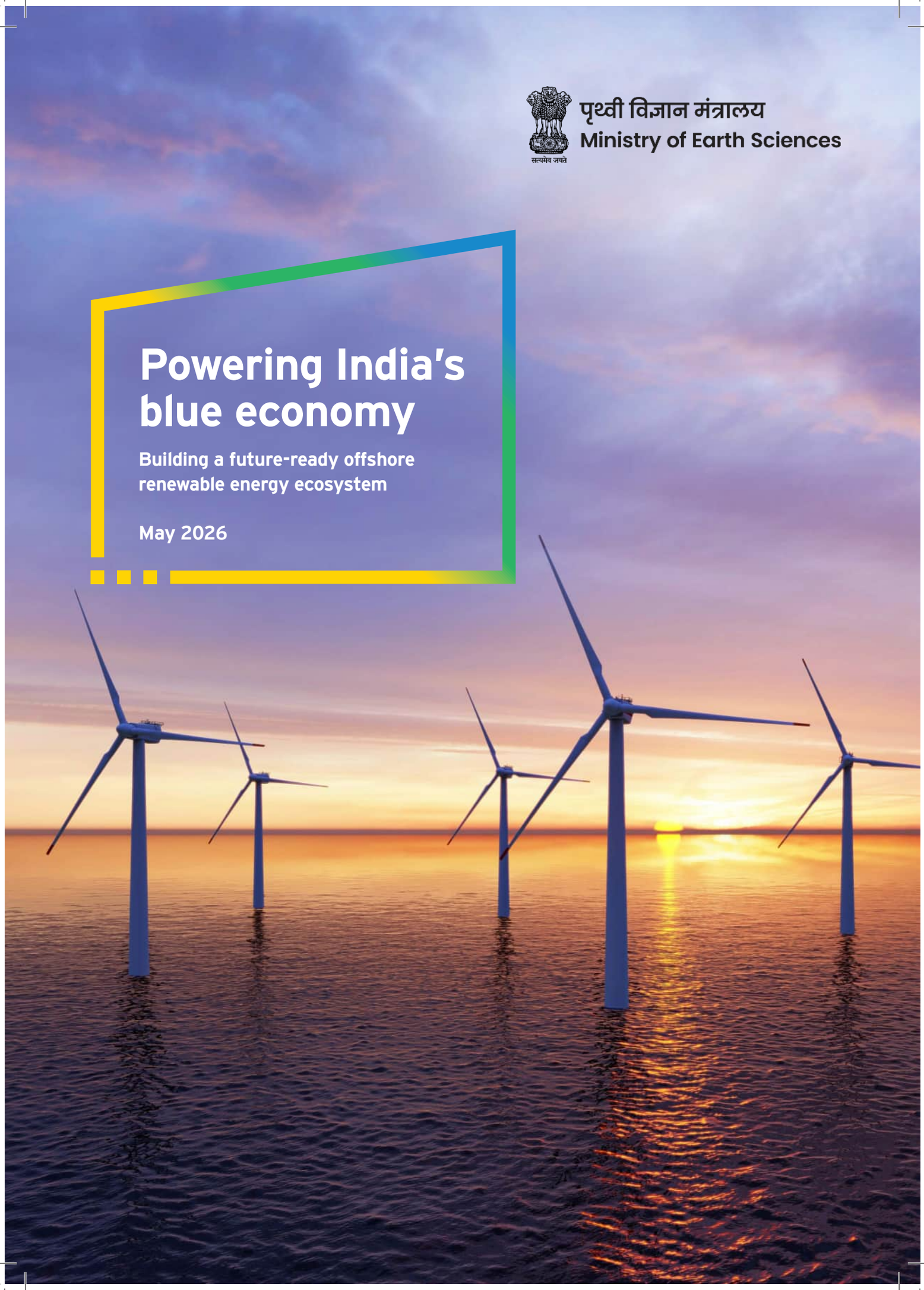


पृथ्वी विज्ञान मंत्रालय
Ministry of Earth Sciences

सत्यमेव जयते

Powering India's blue economy

Building a future-ready offshore renewable energy ecosystem

May 2026

Foreword



Dr. M. Ravichandran

Secretary, Ministry of Earth Sciences

India's vast ocean domain holds significant strategic potential for offshore renewable energy. This sector, when developed, can emerge as a major driver of energy security, clean energy growth and national development towards Viksit Bharat 2047.

The development of offshore renewable energy depends on complexities and a dynamic marine ecosystem shaped by sensitive weather conditions like monsoons, cyclones and sediment transport. Its successful deployment depends not only on policy ambition but also on robust ocean observations, high-resolution resource assessments, long-term environmental baselines and technology validation under Indian conditions. The Ministry of Earth Sciences, through its institutions, particularly via NIOT and INCOIS, has steadily built indigenous scientific and technological capabilities across offshore wind resource assessment, ocean energy research, metocean data generation and pilot-scale demonstratable models. These efforts provide the scientific backbone required to de-risk offshore renewable investments and support informed policy and regulatory frameworks.

This white paper assesses the scope and role of offshore renewable energy within India's blue economy vision, recognizing that global experience demonstrates how marine-based renewables can drive coastal industrial growth and port development. MOs emphasizes strong inter-ministerial convergence with MNRE, coastal state governments, and port authorities to align scientific resource assessments with policy, regulation and infrastructure planning. A mature and diverse offshore renewable portfolio can also strengthen India's regional leadership in the Indian ocean region through indigenous, cost-effective technologies suited to tropical conditions, supported by technical cooperation and capacity building with neighboring countries and small island developing states.

The paper highlights the importance of seabed mapping, metocean observations and indigenous ocean energy research, providing critical scientific foundations for offshore renewable energy. Building demonstratable models and scaling successful pilot deployments will require complementary investments in pilot projects, long-term data systems, and risk-mitigation frameworks. Through sustained financial support, institutional capacity and coordinated governance, India can successfully demonstrate its commitment to clean and green energy. This white paper charts a pathway to operationalize a science-led offshore renewable ecosystem within India's blue economy framework.



Shri. Santosh Kumar Sarangi

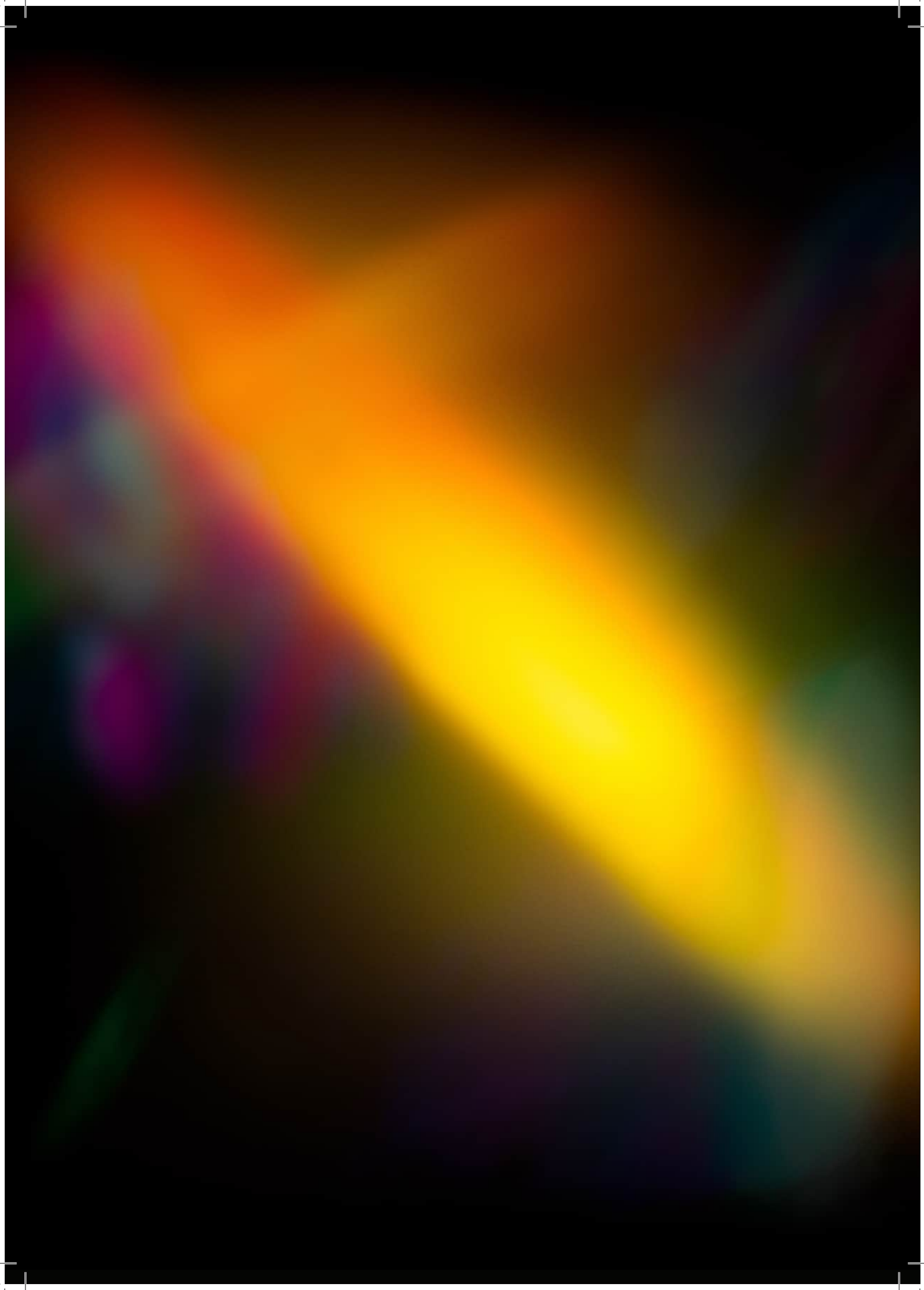
Secretary, Ministry of New and Renewable Energy

India stands at a defining moment in its energy transition, where accelerating climate commitments, rising electricity demand, rising demand for dependence of indigenous technology, and country's economy ambitions converge to make offshore renewable energy a strategic national priority enabling India's energy security, decarbonization goal and achieving vision 2047. At the 26th Conference of the Parties (COP26) in Glasgow, the Hon'ble Prime Minister reaffirmed India's commitment to climate action by announcing that India will achieve 500 GW of non-fossil fuel-based energy capacity by 2030.

India has already proven its commitment, competency and market readiness by harnessing land-based solar and onshore wind energy. To strengthen this renewable revolution, India will require diversification toward high-capacity, land-neutral energy sources. Offshore renewables, including offshore wind, floating solar, OTEC, wave, tidal, salinity-gradient energy and offshore-enabled green hydrogen, offer a reliable pathway to meet future baseload clean energy requirements.

This white paper provides a strategic map for building a future-ready offshore renewable energy ecosystem, with a comprehensive framework to translate this potential into an implementable action plan. The paper highlights the importance of convergence across line ministries – namely ports, environment, power transmission, maritime security and coastal livelihoods – to achieve spatial optimization, robust environmental safeguards and structured stakeholder engagement.

The MNRE views offshore renewable energy as a strategic pillar of India's clean energy transition and is committed to enabling its scale-up through targeted policy, financial and institutional support. This white paper outlines a coordinated pathway that will actively promote pilot-scale deployments, indigenous technology development and mission-mode implementation in partnership with research institutions, industry and state governments. Recognizing the high capital intensity and early-stage risks of offshore projects, the Ministry intends to facilitate viability gap funding (VGF), appropriate market mechanisms, and risk-mitigation frameworks to support investors and developers in building commercially viable projects. By fostering strong government-industry collaboration and strengthening domestic technological capabilities, MNRE aims to transition offshore renewable energy from demonstration initiatives to scalable, bankable and globally competitive projects. The Ministry calls upon all stakeholders to join in advancing this next phase of India's renewable energy journey.



