan="2">JNPA</td></tr>
<tr><td colspan="2">VOCPA</td></tr>
<tr><td colspan="2">DPA</td></tr>
<tr><td colspan="2">CoPA</td></tr>
<tr><td colspan="2">ChPA</td><td>Data under assessment</td><td>In Compliance (Continuous Process)</td></tr>
</table>

Only NMPA is confirmed to be in continuous compliance with Indian rules regarding the provision of shore reception facilities for ship waste. In HDC, garbage generated from ships are collected by Haldia Municipal authority by engaging Re- sustainability Ltd. In KDS Solid wastes generated from Ships are received by port's representative in segregated sealed packets and the same as disposed of as per the regulatory requirements. Additionally, ChPA has reported ongoing compliance for general port waste management, although data regarding ship waste reception is still under assessment. For the remaining ports—including VPA, SMPK (HDC & KDS), MoPA, KPL, MbPA, PPA, JNPA, VOC, and DPA.

At CoPA, effluent discharge from all ships is monitored in compliance with IMO and DG Shipping rules. The discharge of any wastewater, bilge water, oily bilge, or other wastewater generated from ships is strictly prohibited within port waters.

Establishing comprehensive and functional shore reception facilities in compliance with MARPOL and Indian regulations, alongside integrated port waste management systems, remains a critical area for further action.

2.8.1.7 Management of Waste from Ports

The current status of port waste management across Indian major ports indicates partial compliance and inconsistent reporting across various waste categories.

Table 2.8.7: Management of Waste from Ports

<table>
<tr><th colspan="2">Ports</th><th>Solid waste management rules</th><th>Hazardous waste management rules</th><th>C&D waste management rules</th><th>Plastic waste management rules</th><th>E-Waste management rules</th><th>Biomedical Waste management rules</th></tr>
<tr><td colspan="2">NMPA</td><td colspan="6" rowspan="3">In Compliance (Continuous Process)</td></tr>
<tr><td colspan="2">VPA</td></tr>
<tr><td rowspan="2">SMPK</td><td>HDC</td></tr>
<tr><td>KDS</td><td>In process</td><td colspan="5">In Compliance (Continuous Process)</td></tr>
<tr><td colspan="2">MoPA</td><td colspan="6" rowspan="2">In Compliance (Continuous Process)</td></tr>
<tr><td colspan="2">KPL</td></tr>
<tr><td colspan="2">MbPA</td><td colspan="3">In Compliance (Continuous Process)</td><td>Data under assessment</td><td colspan="2">In Compliance (Continuous Process)</td></tr>
<tr><td colspan="2">PPA</td><td colspan="6" rowspan="5">In Compliance (Continuous Process)</td></tr>
<tr><td colspan="2">JNPA</td></tr>
<tr><td colspan="2">VOCPA</td></tr>
<tr><td colspan="2">DPA</td></tr>
<tr><td colspan="2">CoPA</td></tr>
<tr><td colspan="2">CoPA</td><td colspan="6">Data under assessment</td></tr>
</table>

NMPA, MoPA, MbPA, and PPA have reported continuous compliance with solid waste management rules, demonstrating a structured approach to basic waste handling. MbPA and SMPK-KDS have also indicated compliance with plastic waste management rules. In KDS & HDC electronic waste, battery wastes , metal scraps are sold to approved authorized agency through MSTC. However, data on hazardous, construction & demolition (C&D), e-waste, and biomedical waste management is either under assessment or not reported by most ports, including VPA, KPL, VOC, JNPA, DPA, CoPA (as mentioned above under compliance), and ChPA. The lack of consistent compliance across all categories reflects the need for a more holistic and enforceable waste management framework at ports, aligned with national environmental rules and port-level sustainability goals.

2.8.1.8 Structuring and Implementation of Environmental System

The structuring and implementation of environmental systems at major Indian ports show promising progress, though some components remain in early stages of development. Most ports—including NMPA, VPA, SMPK (HDC & KDS), MoPA, KPL, MbPA, PPA, JNPA, VOC, DPA, CoPA, and ChPA—have already established port-approved environmental management guidelines, indicating a strong commitment to regulatory alignment and environmental stewardship. However, the environmental management plans (EMPs) at many of these ports are still in the "in process" or initiated stage, suggesting ongoing formulation or revision to meet evolving standards.

Table 2.8.8: Structuring and Implementation of Environmental System

Ports		Port approved Environment management guidelines.	Environment management plan	Dedicated Environmental cell to monitor and review the environment compliance in the Port - Also provide the strength of Competent person	Independent Annual environmental audit & publication of report on Port website before 30th April every year
NMPA		In Compliance (Continuous Process)			In process
VPA		In Compliance (Continuous Process)			
SMPK	HDC	In Compliance (Continuous Process)			In process
	KDS	In Compliance (Continuous Process)			In process
MoPA		In Compliance (Continuous Process)		In process	
KPL		In Compliance (Continuous Process)			In process
MbPA		In Compliance (Continuous Process)			
PPA		In Compliance (Continuous Process)			In process
JNPA		In Compliance (Continuous Process)			In process
VOCPA		In Compliance (Continuous Process)			
DPA		In Compliance (Continuous Process)			In process
CoPA		In Compliance (Continuous Process)		In process	
CoPA		In Compliance (Continuous Process)			

Regarding the formation of dedicated environmental cells, data is currently missing or not reported for most ports, including the strength and competence level of environmental personnel, which is a critical aspect for effective compliance monitoring. Furthermore, there is no available data on whether ports are conducting independent annual environmental audits and publishing reports on their websites by the stipulated deadline of 30th April each year. To improve overall governance and accountability, ports should prioritize finalizing EMPs, formally establish and staff environmental cells with trained personnel, and implement a transparent audit and reporting mechanism in the public domain.

2.8.1.9 Green Incentive schemes for Ports and Shipping Sector

The current status of green incentive mechanisms for promoting green ports and green shipping across Indian major ports shows that the initiative is still largely at a nascent stage. Ports like MoPA, NMPA and VOCPA are providing green incentives to the ships under Harit Shrey scheme.

Remaining ports like KPL, MbPA, PPA, JNPA, DPA, CoPA, and ChPA are yet to initiate any structured programs or incentives aimed at encouraging the use of alternative fuels, electrification of port equipment, or rewarding vessels utilizing green technologies such as shore power or low-emission fuels.

A few exceptions are seen at VPA and SMPK (HDC and KDS), where early-stage actions have been initiated for green shipping practices, particularly by stevedores and other port users. However, implementation remains limited, with no comprehensive or port-wide green incentive framework currently in place.

Furthermore, there is no reported data or established mechanism at most ports for incentivizing PPP concessionaires or vessels adopting green measures. This underscores the need for a well-defined policy framework at the national and port level to catalyze the transition toward low-carbon port operations and shipping, through clear incentives, regulatory support, and public-private collaboration.

2.8.2 Regulatory Framework and Policy Guidelines

India's major ports operate under a robust yet evolving framework of environmental laws and sustainability guidelines. The regulatory landscape for pollution control is shaped by both national legislation and international maritime protocols, which together provide the legal and technical basis for port-level environmental governance.

At the national level, the Environmental Protection Act, 1986 serves as the umbrella legislation, enabling rules related to water pollution, air quality, and hazardous waste management. Complementary regulations include the Solid Waste Management Rules, 2016, Hazardous Waste Rules, and the Coastal Regulation Zone (CRZ) Notifications, which guide port-related development in ecologically sensitive coastal stretches.

Port authorities are further required to obtain "Consent to Operate" (CTO) certificates from respective State Pollution Control Boards (SPCBs). These consents impose conditions related to air and water discharge, waste segregation, and noise levels. Compliance is monitored through annual reporting, including the submission of Form V returns detailing emissions, energy use, and mitigation efforts.

Internationally, Indian ports are obligated to follow the pollution control conventions under the International Maritime Organization (IMO). These include the MARPOL Convention (Annexes I–VI), which govern oil, sewage, air emissions, garbage, and ballast water from ships. Many ports have also begun aligning their internal procedures with ISO 14001:2015 standards on Environmental Management Systems to improve documentation, third-party verification, and global credibility.

To bridge inconsistencies in enforcement and documentation, the Harit Sagar Guidelines (2023) introduced by MoPSW have provided a thematic structure, assigning measurable benchmarks across nine categories of port environmental performance — including green belt coverage, freshwater reuse, and marine ecosystem conservation. The guidelines encourage the use of third-party agencies for auditing, preferably accredited by NABET (National Accreditation Board for Education and Training), to ensure objectivity and comparability across ports.

NAVIC Cell has proposed that future compliance mechanisms integrate ESG-based reporting frameworks, enabling ports to gradually align with global sustainability disclosure standards such as those promoted under the Green Ports Policy and India's broader National Green Hydrogen Mission. These developments mark a shift from compliance-oriented control to performance-oriented environmental management in the maritime sector.

2.8.3 Good Practices

Several ports across India have demonstrated good practices that align with national sustainability goals and international environmental benchmarks. These efforts not only reflect the diversity of pollution control strategies being employed but also offer replicable models for other ports.

Visakhapatnam Port Authority (VPA) has undertaken extensive rainwater harvesting by constructing recharge pits across institutional zones such as schools, hospitals, and administrative blocks. These installations serve dual purposes: reducing stormwater runoff and conserving freshwater for non-potable use. Similarly, Jawaharlal Nehru Port Authority (JNPA) has rejuvenated multiple lakes within its premises to improve groundwater recharge capacity while acting as natural sedimentation basins.

SMPK has implemented an Integrated Solid Waste Management System in compliance with the Solid Waste Management Rules, 2016. In KDS, ship generated wastes are received in segregated manners in sealed packets. Municipal solid wastes generated in KDS are handed over to KMC on payment of dumping charges. The recyclable and hazardous wastes generated in SMPK are sold/ handed over to authorized handlers.

VOCPA has constructed a gravity settling pond to treat leachate generated from coal yards. The treated water is reused for dust suppression, reducing both particulate pollution and freshwater dependency. MgPA, despite limited space and ecological constraints, has effectively reused STP-treated water for cruise terminal operations, aligning with MARPOL-compliant waste discharge norms.

Internationally, port-led sustainability frameworks like the EcoPorts initiative (EU), Green Marine certification (North America), and ISO 14001 Environmental Management Systems have been used as benchmarking tools for Indian ports. These frameworks promote third-party audits, data transparency, and performance-based incentives, and several Indian ports — including JNPA, Cochin, and Paradip — are now exploring phased alignment with such models.

NAVIC Cell has recommended that such good practices be documented and shared across ports through knowledge exchanges, workshops, and ESG disclosure platforms to accelerate peer learning and improve standardization.

As per report prepared by M/s CII; HDC maintains 39% green cover & KDS maintains 30.36% green cover.

2.8.4 NAVIC Cell 3 Recommendations and Practical Implementation Plan

Based on primary data collected from India's twelve major ports, the NAVIC Cell 3 under the Ministry of Ports, Shipping and Waterways (MoPSW) has identified key challenges and developed port-specific and thematic recommendations to strengthen pollution control systems in alignment with the Harit Sagar Green Port Guidelines and national sustainability goals.

2.8.4.1 Green Belt Cover and Biodiversity

Ports such as Chennai and Paradip face constraints due to limited land availability. NAVIC Cell recommends partnerships with State Forest Departments to undertake afforestation in buffer zones, including mangrove development, shelter belts, and restoration of degraded land. These efforts can be supported under the National Afforestation Programme and aligned with the Ministry of Environment's Compensatory Afforestation Scheme.

2.8.4.2 Conservation of Marine Ecosystem

SMPK (KDS & HDC) has prepared Oil Spill Contingency Plan by engaging Indian Register of Shipping, Mumbai, and obtained approval from Indian Coast Guards Head Quarters, New Delhi on 13.3.2025. Oil Spill Contingency Plan report of SMPK to be revalidated again on January 2030. There are multiple ports reported pending approvals on Oil Spill Contingency Plans (OSCPs) from the Indian Coast Guard. NAVIC Cell urges expedited review mechanisms through regional coordination committees. In ports with limited marine biodiversity (e.g., Mormugao), alternative actions such as artificial reef installation, coastal habitat mapping, and marina development have been proposed.

2.8.4.3 Wastewater Reuse and Freshwater Reduction

High-performing ports like VPA and VOC have invested in STPs and rainwater harvesting. Ports with limited capacity (e.g., MgPA and SMPA) have sought financial and technical support from Sagarmala and internal funds. NAVIC Cell supports targeted funding through green infrastructure grants, alongside uniform freshwater use benchmarks (e.g., litres per tonne of cargo).

2.8.4.4 Solid and Ship-Generated Waste Management

All ports are expected to comply with RRR (Reduce, Reuse, Recycle) protocols and relevant waste management rules. SOPs for ship waste reception, labeling, and traceability are being piloted in VPA and SMPA. NAVIC Cell recommends port-wide implementation, supported by third-party audits from NABET-accredited agencies.

2.8.4.5 Environmental Auditing and Reporting

The Cell recommends annual environmental audits through ISO 14001 or NABET-accredited agencies, with results submitted in Form V to respective State Pollution Control Boards. These should be integrated into digital dashboards for real-time tracking and national ESG alignment.

2.8.4.6 Funding and Support Mobilization

Some ports, such as SMPK, have estimated funding requirements (e.g., ₹18 Cr for green belts, ₹15 Cr for water reuse). Others like MoPA have already secured partial Sagarmala funding (e.g., ₹3.43 Cr for a wastewater pipeline). NAVIC Cell recommends a blended financing model leveraging MoPSW budgetary support, internal port funds, and green bonds where applicable.

