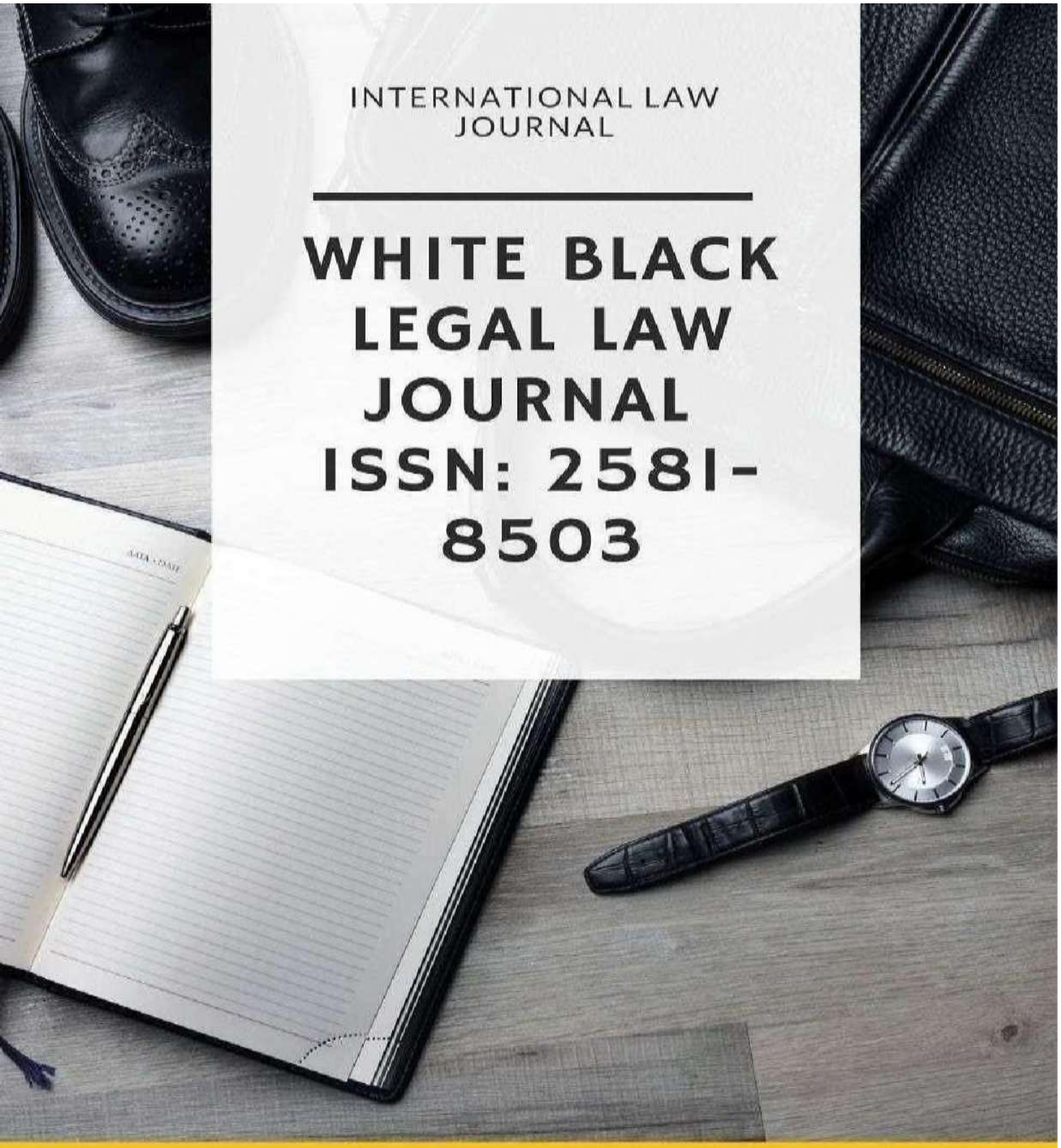

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WHITE BLACK LEGAL is an open access, peer-reviewed and refereed journal provide dedicated to express views on topical legal issues, thereby generating a cross current of ideas on emerging matters. This platform shall also ignite the initiative and desire of young law students to contribute in the field of law. The erudite response of legal luminaries shall be solicited to enable readers to explore challenges that lie before law makers, lawyers and the society at large, in the event of the ever changing social, economic and technological scenario.