Foreword EY



Shri. Rakesh Kumar Mishra

Partner, EY India

India stands at a defining juncture in its development journey, where the convergence of the blue economy and clean energy transition offers an unprecedented opportunity to advance economic growth, sustainability and strategic resilience. As a long-standing advisory partner to the Ministry of Earth Sciences, EY is privileged to support India's vision of leveraging its vast ocean resources to realize the ambitions of Amrit Kaal Vision 2047.

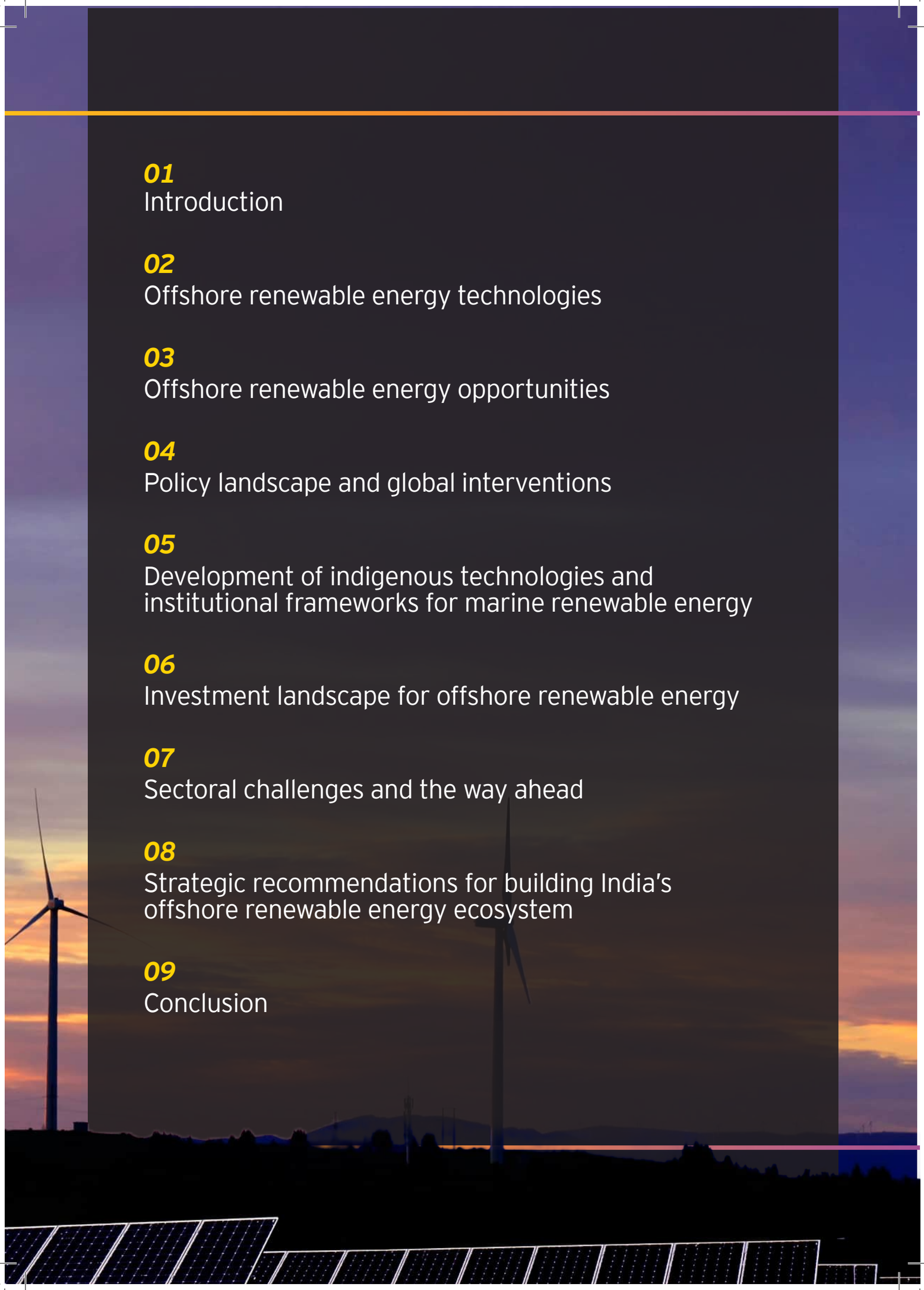
EY brings deep technical and advisory expertise across the full spectrum of the blue economy, including offshore renewable energy, ports and maritime infrastructure, fisheries and aquaculture, coastal tourism and resilience, alongside strong capabilities in renewable energy, climate strategy, and sustainable finance. Over the years, EY has played a catalytic role as an ecosystem enabler, bringing together government institutions, policymakers, industry leaders, investors, global collaborators, and technical and academic institutions to co-create solutions that are both commercially viable and environmentally responsible.

A shared recognition has emerged among stakeholders that renewable energy, particularly offshore renewable energy, will be central to India's long-term sustainability and economic competitiveness. Offshore wind, ocean energy and emerging marine energy technologies have the potential to significantly strengthen India's blue economy, enhance its contribution to GDP, and support national decarbonization goals. Beyond energy security, offshore renewables can drive indigenous technology development, create new industrial value chains, unlock opportunities for start-ups and enable scalable public–private partnership models.

This paper is a product of a series of knowledge papers being developed on thematic sectors of the blue economy that reflect a collective effort to translate scientific insights, policy priorities, and market realities into a coherent pathway for offshore renewable energy development. EY remains committed to supporting the Ministry of Earth Sciences, state governments keen on harnessing their coastal potential, and all stakeholders in shaping a resilient, innovation-driven and globally competitive blue energy future for India.

Contents





01
Introduction

02
Offshore renewable energy technologies

03
Offshore renewable energy opportunities

04
Policy landscape and global interventions

05
Development of indigenous technologies and institutional frameworks for marine renewable energy

06
Investment landscape for offshore renewable energy

07
Sectoral challenges and the way ahead

08
Strategic recommendations for building India's offshore renewable energy ecosystem

09
Conclusion

Executive summary

India stands at a pivotal juncture in its clean energy transition, where the convergence of rising energy demand, escalating climate risks, and rapid blue economy expansion makes the acceleration of offshore renewable energy both urgent and foundational to national progress. As the world's third-largest emitter, with the energy sector contributing nearly 76% of national greenhouse gas emissions, India must diversify beyond land-based renewables to sustain momentum toward its COP26 commitment of 500 GW renewable energy capacity and the Vision 2047 aspiration of energy independence.

Within just four years, during which total installed non-fossil fuel-based capacity stands at 156.83GW and India has transitioned 235.7 GW to non-fossil sources, driven largely by solar power using Agri-PV and rooftop solutions. To meet the rising electricity demand and the futuristic need for round-the-clock clean energy, amidst land constraints, there is a need to diversify sources of renewable energy generation. Offshore renewables, such as offshore wind, floating solar, wave, tidal, salinity-gradient, ocean thermal energy conversion (OTEC) and offshore-enabled green hydrogen, offer a high-capacity, land-neutral, and energy secure pathway to meet the country's long-term needs while catalyzing multi-sectoral economic transformation.

India's exclusive economic zone (EEZ) spans 2.4 million sq. km and hosts an estimated 9,58,000 TWh of marine renewable energy potential , with INCOIS's resource assessments confirming significant prospects across Andaman and Nicobar Islands, Southeast, Southwest and Northwest coastal corridors. These resources, when strategically developed, can decarbonize not only the power sector but also hard-to-abate industries, shipping, cooling, aquaculture, desalination and green hydrogen production strengthening India's blue economy and reinforcing its role as a regional clean-energy hub. Mature global experience demonstrates that offshore renewables create high-quality jobs, enable advanced manufacturing, strengthen coastal infrastructure, and drive innovation in marine sciences. For India, offshore renewable energy also offers an opportunity to support multiple national priorities such as Make in India, port modernization, green hydrogen development, and maritime security, thereby creating wider economic and strategic benefits.

However, unlocking this potential requires decisive action to address structural challenges. Fragmented institutional responsibilities, absence of marine spatial planning, limited transmission and port infrastructure, high capital costs, data gaps, environmental baseline limitations, investor uncertainty, community concerns and underdeveloped offshore manufacturing ecosystems currently constrain sectoral growth. Offshore technologies, especially floating wind, OTEC, wave and tidal, require localized, region-specific engineering, robust metocean datasets and pilot-scale demonstrations suited to India's monsoonal, cyclone-prone conditions. Simultaneously, social acceptance and ecological safeguards must remain central, as coastal communities, fisheries and biodiversity stand at the intersection of development and sustainability imperatives.

To overcome these constraints and realize a globally competitive offshore energy ecosystem, India must adopt a coordinated, multi-sectoral strategy anchored in governance reform, coupled with financial innovation and infrastructure readiness. Key interventions include establishing a National Offshore Energy Authority for unified seabed leasing and single-window clearances, implementing marine spatial planning with biodiversity baselines; creating viability gap funding, sovereign guarantees, blended finance and contract of difference (CfD) -based market designs, modernizing ports and shipyards; accelerating offshore transmission corridors; institutionalizing international cooperation for technology transfer; and deploying blue and green bonds for capital

mobilization. Investments in skills, R&D, indigenous manufacturing, maritime security and circularity frameworks will further strengthen long-term resilience.

This white paper draws upon a combination of policy review, technical analysis and structured engagement with industry stakeholders. The findings and recommendations are informed by interactions with renewable energy developers and technology providers as well. These engagements provided valuable perspectives on key considerations such as cost structures, technology maturity, supply-chain development, data availability, regulatory processes and major challenges. Incorporating industry perspectives helps facilitate recommendations that are pragmatic and aligned with the on-ground operational realities.

The paper also underscores that offshore renewable energy is not merely a technological opportunity, but a national economic and environmental imperative. By acting decisively, India can unlock a new frontier of clean power, catalyze its blue economy, enable energy sovereignty, become a regional leader in offshore renewable deployment and secure a sustainable, prosperous future for generations to come, while opening vast avenues in the clean energy market.



CHAPTER 01



Introduction

India is ranked third highest in the world in GHG emissions . Amidst national sectors, the highest carbon-emitting sector is the energy sector, contributing 76% of the emission load via its heating and production processes. Needless to mention, finding an alternative path for energy production is inevitable and a high-impact intervention towards India's path to decarbonization. In this milieu, the Government of India has committed to generating 500 GW of energy via renewable measures during COP26.

India's Hgh Carbon Emitting Sectors

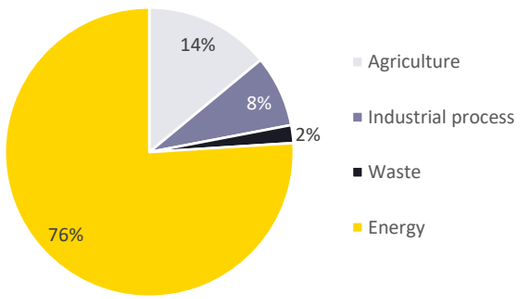


Figure 1.1: India's high carbon emitting sectors

India's power generation sector has witnessed a substantial growth in non-fossil fuel capacity, with non-fossil sources accounting for 235.7 GW, or nearly 49%, of the country's total installed capacity of 476 GW. This transition is driven primarily by the rapid expansion of renewable energy, particularly solar power. Solar capacity has increased significantly from 2.82 GW in 2014 to 110.9 GW in 2025, supported by a parallel strengthening of domestic solar manufacturing capabilities. During this period, solar PV module manufacturing capacity expanded from 2.3 GW to 88 GW, while solar cell manufacturing capacity grew from 1.2 GW to 25 GW. Flagship government initiatives such as the PM-Surya Ghar: Muft Bijli Yojana, launched in February 2024 to promote clean energy expansion and energy self-reliance adoption across one crore households, have played a critical role in accelerating decentralized solar deployment.

