Decarbonising Shipping Vessels in Indian Waterways through Clean Fuel

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Image: CEEW/Kartikeya Jain

Vessels docked near Kochi port waiting for the cargo to be loaded and embark on their voyage.

Executive summary

The waterways sector in India, which comprises coastal shipping and inland waterways transport, is a crucial economic contributor, adding up to USD 1.6 billion (INR 13,007 crore) as gross value added (GVA) in FY20. The government has implemented various initiatives like the *Sagarmala Programme*, *National Waterways Act*, and *Inland Vessels Bill* to develop the waterways sector and enable a modal shift. However, these policies have a limited focus on the clean fuel transition.

In India, around 2,000 passenger vessels and 1,600 cargo vessels operating on inland waterways were registered in 2019. The estimated emissions of the inland waterways transport (IWT) sector stand at about 277,000 tonnes of CO_2 (tCO_2) as of 2019. Around 970 coastal shipping vessels operate as of 2019 in India, accounting for 1.6 million tonnes of fuel oil consumption and 5.1 million tonnes of CO_2 ($MtCO_2$) of emissions.

Government policies envision the annual cargo movement and passenger movement to increase by almost three times on inland waterways and by almost 1.2 times for cargo movement on coastal shipping between 2019 and 2030. The subsequent growth in fuel consumption and emissions will counteract the growth, necessitating adequate measures to avert these negative externalities.

Globally, measures have been taken to reduce emissions from shipping, with the International Maritime Organization (IMO) announcing the ambitious target of reducing emissions by 50 per cent by 2050 compared to 2008. In accordance with this target, alternate fuels, namely, ammonia, hydrogen, liquefied natural gas (LNG), liquid biofuel, methanol, and electricity are being actively explored by the shipping industry.

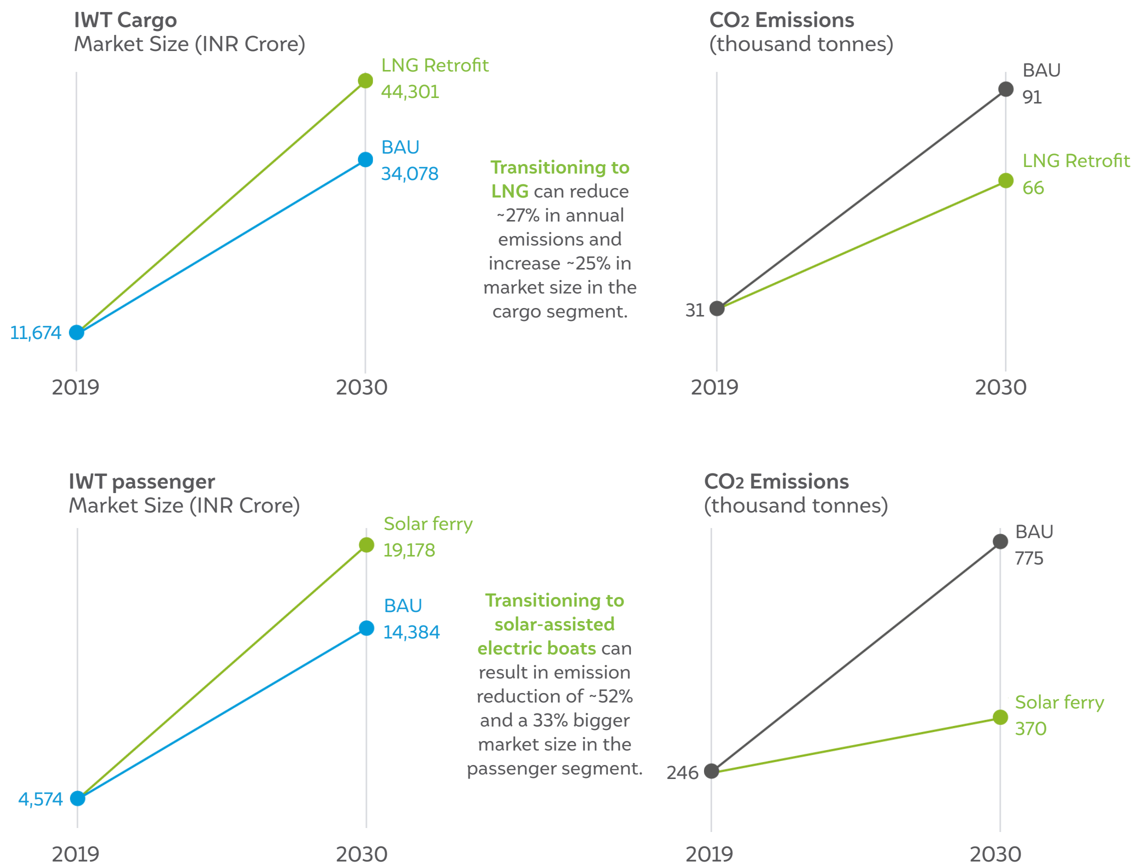
In this study, we assess the potential of two clean technologies – **LNG and solar-assisted electric boats** – in reducing emissions from the IWT sector and coastal shipping. We consider the target of retrofitting 100 per cent of cargo vessels operating on both coastal and inland waterways with LNG systems by 2030, to estimate the maximum potential of a clean fuel transition. For the passenger ferries operating on inland waterways, we assume around 50 per cent transition to solar-assisted electric boats by 2030.

Key findings

IWT passenger and cargo segment: To abate a threefold increase in fuel consumption and, consequently, in emissions, we review the potential impacts of transitioning to LNG in the cargo segment and electric boats in ferries.

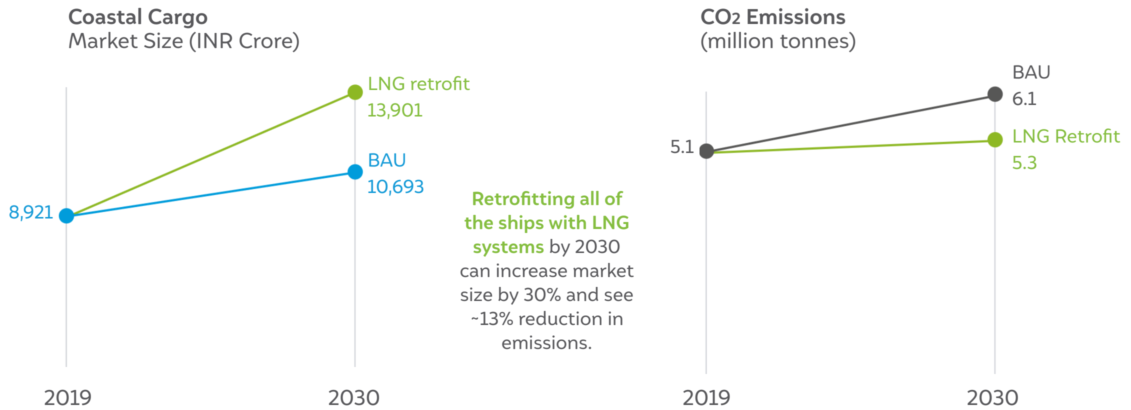
- If 100 per cent of IWT cargo vessels are transitioned to LNG, it will be possible to realise an approximate reduction of 27 per cent in annual emissions and a 25 per cent increase in market size by 2030 as compared to the 2030 business as usual (BAU) scenario.
- In the IWT passenger segment, a transition to solar-assisted electric boats by 2030 will result in an emissions reduction of almost 52 per cent and a market size increase of about 30 per cent, as compared to the 2030 BAU scenario.

Figure ES1 Transitioning to LNG and solar-assisted electric boats can reduce emissions and increase the market size for the IWT segment



Source: Authors' analysis

Figure ES2 Retrofitting cargo ships with LNG system by 2030 can increase market size by 30% and reduce the emissions by 13%



Source: Authors' analysis

Coastal shipping vessels: To reduce the estimated 1.2 - fold growth in residual and distillate oil consumption in coastal shipping vessels by 2030, we review the impact of a potential LNG transition. Assuming 100 per cent of ships are retrofitted with LNG systems by 2030, an emissions reduction of around 13 per cent and a 30 per cent market size increase can be achieved when compared to the 2030 BAU scenario.