2.8.4.7 Future Readiness – Zero Waste and Zero Liquid Discharge (ZLD) Survey

In alignment with global environmental benchmarks and national mandates, the NAVIC Cell under the Ministry of Ports, Shipping and Waterways (MoPSW) has developed a structured evaluation tool to assess India's twelve major ports for future compliance with Zero Waste Discharge (ZWD) and Zero Liquid Discharge (ZLD) objectives. This approach is part of a long-term alignment with the Harit Sagar – Green Port Guidelines and India's circular economy transition targets.

The survey instrument (presented in Annexure II) captures operational, technical, and compliance data across six thematic areas: general compliance, water and wastewater reuse, solid waste segregation, environmental impact monitoring, certification and audits, and regulatory reporting. These indicators are mapped to emerging Indian standards for ZLD infrastructure as published by the Bureau of Indian Standards (BIS) and complement national circular economy principles outlined by the Ministry of Environment, Forest and Climate Change (MoEF&CC).

Globally, programs such as the EcoPorts initiative in the EU and Green Marine in North America have demonstrated the value of voluntary, structured self-assessment tools for pollution control, stakeholder engagement, and performance benchmarking. The NAVIC Cell's ZLD/ZWD survey takes inspiration from these frameworks and is designed to be repeated annually to capture temporal improvements and inform national port performance rankings.

2.9 Green Hydrogen Hubs

Ports, being crucial gateways for international trade and heavy fuel-consuming ecosystems, are uniquely positioned to serve as a green hydrogen hub which can facilitate production, storage, and export of hydrogen and its derivatives such as green ammonia. Development of the green hydrogen hubs at the port are key to achieving the targets envisioned under National Green Hydrogen Mission for 2030. Green hydrogen production relies heavily on the electrolysis of water using renewable electricity. Fortunately, India has immense renewable energy potential that can support its green hydrogen aspirations, but rapid capacity addition is necessary. However, the countries currently installed Renewable capacity sits at only 200 GW, 48% of this total potential.

The Ministry of Ports, Shipping and Waterways has identified DPA, PPA and VOCPA as three major ports to be developed as hydrogen hubs (as shown in Figure 2.9.1). These green hydrogen hubs aim to attract large-scale investments, support renewable energy adoption, enable green mobility solutions like hydrogen-fueled transport within port areas, and foster industry-academia collaboration through centers of excellence.

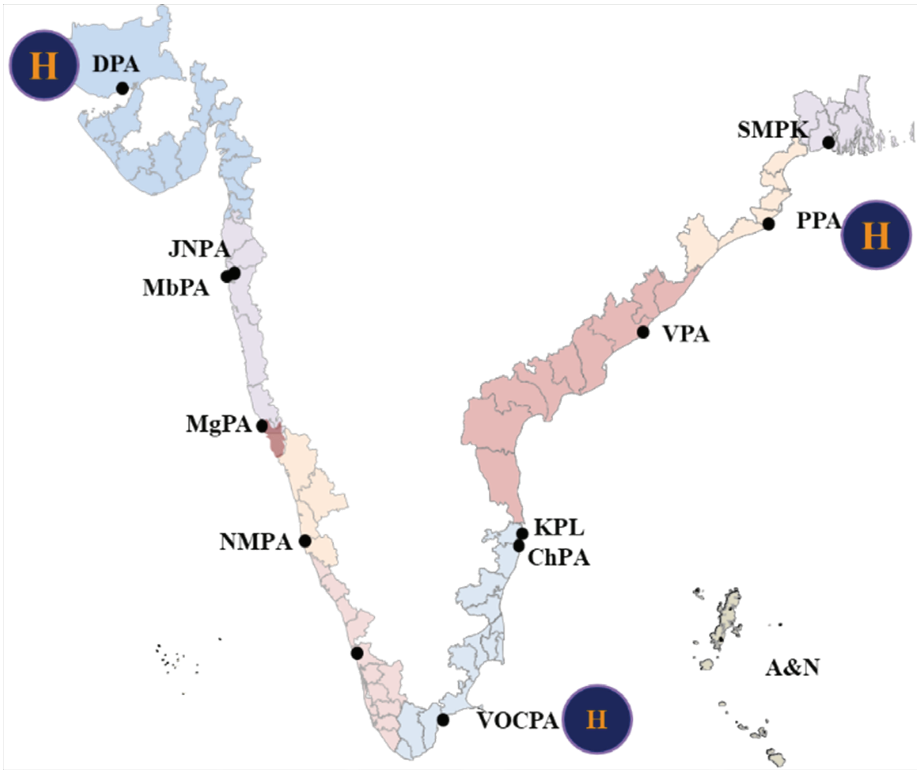

Figure 2.9.1: Identified Green Hydrogen Hubs in India

2.9.1 Targets by the Ports

India's Ministry of Ports, Shipping and Waterways (MoPSW) has initiated the development of green hydrogen hubs at major ports as part of the National Green Hydrogen Mission. The key production targets set for 2030 include:

- DPA: 7 MMT of green ammonia production by 2030.
- VOCPA: 2 MMTPA by 2030 (0.8 MMTPA by 2028).
- PPA: 2 MMTPA to be developed outside the port area on the land to be allocated by the State Government.

2.9.2 Current Status of Green Hydrogen Hubs

The current status of the green hydrogen hubs in selected ports are presented in table 2.9.1.

Table 2.9.1: Status for Green Hydrogen Hubs

Parameters	DPA	VOCPA	PPA
Land Allocated	3,400 acres	501 acres	Will be allocated by State Govt. outside Port area
Green Ammonia Production Target by 2030	7 MMTPA	2 MMTPA (0.8 MMTPA by 2028)	2 MMTPA
Investment in Port Land	~ Rs. 1 Lakh Cr	~Rs. 41,860 Cr	~ RS. 700 Cr through PPP (for terminal)

Parameters	DPA	VOCPA	PPA
Current Status	• CTU Power Infra: Rs. 2775 Cr estimate approved: CEA finalizing site survey. • Water: 300 MLD desalination plant study in progress.	• ACME exploring options to make solar plant fully captive and if needed go for CTU connectivity. • SEMBCORP is exploring general network access for 800 MW at the CTU substation. • Desalination plant to be installed by both the firms	• Dedicated Terminal for Hydrogen: Estimated Completion 2027 • PPA has also initiated the process to construct a jetty for handling green hydrogen or green ammonia, with approximately 40 acres of backup area for intermediate storage facilities.

At DPA, significant progress has been made in establishing a green hydrogen hub. A total of 3,400 acres of land has been allocated, and a ₹2,775 crore power infrastructure proposal for CTU connectivity has been approved, with the Central Electricity Authority (CEA) currently finalizing the site survey. To meet the substantial water requirements for green hydrogen production, a 300 MLD desalination plant study is also underway. Additionally, DPA is setting up a 1 MW electrolyzer-based green hydrogen plant, scheduled for commissioning by September 2025. In parallel, the port is working in partnership with NTPC Renewable Energy Ltd. to launch GH2-powered fuel cell electric buses (FCEVs) by August 2025, aimed at promoting green mobility within the port ecosystem. To support long-term innovation and industry-academia collaboration, a Centre of Excellence for Green Maritime Fuels is being established at Gandhidham.

At VOCPA, 501 acres of land has been allocated for the development of a green hydrogen ecosystem. Private entities such as ACME are exploring the development of fully captive solar power plants, while SEMBcorp is working to ensure 800 MW network access via CTU. Both firms plan to install desalination plants to support hydrogen production. VOCPA's key initiatives include a GH2 demonstration project with a 10 Nm^3 capacity, valued at ₹3.8 crore, the project was completed in March 2025. Additionally, the port has secured ₹35 crore in funding from MNRE for Methanol bunkering and refueling infrastructure. Port is also planning to generate methanol from solid waste produced from the port.

At PPA, land for the green hydrogen hub will be allocated by the State Government outside the port area. A dedicated hydrogen terminal is in the pipeline, with an estimated completion timeline of 2027. This development is planned through Public-Private Partnership (PPP) with an estimated investment of ₹700 crore and will support the port's efforts to emerge as a key player in the national green hydrogen and ammonia supply chain. As of now land and investment are under discussion for the port. PPA has also initiated the process to construct a jetty for handling green hydrogen or green ammonia, with approximately 40 acres of backup area for intermediate storage facilities.

2.9.3 Implementation Roadmap for Green Hydrogen Hub Development

The Green Hydrogen Hub Development Roadmap outlines a clear, phased approach for establishing India's major ports—DPA, VOCPA, and PPA—as key green hydrogen production and export hubs. In the Foundation Phase (2024–2025), the primary focus is on identifying hub locations, finalizing land allocations, and securing critical power infrastructure approvals such as CTU and CEA clearances for high-capacity transmission lines. Table 2.9.2 presents the implementation roadmap for green hydrogen hub.

Table 2.9.2: Implementation roadmap for green hydrogen hub development at the port

Phase	Key Activities & Targets	Timeline
Foundation	• Identified hydrogen hub locations: DPA, VOCPA, PPA • Finalized land allocation (e.g., 3,400 ac at DPA; 501 ac at VOCPA); PPA Govt land pending • Secured CEA/CTU approvals for grid connectivity at hub-scale (e.g., 800 MW line for VOCPA, ₹2,775 Cr CTU for DPA)	2024–2025
Pilot & Infrastructure	• Installed 1 MW hydrogen plant at DPA and 10 Nm^3 green hydrogen electrolyser-based demonstration plants at VOCPA • Setting up desalination facilities (300 MLD at DPA; port-side and captive systems at VOCPA) • Commissioning large-scale renewable energy installations and transmission infrastructure (solar parks and grid connectivity)	2025–2026
Mobility & Bunkering	• Will Deploy GH_2-based FCEV buses (DPA–NTPC RE Buses by Aug 2025). • Established Green Methanol (hydrogen derivative) bunkering and refueling infrastructure (₹35 Cr at VOCPA by Jan 2026)	2025–2026
Scale-up & Commercialization	• Full-scale green ammonia production: 7 MMTPA at DPA; 2 MMTPA at VOCPA & PPA by 2030 • Enable export infrastructure: hydrogen/ammonia terminals, pipelines, ports enhancements • Open public tenders for electrolyzer manufacturing and GH_2 production incentives (via NHGM/SIGHT outlay ₹17,490 Cr).	2026–2030
Market Expansion & Ecosystem	• Support integration with steel, fertilizer, heavy mobility, and maritime applications • Introduce GH_2 certification and standards, develop digital monitoring tools, and build institutional capacity at a national Hydrogen Centre of Excellence	2027–2030

During the Pilot & Infrastructure Phase (2025–2026), demonstration-scale electrolyzer projects and desalination facilities will be installed, supported by renewable energy infrastructure such as solar parks and grid connectivity. The Mobility & Bunkering Phase (2025–2026) includes the deployment of hydrogen-powered FCEV buses and the establishment of hydrogen derivative bunkering infrastructure, such as green methanol fueling stations.

The Scale-up & Commercialization Phase (2026–2030) will drive full-scale production—targeting 7 MMTPA at DPA and 2 MMTPA each at VOCPA and PPA—alongside the creation of hydrogen and ammonia terminals and export-ready infrastructure. Finally, the Market Expansion & Ecosystem Phase (2027–2030) will focus on integrating hydrogen into broader sectors such as steel and fertilizers, standardizing certification, implementing digital monitoring systems, and building national-level institutional capacity through a Hydrogen Centre of Excellence.

3

Inland Waterways: Enabling Clean and Efficient Navigation

3.1 Introduction

India's inland waterways hold immense potential as a sustainable mode of transport, offering an energy-efficient, cost-effective, and environmentally friendly alternative to road and rail networks. Recent data from the Inland Waterways Authority of India (IWAI) highlights this growing significance, with cargo movement rising from 126.15 MMT in 2022–23 to 133.03 MMT in 2023–24—a 5.45% increase. Similarly, cargo traffic at Indian ports reached 1540.34 MMT in 2023–24, marking a 7.5% year-on-year growth and reflecting a robust and expanding maritime ecosystem. However, this continuous upward trajectory—while vital for economic advancement—raises urgent concerns regarding energy consumption, emissions, waste discharge, and the overall ecological footprint of the sector. To address these challenges and ensure long-term sustainability, a shift towards green development of inland waterways is essential. This involves integrating clean propulsion technologies, eco-sensitive infrastructure, and sustainable operational practices across the waterway ecosystem, aligning with India's broader goals of decarbonizing its transport sector and fulfilling its climate commitments.

3.2 Regulatory Framework and Policy Guidelines

To support this transition, a comprehensive regulatory framework has been established under the *Inland Vessels Act, 2021*, published in August 2021. This Act modernizes the legal architecture governing inland navigation and safety. Following this, 11 rules were framed and published by the Inland Waterways Authority of India (IWAI) in June 2022 and 2024, providing operational clarity and enforcement mechanisms. Further, 6 additional rules, including specific provisions for special category vessels and green vessels, are currently under process, indicating a targeted regulatory approach to promote sustainable vessel technologies and operations.

Complementing the regulatory efforts is the evolving policy framework, particularly the introduction of the 'Harit Nauka' Inland Vessels Green Transition Guidelines. These guidelines serve as a roadmap for accelerating the shift to eco-friendly propulsion systems, energy-efficient designs, and reduced carbon footprints across the inland water transport ecosystem. The Harit Nauka initiative embodies

India's commitment to a green maritime future, encouraging innovation, investment, and public-private partnerships to drive the adoption of cleaner technologies in vessel construction, retrofitting, and operations. Together, these frameworks are laying the foundation for a greener, more resilient inland waterways network.