History shows that energy security has been central to economic development. As one of the world's fastest-growing economies, India is experiencing a sharp rise in energy demand and is now the third-largest energy consumer globally. This growth is driven by rapid industrial expansion, urbanization, population growth, and the successful expansion of electricity access through nationwide electrification programs. Increasing adoption of new technologies and the gradual shift from fossil-fuel-intensive systems to cleaner, electricity-based solutions such as electric mobility and electric cooking are accelerating demand for reliable and sustainable energy. Since 2022, India's electricity demand has grown rapidly, at 8% to10% every year and is likely to grow by approximately 57%, i.e., from 1,523 BU (2022–2023) to 2,393 BU by 2031–2032 . Subsequently, by 2047, the Ministry of Power anticipates the country's power demand to reach 708 gigawatts.

Hon'ble Union Minister, Ministry of Power, Shri. Manohar Lal Khattar, in his Viksit Bharat by 2047, was resolute in building the installed power capacity to four times, i.e., 2,100 gigawatts by 2047 .

On the same occasion, the Hon'ble Minister of State for Power and New & Renewable Energy, Shri Shripad Yesso Naik emphasized the need for meticulous planning to align the power sector with emerging priorities and transition towards a diverse and cleaner energy mix, driven by ambitious sustainability targets. To make this vision a reality, significant investments are needed in diverse renewable technologies that would improve production reliability, energy storage solutions, and grid modernization based on sustainable, perennial and dependable clean energy sources.

India is advancing rapidly toward its Amrit Kaal vision of achieving energy security, self-reliance and low-carbon leadership by 2047. As India accelerates its transition towards a sustainable future, its renewable energy (RE) sector has witnessed unprecedented growth.

India's renewable energy transition has reached a decisive inflection point, with solar energy leading the charge and proving that renewable energy (RE) can be a high confidence, socially accepted and rapidly scalable solution when supported by strong policies, demonstrated models and sustained programmatic interventions. The sector's growth is reflected in record utility-scale additions, a nationwide rooftop revolution powered by seven lakh



India's installed capacity for power generation (in GW)

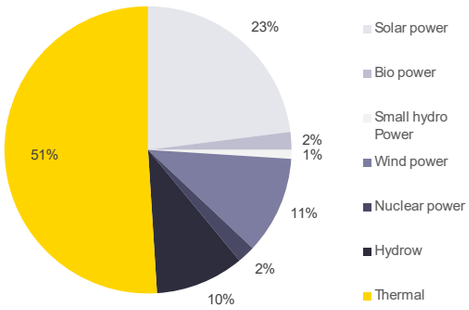


Figure 1.2: India's installed capacity power mix

installations , and expanding domestic manufacturing, which has effectively turned solar adoption into a social movement.

Agrivoltaics, presently under pilot-scale deployment in India, offers complementary benefits but is unlikely to meet future energy demand at scale, especially as land-use pressures intensify. To sustain momentum toward India's NDC targets and long-term decarbonization goals, it is essential to identify and develop alternative large-scale renewable energy opportunities, especially offshore and marine-based systems that reduce land pressure while maintaining the pace of clean energy expansion.

This necessitates accelerated investment in R&D and domestic manufacturing for offshore renewable energy solutions, including offshore / onshore wind, floating solar, wave and tidal energy and ocean thermal energy conversion (OTEC) systems.

Offshore renewables provide large-scale, land-neutral, high-capacity-factor clean power essential for meeting long-term national requirements, decarbonizing energy-intensive industries, and enabling cost-effective green hydrogen production, while also enhancing India's energy security by reducing dependence on fossil-fuel imports and supporting coastal industrialization. Developing domestic production capabilities for turbines, foundations, subsea cables, and offshore platforms will align with "Make in India" and "Aatmanirbhar Bharat," strengthen global supply chains, and position India as a competitive provider of offshore technologies for Asia and the Global South. Collectively, scaling offshore renewable energy is indispensable for meeting India's 2047 goals and enabling a resilient, diversified and future-ready clean energy ecosystem.

Around 3% to 5% of the global GDP is derived from the ocean. The concept of the blue economy focuses on addressing the ecological sustainability of these businesses to enable the sustainability of the economic outcomes. Sourcing clean energy not only improves the sustainability of the business but also resolves energy needs in remote and traditionally underserved areas. Ocean / offshore resource-based renewable energy offers an ideal solution that enables accessible, affordable and clean energy via diverse natural resources available along the coast and offshore. The Government of India is focusing on improving the sustainability of existing as well as upcoming initiatives pertaining to the blue economy and governance. Offshore renewable energy is a direct conjugation of SDG 7 and SGD 14, providing an opportunity for improving public and private collaboration towards climate action.



Figure 1.3: SDGs concerning offshore renewable energy

India, with a coastline of about 11,098 km and an exclusive economic zone (EEZ) of nearly 2.4 million sq.km, has a high prospect of harnessing ~90,000 TWh offshore energy . In this milieu, the Government of India has notified the National Offshore Wind Energy Policy 2015 to enable the use of maritime space within India's EEZ. Tapping the abundant offshore renewable energy has the potential to decarbonize not only the energy sector but shipping, cooling, aquaculture and water desalination to boost the blue economy. They provide significant socio-economic benefits of job creation, providing critical infrastructure for local value chains and enhanced synergies among the different blue economy sectors.

CHAPTER 02



Offshore renewable energy technologies

Offshore renewables can be categorized into marine meteorological, hydro and hydro-kinetic energy forms. The mature and market-ready offshore renewable technologies deployed globally include solar photovoltaic (PV) systems, which dominate new power installations due to falling costs and scalability across floating platforms. Onshore wind is widely established, offering efficient, utility-scale generation in diverse terrains, while offshore wind, particularly fixed-bottom turbines, is commercially mature, delivering high-capacity and stable power. Hydropower, the oldest renewable technology, provides large base-load generation and grid flexibility worldwide.

This chapter dwells deeper into such matured technologies that are suitable in the Indian context.

A Wind turbines

Offshore wind turbines are best suited to coastal regions with strong, consistent wind resources, favorable seabed conditions, and adequate water depths that enable either fixed-bottom or floating installations. Globally, offshore wind technologies fall into two categories:

I. **Fixed-bottom turbines** that have monopile or jacket foundations, anchored directly into the seabed in shallow waters up to about 50–60 meters. Technologically matured with low cost, they are similar in design to onshore turbines built from the ground.

II. **Floating wind turbines** mounted on buoyant platforms secured by mooring lines for deployment in deeper water, enabling access to high-quality wind resources from the deep sea.

Fixed-bottom systems are widely deployed across Europe and Asia, contributing to the world's installed offshore wind capacity of around 83 GW . While floating wind, though still emerging, has expanded installed capacity to approximately 278 MW globally, with leading deployments in Norway, the United Kingdom, Japan, Portugal and the United States. In the Indian context, shallow coastal stretches near Gujarat and Tamil Nadu coasts can support fixed-bottom turbines in the near term, while India's predominantly deeper waters make floating wind more suitable for long-term expansion. Although offshore wind technology has matured globally, its large-scale deployment continues to face several practical challenges. Projects require substantial upfront investment, specialized installation vessels and robust port infrastructure, particularly because of the complexities of operating in harsh marine environments. In the Indian context, offshore wind projects face risks, including frequent cyclone exposure, the absence of established domestic supply chains and limited long-term servicing and maintenance infrastructure, all of which can increase costs, construction timelines and overall project uncertainty.

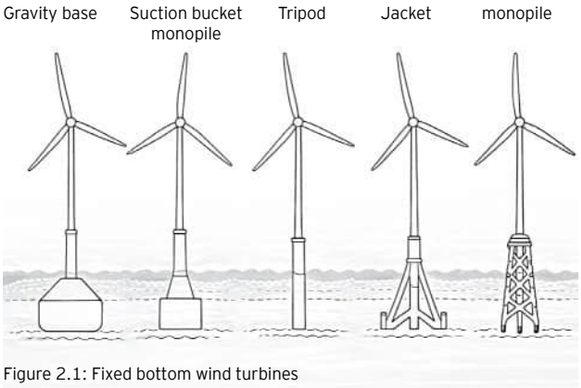


Figure 2.1: Fixed bottom wind turbines

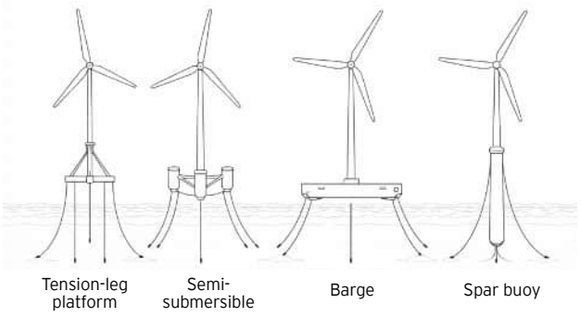
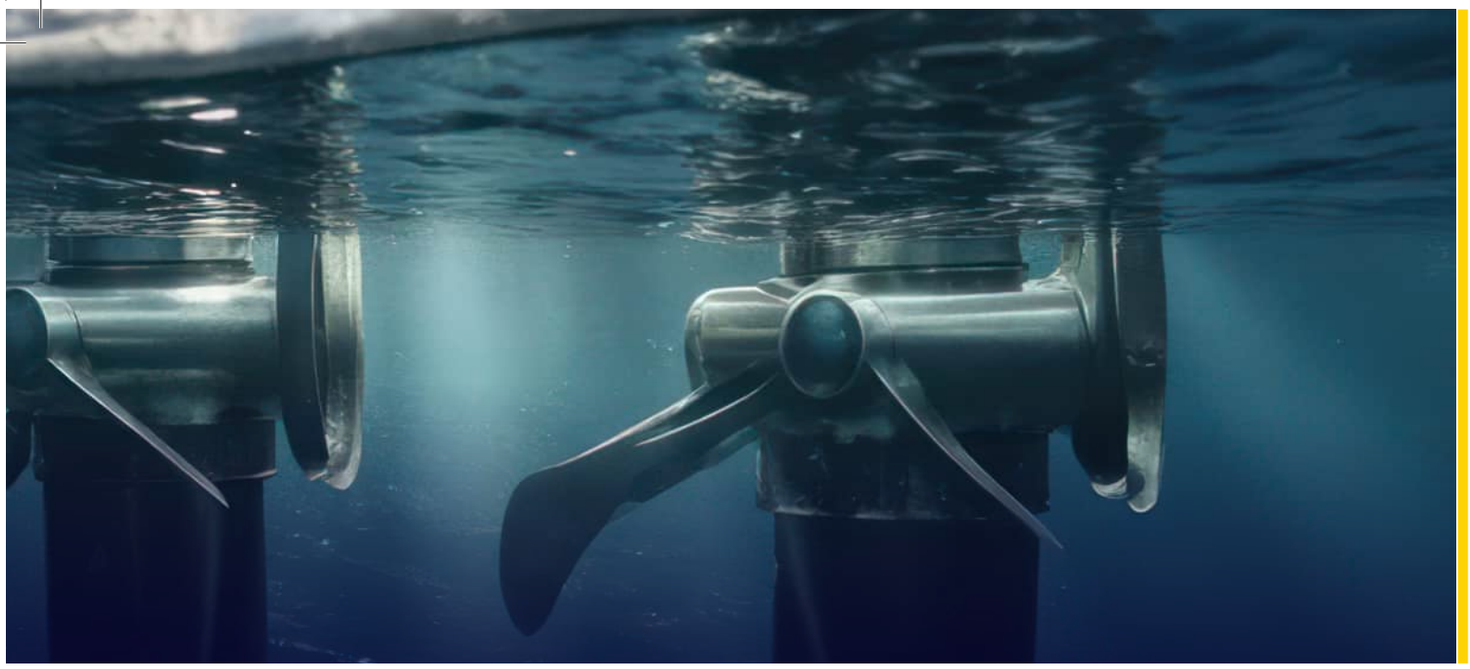


Figure 2.2: Floating wind turbines



B Floating photovoltaic (FPV)

Floating photovoltaic (FPV) technology is an adaptation of conventional solar PV systems for deployment on water bodies such as reservoirs, lakes and sheltered coastal areas. Electrically, FPV systems function in the same manner as land-based solar plants, with PV modules generating direct current (DC) electricity that is collected through combiner boxes and converted into alternating current (AC) by inverters. While small near-shore projects may place inverters on land, most utility-scale FPV installations mount string or central inverters on floating platforms to reduce cable losses, with power transmitted to onshore substations via waterproof or submarine cables. The floating platform, together with its anchoring and mooring system, is an important component of FPV installations, enabling long-term stability under wind, wave and water-level variations. Globally, the dominant configuration is the pontoon-based system with fixed-tilt PV modules. Two main platform designs are used: pure float systems, where PV modules are mounted directly on self-buoyant HDPE floats; these systems represent the most widely deployed and mature technology, and metal-structure on-float systems, where conventional metal trusses support PV modules and are fixed to pontoons providing buoyancy. Most large-scale FPV projects use bottom anchoring, particularly in deep reservoirs, while bank anchoring is limited to small, shallow water bodies.