Key recommendations

We found a **systemic gap and lack of cohesive policy support in adopting alternative fuels**:

- The current literature lacks detailed techno-economic analyses to compare nascent alternatives, including methanol, biofuels, and ammonia, in the Indian waterways sector. The Government of India may consider clean fuel and technology-based investments, incentives, and commercial pilots involving global experts and local entrepreneurs.
- A critical review of the research on low-carbon fuels points to LNG being a promising alternative in coastal shipping and the IWT cargo segment. Electricity emerges as a promising alternative in the IWT passenger segment. However, current policies lack strategies to ensure ecosystem readiness, the availability of new fuels, robust technological alternatives, and retrofitting options.
- India's shipbuilding and ship repair industries are abysmal compared to global capacity. The current policy framework does not provide support schemes and incentives to manage the industry's over-reliance on government orders and limits competitiveness against global players. Moreover, poorly developed ancillary services have stymied the growth of the shipbuilding and ship repair industries.
- High financing costs, a significant tax burden, and limited ship spares availability plague the ship repair industry. Revamping fiscal and collaboration strategies can address such challenges while nudging the industry toward new technologies and low-carbon fuels to further economic development and job creation.

This brief identifies several criteria that need to be considered when choosing an appropriate fuel mix and the consequent impact on emissions. However, a detailed techno-economic analysis is required to compare more nascent alternatives, including methanol, biofuels, and ammonia. The momentum built in transitioning to low-carbon fuels in road transport should be leveraged through cohesive policies to decarbonise the waterways sector in India.

> **A detailed techno-economic analysis is required to compare more nascent alternatives, including methanol, biofuels, and ammonia.**

1. Introduction

Currently, most domestic freight is transported via roads (70 per cent) and a meagre share by waterways (6 per cent) (NITI Aayog, RMI India 2021). The under-utilisation of waterways adds further to emissions in the freight sector. The waterways sector accounts for 95 per cent of India's trade volume and 65 per cent of the overall trade value (MoPSW 2021a). Cargo movement grew at a compound annual growth rate (CAGR) of 4.5 per cent, and the movement of passengers by 5 per cent, over FY11 to FY20 (MoPSW 2021c).

The major commodities handled at Indian ports comprise petroleum, oil and lubricants (POL), coal, and iron ore (MoPSW 2021c). *Maritime India Vision 2030* (MIV 2030) projects three scenarios for traffic, with CAGRs of 3.1 per cent, 4.9 per cent, and 6.5 per cent between FY19 and FY30 (MoPSW 2021a) (see Figure 1).

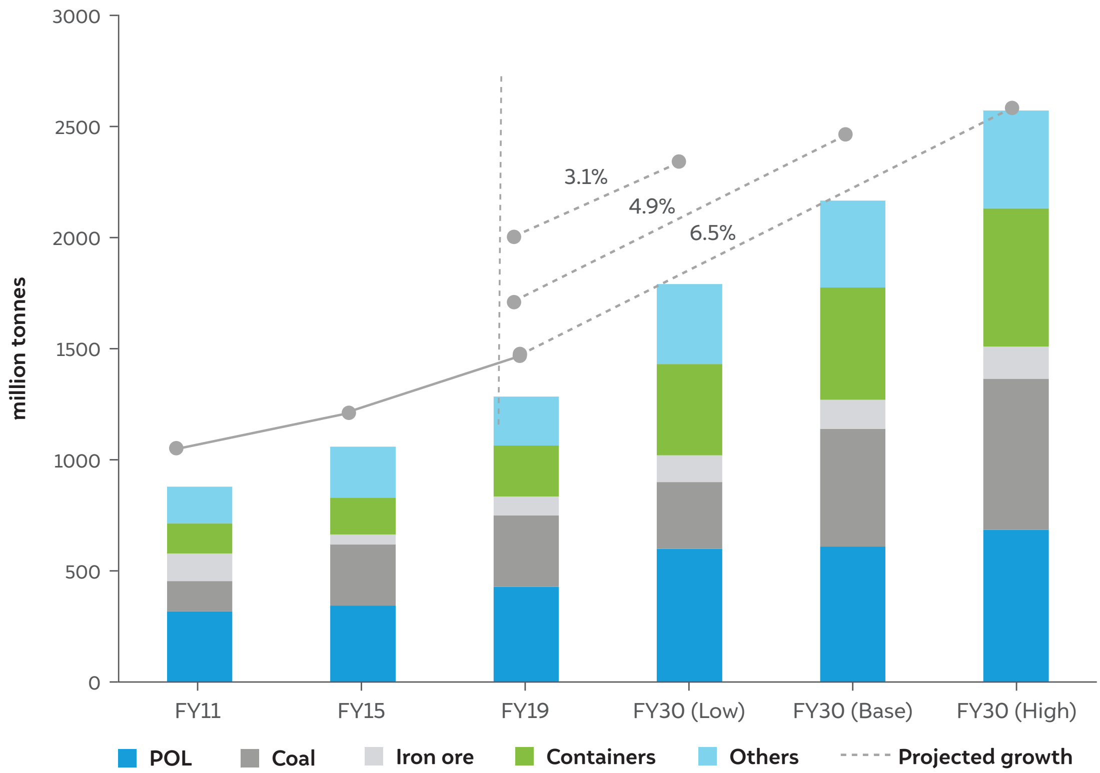
The growth in the waterways sector indicates the need to effectively manage the fuel transition in vessels to in turn manage increasing emissions. The following section provides a broad overview of the waterways sector in India and is critical to assessing the potential of transportation via waterways.

The envisioned growth in the coastal traffic creates a potential for exploration of alternate fuels in the shipping sector.

India is endowed with a long coastline of about 7,500 km with access to the sea on three sides. There are about 12 major and 205 minor/intermediate ports. India has about 34,000 km of navigable inland waterways, comprising canals, rivers, backwaters, creeks, and tidal inlets (MoPSW 2021b) (see Figure 2). The Inland Waterways Authority of India (IWAI) was established for the development, maintenance, and regulation of national waterways for shipping and navigation in 1986 (MoPSW 2021b).