With this thought, we hereby present to you

GREEN SHIPPING AND CLIMATE CHANGE: TRANSFORMING MARITIME TRANSPORT FOR SUSTAINABILITY

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Abstract

The maritime sector, a crucial component of global trade, significantly contributes to greenhouse gas (GHG) emissions, prompting urgent reforms to align with international climate commitments. The International Maritime Organization (IMO) and various national governments are implementing green shipping technologies to mitigate environmental impacts. These technologies encompass alternative fuels (LNG, hydrogen, ammonia, and biofuels), energy-efficient ship designs, wind-assisted propulsion, and digital solutions for optimized fuel consumption. The transition from conventional fossil fuels to sustainable alternatives aims to reduce carbon emissions, enhance fuel efficiency, and improve maritime environmental sustainability. India, as an emerging maritime power, has introduced the National Green Shipping Policy, focusing on integrating green technologies, modernizing port operations, and harmonizing national maritime laws with global standards. The country is also strengthening its monitoring, reporting, and verification (MRV) system to track emissions and enforce compliance. However, challenges persist, including high costs, technological adaptation, and the need for enhanced legal frameworks. To accelerate the adoption of green shipping, comprehensive policies such as defining GHGs in Indian law, enforcing emission limits, promoting carbon markets, and strengthening penalties are recommended. Furthermore, fostering climate governance, judicial oversight, and international cooperation will be crucial in ensuring a sustainable maritime future. Global initiatives, particularly from the European Union (EU) and the United States (US), provide valuable insights into policy-driven technological innovation and regulatory enforcement. This paper examines key legal, technological, and policy developments shaping the green shipping landscape, with a particular focus on India's regulatory framework. It highlights the importance of sustainable innovation, international partnerships, and proactive policy measures in achieving long-term maritime decarbonization goals.

Keywords:

Green shipping, climate change, greenhouse gas emissions, alternative fuels, sustainable maritime transport, IMO regulations, India's Green Shipping Policy, EU regulations, carbon markets, maritime law.

Introduction

Shipping is a fundamental pillar of international trade, facilitating the movement of goods across countries and continents, with over 80% of global trade by volume transported by sea. Its cost-effectiveness, efficiency, and reliability make it the preferred mode for bulk and long-distance transportation, supporting industrial growth and market expansion. By connecting producers with consumers worldwide, shipping enhances globalization, fosters competition, and strengthens global supply chains. Ports act as key intermodal hubs, integrating maritime transport with road, rail, and air networks for seamless logistics. Compared to air or rail transport, shipping offers significantly lower costs, making it the preferred choice for transporting high-volume goods. Additionally, the capability to handle diverse types of cargo, from raw materials to finished products, establishes shipping as an essential component of international supply chains, supporting trade between both developed and developing nations.

Maritime trade is pivotal in connecting global markets, enabling exporters and importers to expand their reach across continents. Key shipping routes like the Suez Canal, Panama Canal, and the Strait of Malacca shorten transit times, thereby reducing the overall cost and duration associated with global commerce. Advances in logistics and containerization have further streamlined operations and enhanced efficiency. As international trade continues to grow, maritime transport remains indispensable for sustaining the global economy.

The legal framework governing international shipping is anchored in global regulations such as the United Nations Convention on the Law of the Sea (UNCLOS), which defines maritime rights and jurisdiction. The International Maritime Organization (IMO) oversees safety, environmental protection, and security through conventions like SOLAS (1974) for maritime safety, MARPOL (1973/78) for pollution prevention, and the ISPS Code for port security. Additionally, the World Trade Organization (WTO) ensures fair and transparent maritime trade practices under agreements like the General Agreement on Trade in Services (GATS), which covers maritime transport services. Together, these elements make shipping the backbone of

global commerce, ensuring smooth trade operations and economic connectivity between nations.

Despite its advantages, the shipping industry significantly contributes to environmental degradation, accounting for approximately 3% of global greenhouse gas emissions. The urgent need to mitigate climate change has led to a growing demand for greener and more sustainable shipping practices.

Greenhouse Gases as Pollutants

Greenhouse gases (GHGs) can be considered direct pollutants because they contribute to environmental degradation by altering the Earth's natural climate system. However, their classification as pollutants differs from conventional air pollutants like sulfur dioxide (SO_2) or particulate matter (PM), which cause immediate harm to air quality and human health.

Greenhouse gases (GHGs) are a significant form of pollution[1] as they alter the natural atmospheric balance, leading to global warming and climate change. Major GHGs such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases originate from human activities, including fossil fuel combustion, industrial processes, deforestation, and agriculture. Unlike conventional pollutants that cause immediate environmental degradation[2], GHGs accumulate over time, trapping heat and disrupting climate patterns. This results in extreme weather events, rising sea levels, biodiversity loss, and economic instability.

Recognizing these impacts, GHGs are classified as pollutants that require regulatory control. In India, GHG emissions and environmental pollution are regulated through various legal frameworks. The Environment (Protection) Act, 1986 empowers the Central Government under Section 3 to take measures for environmental protection, including regulating emissions[3], while Section 5 grants the authority to issue directions to industries and establishments to curb pollution, including GHG emissions[4]. The Air (Prevention and Control of Pollution) Act, 1981 assigns the Central Pollution Control Board (CPCB) the responsibility under Section 16 to set emission standards and improve air quality[5], and Section 19 enables State Governments to declare air pollution control areas and regulate industries contributing to pollution[6]. The Energy Conservation Act, 2001, through Section 14, authorizes the Bureau of Energy Efficiency (BEE) to establish energy efficiency standards, indirectly reducing GHG emissions[7]. The Motor

Vehicles Act, 1988, under Section 110, allows the Central Government to set emission norms for motor vehicles to control air pollution, including GHGs[8]. Additionally, the National Green Tribunal (NGT) Act, 2010, under Section 14, grants the NGT jurisdiction to handle cases related to environmental protection and pollution control, addressing violations that contribute to climate change[9].