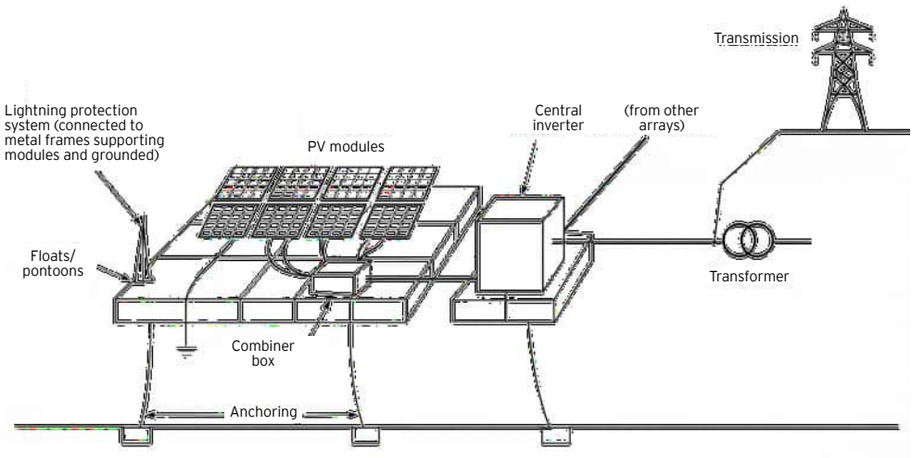


Figure 2.3 Floating photovoltaic (FPV)

Tidal energy

Tidal energy is the energy contained in the movement of ocean water in tides or currents. Derived from both the potential and kinetic movement of ocean water, tidal energy can be harnessed through three principal technologies.

I. **Tidal barrages** are the most mature approach, involve constructing dam-like structures across estuaries with tidal ranges of at least five meters. As water flows through sluice gates and bulb turbines during ebb and flood tides, predictable electricity generation occurs based on the impounded surface area and tidal range.

II. **Tidal stream generators** capture the kinetic energy of horizontal tidal currents using submerged turbines that rotate as water flows past them, although these currents change direction and speed with each tidal cycle.

III. **Dynamic tidal power** (DTP) is still experimental and proposes long, perpendicular coastal dams, typically 30–60 km, which exploit tidal phase differences along their length, especially in shallow coasts with strong oscillating tidal currents.

Together, these technologies illustrate the diverse ways tidal energy can be utilized, offering reliable renewable power where regional geographical and hydrodynamic conditions are favorable. Tidal barrages have been deployed in most of the operational MW-scale tidal energy projects worldwide.

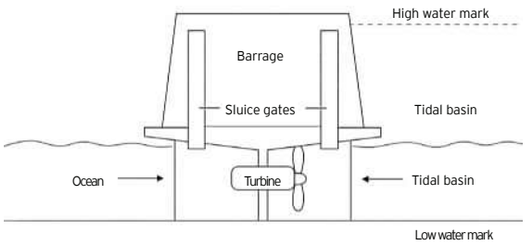


Figure 2.4 Tidal barrages

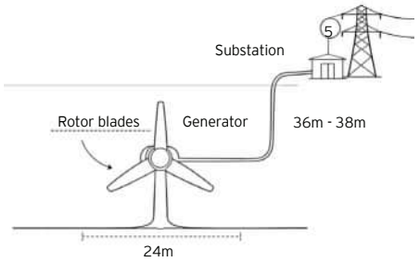


Figure 2.5 Tidal steam generator

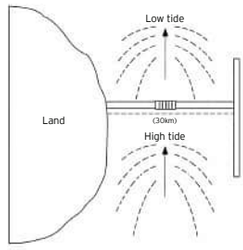


Figure 2.6 Dynamic tidal power

Wave energy

Offshore wave energy systems perform best in coastal regions with strong, consistent winds, deep-water fetch, and energetic wave climates that enable efficient capture of the ocean's wave energy originates from wind transferring momentum to the sea surface, creating oscillating waves whose vertical motion can be harnessed for electricity generation, desalination, or water pumping. Modern wave energy converters (WECs) transform this motion into usable power, as demonstrated by innovations such as IIT Madras's ocean wave energy device. Technologies include:

I. **Point absorbers** are floating buoys that move vertically with wave crests and troughs to drive linear generators or pumps.

II. **Oscillating water columns (OWCs)** are hollow structures in which rising and falling water compresses air to spin bidirectional turbines.

At this stage, wave energy technologies remain commercially nascent due to limited deployment scale, harsh marine operating conditions and complex, site-specific engineering requirements. As research advances and economies of scale emerge, wave energy is expected to become an increasingly viable component of offshore renewable energy portfolios.

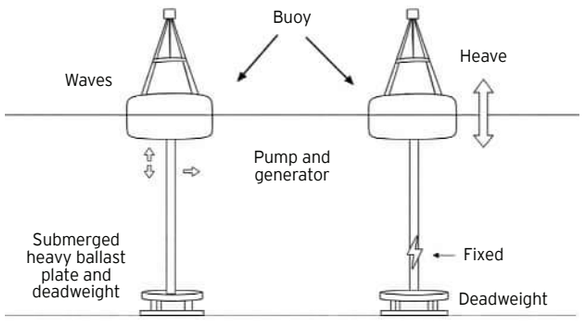


Figure 2.7 Point absorbers

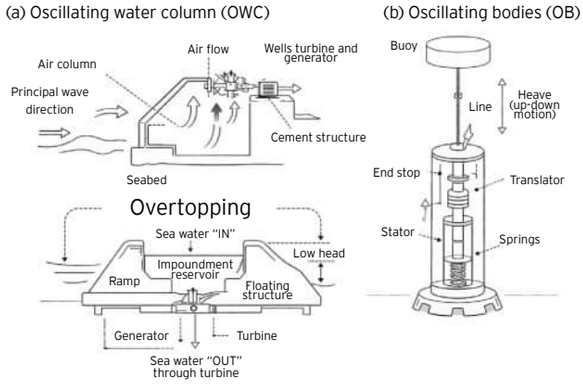


Figure 2.8 Oscillating water columns

Ocean thermal energy conversion

In similar tropical and deep-ocean settings as wave energy, ocean thermal energy conversion (OTEC) offers a promising offshore renewable technology by exploiting the natural temperature gradient between warm surface waters and cold deep-sea waters. Common in tropical regions where surface temperatures remain high year-round, this thermal difference is used to vaporize a working fluid, drive a turbine, and then condense the vapor using cold deep water to complete the cycle, thereby generating electricity . Beyond power production, OTEC systems provide multiple co-benefits such as desalinated freshwater, sustainable cooling through deep-ocean water circulation and nutrient-rich seawater that supports aquaculture and coastal agriculture. These characteristics make OTEC a reliable, base-load renewable energy option for warm-water regions, particularly island regions and tropical coastal states seeking stable, climate-resilient clean-energy alternatives.

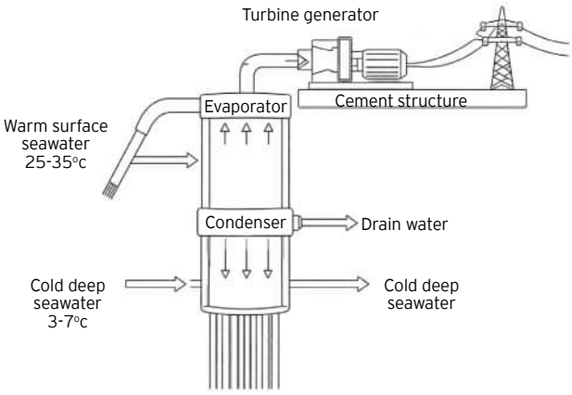


Figure 2.9 Open-cycle Ocean thermal energy conversion system.

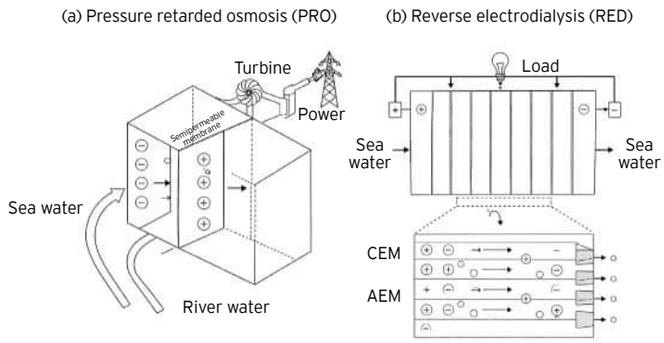


Figure 2.10 Salinity gradient energy

Salinity gradient energy

Salinity gradient power produces energy from the difference in salt concentration between freshwater and seawater. It functions best in regions where large volumes of freshwater and seawater naturally converge, such as estuaries, river mouths, coastal zones and waste streams with high salinity, along with stable hydrological and meteorological patterns that enable continuous flow and mixing. There are two membrane-based technologies:

I. **Reverse electrodialysis (RED)** generates electricity through the movement of salt ions across stacked anion-and cation-selective membranes, converting the salinity gradient directly into electrical potential

II. **Pressure retarded osmosis (PRO)** generates electricity by exploiting the osmotic pressure difference between freshwater and saltwater. Freshwater is drawn through a semi-permeable membrane into pressurized seawater, driving a turbine. In the 1990s, hybrid applications were initiated using concentrated desalination brine.

Currently, both technologies remain capital intensive, with membranes accounting for up to 80% of system costs. Globally, the Netherlands leads in RED-based development, while other countries prioritize PRO depending on local water availability, intended use and technological capability.

The Hooghly estuary has a funnel-shaped mouth and is connected to the Bay of Bengal close to Sagar Island, which is the largest block in the western Gangetic Sundarbans. The Hooghly Estuarine River system connects to the comparatively more saline Bay of Bengal. This change in salinity is an ideal site to be used for extracting salinity-gradient energy.