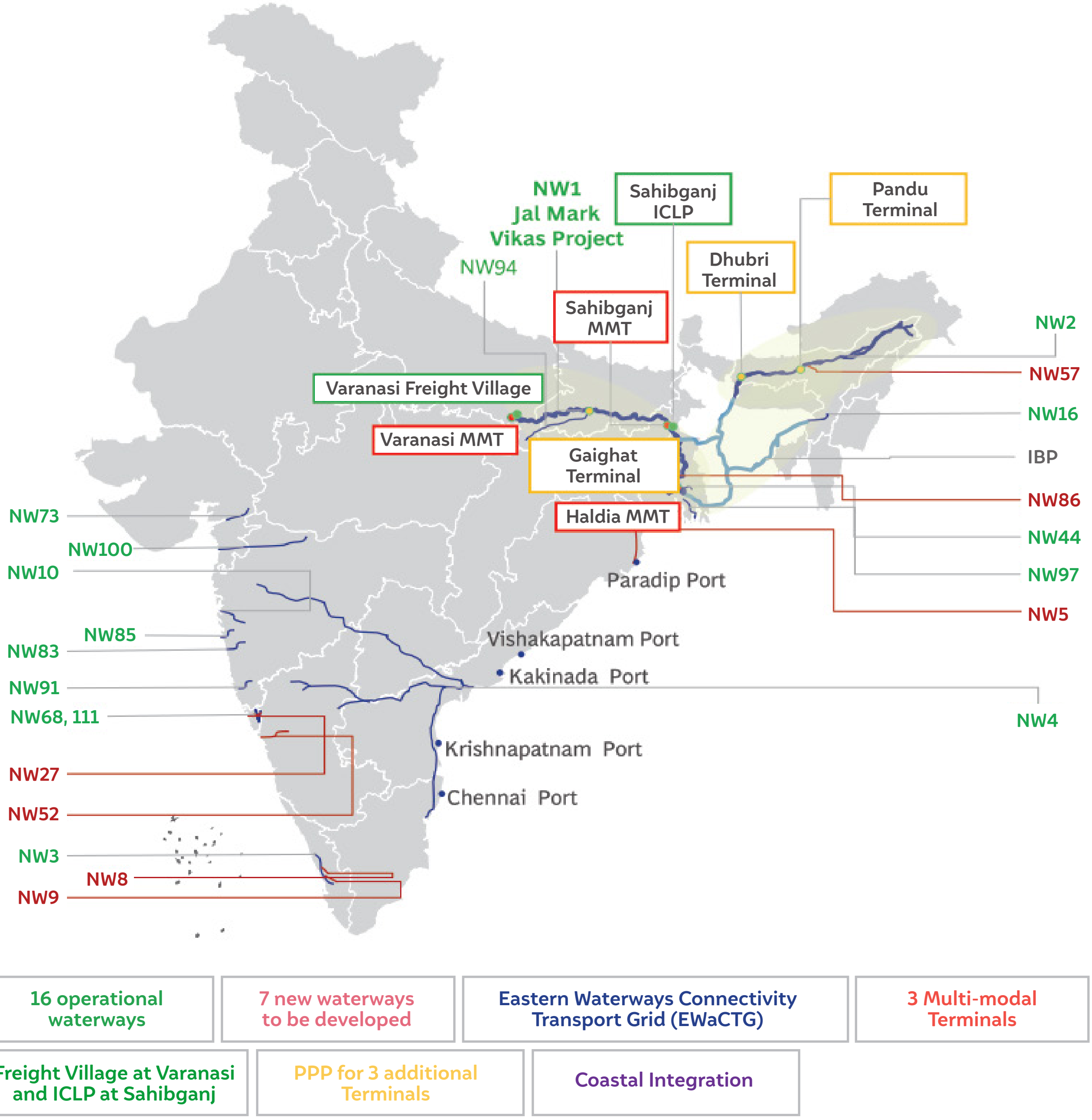
The MIV 2030 aims to make India the top country in the world for ship recycling and among the top 10 countries for shipbuilding (MoPSW 2021a). Currently, India ranks second in the world in ship recycling and 21st in shipbuilding (Prakash 2021). While China, Japan, and South Korea together contribute 90 per cent of the world's shipbuilding capacity, India accounts for less than 0.045 per cent today (Prakash 2021). Further, India ranks among the top five countries in supplying trained manpower, with about 12 per cent of all seafarers globally coming from India (MoPSW 2021a).

Figure 1 **Maritime India Vision 2030 estimates the coastal traffic to increase by 3.1-6.5% in different scenarios from FY19-FY30**



Source: Authors' adaptation from Department of Fisheries 2019.

Figure 2 Overview of the National Waterways in India



Source: MoPSW (2021a)

A clear goal set out by the Ministry of Shipping is to encourage the use of technologies, especially the construction of vessels that use alternative fuels (Directorate General of Shipping 2022).

We, therefore, explore the feasibility of deploying various alternative fuels in medium and small vessels used in IWT and coastal shipping. Maritime operations are not considered in this study. The limited involvement of international bodies, namely, the International Maritime Organization (IMO), creates an opportunity for the Ministry of Ports, Shipping and Waterways (MoPSW) and the Inland Waterways Authority of India (IWAI) to explore the potential of deploying clean fuel technologies in small and medium vessels. The scope of the waterways sector transcends state boundaries. Hence, it is imperative to view the clean fuel transition from a national perspective.

This study first describes the vessel ecosystem in India, collated from secondary literature in section 2. Section 3 provides an overview of the clean fuel technologies used globally, and, by drawing parallels, we explore their potential in the Indian context. Finally, in Section 4, we analyse emission savings and the potential market if a clean fuel transition is realised in India by 2030.

2. The vessel ecosystem in India

The Government of India enacted the *National Waterways Act* in 2016 to provide a boost to the IWT. It declared the creation of 111 national waterways (NW) that will supplement the railways and roadways. Of these, five NWs were already operational before the Act came into force. Out of the newly declared 106 NWs, 18 are feasible for cargo movement, 25 are feasible for tourism/ferry cruises, and the remaining are infeasible for both cargo and passenger movement (MoPSW 2021b).

2.1 Characteristics of cargo movement and vessels across IWT

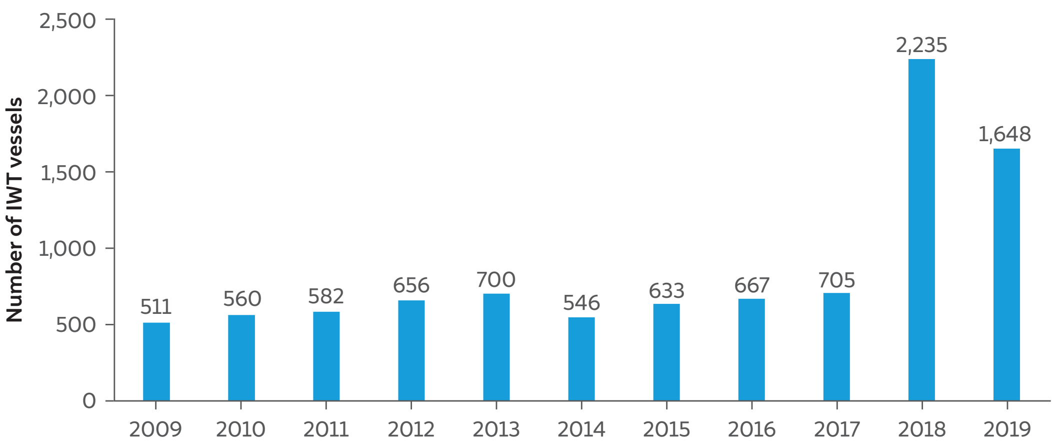
Among the ports in India, almost 80 per cent of the freight is handled at Paradip, Mumbai, Deendayal, Vishakhapatnam, Kamarajar, and Cochin ports. The majority of the traffic movement (60 per cent) is concentrated on NW-1 (Indo-Gangetic rivers), NW-10, and NW-100 (the western coasts in the states of Maharashtra and Gujarat) (MoPSW 2022).

IWT cargo vessel registrations exhibited a stable trend between 2009 and 2017 followed by a steep increase in vessel registrations in 2018 (see Figure 3). This increase in registrations can potentially be attributed to the *Jal Vikas Marg* and the *National Waterways Act* launched by the Government of India in 2016–2017.

The vessels operating in the IWT sector, carrying cargo, typically have a draught of 1.4–1.8 meters. The gross register tonnage (GRT) of these vessels is in the range of 150–500 tonnes, with an average power output of around 520 BHP. The maximum speed of these vessels averages around 9.5 knots. The detailed characteristics of the different vessels operating on inland waterways are highlighted in Table 1.

> **National policies launched by the Government of India has been critical to enhance the vessel ecosystem.**

Figure 3 Registration of IWT cargo vessels was stable over the period of 2009–2017



Source: Authors' adaptation from MOPSW (2021b)

Table 1 Characteristics and types of vessels used in the IWT sector in India

Type of vessel	Dimension	Draught	GRT	BHP	Speed (Knots)
IWT cargo					
Multi-purpose cargo	62 x 10.6 x 2.1 m	1.8 m	774	760	9
General cargo	54.6 x 9.6 x 2.4 m	1.4 m	426	390	9.4
Oil tanker	54.6 x 10.4 x 2.6 m	1.4 m	431	390	8.2
Container	54.75 x 9.59 x 2.3 m	1.4 m	439	390	8.2
Ro-pax	46.5 x 13.3 x 3	1.5 m	388	700	10.8
Self-propelled vessel of 2000 T	77.37 x 15 x 5 m	2.8 m	1,827	1,300	9
Tug 14 TBP	26 x 7.75 x 3.2 m	1.8 m	159	1,318	12.4
IWT passenger					
Ferry	21 x 7 m				6-7

Source: Authors' compilation from various sources

BOX 1 Policies in the IWT sector

Jal Marg Vikas Project, 2014

The Jal Marg Vikas Project (JMVP) was announced in FY15, to augment navigation capacity in National Waterway-1 on the river Ganga, creating about 46,000 direct and 84,000 indirect jobs in the vessel construction industry (IWAI 2018). Further, *Project Arth Ganga* was launched in 2019 to re-engineer JMVP to involve local communities in economic activities along the Ganga River (PIB 2020). The Inland Waterways Authority of India has undertaken the task of implementing the World Bank-assisted JMVP at a total cost of INR 4,634 crore, including activities related to *Project Arth Ganga* at a cost of INR 746 crore. JMVP-II was conceptualised in July 2020 with the objective of boosting socio-economic development and economic benefits to farmers, traders, and the public living around the Ganga and logistical cost reductions. The JMVP-II (*Arth Ganga*) includes, among others, the development of 62 community jetties and 10 (5 pairs) Roll-on/Roll-off (Ro-Ro) terminals in the states of Uttar Pradesh, Bihar, Jharkhand and West Bengal (PIB 2022).