3.3 India's Decarbonization Status and Targets for the Inland Waterways Sector

The Inland Waterways Authority of India (IWAI) has adopted a comprehensive set of green initiatives aimed at transforming India's inland water transport sector into a more environmentally sustainable system. The table reflects IWAI's commitment to decarbonization and energy efficiency across key operational areas. One of the major initiatives is the adoption of renewable energy, where the target is to achieve 1.89 MW by 2030. Although the current installation stands at only 0.06 MW (2.12% progress), a significant milestone was reached with the signing of an MoU with EESL in April 2025. Shore-to-ship electricity has already achieved 100% implementation across 16 terminals, reducing emissions from vessels at berth.

Another core area of focus is improving energy efficiency through modern equipment and infrastructure. Out of a total of 6,975 equipment units, 6,651 have already been upgraded to energy-efficient models—achieving 95% progress. The full transition is planned upon completion of the remaining equipment's service life. Similarly, electrification of cargo handling equipment has been fully implemented for 8 key machines. IWAI has also adopted the "Green Building" concept for its infrastructure, with three new buildings constructed and green certified at MMT Kalughat, while certification for MMT Haldia is awaited. These developments illustrate IWAI's proactive approach to embedding sustainability across operational assets.

IWAI's initiatives further extend to environmental conservation and future-forward green technologies. A green belt development plan is underway, with 345,026 sq. m of green area already developed—29% of the target—aiming for full coverage of available land (407,439 sq. m) by December 2025. One of the more ambitious long-term projects involves the creation of a hydrogen storage and dispensing station, though progress here remains limited. A proposal was submitted to the Ministry of Ports, Shipping and Waterways (MoPSW), but is currently on hold as the Department of Expenditure has not approved the plan. This table underscores both the achievements and the remaining gaps in IWAI's strategy, offering a roadmap for a greener, more sustainable inland waterways system in India.

The Status and targets for Green Initiatives for IWAI presented in table 3.3.1, including the target date of completion

Table 3.3.1: Status and targets for Green Initiatives for IWAI

Initiative	Existing/Total	Target 2030	Current Status	Progress %	Target Completion
Renewable Energy	2.82 MW	1.89 MW	0.06 MW	2.12%	Dec 2025
Shore-to-Ship Power Supply	16 Terminals	16	16	100%	Achieved
Energy Efficient Equipment (LEDs)	6975 Units	6975	6651	95%	Rolling (upon replacement)

Initiative	Existing/Total	Target 2030	Current Status	Progress %	Target Completion
Cargo Equipment Electrification	50 Units	8	8	100%	Rolling (post service life)
Green Building Certification	3 Buildings	3	3	100%	Sep 2025 (Haldia pending)
Green Belt Development	1,129,445 sqm	271,067 sqm	152,507 sqm	13.5%	Dec 2025 (33% by 2030)
Hydrogen Fuel Storage & Dispensing	Nil	1 Station	0	0%	Approval awaited from MoPSW

Digitalization are pivotal for modernizing India's inland waterways ecosystem. By integrating advanced digital tools such as real-time monitoring, navigation aids, and data-driven traffic management, IWAI aims to enhance operational efficiency, safety, and environmental compliance. Table 3.3.2 presents the current digital initiatives in IWAI organization.

Table 3.3.2: Digitalization in IWAI

Initiative	Status
National River Traffic and Navigation System (Nau Darshika)	Report launched; Draft rule under notification
Jalyan & NAVIC Portal	Launched; 12 states onboard
Stakeholder Workshops	Training workshops conducted to onboard states and stakeholders to digital platforms.

3.4 Overview of the Inland Waterways Ecosystem and its Critical Components

3.4.1 Green Inland Vessels

IWAI is steering India's inland fleet towards clean propulsion technologies. It has initiated procurement of Hybrid Electric Catamarans—eight vessels ordered from Cochin Shipyard Ltd (CSL), with two already delivered and six under construction. A Hydrogen Catamaran, developed as a prototype, has completed demonstration trials and awaits final certification. Further, a Hydrogen Vessel Procurement Project involving four hydrogen vessels and associated fuel infrastructure (worth ₹172 crore) has been submitted to the Ministry of Ports, Shipping and Waterways (MoPSW), though the Department of Expenditure (DoE) has not approved the proposal yet. Proposal has been forwarded to Director, Hydrogen mission for consideration and financial support. Confirmation awaited. These efforts underscore IWAI's commitment to next-generation, low-emission vessels.

3.4.2 Financial Assistance and Policy Framework

To support the green transition, IWAI has explored various funding and policy avenues. The proposed Harit Nauka Scheme, aimed at supporting the shift to green vessels, is currently pending approval from the DoE. Parallelly, IWAI is advocating for broader mechanisms like the Shipbuilding Financial Assistance Policy 2.0 and the Maritime Development Fund, which are designed to provide fiscal and policy backing for the industry's decarbonization. These financial instruments are crucial to offset the high upfront costs associated with new green technologies and alternative fuel vessels.

3.4.3 Water Metro Projects

In a push towards sustainable urban mobility, IWAI has identified 41 locations for developing Water Metro systems. Feasibility studies have been initiated for 17 cities, with work orders issued to Kochi Metro Rail Ltd (KMRL), and an inception report already submitted. These water metro systems are envisioned as eco-friendly passenger ferry services, particularly for urban and semi-urban areas, thereby easing congestion and promoting clean, efficient transport on inland waterways.

3.4.4 Methanol Fuel Engine Development

IWAI, under the guidance of MoPSW, is exploring methanol-based propulsion as a viable alternative fuel. A Methanol Committee has been formed to identify suitable engine manufacturers. The committee submitted its final report in December 2024, and Inputs of CSL have been received. IWAI have commented on the inputs and forwarded the same to MoPSW for consideration. A joint meeting between IWAI, CSL, and MoPSW will be convened. Methanol, being cleaner and cheaper than diesel, holds promise for reducing emissions in inland navigation, especially in cargo vessels.

Table 3.4.1 presents a comprehensive framework of the green IWT ecosystem currently functional in the country.

Table 3.4.1: Green IWT Ecosystem

Component	Initiative	Details
Green Inland Vessels	Hybrid Electric Catamarans	8 vessels (@ Rs. 12.12 Cr. each) ordered on CSL; 2 delivered, 6 under construction at HCSL. Total project cost: Rs. 144 Cr.
	Hydrogen Catamaran	1 vessel (@ Rs. 22.62 Cr.) delivered under R&D. Demonstration trials completed, IRS certification received on 20 Jun 2025.
	Hydrogen Vessel Procurement Project	DIB for 4 hydrogen vessels (@ Rs. 22.37 Cr. each) + hydrogen production infrastructure sent to MoPSW. Total cost: Rs. 172 Cr. Proposal has been submitted to Director Hydrogen Mission for consideration and financial support.
Provide Financial Assistance	Harit Nauka Scheme	Under consideration.
	Shipbuilding Financial Assistance Policy 2.0	Ongoing under Ministry consideration.
	Maritime Development Fund	Intended to support green vessel and infrastructure financing.
Water Metro	41 Locations Identified	Work order issued for feasibility studies for 17 metro cities to KMRL, Kochi. Inception report submitted.
Methanol Fuel Engines	Methanol Committee	Formed by MoPSW to identify engine manufacturers. Final report submitted to MoPSW in Dec 2024. CSL comments received. IWAI comments forwarded to Ministry. Meeting with IWAI/CSL/MoPSW to follow.

3.5 Training and Development

3.5.1 Creation of National Inland Navigation Institute- CoE

The Inland Waterways Authority of India (IWAI) has taken a strategic step toward capacity building and skill development in the inland water transport (IWT) sector through the creation of the National Inland Navigation Institute (NINI). Located in Patna, Bihar, NINI is envisioned as a premier center of excellence dedicated to training, education, and research in inland navigation and allied disciplines. The institute aims to address the growing demand for skilled manpower, modern navigation practices, and operational efficiency required to support the expanding IWT network in India. By offering specialized courses in navigation, vessel operations, port and terminal management, and logistics, NINI plays a critical role in professionalizing the sector and aligning it with international best practices.

In addition to human resource development, NINI also serves as a think tank for policy research, innovation, and sustainability in IWT. It collaborates with national and international agencies to advance research on green technologies, hydrodynamic modeling, and river training works. As India moves toward a greener and more efficient water transport system, the role of institutions like NINI becomes pivotal in bridging the knowledge and skills gap. The institute supports IWAI's broader vision of creating a robust, safe, and environmentally sustainable inland navigation ecosystem by nurturing a future-ready workforce and fostering innovation-driven growth in the sector. Figure 3.5.1 present the key locations for setting up of regional Center of Excellence.

Figure 3.5.1: Identified locations of the National Inland Navigation Institute- CoE

3.6 Way forward and Action Plan

To accelerate the green transition of India's inland water transport sector, the Inland Waterways Authority of India (IWAI) has launched several sustainability-driven initiatives. These focus on clean energy adoption, energy efficiency, eco-friendly infrastructure, and future-ready fuel systems, each with clear action plans and targets.

1. Adoption of Renewable Energy

IWAI has signed an MoU with EESL on 11 April 2025 to scale up renewable energy use across its facilities. EESL will conduct site visits and select a RESCO for implementation. The target is to achieve 100% renewable energy compliance by March 2026, which will significantly reduce IWAI's carbon footprint.

2. Adoption of Shore to Ship Electricity

IWAI has successfully implemented shore-to-ship power supply at all 16 identified terminals. This eliminates the need for vessels to use diesel while docked, reducing emissions and improving environmental conditions at ports. The initiative has met its full target.

3. Switching to Energy Efficient Equipment

Nearly 95% of IWAI's equipment, especially lighting, has been upgraded to energy-efficient alternatives such as LEDs. The remaining units will be replaced as they complete their service life, ensuring continued progress toward energy savings and reduced emissions.

4. Electrification of Cargo Handling Equipment

IWAI has electrified all targeted cargo handling equipment. The remaining diesel-operated equipment will be phased out as they age. This move supports cleaner terminal operations and aligns with IWAI's sustainability goals.

5. "Green Building" and Green Belt Development

Three new buildings have been constructed under the green building concept, with certification received for MMT Kalughat and awaited for MMT Haldia. Additionally, IWAI aims to complete 100% greening of available land by December 2025 to improve ecological sustainability.

6. Creation of Hydrogen Storage & Dispensing Station

A proposal for a hydrogen production and dispensing facility has been submitted to MoPSW but is pending DoE approval. IWAI remains committed to integrating hydrogen as a clean fuel for future inland vessels once approvals are secured.

Table 3.6.1: Action plan and timelines towards greening IWAI

Initiative	Way forward & Action Plan
Adoption of Renewable Energy	MOU signed with EESL on 11.04.2025. EESL team shall visit sites. Tendering & selection of RESCO by EESL. 100% target compliance by March 2026.
Adoption of Shore to Ship Electricity	Target achieved.
Switching to Energy Efficient Equipment	All Energy efficient equipment (LED) completed. Equipment shall be change after their service life.
Electrification of Cargo Handling Equipments	Remaining equipment would be replaced by electric equipment on completion of service life.
"Green Building" concept	Green Certificate received for MMT Kalughat & certificate awaited for MMT Haldia.
Green Belt	100% greening of available land by Dec 2025.
Creation of Hydrogen Storage & Dispensing Station	Approval sought from MoPSW for Hydrogen production facility. Proposal have been forwarded to Director, Hydrogen Mission for consideration and financial support for the project.

4

Advancing Low-Carbon Shipping

4.1 Background

India's growing maritime sector, with its extensive coastline and major ports, plays a crucial role in the country's economic development. However, this growth has come with a significant environmental cost, including high greenhouse gas emissions, air pollution, and marine degradation. In this context, there is an urgent need for a comprehensive Green Shipping Policy to guide the sustainable transformation of India's ports and shipping industry. Such a policy is essential to align India's maritime operations with its national climate commitments, including the target of achieving net-zero emissions by 2070, as well as with global standards such as the International Maritime Organization's (IMO) revised greenhouse gas reduction strategy, which calls for zero or near-zero emissions by 2050.

4.2 National Green Shipping Policy

The draft National Green Shipping Policy (NGSP) is a strategic framework aimed at transforming India's maritime sector toward greater environmental sustainability, technological innovation, and international competitiveness. Given that over 95% of India's trade by volume is carried by sea, the shipping industry plays a vital role in the nation's economy. This makes it imperative to adopt a cohesive policy approach that addresses decarbonization, ensures compliance with global environmental regulations, and facilitates the integration of green technologies across maritime operations. The NGSP envisions a sustainable maritime future by aligning domestic goals with international climate commitments and positioning India as a global leader in green shipping practices.

The policy draws upon a comprehensive review of existing maritime initiatives and addresses critical policy and implementation gaps. Beyond its environmental focus, the NGSP is positioned as a driver of economic growth and technological progress. It emphasizes reducing the carbon footprint of shipping and port operations through the adoption of clean energy solutions and emission control mechanisms, thereby enhancing India's global trade competitiveness. The policy also encourages innovation by promoting research and development in alternative fuels, vessel electrification, and low-carbon port infrastructure. Furthermore, it fosters collaboration among industry stakeholders, regulatory authorities, and financial institutions to ensure a unified and coordinated approach to decarbonization. In doing so, it strengthens India's alignment with international environmental standards and the UN Sustainable Development Goals, boosting the nation's regulatory credibility and positioning in the global maritime market.

The NGSP is supported by a detailed scenario-based analysis, which evaluates different maritime growth trajectories, policy implementation pathways, and projected emission trends. This includes medium-growth and conservative scenarios benchmarked against international emissions reduction targets, providing a resilient and adaptable strategy for future decision-making. Alongside this, a comprehensive financial analysis explores the instruments required to support green maritime investments. It highlights the importance of international partnerships, risk-sharing mechanisms, and blended financing models in mobilizing capital for the sector's decarbonization journey.