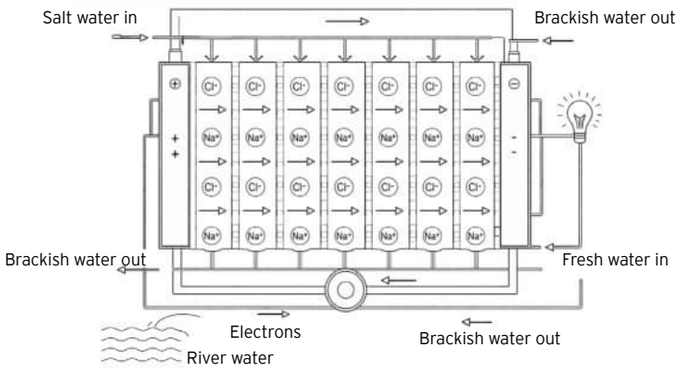


Figure 2.10.1 Reversed electro dialysis

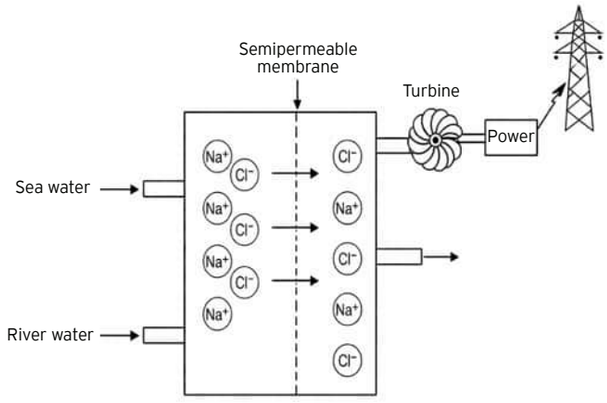


Figure 2.10.2 Pressure retarded osmosis (PRO)

G Ocean current energy

Ocean current energy technologies convert the kinetic energy of steadily flowing ocean currents into electricity using underwater turbines that operate much like wind turbines. Mostly suitable for island territories and straits, these systems rely on factors such as wind, temperature, salinity, seafloor topography and Earth's rotation, which shape current pathways. Marine turbine blades (~20 meter in length) rotate with horizontal water flow and can produce high power even at lower speeds. NIOT has already tested ducted and open-rotor hydrokinetic turbines in the Andaman Islands .

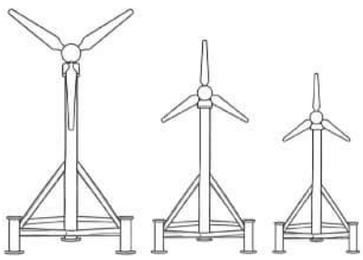
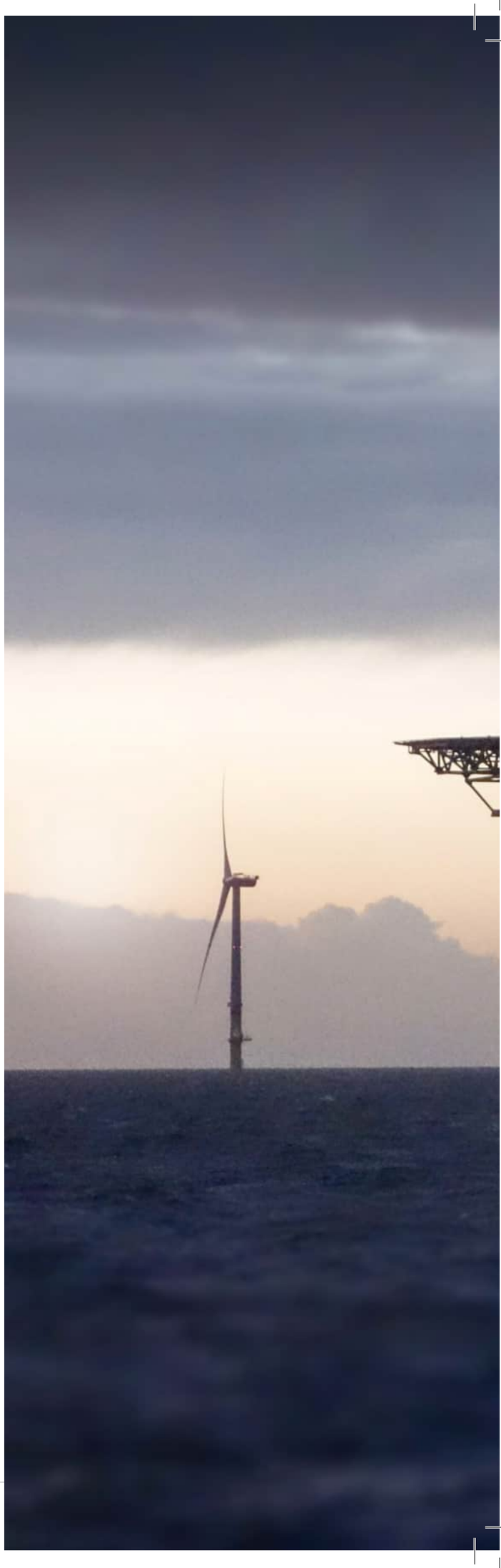
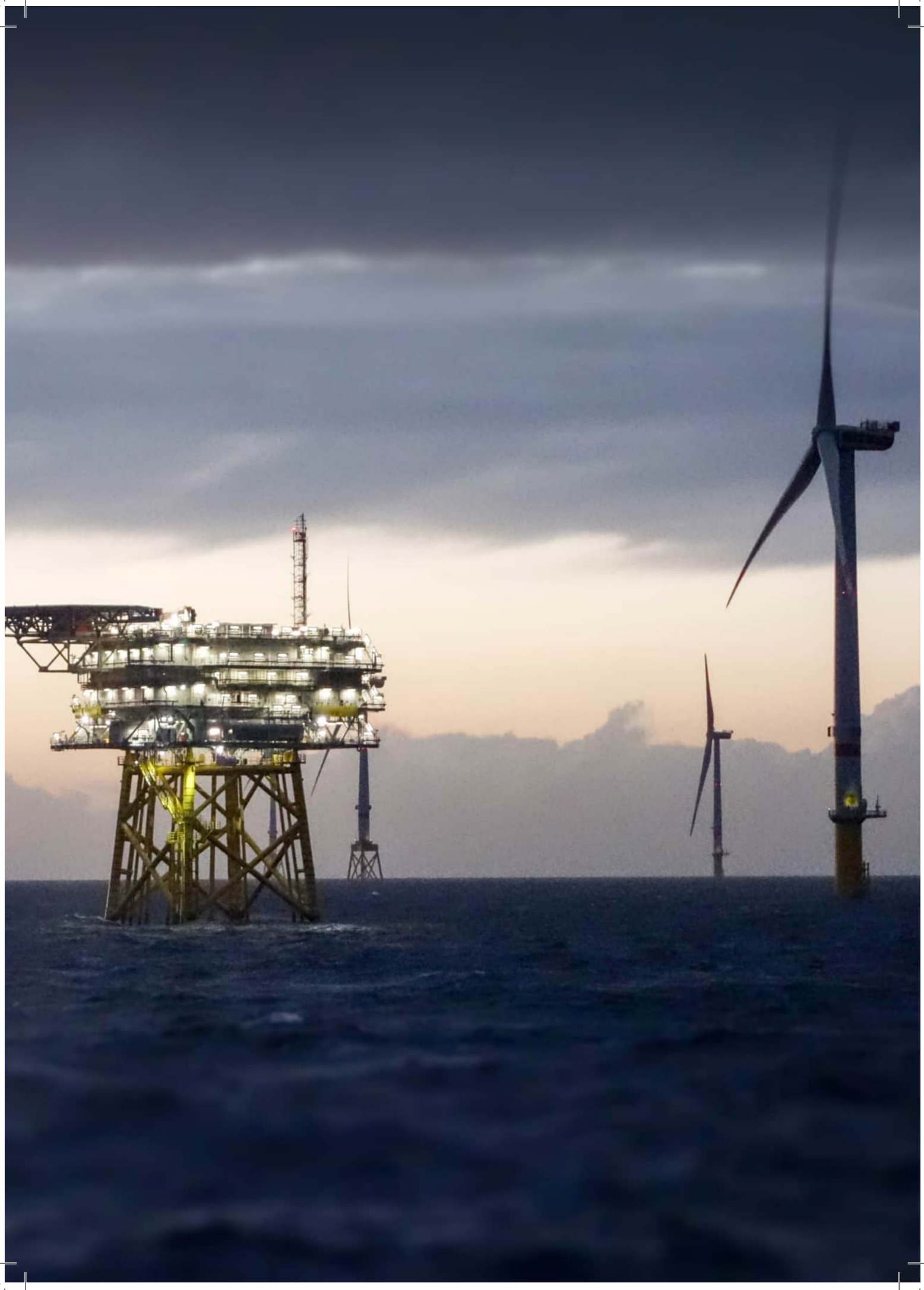


Figure 2.11 Marine turbines

H New technologies

Floating platform systems use buoyant force to enable deployment in deeper and more complex marine environments, beyond the limits of fixed-bottom foundations. At the global level, hybrid offshore solutions that combine floating wind, floating solar, wave energy, and offshore energy storage are being researched and piloted to increase energy generation and optimize the use of shared marine infrastructure. These technological developments are relevant to India, considering its long coastline and ongoing efforts to strengthen indigenous ocean technology capabilities under the blue economy.





CHAPTER 03



Offshore renewable energy opportunities

As India's blue economy expands to integrate decarbonized maritime industries and ocean-based clean energy solutions, the MoES mandate to advance scientific knowledge, innovation and technology development becomes increasingly important. Its role enables the growth of offshore renewable energy, which is technologically robust, ecologically responsible, and aligned with national priorities for sustainable ocean development. The Indian National Centre for Ocean Information Services (INCOIS), under the MoES, has undertaken a comprehensive estimation of marine energy resources across India's EEZ evaluating both marine meteorological energy (solar and offshore wind) and hydro-hydrokinetic forms such as OTEC, seagradient energy, ocean currents, waves and tides, and mapped their potential across five coastal clusters, viz., Andaman and Nicobar Islands, Southeast, Northwest, Southwest and Northeast coasts of India.

The assessment indicates that India's EEZ holds a total marine meteorological and hydrological energy potential of 9,58,433.61 TWh , dominated by high solar resource availability. After solar, wave energy emerges as the most abundant resource across clusters, including the Andaman and Nicobar Islands, Southwest, Northwest and Southeast regions of India. These refined, feasibility-aligned estimates provide a strategic foundation for policymakers and private-sector developers by indicating where large-scale, commercially viable offshore renewable energy zones exist. This enables targeted investment in offshore wind, wave, current and OTEC technologies as part of India's broader clean-energy transition and blue economy sectoral growth paradigm under Vision 2047.

Further, the study reveals that across India's coastal sectors, solar (with Indian sub-continent having an average 300 sunny days/annum) and OTEC resources show the most stable year-round generation, while wind and ocean currents exhibit strong seasonal peaks especially in the Northwest and Southeast of India during the monsoon months. Tidal energy remains relatively steady with minimal variation, except for consistently higher output in the Northwest of India.

Overall, the data reflects a diverse but regionally distinct renewable-energy profile, with monsoon-driven variability shaping wind- and current-based generation.

As reflected in the above graphs, the assessment of renewable energy resources across different maritime regions highlights distinct seasonal and geographical strengths that present opportunities for optimized deployment. Solar energy emerges as a consistently strong and reliable resource across all regions, with peak generation during the pre-monsoon and early summer months and comparatively higher potential in the Andaman and Nicobar, Southwest and Northwest sectors, making it well suited for year-round baseline generation and hybrid applications. Ocean thermal energy conversion (OTEC) demonstrates stable and perennial generation characteristics, particularly in the Andaman and Nicobar region, underscoring its suitability as a base-load renewable option for island territories and remote coastal locations where conventional energy supply is constrained. Wind energy exhibits pronounced seasonal variability, with substantial generation potential during the southwest monsoon, especially in the Northwest sector.