National Waterways Act, 2016

The *National Waterways Act*, which came into force in 2016, declared 106 new national waterways (NW) in addition to the existing five NWs. These include rivers, estuaries, and creeks. This Act allows the union government to develop shipping, transport, and navigation through mechanically propelled vessels (MoS 2020). However, it failed to emphasise the clean fuel technology transition.

Inland Vessels Bill, 2021

In August 2021, the Parliament passed the *Inland Vessels Bill*, which replaces the *Inland Vessels Act*, 1917. The new bill aims to bring all inland waterways and vessel movement on them under the regulatory ambit of the central regime. The bill accounts for ships, boats, sailing vessels, container vessels, and ferries, and stipulates creating a fund that will be used for emergency preparedness, checking pollution, and enhancing navigation (The Indian Express 2021). The bill highlights efforts to maintain a central database to track the movement and identities of all inland vessels.

Source: Authors' compilation

In Alappuzha district, Kerala, we compare the freight movement via IWT versus road transport. The boat considered has a load-bearing capacity of 4–6 tonnes and operates on diesel. The comparison was conducted against an Eicher truck, with a load-bearing capacity of about 7 tonnes. IWT vessels are observed to be 50 per cent more efficient and 20 per cent more cost-effective than their truck counterparts (see Table 2). This suggests the high potential for energy and cost savings through passenger and freight movement by waterways, in contrast to road transport. India is yet to utilize the potential of waterways across its geography for movement.

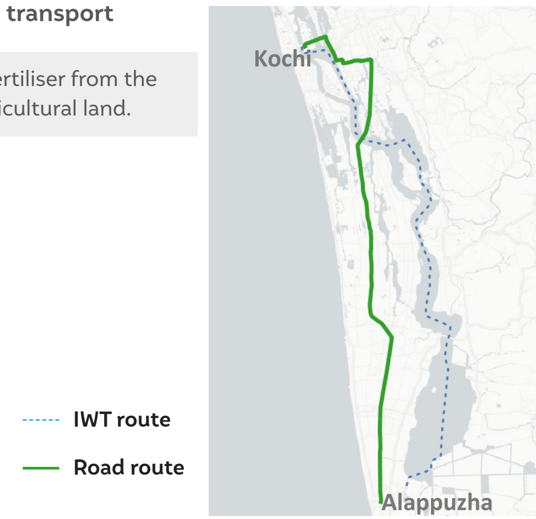
Table 2 IWT vessels are twice as efficient and 15% cheaper than road transport

Materials transported: Construction materials, Rice from the paddy field, fertiliser from the depot to agricultural lands, machines and tractors (using two boats) to agricultural land.

	Road transport	IWT transport	% savings
Fuel consumption	22 litres	11 litres	50%
Transportation cost	INR 7,875	INR 6,700	15%

Road transport vehicle: 7 tonne truck

IWT transport: 4-6 tonne boat



Source: Authors' analysis

2.2 Characteristics of passenger movement and vessels across IWT

About 145 million (1,450 lakh) passengers take ferry rides annually across nine states in India, of which West Bengal accounts for the highest share (see Figure 4). The MIV 2030 identifies integration with other transport modes and first/last mile connectivity as the key factors driving the uptake of ferry operations in certain parts of the country (MoPSW 2021a).

Currently, major passenger movement on ferries is observed in the eastern region, specifically in the state of West Bengal, which accounts for almost 55 per cent of the total passenger ferry movement. The western coast accounts for almost 30 per cent of the total passenger movement by ferries, with the states of Kerala and Maharashtra accounting for the maximum share (Figure 4). This creates an opportunity to further develop the ecosystem to optimise ferry movement and integrate it with other modes of transport.

> **The development of multi-modal links (Kochi water metro) is underway in Kochi.**

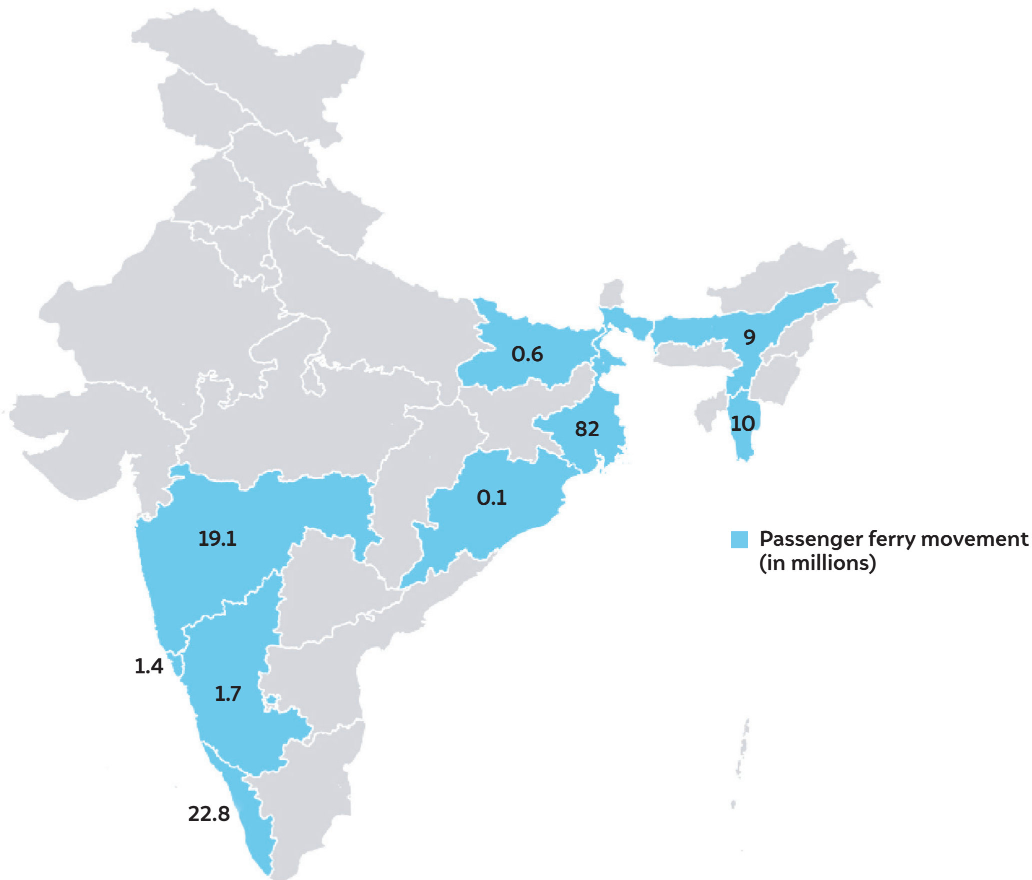
In Kerala, the development of multi-modal links (Kochi water metro) is underway in Kochi. In total, 38 boat jetties with bus services are planned to be connected to Kochi Metro feeder services to enhance city connectivity and public transport services, including for 10 island communities.

2.3 Characteristics of cargo movement and vessels in coastal shipping

As of 2020, India has about 1,463 vessels, of which 68 per cent of vessels are engaged in coastal trade. The Indian shipping fleet has grown at a CAGR of 3.3 per cent and the coastal shipping fleet at a CAGR of 2.7 per cent over the period of 2015–2020 (MoPSW 2021d) (see Figure 5).