At its foundation, the NGSP proposes a set of interconnected policy interventions across three pillars: green finance, green collaboration, and green regulation. Under the green finance pillar, the policy outlines initiatives such as production-linked incentives for manufacturers of green maritime technologies, tax benefits under the Make in India scheme, and the creation of dedicated green economic zones focused on sustainable maritime manufacturing. Financial support mechanisms are also proposed for shipbuilders and port operators, including enhanced shipbuilding assistance schemes, retrofitting risk-sharing mechanisms, and dedicated innovation funds. These instruments aim to lower the cost of transitioning to sustainable practices while encouraging investments in alternative fuels, renewable energy infrastructure, and advanced vessel and port technologies. Collectively, these measures are designed to build a robust green shipping ecosystem that accelerates India's transition toward a low-carbon maritime economy.

The policy also emphasizes the importance of green collaboration, fostering strategic partnerships between domestic and international stakeholders to accelerate the transfer of clean technology, promote skill development, and enhance research and innovation in the maritime domain. Concurrently, a comprehensive set of green regulations is being proposed to ensure real-time monitoring, robust environmental auditing, and transparent reporting across all maritime activities.

4.3 Alternate Fuels

India's Future Fuel Strategy for the Maritime Sector presents an ambitious, structured approach to transform the nation into a global leader in green maritime technology. The strategy lays out a clear, time-bound roadmap aimed at driving a sustainable shift in the maritime fuel mix, scaling up indigenous green fuel production, modernizing port and vessel infrastructure, and establishing green shipping corridors to support a low-emission maritime ecosystem. Spanning the period 2025 to 2047, the roadmap outlines distinct short-, medium-, and long-term objectives, each focused on specific actions across policy, regulation, technology adoption, capacity building, and financing.

4.3.1 Targets for Alternate Fuels

The strategy aims to reduce dependency on conventional fossil fuels by progressively increasing the adoption of cleaner alternatives such as LNG in the short term (2025–2030), followed by green hydrogen, green ammonia, and other zero-carbon fuels in the medium to long term (2030–2047).

Phase I: Short-Term (2025–2030)

The immediate focus is on laying the foundational ecosystem for green shipping. Key priorities include:

- Formulating comprehensive policy and regulatory frameworks for alternative fuels
- Encouraging early adoption of Liquefied Natural Gas (LNG) as a transitional fuel
- Developing green bunkering infrastructure at major ports
- Offering incentives and subsidies for early movers investing in green fuel technologies

Phase II: Medium-Term (2030–2040)

- Building on early momentum, this phase will concentrate on: Mainstreaming the use of green hydrogen and ammonia as primary maritime fuels
- Expanding and upgrading port infrastructure to support multi-fuel bunkering operations
- Enhancing the domestic capability for green fuel production and distribution
- Implementing nationwide capacity-building initiatives to skill the workforce in green technologies

Phase III: Long-Term (2040–2047)

The final phase targets widespread decarbonization across the sector by:

- Scaling up the use of advanced alternative fuels, particularly hydrogen and ammonia
- Deploying sophisticated Monitoring, Reporting, and Verification (MRV) systems to track emissions and progress
- Achieving full integration of green technologies across India's port network and vessel fleet

4.3.1.1 Infrastructure and Fleet Modernization

A key pillar of the strategy is upgrading the maritime fleet and port infrastructure. This includes:

- Implementation of DGS Order No. 06 of 2023 to support green shipbuilding and retrofitting
- Engine modifications for multi-fuel compatibility, enabling existing vessels to transition to low-emission fuels
- Continuous upgrades of port facilities to integrate renewable energy systems, electrified equipment, and emission control measures

4.3.2 Current Status for Alternate Fuels

India's transition to alternative maritime fuels has entered its acceleration phase—LNG bunkering infrastructure and hydrogen/ammonia policy roadmaps are firmly in place, and early hydrogen vessel deployment is underway. While global supply chains for zero-emission fuels still need scaling, India is building a robust foundation to support a greener shipping future.

4.3.2.1 LNG Adoption Is Accelerating Rapidly

India's LNG bunkering market is witnessing exponential growth. In 2024, the market was valued at approximately USD 115 million, with projections estimating an increase to USD 667 million by 2030, growing at a compound annual growth rate (CAGR) of ~32% between 2024 and 2030. Additionally, the country reported USD 6.8 billion in LNG bunkering operations in 2024, expected to surge tenfold to around USD 36.3 billion by 2029 . Major ports in Gujarat and Chennai are expanding LNG terminals, and at least one LNG bunkering station is mandated for each major port by 2030.

4.3.2.2 Progress on Hydrogen-Powered Vessels & Future Fuels

India recently launched its first hydrogen-run ferry, with further projects underway to develop green energy vessels using solar and battery power. Globally, orders for methanol-fuelled ships have reached 119, ammonia vessels at 22, and hydrogen-powered ships at 12, indicating growing interest and potentially emerging opportunities for India. However, challenges remain around scaling up fuel supply chains and infrastructure before wider fleet adoption, expected realistically post-2026–2027.

4.3.3 Challenges for Alternate Fuels

The transition to alternate fuels in Indian shipping is confronted by significant economic and infrastructural challenges. One of the primary barriers is the high capital cost associated with retrofitting existing vessels or building new ships compatible with fuels such as LNG, green hydrogen, and ammonia. These fuels are currently more expensive than conventional marine fuels, and the absence of clear long-term subsidies or tax incentives discourages early adoption. Moreover, limited access to green finance, lack of insurance mechanisms, and risk aversion among financial institutions make it difficult for shipping companies—especially smaller operators—to secure the investment needed for clean energy transitions.

A major bottleneck lies in the underdeveloped fuel supply chains and port infrastructure. India lacks adequate bunkering facilities and storage systems for alternative fuels at most ports. Green fuel production—particularly for hydrogen and ammonia—is still at an early stage, and there are few large-scale commercial projects. The absence of multi-fuel-ready infrastructure and standardized bunkering protocols hinders operational readiness. Additionally, technological immaturity and safety concerns—especially for handling toxic or flammable fuels—pose operational risks. The shortage of trained personnel and lack of national technical standards further compounds the problem.

From a regulatory standpoint, policy uncertainty and fragmented governance slow down momentum. India's maritime regulations on emissions, alternate fuel standards, and vessel design are still evolving and lack robust enforcement. Without a comprehensive framework on carbon pricing, operational incentives, or fuel mandates, private players remain hesitant to invest. Furthermore, the limited role of domestic research and development in green maritime technologies means India remains dependent on imported know-how, restricting innovation and increasing costs. Addressing these challenges will require a coordinated, long-term policy approach that integrates regulation, infrastructure development, financial support, and international collaboration.

4.3.4 Action Plan

In alignment with the upcoming National Green Shipping Policy (NGSP) 2025, NAVIC Cell 3 proposes a multi-layered action plan for accelerating the adoption of alternative fuels and green shipping technologies across India's maritime sector. The NGSP recognizes green shipping as a strategic pillar to achieve India's 2070 net-zero commitment and IMO's 2050 decarbonisation targets, and offers a structured roadmap to guide vessel transition, technology localization, and compliance with international benchmarks.

NAVIC Cell 3 Action Plan – Key Areas of Focus:

1. Operationalization of the National Green Ship Definition and Certification Framework
    a. Support the development of a certification system to recognize vessels adopting low-/zero-emission technologies (fuel cells, electric propulsion, hybrid systems, etc.), aligned with IMO instruments (EEDI, EEXI, CII).
    b. Ensure interoperability with international certifications and access to green finance mechanisms.
2. Promotion of Alternative Marine Fuels
    a. Facilitate pilot projects using green methanol, ammonia, hydrogen, and biofuels, with technical inputs from public shipyards (CSL, GSL, HSL) and integration into local supply chains.
    b. Identify and support bunkering infrastructure development at select ports and IWAI terminals
3. Fleet Modernization and Retrofit Support
    a. Promote retrofitting of existing fleets through financial incentives, green transition grants, and performance-linked financing frameworks.
    b. Explore ESG-linked instruments for green ship retrofits.
4. Digitalization for Energy Efficiency
    a. Mainstream digital ship operations using tools like Just-in-Time (JIT) arrivals, smart routing, and performance analytics.
    b. Coordinate with NLP-Marine and EBS platforms for emissions data monitoring and voyage efficiency.
5. Support for Green Shipbuilding under 'Make in India'
    a. Leverage NGSP's industrial vision to transform Indian shipyards into global design and manufacturing hubs for clean energy vessels.
    b. Prioritize skill development and R&D collaborations through the National Ship Design Centre and Green Maritime Skill Training Missions.
6. Incentives and Enablers
    a. Align green vessel transition with MRV frameworks, baseline inventory building, and integration into carbon markets.
7. Constitution of Decarbonisation Cell (as per MAKV 2047)
    a. The structure constitutes members form CSL, IRS, DRDO, IMU, Major Ports, CSIR,IITs (Mumbai, Delhi, Palakkad & Madras) and Industry players, with support from MNRE, MoEFCC, MoC, MoPSW, DGS.

This NAVIC Cell 3 action framework is designed to converge with NGSP's system-level ambitions, particularly the creation of Green Ship Corridors, enabling ZEV (Zero Emission Vessels) demonstration projects, and anchoring India's role as a pilot country under IMO's Green Voyage 2050.

4.3.5 Good Practices

Some of the good practices adopted by different countries leaders in the adoption of alternate / clean fuels for the green shipping sector are presented in Table 4.3.1 & 4.3.2.

Table 4.3.1: Country wise good practices

Country	Good practices and take aways
Norway	• Support pilot projects, feasibility studies, and green ship renewal through sector-wide collaboration. • Prioritize R&D in clean propulsion and alternative fuels with public sector backing. • Develop financial mechanisms (subsidies, grants, loans, green bonds) for retrofitting, infrastructure, and fuel pilot projects.
Singapore	• Adopt an integrated framework linking green shipping, ports, technology, finance, and regulations. • Leverage India's strategic location to develop an alternative fuel hub with LNG bunkering and emerging fuels. • Establish green corridors with global ports for decarbonization, low-emission fuels, and sustainable trade routes.
South Korea	• Promote conversion of Indian-flagged vessels to greener alternatives with incentives like reduced port dues. • Boosting shipbuilding and maritime industries leading to job creation and economic growth. • Manage marine debris through prevention, collection, and recycling to support a circular economy.
Japan	• Fund zero-emission vessel development using hydrogen, ammonia, and LNG. • Develop infrastructure for electric shipping and vessels. • Invest in workforce training for green maritime technologies.

Table 4.3.2: Key Takeaways from global schemes and programs

Initiative	Key Takeaways for NGSP
Green Shipping Challenge	• Encourage time-bound decarbonization pledges aligned with India's climate goals. • Fund green corridors, pilot projects, and technology innovations. • Promote Digital Twins and operational tools for emissions optimization. • Strengthen global collaboration for knowledge-sharing and alignment.
Zero Emission Maritime Buyers Alliance (ZEMBA)	• Form buyer alliances to scale demand for zero emissions shipping and cleaner fuels. Prepare e-fuels by assessing supply, incentivizing production, and ensuring fleet compatibility. • Build partnerships with logistics firms and environmental groups for global decarbonization.

Initiative	Key Takeaways for NGSP
Mission Innovation – Zero-Emission Shipping	• Set milestones for deploying zero-emission vessels. • Develop zero-emission bunkering hubs at strategic ports for global fuel readiness. • Ensure well-to-wake decarbonization by addressing full lifecycle emissions of fuels.
The SENSREC Project	• Align ship recycling practices with international conventions for safety and sustainability. • Upgrade recycling facilities for safer, eco-friendly waste management.
Katalyst	• Implement a transparent registry to track and verify green fuel use. • Allow carriers flexibility in choosing green fuels to reduce administrative burdens. • Foster industry partnerships for sustainable decarbonization in maritime.
H2Global	• Facilitate markets for clean hydrogen and low-emission fuels through mechanisms like H2Global. • Foster public-private partnerships to accelerate low-emission technologies and infrastructure. • Enable India's involvement in the global hydrogen market for export and import of clean energy products.

4.4 Cochin Shipyard Limited – Shipbuilding & Ship Repair Transition

Cochin Shipyard Limited (CSL) is making notable strides in the transition toward sustainable maritime operations through its growing portfolio of green shipbuilding and repair projects. Currently, CSL's order book includes 25 green vessels, with an estimated value of approximately INR 60 crore from Indian clients and INR 4,100 crore from foreign clients. These vessels represent about 40% of the company's ongoing commercial shipbuilding orders, indicating a substantial shift in market demand toward eco-friendly solutions. The ongoing projects span a wide variety of vessel types, including Commissioning Service Operation Vessels (CSOVs), Service Operation Vessels (SOVs), catamarans, cargo ships, and feeder container vessels.

The company is incorporating a diverse set of alternative fuel technologies into its shipbuilding practices, such as battery-electric propulsion, hydrogen fuel cells, methanol, and wind-assisted systems. This technological diversification reflects CSL's commitment to aligning with global green shipping standards and reducing carbon emissions across vessel categories. Many of these vessels are tailored to international clients, especially in Europe, where regulatory pressures and market readiness for clean fuel technologies are driving demand.

In addition to its confirmed orders, CSL has a strong pipeline of 26 additional green vessels currently under discussion. These include 15 boats for Kochi Metro Rail Limited (KMRL), four hydrogen fuel cell vessels for the IWAI, two feeder container ships and three LNG-fueled container vessels for European clients, and two green tugs compliant with the GTTP. This expanding pipeline underscores Cochin Shipyard's emerging leadership in sustainable shipbuilding, positioning it as a critical enabler of India's green maritime ambitions both domestically and globally.