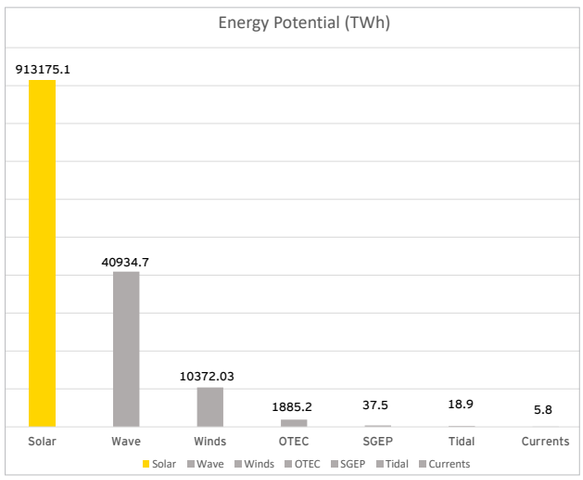


Figure 3.1: Marine met, hydro and hydro-kinetic energy resource potential from the entire Indian EEZ

Source: Marine Energy Atlas, 2024



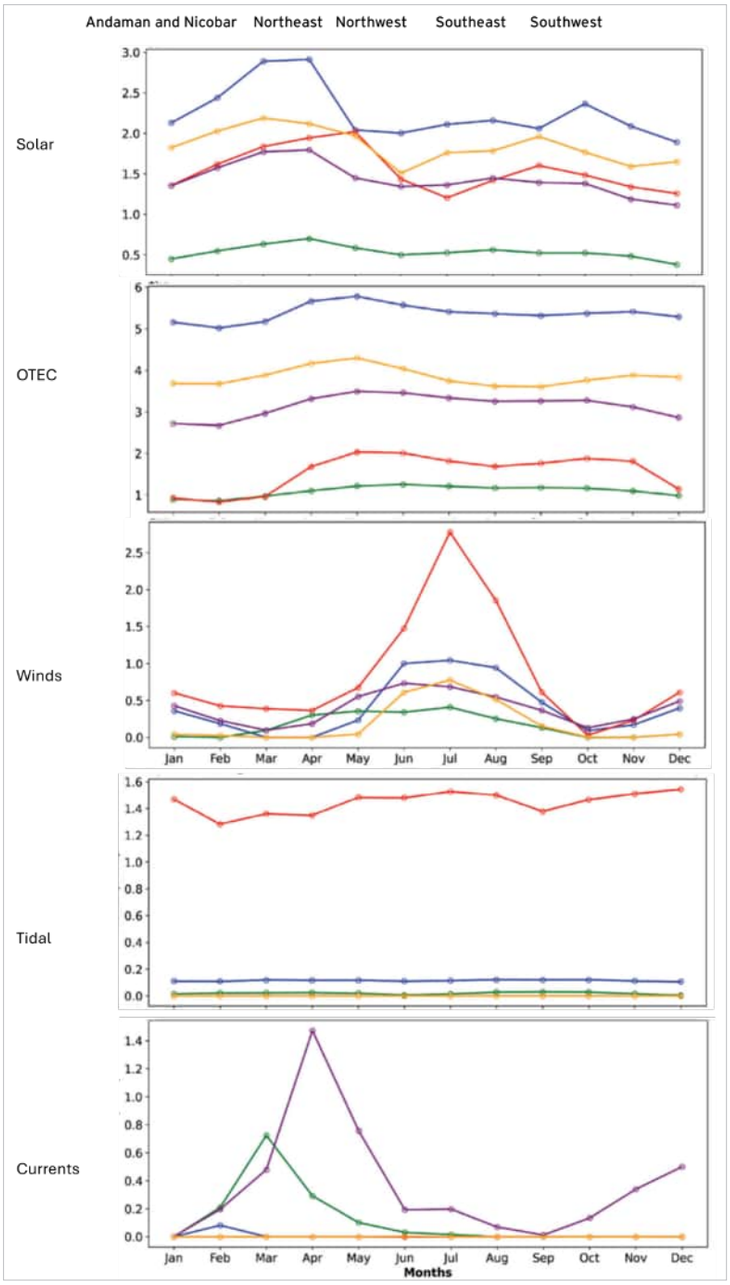


Figure 3.2: Monthly mean resource energy from five sectors (zones) identified from Indian EEZ

Source: Adopted from Marine Energy Atlas, 2024

CHAPTER 04



Policy landscape and global interventions

With the global acceptance of the Paris Agreement and Sustainable Development Goals, building capacities and infrastructure in renewable energy, including international cooperation on the matter, is the need of the hour. A robust regulatory framework, both international and domestic, is essential for the effective promotion, deployment and long-term sustainability of offshore renewable energy. Internationally, clear and harmonized rules are needed to govern activities in maritime zones, enable environmental safeguards, manage transboundary impact and provide legal certainty for investors operating in the exclusive economic zone (EEZ) and beyond national jurisdiction. Frameworks aligned with UNCLOS, the Paris Convention, and emerging global guidance on offshore renewables help to standardize permitting, safety and environmental assessment procedures, reducing project risks.

Domestically, dedicated policies and regulations are crucial to define site leasing mechanisms, grid integration norms, maritime spatial planning, environmental clearances and financial incentives. A predictable regulatory ecosystem enables investor confidence, coordinated development among ports, fisheries and coastal communities, and supports innovation in offshore wind, wave, tidal and ocean thermal technologies. Collectively, strong regulatory frameworks at both levels accelerate responsible offshore renewable energy growth while enabling ecological integrity, navigational safety and long-term energy security. The following table provides an account of international and domestic regulations in place to promote offshore renewable energy.

Category	Policy / convention	Key focus areas
International conventions	UNCLOS (United Nations Convention on the Law of the Sea)	Defines maritime zones Rights for marine resource exploration Environmental protection Sustainable ocean use
	Paris Agreement	Global climate action Emission reduction targets Supports the clean energy transition, including offshore renewables
	IMO Regulations (International Maritime Organization)	Standards for maritime safety Navigation ship traffic Environmental protection affecting offshore energy installations
Domestic policies (India)	Offshore Areas Operating Right Rules, 2024	Regulates exploration Exploitation and production of offshore resources within India's EEZ and territorial waters
	Production-Linked Incentive (PLI) Scheme	Boosts domestic manufacturing of renewable energy equipment (solar, wind and green hydrogen components)
	Renewable purchase obligations (RPOs)	Mandates minimum procurement of renewable power by DISCOMs and obligated entities
	Green Energy Corridors	Developing transmission infrastructure for renewable energy
	Solar Parks Scheme	Creating large-scale installations with shared infrastructure
	National Green Hydrogen Mission	Promoting production, utilization and export



Based on international regulations and steps towards building energy security, various countries have invested in R&D, infrastructure building and the creation of advanced and feasible offshore renewable energy technologies. Globally, the first ever offshore renewable energy facility was commissioned by Denmark in 1991, which harnessed offshore wind energy. Ever since, offshore wind energy projects of more than 75 GW have been installed in 18 different countries, which demonstrates optimal growth in the blue economy sector for countries like the UK, China, Germany, and the Netherlands, apart from Denmark . The offshore renewable energy sector has become a key pillar of the blue economy, helping countries across Europe and Southeast Asia to achieve climate commitments and to strengthen marine resilience and coastal livelihoods.

The following table demonstrates various interventions that helped developed countries with a strong blue economy to undertake successful interventions in improving sustainability, clean energy and optimization of ocean resources.

Countries	**Characteristic**		
	Technology	**Area of intervention**	**Policy**
China	Wind Tidal Wave energy	Capital subsidies Feed-in tariff (FIT) Tax reduction	Renewable Energy Law
Germany	Wind	Auction-based feed-in premiums	Renewable Energy Sources Act (EEG)
USA	Wind Tidal Wave energy	Federal grants Tax credits Loan guarantees	Inflation Reduction Act (IRA)
UK	Wind Wave energy	Contracts for difference (CfD)	Contracts for Difference (CfD)
European Union	All marine renewable energy technologies	Joint research Industry Universities Marine technology centers	Collaborative R&D via Horizon 2020 Roadmap
Norway	Wind energy	Skilling programs for RPL and reskilling Industry driven apprentice programs	NA
Australia	Production, Operations Maintenance of electrical systems	Technical education (TAFE modules)	

CHAPTER 05



Development of indigenous technologies and institutional frameworks for marine renewable energy

The National Institute of Ocean Technology (NIOT), an autonomous institution under the Ministry of Earth Sciences (MoES), is mandated to develop indigenous, reliable and cost-effective ocean technologies for the exploration, utilization and conservation of ocean resources within India's exclusive economic zone (EEZ). As part of its knowledge-building and international engagement efforts, NIOT hosted the International Symposium on Advancements in Marine Renewable Energy (ISAMRE) 2025 in Chennai. The symposium provided a platform for interaction among researchers, technology developers and institutions working on ocean energy systems, with discussions centered on technology development status, deployment challenges and research priorities in marine renewable energy. NIOT has also undertaken offshore wind resource assessment activities, including LiDAR-based measurements, in collaboration with the National Institute of Wind Energy (NIWE) and other national research institutions. These assessments along the Gujarat and Tamil Nadu coasts aim to generate site-specific offshore wind data to support resource characterization and research inputs for offshore wind development in Indian waters.

In parallel, NIOT has developed and demonstrated a set of indigenous, pilot-scale ocean energy and allied technologies, tailored for Indian marine conditions. These include:

A A floating ocean thermal energy conversion (OTEC) system:

NIOT's ocean thermal energy conversion (OTEC) program represents one of the longest-running indigenous ocean energy development efforts in the country. An early one MW-class floating OTEC system was successfully designed, installed and demonstrated in the early 2000s, generating valuable operational and engineering insights. While the system was subsequently decommissioned due to limitations in handling the deep-sea cold-water intake pipelines, the experience significantly strengthened India's technical understanding of offshore OTEC systems. Building on these learnings, NIOT has since advanced OTEC development through laboratory-scale experimentation, component redesign, and system optimization, enabling renewed confidence in the scaled deployment under current technological and engineering conditions.

At present, NIOT is implementing a new OTEC-based freshwater and power generation project at Kavaratti Island, Lakshadweep, which integrates electricity production with freshwater generation using an open-cycle OTEC configuration. The project is under active construction, with key components fabricated and deep-sea cold-water pipeline works underway. In parallel, under the Deep Ocean Mission, NIOT is preparing detailed project reports for large-scale OTEC systems of approximately 10 MW power capacity and 5 million liters per day of freshwater production, reflecting readiness for scale-up beyond pilot demonstrations.

B Small-scale ocean current (hydro-kinetic) turbine:

NIOT has demonstrated small-scale ocean current (hydrokinetic) turbine systems in the Andaman Islands, validating power extraction from marine currents under Indian conditions. Based on the successful demonstration outcomes, system designs and engineering assessments for higher-capacity installations have been completed, with plans for scaled deployments currently under evaluation.

C Low-temperature thermal desalination (LTTD) plants:

NIOT has successfully developed and deployed low-temperature thermal desalination (LTTD) systems using ocean thermal gradients, with multiple plants operational across the Lakshadweep Islands. These systems, with capacities ranging from 1.0 to 1.5 lakh liters per day per plant, currently provide the primary source of freshwater to nine island locations, demonstrating sustained commercial-scale operation in remote and grid-constrained environments. Earlier demonstration systems also validated the feasibility of coupling desalination with ocean thermal energy platforms.



Wave energy:

In addition to earlier wave energy power demonstrations undertaken in the 2000s, NIOT has successfully developed wave-powered navigational and ocean observation buoys, capable of generating onboard power for real-time data transmission. These systems have been deployed at operational ports, including the Chennai Port, and the technology has been transferred to the industry for wider replication. While not intended for grid-scale power generation, these applications demonstrate effective commercial utilization of wave energy for marine infrastructure support.

Hybrid offshore renewable energy systems:

Recently, NIOT has received approval to establish a hybrid offshore renewable energy pilot system combining floating solar photovoltaics and offshore wind energy, with a total capacity of approximately a MW, planned for deployment near Kadmat Island, Lakshadweep. Approved within the last year, the project represents a first-of-its-kind integrated offshore renewable energy system in India and reflects a shift toward multi-source, space-efficient solutions tailored for island and coastal power supply.