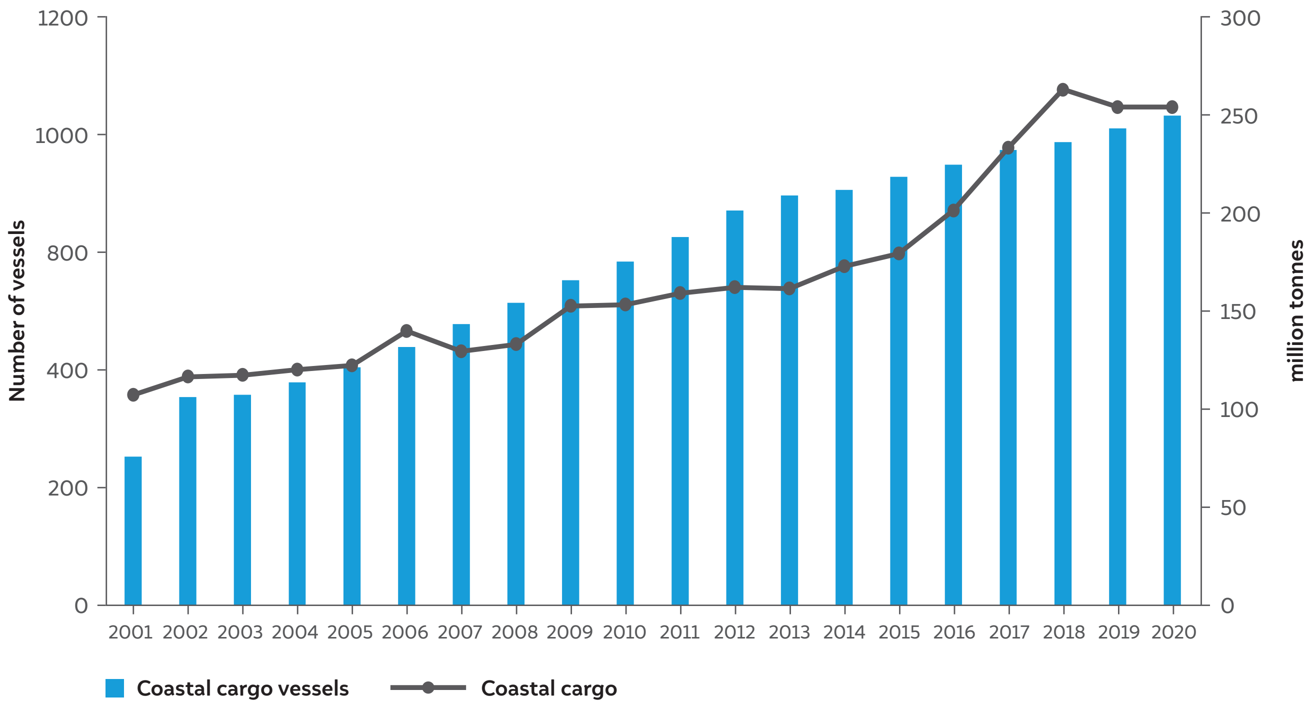
The vessels operating in the Indian coastal shipping sector have a draught of 7–13 metres and gross registered tonnage (GRT) of 3,800–30,000 GRT. The power output of these vessels varies typically from 4,000–6,000 brake horsepower (BHP) with maximum speed ranging from 17–22 knots. The detailed characteristics of the vessels are highlighted in Table 3.

Figure 4 West Bengal has the highest passenger ferry movement in India



Source: MoPSW (2021a)

Figure 5 Coastal freight traffic and the number of vessels has increased by 65% and 40% respectively from 2010 to 2020



Source: Authors' adaptation from MoPSW (2021d)

BOX 2 Key policies in the coastal shipping sector

Sagarmala Programme, 2015

A flagship programme of the Ministry of Shipping, *Sagarmala* aims to promote port-led development in the country by harnessing India's 7,500 km long coastline, 14,500 km of potentially navigable waterways, and strategic locations on key international maritime trade routes. The programme aims to reduce logistical costs for export, import, and domestic trade (MoS 2020). However, the programme does not adequately focus on the supply of alternate fuels at ports or incentives and investments to adopt clean technologies, especially in coastal ships.

Draft Coastal Shipping Bill, 2020

This bill aims to promote coastal trade and ensure that India is equipped with a coastal fleet, owned and operated by Indian citizens. Coastal maritime transport and inland waterways connectivity and trade are the main focus areas for reforms. The bill proposes conditions for issuing licenses, promotes multi-modal connectivity, and mandates maintaining a national register for coastal shipping (Kumar 2020). However, it falls short in adopting innovative mechanisms for promoting new technologies that emit less and are more cost-efficient.

Source: Authors' compilation

Coastal shipping shows a linear relationship between the increased freight traffic and the number of registered vessels. The total freight traffic on coastal routes increased from below 100 million tonnes per annum (MTPA) in 2001 to just under 250 MTPA by 2019. Therefore, deeper analysis is needed to identify critical barriers in attracting freight traffic to coastal shipping.

The share of the coastal passenger traffic at major ports was 84 per cent and the remaining 16 per cent was overseas passenger traffic. The overseas passenger traffic share at major ports has increased to 32 per cent in FY20 from FY15. Unsurprisingly, passenger traffic at non-major ports has largely been coastal (MoPSW 2021c).

Table 3 Characteristics and types of vessels used in coastal shipping in India

Type of vessel	Dimension	Draught	GRT	BHP	Speed (Knots)
Coastal ships					
General cargo	142.69 x 18.25 x 10.15 m	7.33 m	7,511	5,793	16.6
Multipurpose	100.5 x 16.5 x 7.5 m	5.79 m	3,850	4,720	14.3
Container	187.3 x 27.6 x 16.5 m	11.365 m	20,815	24,560	21.7
Oil tanker	180 x 32.2 m	12.47	28,799	-	15.6

Source: Authors' compilation from various sources

2.4 Shipbuilding and the repair ecosystem in India

A thriving shipbuilding industry can boost the 'blue economy', create jobs, and cater to the growing navy fleet. India requires a vibrant and robust shipbuilding and ship-repair industry for both economic and strategic reasons. Over the years FY16 to FY20, employment numbers in the shipbuilding and ship recycling industries have declined by over three times in both the private and public sectors combined (MoPSW 2021b).

With a coastline of 7,500 km and inland waterways potential of over 20,000 km, shipbuilding has been identified as a key sector under the '*Make in India*' initiative. Demand for shipbuilding is also anticipated to increase in response to the newly declared 106 waterways under the *National Waterways Act*, 2016 (MoS 2020). There are a total of 28 shipyards in the country, of which six fall under the central government, two under state governments, and 20 belong to the private sector (MoS 2020). India's private shipbuilding industry is in decline and relies too much on government contracts (Prakash 2021).

Nearly 65 per cent of value addition in the sector comes from ancillary industries such as steel, electronics, electrical equipment, engineering, and port infrastructure. Secondly, unlike say the auto industry, which follows a make-to-stock inventory model, shipbuilding is an order-driven industry, where each vessel is custom-built upon the receipt of the ship-building order (MoS 2020). The order books of the few public-sector shipyards in India always remain full, as 90 per cent of government orders for fleets for the Navy and the coast guard are placed with them. This deprives the private shipbuilding industry of orders and warship-building experience (Prakash 2021).

Order book growth for commercial ships is largely driven by growth in world trade and commerce, generating demand for new ships. Environmental stipulations by international regulatory bodies such as the International Maritime Organization (IMO) also spur demand for the replacement of older polluting ships (MoS 2020). However, the private sector in India has attracted limited foreign and domestic orders due to its limited competitiveness and the lack of adequate support schemes. The limited orders and technology exchange have also hindered the exploration of clean fuel technologies in the sector. While the use of clean fuels in the vessels operating in international waters, will be guided by the IMO, the government should incentivise the adoption of new fuel technologies in IWT and the coastal shipping sector.

The global ship repair market is worth USD 12 billion and is expected to reach USD 40 billion by 2028. The availability of a skilled workforce and the latest technologies are key determinants of competitiveness for this industry, which is currently dominated by shipyards in China, Dubai, Bahrain, and Singapore. Given that 7–9 per cent of global trade passes within 300 nautical miles of its coastline, India's location gives it an advantage. However, India's share in ship repair remains low, at less than one per cent of the global share. The key reasons for this include cost disadvantages due to the high tax burden, the limited supply of ship spares, and the cost of financing, which together make the industry uncompetitive (MoS 2020).