4.5 Shipping Corporation of India (SCI)

SCI is actively advancing its green shipping agenda through initiatives focused on assets capable of using alternative fuels in future and adoption of energy efficient technology on existing vessels. A major component of this strategy is the tendering for acquisition of Platform Supply Vessels (PSVs) equipped with green methanol propulsion. SCI has floated tenders for two PSVs with an option for two more. The tender is at advance stage of evaluation and is likely to be awarded soon with deliveries anticipated by 2028. The vessels shall also be equipped to receive Shore Power Supply at Indian Ports. In parallel, under Phase 1 of the GTTP, SCI plans to bid and acquire green tugs contingent on the tender outcome. will also be part of the Green Shipping Corridor between VoCPA and DPA and a tripartite MOU to operationalise it shall be executed shortly.

SCI is implementing a range of technical retrofitting measures to reduce greenhouse gas (GHG) emissions across its fleet. These include the installation of Propeller Boss Cap Fins on select vessels during dry docking, which are expected to yield about 2% GHG reduction, with one vessel already completed. Furthermore, SCI has conducted a successful trial of B24 biofuel blend on one vessel, achieving a significant 19% GHG reduction. Encouraged by this outcome, vessels undergoing dry docking are being prepared with B24-ready bunker tanks, aiming for an 18–19% emissions reduction when the fuel is used.

To further improve energy efficiency, SCI is also adopting low-friction hull coatings for its international fleet. This technology, when applied during routine dry docking, can result in approximately 4% GHG reduction by minimizing drag and improving fuel efficiency. One vessel has already been treated, with more expected to follow based on the outcome of vessel's performance applied with such coating.

Installation of LED lights has been completed on Bulk carriers, Container vessels, Offshore vessels and in phased manner on tankers. Apart from above initiatives, all vessels in SCI fleet strictly comply with MARPOL regulations. This includes proper segregation and disposal of garbage, adherence to sewage treatment and discharge norms to ensure responsible marine operations.

These combined initiatives reflect SCI's commitment to decarbonizing its operations through a multi-pronged strategy involving both clean fuel transition and retrofitting of existing assets, thereby positioning itself as a key player in India's maritime sustainability journey.

5

Maritime Skills for a Green Future

5.1 Background

The success of India's green maritime transition ultimately rests on human and institutional capacity. While ports, inland terminals, and shipyards are advancing through the installation of shore power systems, electrification of cranes and tugs, pilot projects on hydrogen and methanol fuels, and digitalisation of operations, the long-term effectiveness of these measures depends on the availability of skilled personnel, adaptive management systems, and robust regulatory oversight. Strengthening competencies and institutional frameworks will be essential to ensure that technological investments translate into measurable environmental and operational gains.

The Changing Landscape of Maritime Capacity Building

The Government of India's policy thrust during recent period has been remarkable. A ₹69,725 crore package launched in late 2024 seeks to revitalise maritime ecosystem through expanding domestic shipbuilding capacity, introducing innovative financing mechanisms, advancing technical and skill development, and implementing comprehensive institutional reforms.

Under the Shipbuilding Development Scheme, ₹19,989 crore has been earmarked to scale domestic production to 4.5 million Gross Tonnage annually and to establish mega shipbuilding clusters and ship technology centres. Complementing this is the extension of the Shipbuilding Financial Assistance Scheme till 2036, supported by a ₹24,736 crore corpus, and the creation of a Maritime Development Fund to enhance access to long-term project financing.

At the same time, India's port infrastructure is expanding at an unprecedented pace. Major ports alone reached a capacity of 1,630 million tonnes per annum (MTPA), with total port capacity across India standing at 2,690 MTPA as of March 2024. The Maritime India Vision 2030 and Amrit Kaal Vision 2047 envisage this scaling up to 10,000 MTPA, alongside cleaner operations, energy efficiency, and climate resilience.

Modernisation projects worth over ₹32,000 crore have already been completed, contributing 230 MTPA of additional capacity, while upcoming ports such as Vadhavan will further reinforce India's container handling strength. The Jawaharlal Nehru Port Authority (JNPA) crossed the milestone of 10 million TEUs in 2025, setting a new benchmark in operational efficiency and smart port technology adoption.

A Human Capital Pivot

The true hallmark of this maritime transformation lies in people — the engineers, operators, managers, and policymakers who will steer India's ports and ships into a low-emission, high-technology era. Recognising this, the government has made capacity building and skill development a national priority.

A target has been set to train 50,000 youth in world-class maritime skills over the next decade, particularly from the North-Eastern region, through initiatives like the Maritime Skill Development Centre (Guwahati) and the Centre of Excellence at Dibrugarh.

Furthermore, the Indian Maritime University (IMU) and Industrial Training Institutes (ITIs) are being aligned under a new maritime skilling framework that includes collaborations with the Indian Navy, National Cadet Corps (NCC), and industry partners. The upcoming Indian Ports Act, 2025 reinforces this direction by establishing the Maritime State Development Council (MSDC) — providing a statutory platform for Centre–State coordination on capacity building, port modernisation, and maritime education.

Why This Chapter Matters

Building physical capacity alone is no longer sufficient. Human and institutional capacity building is now the defining pillar that will determine how effectively India's maritime ambitions are realised. This chapter, therefore, focuses on:

Strengthening the ecosystem for maritime education, training, and re-skilling, aligned to national and international best practices;

Exploring how institutes such as Indian Maritime University (IMU) and Maritime Training Institutes (MTIs), IITs, ITIs and National Inland Navigation Institute (NINI) can jointly design and deliver next-generation courses in green port management, alternative fuels, digital transformation, and environmental compliance;

Drawing lessons from leading global models, such as the World Maritime University's Executive and Professional Development Courses (EPDCs), to propose an adaptable Indian framework for maritime executives and practitioners; and

Highlighting the NINI as a case study in practical, hands-on, and industry-oriented capacity building that can be replicated across port ecosystems.

Towards a Skilled and Sustainable Maritime Future

India's maritime capacity building journey is transitioning from conventional seafaring and port operations training to a holistic, future-oriented model — one that blends technical proficiency, environmental literacy, and strategic foresight. The integration of digital technologies, renewable energy systems, and decarbonisation imperatives demands a workforce that can think beyond silos, operate across disciplines, and innovate for sustainability.

As India progresses towards the targets set under the Maritime India Vision 2030 and Amrit Kaal Vision 2047, strengthening human capital is integral to building national maritime resilience. The following sections of this chapter outline how this can be achieved through modular, impact-driven, and globally benchmarked training pathways — building the maritime professionals of tomorrow, today.

5.2 Institutional Models for Maritime Capacity Building: Lessons from India and the World

The National Inland Navigation Institute (NINI), Patna — A Living Example of Applied Maritime Training

As India expands its network of inland waterways and green port operations, the National Inland Navigation Institute (NINI) at Patna stands out as a successful homegrown model of applied maritime training. Established under the Inland Waterways Authority of India (IWAI) and supported by the Ministry of Ports, Shipping and Waterways (MoPSW), NINI functions as a Centre of Excellence for Inland Water Transport (IWT) — nurturing a new generation of navigators, engineers, and port operators.

NINI's pedagogy is anchored in hands-on, industry-oriented learning. Its training framework combines classroom instruction, simulator-based exercises, and field attachments on operational vessels and terminals. The institute's infrastructure includes state-of-the-art navigation simulators, workshops for mechanical and electrical systems, computer-based e-navigation labs, and hydrographic training facilities — enabling trainees to gain real-world experience under supervised conditions.

A hallmark of NINI's approach is its alignment with the National Skill Qualification Framework (NSQF) and the Directorate General of Shipping (DGS) certification pathways. This ensures that its courses are nationally recognised and industry-relevant, ranging from foundational certificates for deck and engine personnel to advanced modules on port management, cargo handling, hydrographic surveying, and vessel maintenance.

Beyond technical proficiency, NINI instils professional ethos and safety discipline — essential attributes for operating in environmentally sensitive inland and coastal ecosystems. Its outreach to youth from riverine states, particularly in Bihar, West Bengal, and the Northeast, has created an inclusive training pipeline that supports both employability and regional development.

In recent years, NINI has been evolving towards broader sustainability themes, integrating modules on environmental protection, energy efficiency, and digital navigation systems. This makes it an ideal nucleus for piloting "Green Inland Navigation" and "Sustainable Port Operations" training packages, in collaboration with IMU, NCoEGPS, and MoPSW's Capacity Building Division. The model can be extended to other maritime clusters through Maritime Skill Development Centres (MSDCs) and port-based training academies.

NINI thus exemplifies how a focused, technically equipped, and practically oriented institution can create real impact on workforce readiness. Its success also highlights the value of institutional autonomy, close industry linkage, and outcome-based pedagogy — principles that can be replicated across India's maritime training ecosystem.

World Maritime University (WMU), Malmö — Global Benchmark for Executive and Professional Development

While NINI represents excellence in technical and field-level training, the World Maritime University (WMU) in Malmö, Sweden, serves as the global benchmark for executive and professional development in the maritime domain. Established by the International Maritime Organization (IMO), WMU provides postgraduate and mid-career education that directly addresses the evolving challenges of maritime governance, sustainability, and innovation.

A distinctive feature of WMU's capacity building approach lies in its Executive and Professional Development Courses (EPDCs). These are short-duration, high-impact programs designed to provide targeted upskilling for mid- and senior-level maritime professionals worldwide. WMU's EPDCs have trained thousands of officials — from port authorities, ministries, classification societies, and shipping lines — on subjects ranging from maritime safety and environmental protection to digital transformation, alternative fuels, policy formulation, and ESG strategy.

What makes the EPDC model effective is its co-design philosophy. Each course is developed in partnership with the client — often a national maritime administration, port authority, or international organisation — ensuring that content is context-specific and outcome-driven. Participants are encouraged to engage in case-based learning, simulations, and group projects that link global best practices to local policy or operational challenges.

WMU's expertise in curriculum design, its international faculty pool, and its multi-stakeholder learning environment ensure that graduates not only gain technical and strategic knowledge but also build networks of collaboration across nations and disciplines. The courses are typically delivered in five-day intensive formats, hosted either in Malmö or at the client's location, allowing flexibility and accessibility for working professionals.

For India, the WMU model offers a ready template for executive-level capacity building within the framework of IMU and other similar organisations. Adapting the EPDC approach to Indian conditions could help design a suite of Executive and Professional Development Programs (EPDPs) — focusing on topics such as Green Port Management, Alternative Fuels and Bunkering Safety, Digital Port Governance, and Maritime Policy Implementation.

Towards an Indian Model of Maritime Excellence

Taken together, the NINI and WMU models represent two complementary pillars of capacity building — the first rooted in technical, operational, and simulator-based training, and the second in strategic, policy-oriented, and executive learning.

India's future maritime skilling framework can effectively integrate both:

NINI and MSDCs can anchor the *technical and operational tier*, delivering practical, field-ready training.

IMU, supported by MoPSW and international partners like WMU, can anchor the *executive and leadership tier*, creating a cadre of maritime professionals capable of managing sustainability transitions, innovation strategies, and global partnerships.

Establishing this dual-tier approach will not only address immediate manpower requirements but also build the institutional muscle needed to achieve India's long-term Maritime Vision 2047 goals. As the sector embraces digitalisation, decarbonisation, and diversification, such an integrated framework will ensure that skills development remains the backbone of maritime transformation.

5.3 Green Skills Curriculum and Modular Training Pathways – Global Best Practices

India's maritime sector is entering a period of unprecedented technological and environmental transformation. To meet the dual imperatives of operational excellence and decarbonisation, workforce development must extend beyond traditional seafaring and port operations. A green skills curriculum, delivered through modular, stackable pathways, ensures that personnel at every level—from operational staff to senior executives—can contribute effectively to India's maritime sustainability goals.

5.3.1 Key Skill Domains and Global Best Practices

The curriculum is structured around four core domains, integrating lessons from leading international practices:

1. Green Port Operations and Sustainability Practices
   - » Energy-efficient terminal operations, waste management, and pollution control.
   - » Shore-to-ship power integration, electrification of port equipment, and adoption of renewable energy solutions.
   - » Global example: Research from Southeast Asia emphasizes embedding green technologies into maritime curricula via simulation labs, workshops, and industry-driven curriculum updates, supported by robust feedback mechanisms. This significantly improves sustainability awareness and operational engagement.
2. Alternative Fuels and Energy Transition
   - » Handling hydrogen, ammonia, methanol, LNG, and battery-electric propulsion safely and efficiently.
   - » Fuel logistics, bunkering procedures, and emissions monitoring.
   - » Maintenance and troubleshooting for hybrid and electric vessel systems.
   - » Global example: European studies demonstrate that blending hands-on practical modules with digital tools allows seafarers and port personnel to upskill effectively in alternative fuels and energy-efficient operations.
3. Digitalisation and Smart Port Management
   - » Port Community Systems (PCS), terminal automation, and IoT-enabled asset monitoring.
   - » Data analytics for operational efficiency, predictive maintenance, and ESG compliance.
   - » Cybersecurity fundamentals for ports and shipping operations.
   - » Global example: Indonesia's holistic maritime literacy framework highlights interdisciplinary training combining digital, operational, and policy knowledge to strengthen sustainability decision-making across port ecosystems.
4. Regulatory, Safety, and ESG Compliance
   - » IMO and national maritime regulations, including environmental and safety standards.
   - » Risk assessment, incident response, and safety drills.

» ESG reporting, corporate social responsibility, and sustainability governance.

» Global example: Actionable "sustainability thinking" frameworks identify sub-competencies like climate strategy, resource efficiency, and ethical decision-making, with competency-based assessments aligned to industry needs.