On the international level, greenhouse gases (GHGs) are explicitly recognized under various agreements aimed at addressing climate change. The United Nations Framework Convention on Climate Change (UNFCCC, 1992) was the first international treaty to acknowledge GHG emissions[10] as a key factor in global warming and climate change. Building on this, the Kyoto Protocol (1997) established legally binding[11] emission reduction targets for specific GHGs, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Further strengthening global climate action, the Paris Agreement (2016) reinforced commitments to limit GHG emissions by promoting sustainable practices[12] and enhancing international cooperation to mitigate climate change impacts.

Maritime Law and Green Shipping Technology

Maritime law, also known as admiralty law, regulates activities on the seas and oceans, including shipping, navigation, marine resource management, and environmental protection. It establishes guidelines for ship registration, ownership, safety standards, maritime labor, and liability while addressing issues such as pollution control, salvage, and collision disputes. With the increasing focus on sustainability, maritime law is evolving to support the adoption of green shipping technologies aimed at reducing environmental impact and improving energy efficiency. These technologies include alternative fuels (LNG, hydrogen, ammonia, and biofuels), emission control systems (carbon capture, scrubbers), and energy-saving measures (wind-assisted propulsion, air lubrication). Regulatory bodies like the International Maritime Organization (IMO) have introduced measures such as the IMO 2020 Sulfur Cap and the IMO 2050 Strategy to cut greenhouse gas emissions and promote cleaner shipping practices[13]. As the maritime industry, which handles over 80% of global trade by volume, accounts for nearly 3% of global CO_2 emissions, the integration of green shipping technologies into maritime law marks a significant step toward achieving long-term environmental sustainability.

Scope of Green shipping technology

Green shipping technology encompasses a range of innovations and practices designed to reduce the environmental impact of maritime operations by improving the energy efficiency and sustainability of ships. It includes the use of alternative fuels such as LNG (Liquefied Natural Gas), hydrogen, ammonia, and biofuels to reduce greenhouse gas emissions[14] and improve fuel efficiency. Emission control systems[15], including scrubbers and carbon capture systems, help limit sulfur dioxide (SO_2) and nitrogen oxides (NOx) emissions. Energy efficiency measures such as air lubrication systems, optimized hull designs, and wind-assisted propulsion reduce fuel consumption and enhance operational performance. Renewable energy sources like solar panels, wind turbines, and battery storage provide cleaner power for onboard operations, while AI-based route optimization, weather-based navigation, and predictive maintenance further contribute to reducing emissions and fuel use. Waste and water management systems, including ballast water treatment and advanced filtration, help prevent marine pollution and support environmental compliance.

However, standard shipping containers used for cargo transport are not classified as green shipping technology unless they are integrated with energy-saving or emission-reducing features, such as solar-powered refrigerated containers. Similarly, port infrastructure improvements like shore-side power (cold ironing) and green port systems, while beneficial to maritime sustainability, are not considered part of green shipping technology but rather fall under broader port-based environmental initiatives.

The evolution of Green Shipping Technologies

In the early stages of maritime history, ships were naturally eco-friendly, relying solely on wind power for navigation. Sailing ships dominated global trade routes until the 19th century when the introduction of coal and steam engines significantly increased the efficiency of maritime transport. However, this shift also marked the beginning of increased pollution and reliance on fossil fuels. While steam engines improved the speed and reliability of shipping, they contributed to environmental degradation due to coal combustion. Early efforts to address these issues included improvements in steam engine fuel efficiency and initial discussions on alternative fuel sources, although large-scale adoption remained limited due to technological and economic constraints.

The 20th century saw a major shift with the introduction of diesel-powered ships, which improved fuel efficiency but significantly increased carbon emissions. The mid-20th century expansion of global trade further amplified the environmental footprint of shipping. In response to growing pollution and oil spill incidents, regulatory frameworks emerged to address environmental concerns. Key milestones included the MARPOL Convention (1973/1978) by the International Maritime Organization (IMO), which introduced measures to prevent marine pollution from ships. Additionally, ballast water management programs were established to protect ecosystems from invasive species. The oil crisis of the 1970s sparked a renewed interest in energy efficiency, leading to the introduction of hull coatings and engine optimizations aimed at reducing fuel consumption and emissions.