Collectively, NIOT's portfolio of marine renewable and allied ocean technologies reflects a progression from early-stage demonstrations to operational systems, construction-phase projects, and DPR-ready scale-up initiatives. While several technologies remain capital intensive and face deployment challenges in offshore environments, the cumulative experience gained through indigenous design, long-duration field operation, decommissioning-related learnings and recent mission-backed approvals indicates a growing level of technical maturity. This foundation positions India to move from isolated pilots toward structured public-private partnerships (PPP), risk-sharing mechanisms and investor-led deployment in marine renewable energy over the coming decade.

CHAPTER 06



Investment landscape for offshore renewable energy

India's offshore renewable energy sector is transitioning from early-stage pilots toward structured commercial deployment. With indigenous technology demonstrations led by NIOT and resource assessments by INCOIS, the foundation for investment readiness is emerging. However, given the capital-intensive and infrastructure-heavy nature of offshore projects, a clearly articulated investment framework is essential to attract domestic and international capital. This chapter provides investors and industry stakeholders with a consolidated view of pilot maturity, market-ready technologies, public financing mechanisms, multilateral support and PPP opportunities in India's offshore renewable ecosystem.

Technology maturity and pilot readiness

India's offshore renewable energy sector is progressing steadily, supported by successful pilot demonstrations led by NIOT and the availability of globally mature offshore technologies. These developments indicate that the sector is moving beyond experimentation toward scalable deployment. For investors, this provides confidence that offshore renewable energy in India represents a credible and growing opportunity within the clean energy transition and the details of the technologies are mentioned below.

A. Demonstrated and operational

Under its indigenous ocean technology program, NIOT has advanced marine renewable applications from research to sustained field deployment. LTTD plants operating in Lakshadweep, with capacities of approximately 1–1.5 lakh liters per day, use natural ocean temperature gradients to supply freshwater in remote island conditions, demonstrating reliable long-term performance. In addition, NIOT has deployed wave-powered navigational and observation buoys at the Chennai Port, generating onboard power from wave motion for lighting and real-time data transmission. The technology has been transferred to industry for wider replication. These operational systems reflect the successful transition of indigenous marine renewable technologies into functional, field-tested solutions with replication potential for islands, ports and coastal infrastructure.

B. Advanced pilot / under implementation

Building on earlier pilots, NIOT is advancing marine renewable systems toward scalable deployment. At Kavaratti in Lakshadweep, an open-cycle OTEC project is under implementation to generate both electricity and freshwater using natural ocean temperature gradients, while detailed project reports for ~10 MW OTEC plants have been prepared under the Government of India's Deep Ocean Mission to enable future scale-up. NIOT has also received approval for a ~1 MW hybrid offshore pilot near Kadmat Island, combining floating solar and offshore wind to optimize marine space and improve capacity utilization. In the Andaman Islands, small-scale hydrokinetic ocean current turbines have been successfully demonstrated, with scale-up assessments underway. Together, these initiatives indicate a clear progression from pilot validation to pre-commercial readiness, strengthening the case for future PPP-led deployment.

C. Market-ready globally, early-stage in India

Several offshore renewable technologies are already commercially mature, though still at an early stage in India. Fixed-bottom offshore wind, with over 83 GW installed worldwide, is a proven utility-scale technology suitable for India's shallow coastal zones, while floating offshore wind is expanding rapidly in deeper waters and holds long-term relevance for India's coastline. Floating solar PV and offshore wind-linked green hydrogen models are also gaining global traction as scalable, bankable solutions.



2 Public finance and government support mechanisms

Recognizing the higher infrastructure requirements of offshore renewable energy, the Government of India has introduced structured fiscal support through cabinet-approved measures. In June 2024, the Union Cabinet approved an INR7,453 crore VGF scheme to support one GW of offshore wind capacity (500 MW each in Gujarat and Tamil Nadu), including port upgrades, to bridge early tariff gaps and improve project bankability. Offshore leasing frameworks have been operationalized through the National Institute of Wind Energy with structured model A (VGF model), model B (non-VGF, exclusivity) model C (non-VGF, no exclusivity) provide transparent entry pathways for developers. Complementing this, the Ministry of New and Renewable Energy launched the INR19,744 crore National Green Hydrogen Mission in January 2023, while the INR24,000 crore Production Linked Incentive (PLI) scheme for high-efficiency solar PV modules and electrolyzer incentives further strengthens domestic manufacturing capacity. Together, these notified schemes create a layered public finance framework to de-risk early offshore projects and support commercial-scale deployment.

3 Multilateral and international finance

Offshore renewable energy aligns with global climate finance priorities under the Paris Agreement, enabling access to concessional and blended funding for early-stage deployment. The World Bank, through its Energy Sector Management Assistance Program (ESMAP), has supported offshore wind development globally by providing technical assistance on resource assessment, transmission planning, market design and investment structuring. Such multilateral engagement can offer concessional financing, blended finance mechanisms, grid integration advisory support and risk mitigation instruments to strengthen project bankability in emerging markets such as India.

4 Public–private partnership (PPP) opportunities

India's offshore renewable ecosystem is supported by established public institutions and Cabinet-approved frameworks that strengthen early project viability. NTPC Limited, through NTPC Green Energy, provides renewable development experience and financial strength to anchor offshore projects, while Power Grid Corporation of India Limited has implemented Green Energy Corridors under the oversight of the Central Electricity Authority, offering a tested model for regulated transmission that can extend to offshore evacuation. Cochin Shipyard Limited and port modernization initiatives under the Ministry of Ports, Shipping and Waterways further support offshore logistics and installation readiness.

5 Risk mitigation instruments for investors

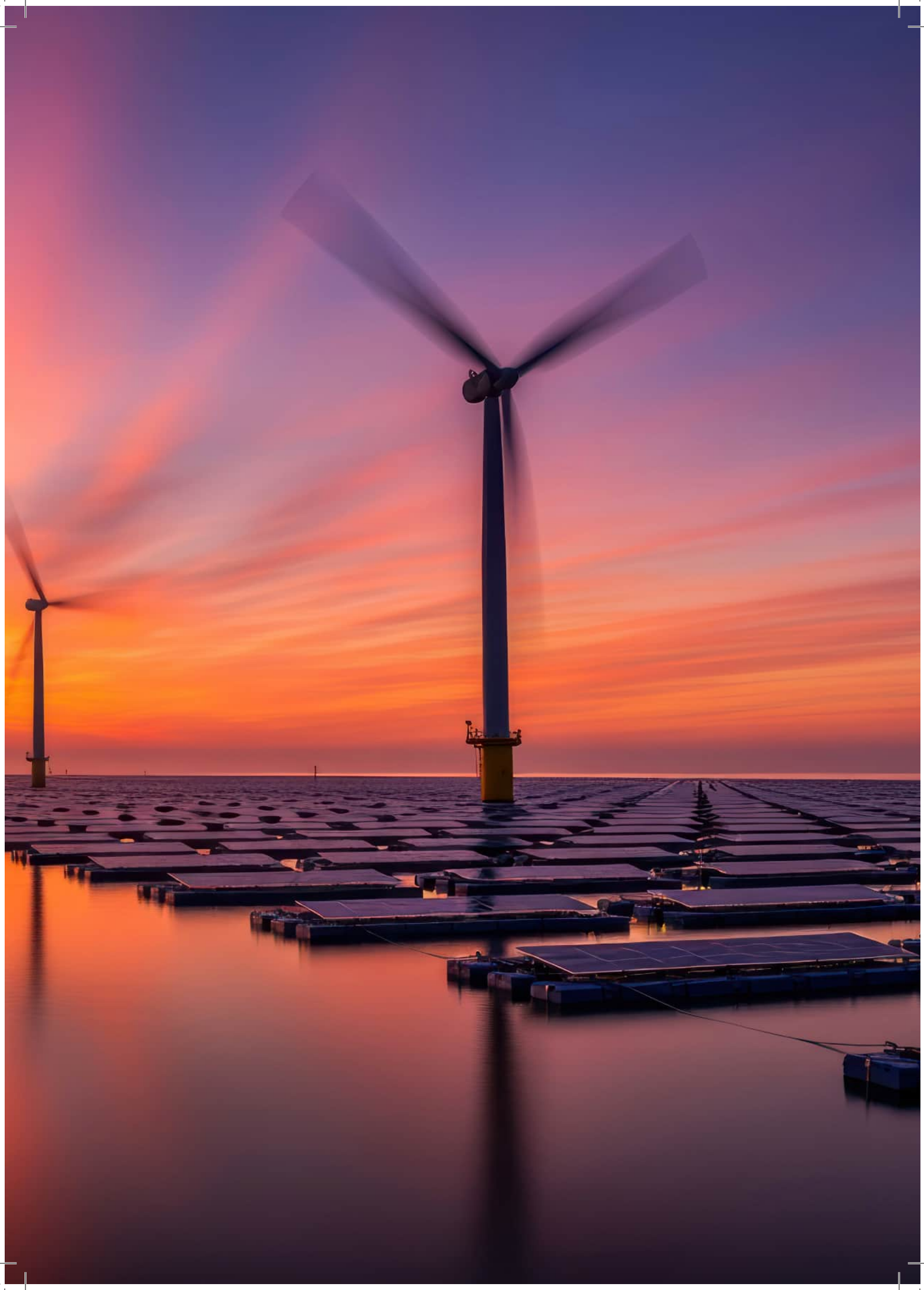
From an investor's perspective, offshore renewable energy requires structured risk mitigation because of higher capital intensity and longer development timelines. The VGF scheme also offers offshore wind, including port upgrades, which directly improves early-stage bankability and signals sovereign commitment. Access to multilateral concessional finance, engagement with the World Bank for technical support, and India's issuance of Sovereign Green Bonds from FY 2022–23, as notified by the Ministry of Finance, further strengthen the financing ecosystem. Structured competitive procurement under the Ministry of New & Renewable Energy, regulated transmission frameworks overseen by the Central Electricity Authority, and pre-identified offshore wind zones mapped by the National Institute of Wind Energy collectively reduce revenue, regulatory and transmission risks. With demonstrated indigenous marine technologies and institutional anchors such as NTPC Limited and Power Grid Corporation of India Limited, offshore renewable energy in India is evolving into a structured, policy-backed infrastructure asset class suited for long-term institutional and climate-aligned investors.