5.3.2 Executive Modules: Leadership and Strategic Decision-Making

For senior officials, policymakers, and port CEOs, Executive and Professional Development Programs (EPDPs) focus on strategy, policy, and cross-sector integration:

- Green Port Management & Governance: Frameworks for energy transition, ESG implementation, and climate resilience.
- Policy & Regulatory Compliance: Understanding national and international maritime regulations, including IMO Revised GHG Strategy 2023 and Indian Ports Act 2025.
- Maritime Finance & Green Investment: Leveraging PPP models, the Maritime Development Fund, and climate financing for decarbonisation initiatives.
- Innovation & Change Leadership: Leading digital transformation, fostering sustainability culture, and developing adaptive workforce capacity.

Delivery: 3–5 day intensive modules, blended learning, simulations, and case-based projects, featuring faculty from IMU, IITs, NCoEGPS, and international partners such as WMU, DNV etc. Certification is awarded by IMU with DGS endorsement where statutory knowledge is required.

Global best practice: WMU and European models show that stackable, short-duration, competency-focused courses (e.g., "Carbon Management 101," "Alternative Fuels Basics") allow executives to upskill continuously and respond to technological and environmental changes effectively.

5.3.3 Technical and Operational Modules: Applied Skills

For engineers, operators, technicians, and supervisors, hands-on operational modules develop field-ready competencies:

- Simulator-Based Navigation & Vessel Handling: Inland and coastal scenarios with energy-efficient manoeuvres and alternative fuel operations.
- Port Equipment Operations: Electric and hybrid cranes, automated cargo systems, and berth-side energy optimisation.
- Maintenance Clinics: OEM-led training on engine systems, propulsion, and electrical/battery systems.
- Internships and Shipboard Attachments: Practical experience via SCI and major ports for exposure to real-world operations and green technology deployment.

Certification aligns with NSQF levels, DGS statutory compliance, and IMU accreditation, ensuring national recognition and international employability.

Global best practice: The UK's Green Skills Matrix provides an innovative reference for stackable training pathways, enabling maritime professionals to select modules appropriate to their role and career stage. Similarly, blended digital and practical delivery, as practiced in Europe and Southeast Asia, maximizes accessibility and effectiveness for upskilling the current workforce.

5.3.4 Modular and Stackable Learning Pathways

- Modules are stand-alone yet stackable, enabling personnel to progress from foundational to advanced technical or executive levels.
- Continuous learning is supported through e-modules, micro-certifications, and knowledge portals hosted by NCoEGPS.
- Train-the-Trainer initiatives build capacity at NINI, MSDCs, and port academies, ensuring scalability and sustainability.

5.3.5 Regional and Inclusive Focus

- Priority access for youth from riverine and North-Eastern states, ensuring equitable career opportunities.
- Training locations across NINI, MSDCs, and port academies allow regional skill development and practical exposure.
- Industry-led internships and mentorship programs support placement and career pathways while reinforcing sustainability literacy.

5.4 Industry-Academia-Government Collaboration Mechanisms

The successful development of a green maritime workforce requires more than curriculum design—it demands strong collaboration between industry, academic institutions, and government agencies. Such partnerships ensure that training remains practical, current, and aligned with both operational realities and sustainability goals. India's experience, coupled with global best practices, offers valuable insights into building an integrated ecosystem that bridges theory, practice, and policy.

Academic Institutions as Knowledge Hubs

Institutions like the Indian Maritime University (IMU), NINI, and Maritime Skill Development Centres (MSDCs) play a central role in translating global best practices into locally relevant training. IMU leads academic and executive programs, develops curricula in collaboration with NCoEGPS, and ensures certification through DGS where statutory compliance is required. NINI and MSDCs provide hands-on, simulator-based, and field training, allowing students and trainees to experience real-world operations in ports, inland waterways, and vessels.

Globally, universities and training centres that integrate experiential learning and industry engagement—such as WMU in Sweden—demonstrate that combining classroom instruction with applied, project-based learning enhances both technical skills and strategic thinking. In Southeast Asia, for example, partnership-driven curriculum updates and regular feedback loops with industry stakeholders ensure that graduates are immediately employable and environmentally conscious.

Industry as a Practical Platform

Shipping companies, port operators, OEMs, and classification societies form the backbone of applied training. The Shipping Corporation of India (SCI), along with other major shipping companies, provides trainees with access to fleet operations, shipboard internships, and pilot projects involving alternative fuels and electric harbour craft. Ports contribute berth-side demonstrations, operational simulations, and access to automated terminal systems, enabling trainees to apply classroom and simulator-based knowledge in live operational settings.

OEMs and classification societies bring technical expertise, safety standards, and equipment-specific knowledge to the training ecosystem. They conduct maintenance clinics, co-design specialized modules, and support R&D initiatives. International collaborations, such as faculty exchanges with WMU or joint programs with IMO, further enrich learning by exposing trainees to global best practices and standards.

Government as Facilitator and Enabler

The Ministry of Ports, Shipping and Waterways (MoPSW), through NAVIC Cell 3, provides strategic direction, policy guidance, and funding to integrate green technologies and practices into maritime training. The Directorate General of Shipping (DGS) ensures statutory compliance, accreditation, and quality assurance for courses, while also monitoring adherence to safety and environmental standards. Through these mechanisms, government agencies create an enabling environment where industry and academia can innovate, pilot, and scale green skills initiatives effectively.

Integrated Collaboration in Practice

A collaborative approach also extends to curriculum co-design, internships, and faculty exchange programs. For instance, NCoEGPS curates modular green skills content, links industry case studies with practical exercises, and supports pilot programs with SCI and port operators. These programs are regularly evaluated and updated based on outcomes, ensuring continuous improvement.

International experience underscores the benefits of such integration. The UK's Green Skills Matrix, for example, provides a structured overview of stackable training units mapped to career stages, bridging academic learning with industry needs. In Europe and Southeast Asia, multi-stakeholder collaboration in maritime education has consistently led to faster adoption of sustainable technologies, higher employability, and stronger alignment between workforce skills and environmental targets.

Regional Inclusivity and Capacity Building

Collaboration mechanisms also address regional development and inclusivity. Partnerships between central agencies, local training centres, and ports provide access to youth from riverine and North-Eastern regions, creating equitable career pathways. Industry and academia jointly mentor trainees, ensuring that technical knowledge is complemented by operational experience, sustainability awareness, and career guidance.

In essence, an effective industry-academia-government ecosystem integrates knowledge creation, practical experience, regulatory compliance, and strategic oversight. By fostering sustained collaboration, India can ensure that its maritime workforce is not only technically competent but also environmentally conscious, globally aware, and ready to lead the country's green maritime transition.

5.5 Recommendations: Designing a Collaborative Framework for Maritime Capacity Building in India

Building a future-ready maritime workforce requires a cohesive framework where policy, academia, industry, and operational training work in synergy. Drawing from the global and national examples highlighted in Sections 5.3 and 5.4, India can adopt a dual-tiered, modular, and collaborative approach that ensures both technical excellence and executive leadership in green maritime operations.

5.5.1 Integrating Dual-Tiered Training with Stakeholder Collaboration

The workforce framework should reflect the dual-tiered approach:

- The Executive & Leadership Tier targets senior officials, port CEOs, and policymakers. It focuses on strategic management, ESG leadership, and innovation adoption. Executive modules, delivered through IMU/EPDC-style programs, incorporate global best practices from WMU and European models, using case studies, simulations, and action planning workshops.
- The Technical & Operational Tier addresses engineers, technicians, operators, and supervisors. Training combines hands-on practical learning, simulator exercises, shipboard attachments, and berth-side demonstrations. NINI and MSDCs deliver operational modules, while industry partners such as SCI, OEMs, and ports provide real-world exposure, pilot projects, and internships. DGS ensures statutory compliance and certification, maintaining national and international standards.

This integration ensures that knowledge creation, practical application, and strategic decision-making are aligned within the same collaborative ecosystem, reinforcing the points discussed in Section 5.4.

5.5.2 Prioritized Green Skill Domains

Based on Sections 5.3 and 5.4, the chapter recommends focusing on eight pragmatic skill domains that align with India's green maritime transition:

1. Green Port Operations & Strategic Management: Leadership, ESG strategy, green concession frameworks, and stakeholder engagement. Critical for decision-making and organizational sustainability. Delivered as executive EPDP modules with action-planning exercises.
2. Renewable-Energy & Storage Systems for Ports: Solar PV design, grid integration (RESCO/open access), energy storage, and O&M. Practical labs and case studies prepare port teams and energy managers for operational implementation.
3. Shore-to-Ship (Cold-Ironing) Operations: Electrical safety, high-voltage management, cable handling, tariff models, and port-ship coordination. Classroom learning is complemented by berth-side demonstrations for operational realism.
4. Electrification & Maintenance of Port Equipment and Electric Harbour Craft: Battery systems, predictive maintenance, retrofit limitations, OEM engagement, and lifecycle costing. Simulator exercises and OEM-led clinics support skill-building for the GTTP rollout.
5. Alternative Fuels & Bunkering Safety (H_2, Methanol, LNG, Ammonia): Safe storage, dispensing practices, port bunkering protocols, regulatory compliance, and emergency response. Scenario drills and tabletop exercises strengthen readiness.

6. Pollution Control & Ballast Water Management: Compliance with BWM conventions, oily waste reception, effluent management, and practical technician training on BWT plants.
7. Digital & Data Skills for Ports: Emissions accounting, GHG inventory, predictive analytics, and Port Community Systems. Hands-on labs teach KPI extraction and environmental performance monitoring.
8. Green HR & Institutional Capacity: Embedding green competencies in job descriptions, linking training to performance appraisal, and gender-responsive recruitment. Builds organizational capability for sustainability.

These domains are stackable and modular, allowing progression from foundational to advanced skills, ensuring continuity between operational, technical, and executive training pathways as discussed in Section 5.3.

5.5.3 Operationalizing Collaboration Across Stakeholders

Effective implementation depends on active collaboration among government, academia, and industry, as outlined in Section 5.4:

- Government (MoPSW, DGS): Provides strategic direction, funding, statutory oversight, and certification. DGS ensures national and international compliance.
- Academic Institutions (IMU, NINI, MSDCs): Lead curriculum design, certification, and delivery, combining classroom learning with simulations and practical exercises.
- Industry Partners (SCI, Major Ports, OEMs): Provide operational platforms, fleet access, pilot projects, and co-financing for training infrastructure.
- NCoEGPS: Acts as the knowledge hub, curating green curricula, linking national and international expertise, hosting e-learning platforms, and facilitating knowledge-sharing across the ecosystem.

By embedding the dual-tiered model into this collaborative network, the framework ensures learning remains relevant, practical, and strategically aligned, directly supporting NAVIC Cell 3's green maritime objectives.

5.5.4 Regional Inclusivity and Continuous Learning

The framework prioritizes regional inclusivity, providing access to youth from riverine and North-Eastern states. Stackable modules, micro-certifications, and e-learning platforms ensure lifelong learning, enabling personnel to upskill progressively. Industry-led mentorship, internships, and placement pathways transform knowledge into tangible career opportunities, strengthening workforce readiness while fostering sustainability culture.

5.5.5 Continuous Monitoring and Improvement

A dynamic feedback loop is essential. Training outcomes, adoption of green technologies, and alignment with regulatory frameworks should be regularly monitored and evaluated. Lessons learned should feed back into curriculum updates, practical exercises, and executive programs, ensuring that capacity-building efforts remain current, effective, and aligned with India's Maritime India Vision 2030 and Amrit Kaal Vision 2047.

5.5.6 Green HR and Institutional Capacity

A sustainable maritime workforce is not built through technical training alone—it also requires organizational structures, policies, and human resource practices that embed environmental responsibility and green competencies into the very fabric of maritime institutions. Green HR ensures that sustainability is not an add-on but a core part of institutional culture and talent management.

Key Elements of Green HR in Ports and Maritime Organizations:

- Competency Mapping: Job descriptions, performance appraisals, and career pathways should integrate green skills. For example, operational roles may include competencies in alternative fuel handling, energy-efficient equipment operation, or ballast water management, while leadership roles focus on ESG strategy, green procurement, and stakeholder engagement.
- Training Integration: Green HR coordinates with the dual-tiered training framework to ensure employees at all levels have access to appropriate technical, digital, and executive development programs. Modular training pathways, as outlined in Sections 5.3 and 5.5, are mapped to individual career stages, enabling progressive upskilling and reskilling.
- Recruitment and Inclusion: Gender-responsive and regionally inclusive recruitment policies expand access to green maritime careers, particularly for youth from riverine and North-Eastern states. This enhances workforce diversity while supporting equitable participation in India's maritime transition.
- Performance and Incentives: Linking green competencies to key performance indicators (KPIs) and appraisals reinforces accountability and motivates adoption of sustainable practices. Incentive structures can reward energy savings, innovation in green operations, or successful completion of specialized training modules.
- Organizational Culture: Embedding sustainability into organizational norms—from daily operations to strategic planning—ensures that green initiatives are internalized rather than treated as compliance obligations. Workshops, awareness campaigns, and leadership engagement play a critical role in fostering this culture.

By implementing Green HR practices, ports, shipping companies, and maritime institutions can institutionalize sustainability, creating an environment where trained personnel are empowered, recognized, and motivated to apply green skills. This complements the technical and executive training recommendations outlined earlier and ensures that India's green maritime workforce is operationally effective, strategically aware, and institutionally supported.

5.6 Conclusion: Building India's Green Maritime Workforce

India's maritime sector stands at a pivotal moment. The convergence of digital transformation, decarbonization imperatives, and operational modernization presents both challenges and opportunities. The success of India's green maritime transition depends not only on infrastructure or technology deployment but fundamentally on human capital—the skills, competencies, and institutional support that enable people to operate, innovate, and lead sustainably.