The 21st century marked the rise of modern Green Shipping Technologies driven by stricter environmental regulations and technological breakthroughs. In the 2000s, the introduction of liquefied natural gas (LNG) as a marine fuel helped reduce sulfur emissions and meet the IMO's sulfur cap regulations. The 2010s saw the rise of digitalization, artificial intelligence (AI), and the Internet of Things (IoT), enabling real-time route optimization, emissions monitoring, and predictive maintenance. Hybrid and electric ship propulsion systems were introduced, including battery-powered ferries and hybrid engines, to reduce emissions and fuel dependency. Cold ironing, which involves connecting ships to shore-side power while docked, became a widely adopted measure to cut portside emissions. This practice allows ships to turn off their auxiliary engines and rely on cleaner electrical power from the shore, significantly reducing noise and air pollution in port areas. These advancements demonstrate the shipping industry's commitment to sustainable operations while maintaining efficiency.

The acceleration of green shipping technologies in the 2020s has been largely influenced by the IMO 2020 Sulfur Cap, which limited the sulfur content in marine fuels to 0.5%, driving the adoption of alternative fuels like hydrogen, ammonia, and methanol. Major shipping companies have begun investing in methanol-powered vessels and hydrogen fuel cells for carbon-neutral operations. Onboard carbon capture and storage (CCS) technologies have emerged to capture emissions directly from ships. Air lubrication systems, wind-assisted propulsion, and solar panels have gained traction as additional measures to enhance energy efficiency. Looking ahead, the future of green shipping includes the development of zero-emission ships powered by hydrogen, ammonia, and even nuclear energy. Smart ports powered by renewable energy and integrated with AI and blockchain for carbon tracking are expected to

play a key role in achieving the IMO's goal of cutting GHG emissions by at least 50% by 2050.

Major Incidents That Triggered Global and National Focus on Green Shipping Technologies

Several catastrophic maritime and environmental incidents have played a key role in driving the adoption of green shipping technologies. These incidents exposed the severe environmental consequences of conventional shipping practices, including oil spills, pollution, and emissions, prompting governments, regulatory bodies, and the shipping industry to adopt cleaner and more sustainable practices.

The *Exxon Valdez Oil Spill (1989)*[16] in Alaska, USA, remains one of the worst environmental disasters in maritime history. Approximately 260,000 barrels (41 million liters) of crude oil spilled into Prince William Sound, causing long-term ecological damage to marine ecosystems, fisheries, and local wildlife. In response, the Oil Pollution Act (OPA) of 1990 was enacted in the US, mandating double-hull designs for oil tankers and strengthening liability and cleanup requirements. This incident marked a turning point in recognizing the need for stricter environmental regulations in the shipping industry.

The *Erika Oil Spill (1999)*[17] in the Bay of Biscay, France, involved the sinking of the Maltese-flagged tanker Erika, which released 30,000 tons of heavy fuel oil and polluted over 400 kilometers of French coastline. This disaster prompted the creation of the International Oil Pollution Compensation Fund and stricter ship inspection rules within the European Union (EU). The IMO also strengthened safety standards under the MARPOL Convention, driving increased focus on ship maintenance and fuel quality.

The *Prestige Oil Spill (2002)*[18] *off the coast of Galicia*, Spain, involved the sinking of the Greek- owned oil tanker Prestige, which spilled over 63,000 tons of heavy fuel oil into the Atlantic Ocean. The incident caused massive ecological damage and economic losses for the fishing industry. In response, the IMO introduced new regulations requiring the phasing out of single-hull tankers and improving port-state control and liability for pollution. This highlighted the importance of vessel design and operational safety in preventing future spills.

The *Deepwater Horizon Oil Spill (2010) in the Gulf of Mexico, USA*[19], resulted from the

explosion of BP's offshore drilling rig, releasing over 4.9 million barrels of oil, making it the largest marine oil spill in history. It caused severe damage to marine biodiversity and Gulf Coast fisheries. The disaster prompted the IMO to push for stricter offshore drilling regulations and increased focus on alternative fuels and emission control systems, accelerating the shift toward cleaner maritime operations.

The *IMO's Sulfur Cap Violation Cases (2015–2020)*[20] highlighted the environmental and health impacts of sulfur dioxide (SO_2) and nitrogen oxides (NOx) emissions from ships, which are linked to acid rain and respiratory diseases. Violations of the MARPOL Annex VI sulfur cap (0.5% from 2020) led to increased adoption of exhaust gas cleaning systems (scrubbers) and alternative fuels like LNG, hydrogen, and ammonia to comply with international emission limits.

In India, the *MT Pavit Incident (2011)*[21] involved the grounding of the oil tanker MT Pavit off Juhu Beach in Mumbai, raising concerns over ship maintenance and fuel leaks. This incident led to increased monitoring of foreign-flagged ships and enhanced emergency response and spill containment capabilities.

The *MSC Chitra Collision (2010[22])* off Mumbai involved a collision between the Panama-registered vessel MSC Chitra and MV Khalijia-III, which spilled over 800 tons of fuel oil and hazardous chemicals into the Arabian Sea. The spill caused significant marine pollution and disrupted Mumbai port operations. The incident prompted improved vessel traffic management and contingency planning for oil spills, reinforcing the need for better operational control.