In tandem with the IMO targets, the Indian government should incentivise the adoption of new fuel technologies in IWT and the coastal shipping sector.

3. Alternative fuels for coastal and inland waterways

The potential of alternate fuel technologies has been explored in the global context. However, in this study, we draw parallels from the global experience and analyse the potential of alternative fuel technologies for vessels in the Indian context. A general comparison of various alternative fuel types can be found in Figure 6. It is to be noted that the relative competitiveness of fuels will vary depending on specific scenarios comprising local conditions, ship specifications, access to energy carriers, and so on (DNV GL 2019).

3.1 Functional criteria and the fuel choice trade-offs balance

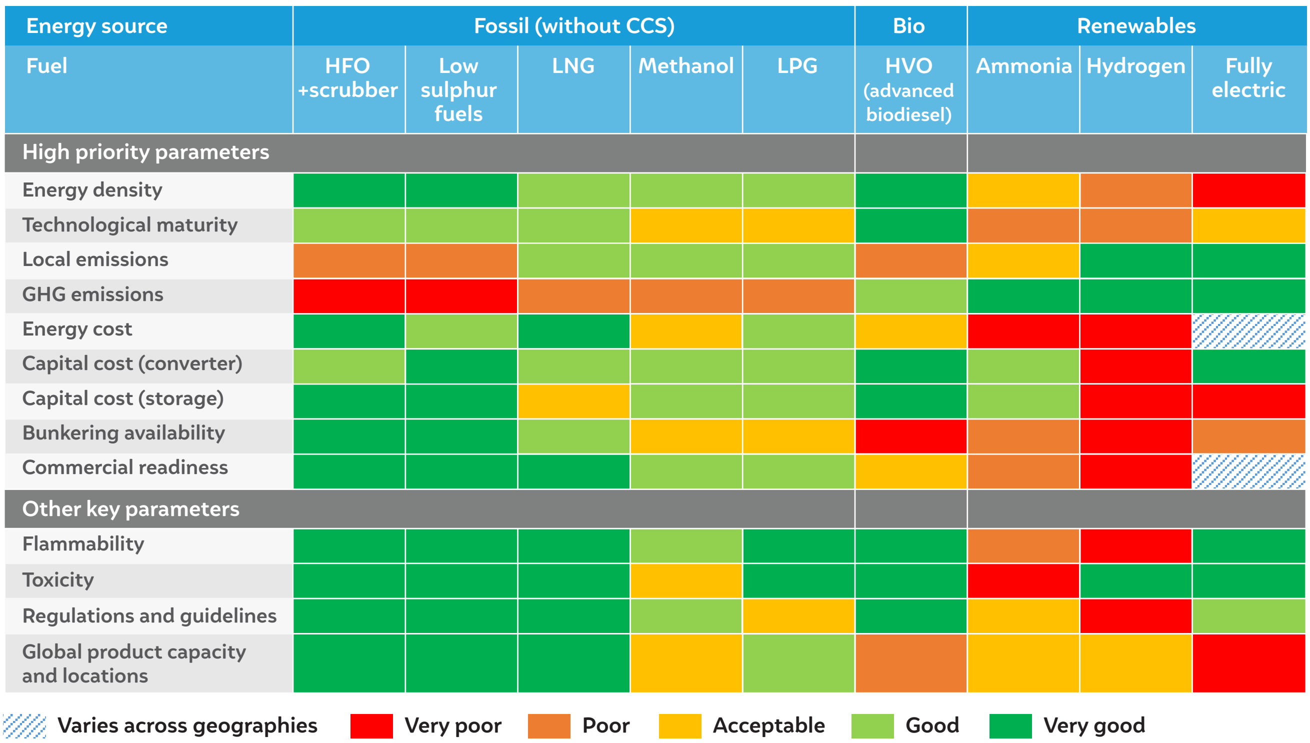
The adoption of alternative fuels in water transport is governed by physio-chemical characteristics such as low flash points, toxicity, higher volatility, and energy density. LNG, biodiesel, electricity, and methanol are the preferred alternative fuels in the marine and inland waterways sectors. The extended list of options, however, includes fuels such as hydrogen, ethanol, dimethyl ether, biogas, and synthetic fuels, which are all sulfur-free. LNG conversion would involve the refitting of engines and the installation of pressurized fuel storage onboard. Globally, methanol has been used to a limited extent with the latest generation of diesel technologies. Smaller vessels deployed in coastal waters may be best suited for biofuel use (Moirangthem 2016).

Ideally, fuels that are lightweight (having higher gravimetric energy density) and require less space (higher volumetric energy density) are preferred in the waterways sector. However, the following trade-offs emerge when comparing clean fuels with conventional fuels. Hydrogen-based fuels are lightweight when compared to conventional fuel; however, they require significantly more space (DNV GL 2019). Battery cell technologies are heavier and require more space as compared to conventional fuels (DNV GL 2019).

3.2 LNG is commercially ready, technologically adept, and affordable

LNG is suitable for small and medium vessels engaged in coastwise trade or operating as fixed-route ferries. Large ships that use LNG are limited to LNG cargo carriers on international voyages. An LNG bunkering network is critical to the widespread adoption of LNG-powered ships. The energy density of LNG is 2.4 times that of CNG and has a 40 per cent lower volumetric density compared to diesel (McGill, Remley, and Wither 2013; DNV GL 2019).

Figure 6 Comparison of different alternative fuels



Source: DNV GL (2019)

Among the alternative fuel options available for maritime shipping, LNG is the fuel of choice for several reasons. These include its lower SOx and NOx emissions and its cost-effectiveness compared to marine gas oil (MGO) as well as heavy fuel oil in some regions. Additionally, it emits approximately 25 per cent lesser greenhouse gases (GHGs) than conventional marine fuels while providing the same amount of power. However, when considering its entire lifecycle, including upstream emissions, combustion emissions, and unburned methane, LNG emits 70–82 per cent more GHGs as compared to MGO (Pavlenko et al. 2020). Researchers, thus, argue that LNG can serve as a temporary transition fuel at best (Englert et al. 2021a).

3.3 Liquid biofuels have good energy density and technological maturity

Liquid biofuels are another alternative fuel that the shipping industry is exploring to replace conventional marine bunker fuels and use as drop-in fuels in the near term. The lifecycle GHG emissions of these biofuels depend on the production pathway. Advanced biofuels produced from lignocellulosic or waste biomass have the highest GHG reduction potential. However, these pathways are technologically complex and expensive (Zhou et al. 2020).

3.4 Methanol has decent energy density and local emission reduction potential

Methanol gained global attention when one of the world's largest container logistics companies, AP Moller – Maersk, announced its plans to launch the world's first carbon-neutral line vessel in 2023 (Maersk 2021). Research finds that methanol is a better alternative to LNG from an infrastructure standpoint. LNG needs insulated refrigerated tanks to maintain its liquefied state, while methanol occurs in a liquid state at ambient temperatures and pressure and can be used in ships with minimum modification. This makes the transition to methanol easier and more affordable compared to alternative options.

However, the lifecycle GHG emissions from methanol are limited by the source from which it is derived. Grey methanol, derived from natural gas, does not offer any GHG benefits when compared to MGO. Methanol has to be derived from biomass feedstocks or renewable electricity to be a completely green fuel. Currently, the shipping industry's biggest obstacle with green methanol is not deploying it on ships but sourcing it. The commercialisation of green methanol's two inputs, carbon from direct air or point source capture, and hydrogen from renewable energy-powered electrolysis, is at a nascent stage, and there is a limited supply of sustainable biomass for producing cellulosic bio-methanol (Martin 2021).