This chapter has outlined a comprehensive roadmap for developing a future-ready workforce. It emphasizes the integration of technical proficiency, environmental literacy, strategic leadership, and operational experience, ensuring personnel are prepared for emerging technologies, alternative fuels, energy-efficient operations, and digital governance systems. By fostering a modular, competency-based approach combined with practical training, simulation exercises, and real-world exposure, India can build a workforce that is both operationally capable and environmentally conscious.

Central to this effort is a coordinated, collaborative ecosystem where academic institutions, industry partners, government agencies, and knowledge hubs work in synergy. Strategic oversight, regulatory compliance, curriculum design, industry mentorship, and international benchmarking collectively ensure that training programs are contextually relevant, globally informed, and scalable. Regional inclusion and Green HR practices further embed sustainability into organizational culture and workforce development, linking competencies to performance, career progression, and gender-responsive recruitment.

By adopting this structured, dual-tiered approach—combining executive leadership programs with hands-on technical training across key green skill domains—India can ensure continuity, adaptability, and lifelong learning across its maritime workforce. Regular monitoring, evaluation, and feedback loops will maintain program effectiveness, align skills with evolving policy and technology, and reinforce operational and strategic readiness.

Investing in human capital is no longer ancillary; it is central to India's maritime resilience. Through an integrated, practical, and forward-looking framework, India can cultivate a maritime workforce that is capable, confident, and ready to lead the nation's green maritime transformation, achieving national ambitions while serving as a global benchmark for sustainable maritime development.

6

Anchoring the Transition with Green Finance

6.1 Background

Finance plays a critical role in facilitating the transition towards a green maritime sector. The development of green port infrastructure that is including renewable energy integration, shore-to-ship power systems, port electrification, and pollution control measures which required robust and sustainable financial mechanisms to ensure effective and timely implementation. Green finance refers to a structured framework of financial instruments, capital flows, and investment mechanisms dedicated to supporting environmentally sustainable initiatives. It is integral to achieving global sustainability targets and maritime decarbonization goals. By enabling investments in clean energy, low-emission transport systems, energy efficiency, pollution mitigation, and circular economy practices, green finance serves as a key enabler for accelerating the maritime sector's shift towards climate resilience and environmental stewardship.

6.2 Targets for Green Finance in Maritime Sector

To provide financial assistance and incentivizing the green transition towards decarbonization of Indian maritime sector by 2030, it has been proposed that at least 30% of all capital expenditure in major ports be allocated to green initiatives, including, adoption of renewable energy, shore power integration, electrification of cargo handling equipment and vehicles, cold storage facilities, LNG and hydrogen fuel bunkering infrastructure, and pollution control activities.

For this, several targets are identified for smooth transition towards decarbonization goals. Some are discussed below.

i. Undertake financial need assessment across various areas of green initiatives.
ii. Map financial requirements for short-, medium- and long-term projects.
iii. Identify possible sources of funds including internal resources, soft loans from domestic and international financial institutions, grants/subsidies from government institutions, and review existing financial schemes for adoption of various green initiatives across ports, shipping and waterways.
iv. Identifying the implementable good global practices.

6.3 Current status of Finance for Green Transition of Maritime Sector

As part of the NAVIC Cell 3 outcomes, a dedicated subgroup was constituted to specifically explore and assess various financial mechanisms for supporting green initiatives in the port sector. This subgroup undertook a comprehensive exercise to identify and analyze potential sources of finance aligned with the requirements of green infrastructure development across major ports.

As part of this initiative, financial data was systematically gathered from ports to assess investment requirements across critical areas, including renewable energy deployment, shore-to-ship power systems, port electrification, pollution control measures, and energy-efficient infrastructure. The objective of this assessment is to guide the development of appropriate financing models that effectively combine public funding, private sector participation, and multilateral support. These insights aim to facilitate a smoother, scalable, and economically viable transition toward sustainable maritime operations. Table 6.2.1 outlines the estimated financial implications for the ports.

Table 6.2.1: Financial implications for green projects across major ports, CSL and SCI

S. No	Name of Entity		Total finance required (INR Cr.)
1	PPA		106
2	SMPK	HDC	149
		KDS	87
3	NMPA		120
4	ChPA		160
5	CoPA		309
6	MbPA		100
7	VPA		755
8	JNPA		587
9	DPA		900
10	MgPA		30
11	VOCPA		670
12	KPL		350
13	SCI	Ship	1680
		Shore to ship Power	340
14	CSL		310
Total			6653

The total estimated financial requirement across all identified entities stands at ₹6,653 crore, covering investments in shore power infrastructure, vessel retrofitting, and port-side upgrades. SCI accounts for a major share, with ₹1,680 crore allocated for ship-related investments and ₹340 crore for shore power systems. Among the ports, DPA requires ₹900 crore, followed by VPA with ₹755 crore. Other notable funding needs include VOCPA (₹670 crore), JNPA (₹587 crore), and KPL with ₹350 crore. Ports such as CoPA, ChPA, and SMPK also reflect significant investment requirements, underscoring the scale and urgency of India's ongoing green transition and port modernization efforts.

6.3.1 Entity wise Mapping of Sources of Finance:

Table 6.3.1: Entity wise Mapping of Sources of Finance

Name of Entity	Sources of Finance			
	Self-Financing	Government Schemes	Domestic/International borrowing from financial institutions	Others
NMPA	Internal resources			
DPA	Internal resources			
VPA	Internal resources			
VOCPA	Internal resources			
JNPA	Internal resources		World Bank	
ChPA	Internal resources			
MbPA	Internal resources			
CoPA	Internal resources	Sagarmala		
SMPK	Internal resources	Sagarmala		
KPL	Internal resources			IOCL
MgPA	Internal resources	Sagarmala		
SCI	Internal resources	NGHM		Bank Loans
CSL	Internal resources	Sagarmala		SBFAP

The Major Ports are utilizing internal resource as major source of funding for all decarbonization related projects, reflecting their strong capacity for self-sustenance and revenue generation. External borrowing and international funding Limited to JNPA receiving support from the World Bank and SCI utilizing bank loans. KPL stands out for adopting diversified funding through IOCL partnership, suggesting a move toward public–private collaboration. While SCI and CSL exhibit a relatively broader financial base by combining internal, government, and institutional sources. The ports like, CoPA, SMPK and MgPA are utilizing Sagarmala funding for green projects like developing solar power plant, port electrification and implimanting energyy efficient measures. Overall, the financing pattern highlights a conservative approach among Indian major ports, with limited engagement in international and private funding avenues. This indicates potential for greater diversification through multilateral funding, PPP models, and central government initiatives to support modernization and the transition toward greener and smarter port infrastructure.

The data provided by the ports represents the estimated funding requirements for implementing various Green Initiatives by 2030. As per the data pertaining to PPA, KPL, JNPA, VPA, ChPA, MgPA and NMPA it can be inferred that for shore power infrastructure accounts for the largest share i.e. 1210 Cr INR of the projected investment, followed by renewable energy projects. Approximate 360.35 Cr INR total average investment is required per port to complete the targets as per MIV 2030.

6.4 Challenges in Green Financing in India

Green financing, while essential for driving sustainability, faces several key challenges across sectors, including shipping. In Table 6.4.1, the challenges and issues associated with green financing are noted below.

Table 6.4.1: Mapping broader issues and description

Broader Issues	Description
High upfront Costs for Green Projects	Implementing green technologies and infrastructure at ports requires substantial upfront investment, which can be a barrier for many stakeholders.
Limited Access to Capital	Many green projects struggle to access adequate financing due to the perceived higher risks and longer payback periods associated with sustainable investments.
Financial Risk	Green investments in ports carry financial risks related to high upfront capital costs, uncertain returns due to evolving technologies, and regulatory requirements. Additionally, limited access to affordable long-term financing and market readiness for green solutions can impact the bankability of such projects.
Institutional Framework	Lack of robust institutional framework to support green financing in India

6.5 Financial Schemes to Support Green Transition of Indian Maritime Sector

Green finance has emerged as a critical enabler of decarbonization, leveraging instruments such as green, sustainability-linked, and transition loans and bonds to mobilize capital toward climate-aligned goals. Institutional investors and banks are increasingly channeling substantial funds into ESG-compliant initiatives, with the maritime sector actively participating through asset- and corporate-level financing. Green finance supports vessel retrofits or acquisitions that meet standards like the EU Taxonomy or Climate Bonds Initiative, while sustainability-linked finance ties corporate borrowing costs to achieving measurable environmental performance targets (e.g., AER reductions). Transition finance, guided by frameworks such as the ICMA's Climate Transition Finance Handbook, supports companies with credible net-zero pathways and interim decarbonization milestones—collectively fostering broader access to capital, improved financing terms, and enhanced reputational value. Table Shows some of the key financial interventions to support green transition.

Table 6.5.1: Financial Interventions to support Green Transition

1	Maritime Development Fund	• To support Indian maritime industry's financial needs by providing financial assistance to ventures for green transition in shipping, ports, IWT. • To provide financial support to organizations involved in shipping, shipbuilding, ports, coastal shipping, IWT, and other maritime infrastructure for new projects, capacity expansion, etc
2	Sagarmala Programme	• Though predominantly focused on enhancing port infrastructure and efficiency, the 'Sagarmala Programme' also encompasses opportunities for integrating sustainable practices within its projects. • Funding could be directed towards environmental preservation, coastal community development, and projects that enhance the energy efficiency of port and maritime operations.
3	Shipbuilding Financial Assistance Policy 2.0:	• Offers subsidy on the contracted price/fair value for vessels constructed in India, with a 10-year period from 2024 to 2034. • Offers subsidies of for specialized vessels, green vessels and other highly specialized vessels
4	International Collaboration and Financing	• Working with international organizations and foreign governments to secure funding and technical assistance for green maritime projects. This could involve collaboration with entities like the World Bank, and the Asian Development Bank.
5	Credit Enhancement Scheme by IIFCL	• India Infrastructure Finance Corporation Limited (IIFCL) also launched a dedicated scheme known as the 'credit enhancement scheme' for funding viable infrastructure projects with bond tenors above five years

6.5.1 Maritime Development Fund

The Maritime Development Fund (MDF), as India's shipbuilding strategy, is a central financial intervention aimed at catalyzing the country's maritime sector growth. Announced in the Union Budget 2024–25, the fund is intended to provide long-term, affordable capital to boost shipbuilding, vessel retrofitting, and ship repair capabilities in India. Structured as a blended finance mechanism, it combines government equity with institutional and private investment to address the chronic capital shortage faced by the sector.

The fund is designed to improve India's competitiveness in the global shipbuilding market, where the country currently holds a minimal share. It aims to encourage technological modernization, foster green shipbuilding practices (such as LNG- and battery-powered vessels), and support the growth of port-linked infrastructure. While policy momentum is strong, the article notes that clear implementation timelines and active stakeholder engagement are now critical to translating this initiative into real industrial and employment outcomes.

The Indian government, through the Union Budget 2025–26, announced the establishment of a ₹25,000 crore Maritime Development Fund to boost the sector's infrastructure and financing ecosystem. Structured with 49% government backing, the remaining capital is to be mobilized from major ports, financial institutions, PSUs, sovereign funds, and private investors. The scheme has cleared up the Expenditure Finance Committee (EFC) appraisal and is currently awaiting cabinet approval.

6.5.2 Shipbuilding Financial Assistance Policy of India

India's Union Budget 2025–26 introduced the enhanced Shipbuilding Financial Assistance Policy (SBFAP 2.0), representing a strategic shift aimed at positioning India among the world's top five shipbuilding nations by 2047 under the Maritime Amrit Kaal Vision. The upgraded policy allocates a substantial ₹18,090 crore—boosted from ₹4,000 crore under the original 2016 policy—to support domestic shipyards. Despite only 18 of 39 registered shipbuilders benefiting by 2024, the refreshed framework features stronger funding, improved incentives, and operational enhancements to stimulate local production. Complementary targets include reducing vessel turnaround times (from 25 to under 20 hours by 2030) and boosting daily ship output (from 16,000 to over 30,000 GT), demonstrating the government's coordinated vision to modernize India's maritime manufacturing ecosystem through infrastructure development, efficiency drives, and policy integration.

6.5.3 Sagarmala Programme

The Sagarmala Programme is the flagship initiative of the Ministry of Ports, Shipping, and Waterways to promote port-led development in India. It aims to harness the nation's coastline and navigable waterways to reduce logistics costs and enhance trade competitiveness. The program is structured around five pillars: port modernization, connectivity enhancement, port-led industrialization, coastal community development, and promoting coastal and inland shipping. Around 839 projects worth ₹5.79 lakh crores have been identified for implementation to achieve these goals. Achievements include a 118% growth in coastal shipping and nine Indian ports ranking in the world's top 100. The initiative has been expanded with Sagarmala 2.0 and the Sagarmala Startup Innovation Initiative (S2I2). This program is central to India's Maritime Amrit Kaal Vision 2047, aiming for global maritime leadership.

6.5.4 International Collaboration and Financing

The World Bank and the Asian Development Bank (ADB) are pivotal in transforming India's maritime infrastructure into sustainable, green ports. The World Bank contributes by developing frameworks for greening ports, promoting nature-based solutions for climate resilience, and funding key initiatives like the Strengthening Coastal Resilience and the Economy (SHORE) project. Concurrently, the ADB provides significant financial backing, including a substantial loan for green infrastructure and support through its Sustainable and Resilient Maritime Fund, aiming to decarbonize the sector. Both institutions offer crucial technical expertise and policy guidance to enhance energy efficiency, reduce emissions, and integrate digital solutions, collectively steering India's ports towards a more environmentally responsible and climate-resilient future.