The *MV Rak Carrier Oil Spill (2011)*[23] near Mumbai involved the sinking of the Panama-flagged MV Rak Carrier, which released 325 tons of fuel oil and 56,000 tons of coal into the Arabian Sea, severely affecting marine life and local fisheries. This incident resulted in enhanced oil spill response protocols and mandatory double-hull designs for oil tankers to prevent similar disasters.

Cyclone Tauktae (2021) caused severe damage to Indian ports and shipping infrastructure along the west coast of India, resulting in oil and debris spills from damaged vessels[24]. This reinforced the need for climate-resilient port infrastructure and low-carbon, energy-efficient vessels capable of withstanding extreme weather events, highlighting the connection between

environmental sustainability and maritime resilience.

The *Alang Shipbreaking Pollution (2016–2018[25])* in Gujarat exposed severe environmental violations in the world's largest ship recycling yard. Improper handling of hazardous materials like asbestos, PCBs, and oil residues led to the adoption of the Hong Kong Convention for Safe and Environmentally Sound Recycling of Ships (ratified in 2019). This encouraged green shipbreaking practices, including proper waste disposal and worker safety, aligning maritime operations with global environmental standards.

Green Shipping Technologies: Prevention Over Cure

The maritime industry, which contributes around 3% of global greenhouse gas (GHG) emissions, has a direct and often irreversible impact on the atmosphere and marine ecosystems. Unlike deforestation or industrial pollution, emissions from shipping including CO_2, SOx, and NOx occur directly over the ocean, where they are absorbed by the atmosphere and water. Once carbon dioxide enters the atmosphere, it remains for centuries, trapping heat and causing long-term climate change. Similarly, sulfur and nitrogen oxides accelerate ocean acidification, which leads to coral bleaching and the collapse of marine biodiversity. Oil spills and ballast water discharge introduce toxins and invasive species into fragile ecosystems, causing damage that cannot be fully undone. While trees can be replanted and polluted rivers can be cleaned, atmospheric and marine damage from shipping emissions is far harder, not possible, to reverse. This is why green shipping technologies are not just about innovation, they are about preventing harm before it becomes permanent.

Green shipping technologies target emissions at the source to avoid irreversible damage. Transitioning from heavy fuel oil (HFO) to low-emission alternatives such as liquefied natural gas (LNG), hydrogen, and biofuels reduces the environmental footprint of maritime trade. Technologies like air lubrication systems which reduce friction by creating a layer of air under the hull, rotor sails which use wind power to assist propulsion, and exhaust gas cleaning systems scrubbers have already shown significant reductions in emissions. Battery-powered and hybrid ships are being introduced for short-sea shipping, with Norway's Ampere ferry cutting emissions by 95%. Regulatory frameworks like the IMO Sulfur Cap 2020, the EU Emissions Trading Scheme (ETS), and MARPOL Annex VI have imposed strict emission limits and financial penalties for non-compliance, pushing the industry toward cleaner

operations. However, the rise of these technologies has triggered patent and licensing disputes over fuel injection systems, hybrid engines, and scrubber designs.

The maritime industry faces a stark reality. If shipping emissions are not drastically reduced, they could account for 17% of global CO_2 emissions by 2050. Melting Arctic ice is opening new shipping routes, but increased traffic threatens to accelerate environmental damage. Coral reefs and Arctic ice, once lost, cannot be restored. Rising sea levels and ocean acidification threaten coastal infrastructure and marine ecosystems, leaving future generations with irreversible damage. The goal of net-zero emissions by 2050 is not just ambitious, it is essential for global environmental stability. Green shipping technology represents a shift from crisis management to proactive environmental protection, cutting emissions at the source, designing sustainable ships, and ensuring that maritime trade becomes part of the climate solution rather than the problem.

Green shipping technology has significantly benefited from the evolution of various legal doctrines and principles aimed at promoting sustainable practices, encouraging innovation, and ensuring environmental protection. The Polluter Pays Principle drives the adoption of cleaner technologies by holding shipowners financially accountable for pollution, encouraging the use of low-emission fuels and advanced emission control systems to avoid penalties under regulations like IMO's Sulfur Cap[26]. The Precautionary Principle supports the early adoption of green shipping technologies, even without complete scientific certainty, by encouraging the use of LNG, hydrogen, and ammonia-based propulsion systems[27] to mitigate long-term environmental risks[28]. The No-Harm Principle ensures that states and shipowners prevent cross-border environmental damage, promoting cleaner ballast water treatment systems and spill prevention technologies[29]. The Sustainable Development Principle balances economic growth with environmental protection by encouraging the retrofitting of ships with energy-efficient designs and supporting green port infrastructure, as seen in India's Maritime Vision 2030[30]. The Common but Differentiated Responsibilities (CBDR) Principle[31] recognizes the financial disparity between developed and developing nations, enabling developing countries to receive financial and technical support for adopting green shipping technologies through flexible compliance timelines under the IMO's Energy Efficiency Design Index (EEDI).