3.5 Ammonia and hydrogen have high GHG emission reduction; however, high energy costs and toxicity remain a barrier

Ammonia and hydrogen are the other two alternatives that offer a variety of production pathways. Both of these fuels require minimal engine modifications and are used in the same way as heavy fuel oils. This allows for these fuels to benefit from the existing powertrain supply chain, including manufacturing and servicing. However, various research studies have argued in favour of ammonia over hydrogen. Hydrogen requires bulky, complex, and expensive storage systems, unlike ammonia, which does not require any expensive warehousing and occupies less space for the same amount of energy content. However, ammonia is toxic to human and aquatic life, and its toxicity will have to be managed through design and operational measures (Englert et al. 2021b).

3.6 Electric boats have zero exhaust emissions and fairly mature technologies

Fully electric systems offer the possibility of zero lifecycle emissions when powered by renewable electricity. The low energy density of electric systems translates to significant storage costs, which in turn limits their application to a few vessel types and sizes deployed across short distances.

India's first solar-powered electric ferry boat, ADITYA, has been in operation in Kerala since 2017. This boat can carry 75 passengers and was developed by a local manufacturer. It saves the Kerala Water Transport Department around INR 46 lakhs annually (Verma 2020).

> **While the technology matures to adapt clean fuels like hydrogen or electricity, LNG can serve as a temporary transition fuel.**

As is evident from the above discussion, complex decision-making based on lifecycle emissions, appropriate production pathways, infrastructure requirements, and a host of other techno-economic criteria will determine the optimal fuel mix. Further research for the Indian context is warranted to develop a phase-wise approach (starting with small and medium ships) for alternative fuel adoption and tracking the innovation already taking place on this front globally.

4. Emissions reductions and potential market by 2030 in India

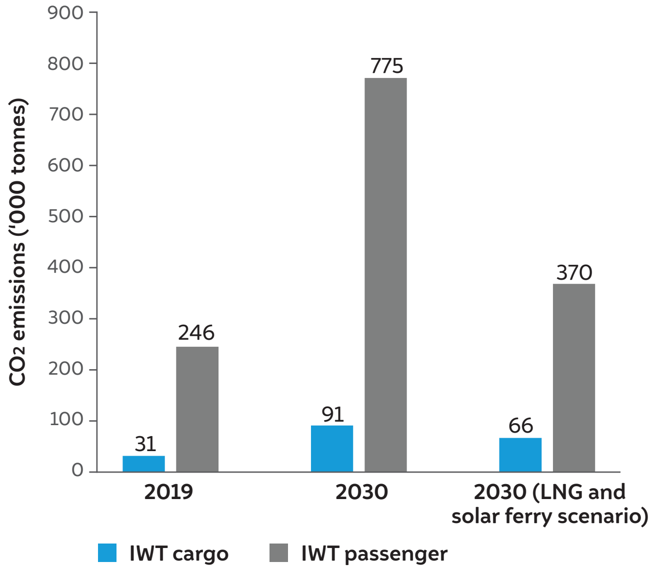
The Ministry of Ports, Shipping and Waterways has laid out an ambitious vision for India in 2030. India has 16 national waterways for cargo and ferry movement in FY20, and the MIV 2030 has expected the annual cargo movement to increase by almost 3 times for passenger and cargo movement in 2019–2030 (MoPSW 2021a). This growth in cargo and passenger movement through inland waterways and coastal shipping presents India with a huge market opportunity. Hence, there is a need to assess the market potential and explore the feasibility of implementing alternate fuel technologies. The following section explores two alternative technologies, namely, solar electric boats for IWT and LNG fuel-operated vessels for coastal shipping. The methodology and assumptions for these calculations have been detailed in the annexure.

4.1 Inland waterways

With the growth in cargo movement across national waterways, we estimate fuel demand to increase by about three times, resulting in a threefold increase in GHG emissions (from 31,000 tonnes of CO_2 to 91,000 tonnes of CO_2) in 2030. Assuming an alternative fuel scenario where all the IWT cargo vessels are retrofitted with LNG, the energy consumption will be about 1,200 terajoules (TJ). Further, the transition to LNG systems will lead to about 26,000 tonnes of CO_2 emissions abatement in 2030.

In the case of passenger transport through inland waterways, we estimate the energy demand to grow threefold by 2030 (from 2,807 TJs in 2019 to 8,827 TJs in 2030). If all small boats carrying passengers are electrified by 2030, emissions may be reduced by almost 52 per cent (see Figure 7).

Figure 7 CO_2 emissions from the IWT segment can be abated by 30-50% by using alternative fuel technologies



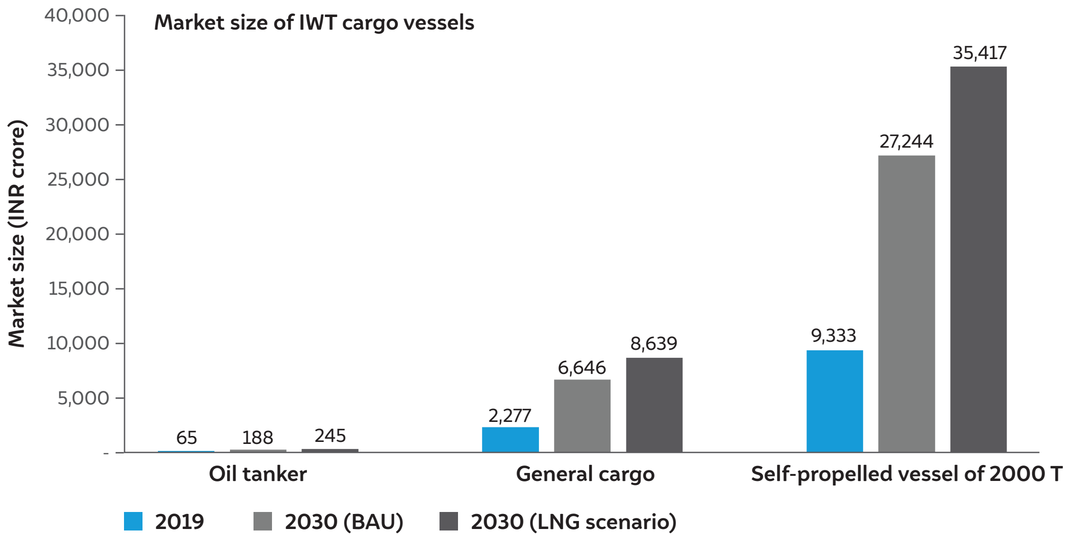
Source: Authors' analysis

According to the latest statistics on inland waterways in India, India has 1,648 self-propelled cargo and passenger-cum-cargo vessels transporting about 69 MTPA of cargo on national waterways in India (MoPSW 2021b). Assuming a target of 200 MTPA cargo traffic by 2030, about 4,811 vessels will be required by 2030. This works out to about 2,506 self-propelled vessels of 2000 tonnes, 2,241 vessels for general cargo, and 64 oil tankers.

Assuming the costs are as listed in the Annexure 2, we estimate the market size for cargo vessels to increase by about three times in the business as usual (BAU) scenario in 2030. Further, given the technological maturity and global uptake of LNG, we explore the market size for retrofitted LNG vessels. Assuming all the vessels are retrofitted with LNG systems, this would create a market size of about INR 44,300 crore (1.3 times compared to BAU) in the LNG scenario.

Similarly, in 2019, 2,033 passenger ferries transported 22 crore passengers (MoPSW 2021d). To support the passenger traffic target of 70 crore by 2030, about 6,393 passenger ferries will be needed. Thus, we estimate the market size of passenger ferries to grow by about four times between 2019 and 2030. If 100 per cent of passenger ferries were to be replaced by solar-electric ferries by 2030, it would present a market size of INR 19,178 crore in 2030.