6.5.5 Credit Enhancement Scheme by IIFCL

IIFCL's proactive stance is further demonstrated by its pioneering role in the Indian financial sector. It holds the distinction of being the first NBFC-IFC in India to obtain an ESG (Environmental, Social, and Governance) rating, a clear signal to the market of its commitment to sustainability.

As of late 2022, IIFCL had sanctioned a total of ₹8,244 crore to approximately 20 distinct port projects. Its financing has touched 5 of the 12 major ports and 15 non-major ports, showcasing a nationwide footprint. The list of strategic projects that have benefited from IIFCL's financial assistance includes established major ports like Paradip Port and Tuticorin, private terminals such as Essar Vizag Port, and critical non-major ports like Krishnapatnam and Karaikal. Demonstrating its commitment to capacity creation, IIFCL has also financed greenfield projects, most notably the new Ramayapatnam port in Andhra Pradesh. This long history of engagement, dating back to at least 2008 when ports constituted a portion of their loan assistance, underscores a long-term commitment to the sector's growth and development.

6.5.6 RECs- A Mechanism for Carbon Financing:

Renewable Energy Certificates (RECs) have emerged as a powerful instrument for ports and maritime operators seeking to transition toward cleaner operations and attract sustainability-linked financing. Each REC represents proof that one megawatt-hour of electricity has been generated from renewable sources such as solar, wind, or hydro power and fed into the grid. By purchasing RECs, a port effectively ensures that an equivalent portion of its energy use is offset by renewable generation elsewhere, even if the clean power is not physically delivered to the site.

RECs do more than offset emissions, they strengthen the financial credibility of sustainability projects. For ports aiming to modernize operations with electrification, automation, and clean power integration, access to capital is often a key challenge. RECs act as verifiable instruments that document renewable electricity usage, which is a priority benchmark for green finance eligibility.

Ports can mobilize capital for sustainability projects through instruments such as green bonds and sustainability-linked loans. Green bonds enable ports to finance initiatives like shore power systems, renewable energy integration, and energy-efficient infrastructure at lower borrowing costs, especially when supported by Renewable Energy Certificates (RECs) or equivalent clean energy commitments. Similarly, sustainability-linked loans reward ports for achieving environmental performance targets—REC-backed renewable energy use can help secure better loan terms or reduced interest rates.

Additionally, blended finance mechanisms and ESG-focused funds can be leveraged to attract concessional financing for large-scale green projects. Verified REC documentation serves as credible proof of renewable energy consumption, enhancing a port's ESG profile and credibility with international investors, sovereign green funds, and development institutions.

Ultimately, RECs form a bridge connecting environmental performance with financial opportunity. They allow ports to demonstrate tangible action toward renewable energy adoption, attract institutional investors committed to decarbonization, and unlock long-term funding for critical green infrastructure.

Roadmap for the Major Port for utilizing RECs

Objective:

- To advance towards carbon neutrality by 2030 through the electrification of key port operations and the integration of renewable energy-backed power consumption.

Key Initiatives:

- Electrification of Port Equipment: Transition of dockside cranes, yard tractors, and cargo handling systems to electric operation.
- Implementation of Shore Power System: Installation of a high-capacity shore power facility to supply electricity to berthed vessels, eliminating the need for auxiliary engine use.
- Energy and Emission Targets:
- Estimated Annual Electricity Consumption: 50,000 MWh.
- Renewable Energy Certification: Procurement of Renewable Energy Certificates (RECs) equivalent to total annual consumption, i.e., 50,000 MWh, at an estimated cost of ₹10 crore (₹2,000 per MWh).
- Emission Reduction Potential: Approximately 40,000 tonnes of CO_2 equivalent avoided per year, based on a grid emission factor of 0.8 tCO_2/MWh.
- Financial Integration and Benefits:
- Green Financing Alignment: REC-backed electricity use enhances eligibility for green bonds and sustainability-linked loans by demonstrating renewable energy adoption to investors and lenders.
- Cost Recovery Mechanisms: REC expenditure can be treated as an operational cost, recoverable through green tariff premiums or service-based user fees.
- Improved Project Viability: Verification of REC-backed renewable usage strengthens creditworthiness, potentially reducing borrowing costs and improving project Internal Rate of Return (IRR) by 0.5–1%.

6.6 Global Best Practices in Green Maritime Finance

Case Study 1: Global Green Maritime Finance: A Case Study and Takeaways for India

Japan's Green Innovation (GI) Fund:

- Key Initiative and Financing agency: The cornerstone of Japan's strategy is the ¥2 trillion (1.16 Trillion in Indian rupees) Green Innovation (GI) Fund, a long-term industrial policy tool financed by the Japanese Government and managed by the New Energy and Industrial Technology Development Organization (NEDO). Its flagship maritime project is the "Next-Generation Ship Development" initiative.
- Financial mechanism: The GI Fund provides large-scale, "patient capital" with a 10-year horizon to de-risk private investment in high-cost, pre-commercial technologies. It fosters powerful public-private consortia, bringing together shipbuilders, engine manufacturers (like Japan Engine Corporation), and shipping lines (like NYK) to ensure technology is commercially viable. This is a "system-of-systems" approach, concurrently funding vessel technology (ammonia and hydrogen engines), fuel supply chains, and port infrastructure under the Carbon Neutral Port initiatives like shore to ship projects and alternative fuel adoption to solve the "chicken-and-egg" problem.
- Challenges & Mitigation:
  - » Challenge: Extreme high cost and technological uncertainty of new fuels, making the private sector hesitant to invest alone.

    Mitigation: The government's long-term public funding acts as "pump priming," absorbing initial R&D risks and sending a powerful market signal that encourages private co-investment.
  - » Challenge: Lack of integrated infrastructure for new fuels.

    Mitigation: The fund's holistic strategy ensures that vessel development, fuel production, and bunkering infrastructure projects advance in parallel, creating a complete and functional ecosystem.
- Specific Achievements & Outcomes:
  - » Development of the world's first commercial ammonia-fueled marine engine.
  - » Successful demonstration of the ammonia-fueled tugboat *Sakigake*, which achieved a GHG emissions reduction of over 90% compared to conventional fuel.
  - » Established a clear technological first-mover advantage for Japan's maritime industry, with commercial operation of ammonia-fueled ships targeted for 2028.

Other International Green Finance Models

- Singapore (Maritime Singapore Green Initiative):

Singapore's strategy is intrinsically linked to its status as the world's preeminent maritime hub and largest bunkering port. The Maritime Singapore Green Initiative (MSGI), backed by over S$100 million in funding, employs a suite of incentive-based programs to attract and anchor green shipping activities. The Green Ship Programme and Green Port Programme offer significant concessions on port dues and vessel registration fees for ships that exceed IMO environmental standards or utilize low- and zero-carbon fuels when calling at Singapore. This "Global Hub" model focuses on creating enabling conditions for the green transition. Singapore is investing heavily in developing the world's first multi-fuel bunkering standards and infrastructure for fuels like ammonia and methanol. A critical component of its strategy is investment in "soft infrastructure," most notably through the establishment of the Maritime Energy Training Facility (METF). The METF is a pioneering initiative to upskill the global seafaring workforce in the safe handling of new and hazardous fuels, addressing a critical bottleneck in the industry's transition.

- United Kingdom (UK SHORE Program):

The United Kingdom has pursued an "Innovation Ecosystem" model through its UK Shipping Office for Reducing Emissions (UK SHORE) programme. Established with an initial budget of £206 million and since expanded, UK SHORE's primary instrument is the Clean Maritime Demonstration Competition (CMDC). The CMDC operates through multiple, successive funding rounds, awarding grants on a competitive basis for projects at various stages of development, including feasibility studies, pre-deployment trials, and full-scale technology demonstrations. This approach is deliberately technologically agnostic, supporting a wide portfolio of solutions ranging from electric and hydrogen propulsion to ammonia, methanol, and even modern wind power. The model is designed to foster a broad and diverse innovation landscape, supporting over 200 projects and 500 organizations, many of which are small and medium-sized enterprises (SMEs). A key objective is to leverage public funds to attract private investment, which has so far exceeded £110 million, demonstrating a successful public-private partnership dynamic.

- Norway (NOx Fund):

Norway presents a unique "Industry Co-op" model that is not primarily funded by direct government budgets. In 2008, facing a state-imposed tax on nitrogen oxide (NOx) emissions, Norwegian business organizations established the NOx Fund as an alternative. Under this environmental agreement, participating companies pay into the fund at a rate lower than the official government tax. The collected capital, amounting to around one billion NOK annually, is then reinvested back into the industry to finance concrete NOx reduction measures. While the primary target is NOx, many of the supported technologies—such as LNG-fueled engines, battery-hybrid systems, and NOx cleaning catalysts—have significant co-benefits for reducing GHG emissions. This industry-led, self-funding mechanism has been highly successful, accelerating the adoption of green technologies, particularly in the maritime sector, and serves as a key pillar of the government's broader "Action Plan for Green Shipping".

I. Key Takeaways for the Indian Maritime Sector from case study

- Operationalize the Maritime Development Fund (MDF) with a Credible Framework: India's recently expanded ₹70,000 crore ($8.4 billion) MDF is a powerful tool. To succeed, it must be managed with a clear, independent, and expert-led governance structure, similar to Japan's NEDO, to attract the targeted 51% private and international capital.
- Adopt a "System-of-Systems" Investment Strategy: Avoid funding projects in isolation. India should strategically link MDF financing for green vessels with the Sagarmala Program's funding for port infrastructure (like Green Hydrogen Hubs) and incentives for fuel producers. This integrated approach, proven effective by Japan, is crucial for building a complete green ecosystem.
- Use Public Funds to De-risk and Catalyze Private Investment: The high "green premium" for new

technologies is a major barrier. The MDF and Sagarmala's Viability Gap Funding (VGF) should be prioritized for first-of-a-kind pilot projects and long-term R&D to build investor confidence, mirroring the GI Fund's "patient capital" model.

- Foster Public-Private Consortia: Actively use funding mechanisms to encourage collaboration between Indian public sector undertakings (Cochin Shipyard, SCI), major ports, and private technology firms. This ensures that innovation is aligned with commercial needs and accelerates development.
- Invest in Workforce Development ("Soft Infrastructure"): The transition to new fuels like ammonia requires a massive upskilling of seafarers and port workers. India should learn from Singapore's proactive approach and invest in dedicated training facilities and programs to create a skilled workforce ready for the green transition.
- Create a Complete Incentive Package: Combine supply-side incentives, such as the revamped Shipbuilding Financial Assistance Policy (SBFAP) which offers up to 30% assistance for green vessels, with demand-side incentives like rebates on port dues for green ships, as mandated by the 'Harit Sagar' Green Port Guidelines. This creates both push and a pull from green technologies.

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Conclusion

NAVIC Cell 3's comprehensive assessment of green initiatives and pollution control measures in the Indian maritime sector provides a consolidated overview of progress across ports, shipping, and inland waterways. The evaluation covers Shore-to-Ship (STS) power implementation, renewable energy adoption, electrification of port equipment and vehicles, switching to energy-efficient equipment, marine ecosystem conservation, waste and wastewater management, green incentives, environmental management plans, and capacity-building initiatives. These efforts are benchmarked against the Harit Sagar Guidelines, Maritime India Vision 2030 (MIV 2030), and Maritime Amrit Kaal Vision 2047 (MAKV 2047), providing a comprehensive view of the current status, targets, and implementation till 2030.

The findings indicate that Indian maritime sector is steadily advancing its sustainability agendas. As of 2023–24, renewable energy accounted for 15.48% of electricity consumption across major ports, with total consumption of 488.24 GWh and 75.6 GWh sourced from renewable energy. By 2029–30, total electricity demand is projected at 777.76 GWh, with renewable sources expected to supply 512.09 GWh, achieving nearly 65% of projected consumption. Ports such as New Mangalore Port Authority and Mormugao Port Authority have already reached 100% renewable energy for port consumption. Mumbai Port Authority and Deendayal Port Authority (DPA) have exceeded 2030 targets with 87% and 69% renewable shares, respectively, while other ports, including Kamarajar Port Limited, V.O. Chidambaranar Port Authority, Visakhapatnam Port Authority, Jawaharlal Nehru Port Authority, Cochin Port Authority, and Paradip Port Authority, are on track to achieve the 60% renewable energy target by 2030.

Shore-to-Ship power implementation has also made notable progress, with Phase I completed at all major ports targeting port-stationed vessels and different levels of completion for coastal and EXIM vessels. Electrification of cargo-handling equipment and harbor crafts has advanced, with achievement of target of 50% electrification of Cargo handling equipment. Inland waterways have similarly embraced renewable energy, shore to ship power supply, energy-efficient equipment, and emerging hydrogen infrastructure, signalling a forward-looking approach to decarbonization. Similarly, adoption of various pollution control measures including waste and wastewater management, water conservation techniques improved compliance with national environmental standards. These initiatives collectively ensure that environmental sustainability is embedded in ports, shipping, and IWAI operations. Building on the concerted efforts, NAVIC Cell 3's assessment underscores that the Indian maritime sector is on a clear trajectory toward sustainability, with measurable progress across ports, vessels, and inland waterways.

NAVIC Cell 3 has provided actionable recommendations and action plans to support continued progress. Accelerated deployment of STS power, expansion of renewable energy generation, structured electrification of port and vessel equipment, promotion of energy-efficient systems, and strengthened environmental management practices have been identified as key levers to achieve sustainability targets. Capacity-building and training programs have been emphasized to equip personnel with the skills required for successful implementation of green initiatives. Continued stakeholder collaboration, technological integration, and regulatory support will further strengthen these outcomes, ensuring that India's maritime ecosystem evolves into a resilient, energy-efficient, and environmentally responsible framework, contributing significantly to the nation's broader Net Zero 2070 vision.

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