The Intellectual Property and Innovation Principle protects advancements in green technology, such as LNG engines and hybrid propulsion systems, while encouraging cross-licensing and

patent pools to prevent litigation and promote collaborative innovation[32]. The Technology Transfer and Capacity Building Principle facilitates the global spread of green shipping technology by encouraging joint ventures and financial support from global institutions, as reflected in India and Singapore's agreement to create a Green Shipping Corridor[33]. The Duty to Cooperate in Environmental Protection strengthens international collaboration in reducing emissions and improving fuel efficiency[34], with the EU and US coordinating efforts to establish zero-emission maritime zones. The Principle of Energy Efficiency promotes the development of fuel-efficient hull designs and propulsion systems, encouraging compliance with the EEDI and Ship Energy Efficiency Management Plan (SEEMP). The Shipowner's Duty of Care reinforces the responsibility of shipowners to maintain and upgrade equipment to meet emission and safety standards, as highlighted by stricter regulations following the Exxon Valdez oil spill. Finally, the Emission Trading and Carbon Pricing Principle creates financial incentives for shipowners to adopt cleaner technologies by introducing carbon pricing mechanisms and emission credit markets, as demonstrated by the inclusion of maritime emissions in the EU's Emissions Trading System (ETS) in 2024. Collectively, these principles create a balanced regulatory framework that encourages technological innovation, promotes environmental accountability, and facilitates global cooperation for a more sustainable maritime industry.[35]

Adoption of Green Shipping Technologies in India

India has made notable progress in adopting green shipping technologies to meet global environmental standards and improve maritime sustainability. LNG and alternative fuels are being introduced at major ports, with Petronet LNG establishing LNG bunkering facilities at Kochi and Dahej ports, and JNPT setting up India's first LNG bunkering terminal in 2023. Shore-side power systems have been installed at ports like JNPT and Chennai, allowing ships to switch off engines while docked, significantly reducing emissions of sulfur oxides (SOx) and nitrogen oxides (NOx). The IRS has certified energy-efficient ship designs under the EEDI framework, encouraging shipowners to adopt optimized hull designs and propulsion systems. Scrubbers and exhaust gas cleaning systems are being installed on Indian-flagged ships to comply with MARPOL Annex VI's sulfur cap, and some vessels have started adopting onboard carbon capture and storage (CCS) systems to further minimize emissions.

"Five Green Technology Innovations That Are Transforming the Shipping Industry[36]" this aimed at reducing the environmental impact of maritime operations.

1) **Scrubbing and Carbon Capture**: Implementing carbon capture technologies on ships to remove CO_2 emissions during voyages. This approach leverages existing land-based carbon capture methods adapted for maritime use. Challenges include storage of captured carbon and the energy consumption of the capture process.
2) **Air Lubrication Systems**: Utilizing air bubble systems beneath ship hulls to reduce friction between the vessel and water, leading to improved fuel efficiency and reduced emissions.
3) **Alternative Fuels:** Exploring the use of alternative fuels such as hydrogen and ammonia[37] to power ships, aiming to significantly cut down greenhouse gas emissions.
4) **Wind-Assisted Propulsion**: Reintroducing wind power through modern sail designs and kites to assist in propelling ships, thereby reducing reliance on fossil fuels and lowering emissions.
5) **Energy Efficiency Technologies**: Implementing various energy-saving technologies, including advanced hull designs and waste heat recovery systems, to enhance overall vessel efficiency and reduce environmental impact.

These innovations represent the industry's commitment to adopting sustainable practices and reducing its carbon footprint.

India's National Green Shipping Policy and Global Maritime Partnerships

India is actively advancing its commitment to sustainable maritime practices through the development of a National Green Shipping Policy (NGSP). This policy aims to provide a comprehensive framework for promoting environmental sustainability, innovation, and regulatory compliance within the maritime sector. The Green Shipping Conclave 2025, scheduled for February 20, 2025, in Mumbai, serves as a pivotal platform for stakeholders to discuss and shape this policy. During the conclave, a consultative draft of the NGSP is expected to be released for stakeholder engagement and feedback.

The NGSP is envisioned to align with global environmental standards and India's broader sustainable development goals. It will address key areas such as the adoption of green fuels, energy-efficient technologies, and sustainable port operations. The policy discussions at the conclave will focus on port decarbonization, green financing mechanisms, and international cooperation for reducing maritime emissions.

In addition to national efforts, India has recently signed a Letter of Intent (LOI) with Singapore to collaborate on maritime digitalization and decarbonization projects. This partnership aims to establish a Singapore-India Green and Digital Shipping Corridor (GDSC), enhancing innovation and accelerating the adoption of low-emission technologies in the maritime sector.

These initiatives reflect India's proactive approach to integrating green technologies into its maritime industry, fostering sustainability, and contributing to global efforts in reducing greenhouse gas emissions from shipping.