Figure 8 Retrofitted LNG vessels in IWT cargo vessels can create a market size of around INR 44,300 crore by 2030



Source: Authors' analysis

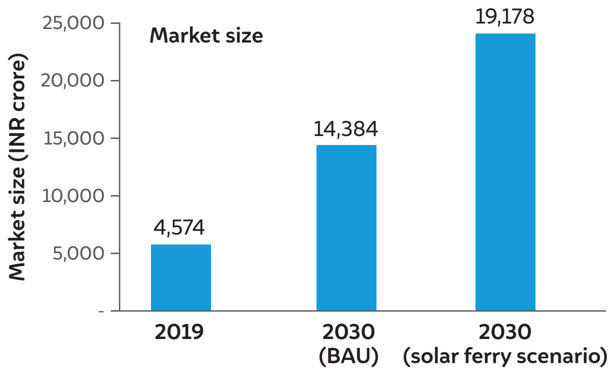
4.2 Coastal shipping

The residual fuel oil and distillate oil demand from coastal shipping for freight transport is estimated to increase by 1.2 times each in 2030 when compared to 2019. This will lead to an increase in CO2 emissions from 5 MtCO2 in 2019 to 5.5-6.1 MtCO2 in 2030. If 100 per cent of these coastal vessels are retrofitted by LNG systems, the emissions in 2030 will be in the range of 4.8-5.3 MtCO2, resulting in a 13 per cent reduction in emissions (see Figure 10).

With an increase in coastal cargo traffic from 231 MTPA to between 259–286 MTPA in 2030, we estimate the ship vessel numbers to increase from 972 in the year 2019 to between 1,060–1,165 in 2030. This growth is set to create a market opportunity of about INR 9,733–10,693 crore by 2030 (see Figure 11). Assuming a scenario where 100 per cent of these vessels are retrofitted with LNG systems, the market size in 2030 is set to grow to INR 12,653–13,900 crore.

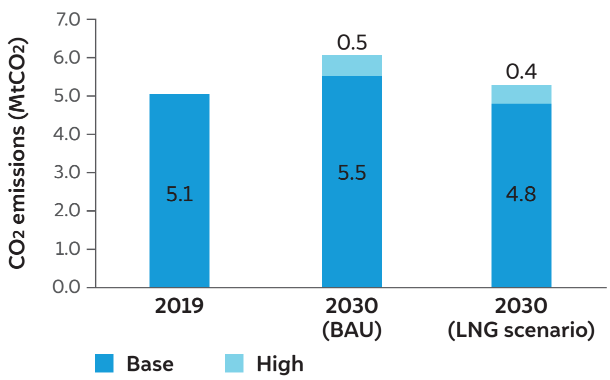
> A transition to clean technology in both IWT and coastal shipping sector can result in a slew of gains in terms of market potential and emission abatement.

Figure 9 A transition to solar-assisted electric boats in the IWT passenger ferries can create a market size of around INR 19,000 crore by 2030



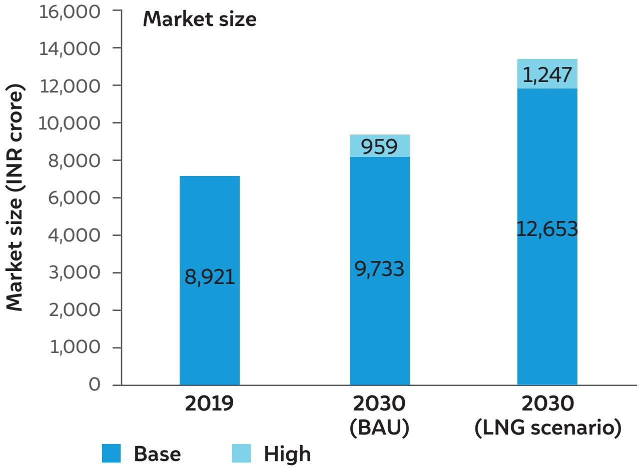
Source: Authors' analysis

Figure 10 CO_2 emissions from coastal cargo vessels in 2030 can be reduced by 13% as compared to a BAU scenario



Source: Authors' analysis

Figure 11 Retrofitting existing vessels with LNG systems has the potential to increase market size by almost 30 per cent



Source: Authors' analysis

5. Four levers to accelerate clean fuel technology adoption

India's navigable coastline and inland waterways present an opportunity for mode shift for both passenger and freight transport. The Indian government needs to mobilise the uptake of low-carbon fuels in water transport as it has in road transport. While a variety of alternative fuels are in various stages of deployment globally, a comprehensive assessment of their techno-economic feasibility in various end-use segments and for different vessel types in India is missing today. This brief identifies several criteria that need to be considered when choosing an appropriate fuel mix and provides a critical analysis of various alternatives. Policy interventions to spur further innovation on this front and integrate it with the existing low-carbon fuel push in the road segment are needed.

Assuming IWT fleets for cargo and passenger transport are replaced with LNG and solar electric boats respectively, GHG emissions reductions of up to 27 per cent and 52 per cent are theoretically possible. For coastal shipping, retrofitting the entire fleet with LNG systems will result in a 13 per cent reduction in emissions.

The practical feasibility of these extreme scenarios notwithstanding, there are significant gains that can be realised by implementing farsighted and well-designed policies to promote alternative fuel adoption in water transport.

Given India's national targets for electrification and adoption of hydrogen and other low-carbon fuels, applications in water transport present an immediate opportunity. This is especially important given the anticipated rise in domestic demand for passenger and cargo vessels to meet the goals of the MIV 2030.

The MIV 2030 estimates that the cargo fleet and passenger fleet will triple in 2030, which offers an excellent opportunity to spur the adoption of a fuel-efficient and low-carbon fleet. To facilitate the adoption of clean technologies, the following four levers can be considered:

- **Generate awareness through government-initiated pilots and forging alliances**

  The current literature lacks a detailed techno-economic analysis to compare nascent alternatives, including methanol, biofuels, and ammonia. Given that these technologies are still nascent, it is imperative to undertake pilots for clean technologies in prominent geographies, especially in global leading hubs. The pilots will assist in generating awareness and identifying potential barriers that may hinder wide-scale adoption.

  Currently, the government procures the bulk of vessels manufactured in India, providing it with an ideal first-mover advantage to adopt clean technologies in its fleet. This will further prompt the private sector to invest in the adoption of clean technologies.

- **Facilitate the ecosystem for clean fuel adoption**

  To further develop the shipbuilding industry through the adoption of new technologies and alternative fuels, further exploration on the policy front is required. A critical review of research on low-carbon fuels indicates that LNG and electricity are promising alternatives in the waterways sector. However, current policies lack strategies to ensure ecosystem readiness, the availability of new technology alternatives, and retrofitting options.

  Increased adoption of alternate fuel technologies will give rise to the need to develop pertinent infrastructure in tandem. To ensure a steady supply of alternate energy for vessels, key stakeholders in the ecosystem will have to pre-empt the growth of demand for vessels and the subsequent energy requirements. The LNG fuel distribution network, and the charging infrastructure for electric boats, would require stakeholders to collaborate and ensure the timely establishment of necessary ancillary infrastructure.

- **Propel India's shipbuilding and ship repair industries**

  India's shipbuilding and ship repair industries constitute less than one per cent of the global share in terms of capacity (MoPSW 2021a). India's private shipbuilding industry is constrained by an over-reliance on government orders, limited competitiveness against global players, poorly developed ancillary services, and a lack of support schemes. In the ship repair industry, the cost of financing, the tax burden, and limited ship spare availability contribute to a lack of competitiveness. They also present a significant market opportunity for India's fledgling shipbuilding industry. The current policy framework fails to provide support schemes and incentives to manage the industry's over-reliance on government orders, limited competitiveness with global players, and poorly developed ancillary services, which stymy its growth.

> India's national targets for electrification and adoption of hydrogen and other low-carbon fuels can be leveraged for the water transport sector.

- **Employ economic instruments to expedite clean technologies**

  Revamping fiscal and collaboration strategies can address challenges within the ship repair industry while nudging it toward new technologies and low-carbon fuels to further economic development and job creation.

  The policy timelines and vision set by the government provide an opportunity for stakeholders to develop pertinent economic instruments that may abet the high costs of alternate technologies. Economic instruments can play a critical role in bringing parity in the costs of clean and conventional fuel technologies. These instruments will be pivotal for both public-sector undertakings (PSUs) and the private sector, to expedite clean fuel technology procurement.

The growth of passenger and freight transport on roads cannot continue unabated. Passenger and freight transport through coastal shipping and inland water transport should increasingly curb emissions from transport. Existing policies target increased mode-sharing, but policies that enable alternative fuel adoption in waterways are notably absent today. Adoption of these fuels could further enhance the sustainability and economics of water-based transportation while reducing oil imports and aiding India's transition to a net-zero future.

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