India's Maritime Legal Regime: Harmonizing National Statutes with Global Shipping Standards

Indian maritime law operates under a blend of domestic legislation and international conventions that govern shipping operations, environmental protection, and port management. The Merchant Shipping Act, 1958 serves as the cornerstone legislation regulating ship registration, safety standards, pollution control, and crew working conditions. It has been amended over time to align with global maritime standards such as the International Convention for the Prevention of Pollution from Ships[38] (MARPOL), facilitating the adoption of green shipping technologies like low-sulfur fuels and exhaust gas cleaning systems. The Indian Ports Act, 1908 provides port authorities the power to adopt green technologies such as shore-side power and LNG bunkering, enabling ships to minimize emissions while docked. The Environmental Protection Act, 1986 empowers the government to regulate pollution from ships and ensures that new shipbuilding and port infrastructure projects meet environmental impact assessment (EIA) requirements. The Coastal Regulation Zone (CRZ) Notification, 2011 restricts port and shipyard activities in ecologically sensitive coastal areas, encouraging environmentally sustainable practices. The proposed Indian Ports Bill, 2022 aims to modernize port governance and infrastructure, encouraging the use of low- emission fuels, shore-side power, and uniform environmental standards across major and non- major ports.

India's maritime sector is regulated by several key authorities to ensure compliance with green shipping standards. The Directorate General of Shipping (DGS), under the Ministry of Ports, Shipping, and Waterways, is the principal authority responsible for implementing MARPOL and the Ballast Water Management (BWM) Convention. It oversees ship inspections, certification, and environmental compliance, while also issuing guidelines on energy efficiency

and emission reduction. The Indian Register of Shipping (IRS) certifies ship safety and environmental standards in alignment with IMO and International Association of Classification Societies (IACS) requirements. IRS certification under the Energy Efficiency Design Index (EEDI) ensures ships meet global environmental benchmarks. The Ministry of Environment, Forest and Climate Change (MoEFCC) regulates environmental compliance for shipbuilding and port operations, conducting EIAs and monitoring waste disposal from ships. The Central Pollution Control Board (CPCB) enforces ballast water treatment and emission control standards under MARPOL Annex VI, monitoring pollution levels at ports and ensuring compliance with environmental regulations.

International Maritime Organization (IMO) Initiatives

The IMO, a specialized agency of the United Nations, plays a leading role in setting global standards for maritime safety and environmental protection[39]. The IMO's most significant contribution to green shipping technology is MARPOL Annex VI, which regulates air pollution from ships by setting limits on sulfur oxide (SO_x) and nitrogen oxide (NO_x) emissions. In 2020, the global sulfur cap was reduced to 0.5% from 3.5%, compelling shipowners to switch to low-sulfur fuels or install exhaust gas cleaning systems (scrubbers).

To improve the energy efficiency of ships, the IMO introduced the Energy Efficiency Design Index (EEDI) in 2013, which sets minimum efficiency standards for newly built ships, and the Ship Energy Efficiency Management Plan[40] (SEEMP), which mandates operational efficiency improvements. In 2023, the IMO adopted the Carbon Intensity Indicator (CII) to measure and regulate the carbon intensity of existing ships, driving further adoption of fuel-efficient designs, wind-assisted propulsion systems, and alternative fuels like LNG, hydrogen, and ammonia. The IMO's Initial GHG Strategy aims to reduce shipping emissions by at least 50% by 2050 compared to 2008 levels, with a long-term goal of achieving net-zero emissions by the end of the century.

Green Shipping Policies: EU Regulations and US Technological Innovations

European Union (EU) Regulations and Green Shipping Initiatives

The European Union has been at the forefront of green shipping technology through stringent regulations and market-based mechanisms. In 2024, the EU extended its Emission Trading System[41] (ETS) to cover maritime emissions, requiring shipowners to purchase emission

allowances for CO_2 emissions from ships traveling within the EU and those entering or leaving EU ports. The FuelEU Maritime regulation, set to take effect in 2025, mandates a gradual reduction[42] in the carbon intensity of maritime fuels, encouraging the use of biofuels, synthetic fuels, and alternative propulsion systems.

The EU has also invested in green port infrastructure, promoting the development of onshore[43] power supply (OPS) systems to allow ships to switch off engines and reduce emissions while docked. The Green Shipping Corridors initiative encourages member states and shipping companies to establish zero-emission maritime routes[44], with the goal of creating an emission-free shipping network by 2035.

United States Policies and Technological Developments

The United States has adopted a mixed approach of regulatory standards and incentives to promote green shipping. The Oil Pollution Act (1990) imposes strict liability on shipowners for oil spills and requires double-hull designs for tankers to prevent leaks[45]. The Clean Air Act empowers the Environmental Protection Agency (EPA) to set emission limits[46] for ships operating within 200 nautical miles of the US coast (designated as an Emission Control Area or ECA).

To support technological innovation, the US government has funded research into hydrogen and ammonia-based propulsion systems through the Department of Energy (DOE) and the Maritime Administration (MARAD). The US is also working with Canada and Mexico to develop a North American Green Shipping Corridor, aiming to reduce emissions across key trade routes.

Conclusion

Green shipping technologies have emerged as a crucial solution to mitigate the environmental impact of the maritime industry, which contributes approximately 3% of global greenhouse gas emissions. Emissions from shipping, including CO_2, SOx, and NOx, have long-lasting and often irreversible effects on the atmosphere and marine ecosystems, leading to ocean acidification, coral bleaching, and climate change. Technologies such as low-carbon fuels (LNG, hydrogen, biofuels), energy-efficient ship designs (rotor sails, air lubrication), and exhaust cleaning systems (scrubbers) aim to reduce emissions at the source. Regulatory

frameworks like the IMO Sulfur Cap (2020), the EU Emissions Trading Scheme, and MARPOL Annex VI have created legal pressure to accelerate this transition. India's Maritime Vision 2030 also reflects a commitment to sustainable shipping through green port infrastructure and alternative fuels. The shift toward green shipping is not just about compliance, it's about preventing environmental damage that cannot be reversed. A sustainable maritime future requires a coordinated effort among regulators, shipbuilders, and maritime nations to balance technological innovation with environmental responsibility.

Recommendations:

Recommendations for Greenhouse Gas (GHG) Emissions Regulation in India

Based on the discussion, the following key recommendations can be made for GHG emissions regulation in India:

1) **Enact a Comprehensive National Law**

   India must introduce a Greenhouse Gas (Prevention and Control) Act to regulate and control GHG emissions at a national level. This law should clearly define GHG emission standards, establish sectoral limits, and impose penalties for non-compliance. Additionally, it must provide a legal mandate for emission reduction strategies that align with India's commitment to achieving Net-Zero emissions by 2070.

2) **Define Greenhouse Gases in Indian Law**

   To ensure regulatory clarity, Indian environmental laws should formally define "Greenhouse Gas (GHG)" in alignment with international frameworks such as the Kyoto Protocol and the Paris Agreement. The definition should explicitly include Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur hexafluoride (SF_6) while allowing flexibility to incorporate new climate-altering gases in the future.

3) **Establish a Monitoring, Reporting, and Verification (MRV) System**

   A well-structured Monitoring, Reporting, and Verification (MRV) system is essential for tracking GHG emissions. India should implement a National GHG Inventory Registry to document emissions across all sectors. This system must mandate annual GHG emissions reporting for industries exceeding prescribed emission thresholds and introduce independent third-party audits to verify reported emissions, ensuring transparency and accountability.

4) **Develop and Regulate Carbon Markets**

   A National Carbon Trading System should be established to enable businesses to trade

carbon credits and offset excess emissions. To create financial incentives for emission reduction, India must introduce either a cap-and-trade system or a carbon tax. Additionally, strong regulatory oversight must be implemented to prevent fraudulent trading practices and ensure the credibility of the carbon market.

5) **Enforce Sectoral Emission Limits**

Setting sector-specific GHG emission limits is crucial to controlling emissions from key industries such as energy, manufacturing, agriculture, waste management, and transportation. Progressive reduction targets should be established to ensure India remains on track to meet its Nationally Determined Contributions (NDCs) under the Paris Agreement.

6) **Strengthen Penalties and Enforcement Mechanisms**

A strict enforcement framework is necessary to deter non-compliance with GHG regulations. Industries exceeding emission limits should face fines ranging from ₹5,00,000 to ₹5,00,00,000, depending on the severity of violations. Additionally, repeat offenders should have their licenses suspended or revoked, while the Central and State Pollution Control Boards (CPCB & SPCBs) must be empowered to conduct inspections and take corrective action when necessary.

7) **Promote Innovation and Technology Adoption**

Encouraging the adoption of low-carbon and renewable technologies is essential for India's transition to a sustainable economy. Financial incentives and subsidies should be provided to industries investing in clean energy solutions. Additionally, mandatory adoption targets for energy-efficient technologies should be introduced in high-emission industries, and a Green Climate Fund should be established to support research and development in climate- friendly innovations.

8) **Establish Climate Governance and Judicial Oversight**

To enhance environmental governance, India should establish a Climate Tribunal or expand the National Green Tribunal (NGT) jurisdiction to address GHG-related disputes. Furthermore, citizens and environmental groups must have the right to file Public Interest Litigations (PILs) to challenge regulatory non-compliance, ensuring public participation in climate governance.

9) **Ensure Climate Justice and Equity**

A just transition to a low-carbon economy must prioritize climate justice and equity by protecting workers and vulnerable communities affected by decarbonization policies. India should implement Just Transition policies to support displaced workers and

ensure social security measures. Additionally, targeted funding and policy support should be directed toward climate adaptation measures in high-risk regions.

10) Align with International Commitments

India's GHG regulations must be aligned with international climate commitments, including the Paris Agreement, Kyoto Protocol, and the UNFCCC guidelines. Strengthening India's participation in global carbon markets and international emission reduction programs will reinforce its commitment to combating climate change and maintaining global leadership in sustainable development.

These recommendations will help India build a strong, enforceable, and forward-looking legal framework to effectively regulate GHG emissions while balancing economic growth and environmental sustainability.

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