6 Private investment in India's renewable energy sector

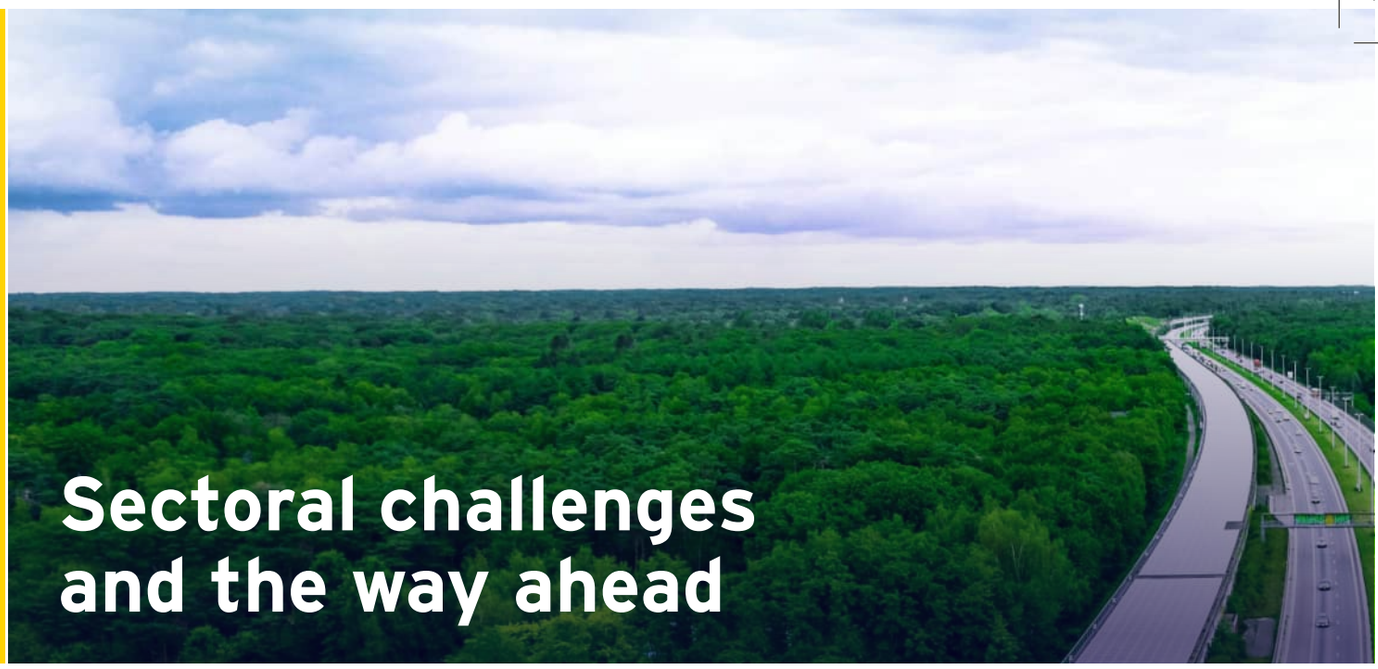
India is still in the beginning stages of developing offshore wind energy projects, but many major private energy firms have multi-gigawatt (GW) portfolios of onshore wind and solar resources, which will place them at an advantage when the government auctions and establishes regulatory mechanisms for offshore wind. Furthermore, many of India's largest independent power producers each operate with more than 1 GW of wind capacity and hundreds of more GWs of total renewables; therefore, both the technical and financial capabilities to support offshore developments already exist to a great degree within the private sector . Private entities have significantly committed to other renewable technology areas like battery storage, utility-size solar and wind, deploying large amounts of capital through commercial-scale electricity generation projects. An example of recent leading private investment commitments made towards clean energy projects is roughly INR36,000 crore (approximately US$4.5 billion), which includes 5 GW of solar generation capacity, one GW of wind generating capacity and 5 GWh of battery storage systems. The scale of these investments shows the willingness of Indian private energy developers to invest in large commercial projects involving offshore renewable energy when the governmental energy markets eventually issue tenders for construction services of these types of electricity generation facilities.

Government evaluations further support the long-term potential of the coast of Gujarat with its approximately 35 GW of technical offshore wind potential. The size of this resource base demonstrates the scale of investment possibilities for the future, and hence private firms are looking to the offshore renewable market as they prepare to get involved due to advancements in policy development, transmission planning and auction development .





CHAPTER 07



Sectoral challenges and the way ahead

India's offshore renewable energy potential represents one of the most promising pathways for meeting its long-term decarbonization goals, enhancing energy security and positioning the country as a global clean-energy leader. Yet the transition from conventional energy systems and land-based renewables to a future where offshore wind, offshore solar, OTEC, wave, tidal and hydrogen-based offshore solutions contribute significantly to national capacity demands of energy.

Despite having significant potential and mature technologies that can effectively harness India's offshore renewable energy potential, the sector still faces a plethora of structural challenges that shape this emerging sector. These challenges are not impediments to ambition, but critical markers that reveal where strategic policy interventions, institutional reform, technological innovation and public investment must be concentrated. It requires a clear-eyed understanding of the challenges that currently withhold India's sectoral trajectory. The offshore environment presents a fundamentally distinct set. These are articulated below to provide a roadmap for decision-makers and investors to understand the systemic gaps that must be addressed to unlock India's full offshore potential.

A Policy and institutional fragmentation:

India's offshore ambitions confront a fragmented institutional landscape. For instance, the responsibilities for seabed allocation, environmental clearances, ports, maritime security, and energy markets are split across MNRE, MoEFCC, MoPSW, defense and state governments. Existing onshore-focused rules do not fully address leasing, long-term risk allocation, seabed rights, or inter-agency approvals. This regulatory complexity lengthens timelines and increases perceived policy uncertainty and risk for investors , undermining the steady, large-scale project pipeline required to scale offshore capacity from pilots to GW programs.

B Permitting marine spatial planning and competing sea uses:

Offshore development must complement and not conflict with industrial activities such as fisheries, shipping lanes, naval zones, port expansions and coastal industries. India lacks a comprehensive national marine spatial planning (MSP) system with pre-zoned lease areas and detailed ecological/social mapping; absence of such zoning creates overlapping claims, prolonged clearances and litigation risks that delay projects. Without science-led MSP and pre-developed zones, developers face high selection and stakeholder-conflict risks, raising costs and timelines for every project. India's current demarcation of MSP is limited and has no or little access to investors and private-sector partners.

C Transmission, evacuation and grid integration:

Evacuating offshore energy generation requires subsea cables, offshore substations and often high voltage direct current (HVDC); Central Electricity Authority estimates place offshore transmission costs at ~INR28.1 million/MW , three times onshore evacuation costs , making transmission a major cost and coordination challenge. India's coastal transmission corridors and HVDC planning remain nascent; without coordination, long-range evacuation planning and investment, generated power risks being stranded or curtailed, undermining project bankability and system reliability.

D Ports, heavy-lift vessels and marine logistics:

Large offshore projects depend on heavy-lift ports, marshaling yards, jack-up and cable-laying vessels and service operation vehicles (SOVs) . India currently has a limited fleet and port infrastructure for a multi-GW deployment. While the SOVs launch at Cochin Shipyard is a positive development, domestic heavy-lift and installation capacity still lags in creating global competency, forcing reliance on foreign vessels with higher mobilization costs and lead times. This logistical shortfall inflates capex and may cause scheduling delays that imperil project economics.



E Domestic manufacturing and supply-chain readiness:

Key offshore components, including large turbines, subsea cables, corrosion-rated foundations and electrolyzers for green hydrogen, require advanced manufacturing and specialized inputs. India's domestic industrial base is not yet scaled for these high-precision, large-volume products and global OEM concentration remains high. Uncertain demand signals and long localization lead times deter OEM investments, forcing high import dependence that raises costs, exposes projects to global supply chain disruptions and creates strategic vulnerabilities.

F Financing high capex and insurance limitations:

Offshore projects have higher capital intensity; recent analysis estimates offshore wind capital costs in India at INR180–200 million/MW, with levelized cost of energy (LCOE) estimates of INR12–14/kWh — well above onshore alternatives. MNRE has also acknowledged that the domestic financing ecosystem is cautious given the limited track-record, while marine insurance for cyclone, cable and vessel risks is nascent, increasing premiums and recognizing the need to provision for concessional finance, blended instruments, or government guarantees such as VGF allocations.

G Technology maturity and metocean data gaps:

Floating wind, OTEC, wave and tidal systems need long-term, site-specific metocean, geotechnical and sedimentation data. India's coastline is diverse and often impacted by monsoonal cycles, high sediment loads and cyclones. The country also lacks comprehensive long-duration measurements and validated local pilot projects, with data legacy and significant data size. This data scarcity raises energy-yield and design uncertainties, inflates contingency allowances, and deters OEMs and financiers that require robust resource assessments to underwrite projects.

H Environmental baselines, biodiversity and EIA challenges:

A robust environmental impact assessment requires long-term baselines on fisheries, benthic habitats, marine mammals and bird migration. India's nationwide marine biodiversity datasets are patchy. Without comprehensive baseline studies and cumulative impact assessments, projects risk causing ecological harm or igniting community opposition. Weak EIA capacity and staggered approvals often increase litigation, delay and project costs.

I Socio-economic impacts and community acceptance:

Coastal communities, especially small-scale fishers, face potential loss of fishing grounds, gear damage and navigational risks from exclusion zones. Poorly structured consultations and absent benefit-sharing arrangements generate opposition and legal challenges. Without transparent engagement, livelihood safeguards and local employment commitments, projects risk protracted delays and reputational damage that can deter investors and slow deployment. Stakeholder consent is therefore a core project risk. Until and unless regulations regarding ocean leasing are in place, the insecurity pertaining to community opposition shall continue to grow.

J Operational safety, O&M capacity and skilled workforce:

Offshore operations and maintenance demand certified technicians, divers, marine engineers, DP-class SOVs and advanced remote diagnostics. India currently lacks sufficient trained offshore personnel and a mature offshore O&M ecosystem. Harsh Indian Ocean conditions, from monsoons to cyclones, necessitate rigorous safety practices; shortfalls increase downtime and O&M costs. Building training pipelines, maritime safety regimes and domestic service capacity are essential to enable cost-effective, reliable operations.

K Cybersecurity and critical-infrastructure protection:

Offshore plants, subsea cables and hydrogen facilities rely heavily on digital control systems; cyber vulnerabilities could disrupt generation, electrolysis processes, or grid stability. India's wind sector assessments flag emerging cybersecurity concerns alongside the need for national OT/IT standards . Coupled with physical maritime security risks, inadequate protection amplifies operational and national security risks for critical offshore assets. Establishing robust cybersecurity protocols and defense-civil coordination is imperative.

L Decommissioning, lifecycle management and circularity:

India lacks clear regulations governing decommissioning liabilities, blade recycling and end-of-life asset management for turbines, subsea cables and platforms. International experience shows decommissioning can be costly and environmentally sensitive. Without decommissioning bonds, recycling pathways and lifecycle standards, long-term public liabilities and marine debris risks increase, creating regulatory and investor uncertainty. Lack of policy on circularity and end-of-life financing adversely impacts investors' confidence and sustainability concerns.

M Market design and revenue certainty:

Current market mechanisms in India are structured around low-cost onshore generation; offshore projects require long-tenor, predictable revenue models such as contract of difference (CFD), take-or-pay PPAs or hydrogen offtake agreements. With a lack of clear tariff frameworks, robust procurement and offtake designs, curtailment protections and dispute resolution tailored to offshore risk, developers face revenue uncertainty that elevates financing costs and deters investment.

N Interagency coordination and financing of common infrastructure:

Scaling offshore energy requires shared assets like export corridors, offshore substations, ports and hydrogen pipelines that require coordinated planning and pooled financing among central and state agencies. Lack of clear ownership models, regulated returns, or public-private financing mechanisms for common infrastructure projects force developers to internalize disproportionate upfront costs , slowing deployment.

O Economic viability and tariff competitiveness:

Economic viability and tariff competitiveness remain primary challenges for offshore renewable energy in India. Offshore projects, particularly offshore wind, entail significantly higher tariffs compared to onshore wind and solar projects, which are being contracted less in a highly price-sensitive market. This disparity arises from substantially higher capital expenditure driven by complex marine engineering, specialized vessels, offshore foundations and harsh operating conditions, with costs increasing exponentially as water depth rises. Additional financial pressures stem from higher insurance premiums, operations and maintenance requirements and risk exposure to cyclones and marine environments. Even onshore renewable projects in India face return pressures, with several awarded projects struggling to reach financial closure due to marginal viability. In the absence of targeted financial support mechanisms such as viability gap funding, tariff support, or assured return frameworks, offshore renewable projects remain commercially challenging and unattractive for both developers and power off takers.

P Lack of supporting infrastructure and committed offtake:

The absence of enabling infrastructure and assured offtake is a major barrier to offshore renewable energy development in India. Offshore projects require high-cost evacuation systems such as undersea cables, offshore substations, port facilities and grid integration, all of which involve long lead times. The lack of committed offtake arrangements creates revenue uncertainty, increasing project risk and limiting developer interest. Clear government or utility-led responsibility for shared infrastructure and long-term offtake would be essential to de-risk projects and attract private investment.

Q Site-specific geographic and environmental constraints

Site-specific geographic and environmental conditions along India's coastline pose distinct challenges for offshore renewable energy development. As highlighted in offshore wind potential assessments, the west coast is characterized by rapidly increasing water depths close to the shoreline, which directly influence foundation selection and significantly increase installation and construction costs, often necessitating advanced or floating foundation technologies. In contrast, the east coast benefits from comparatively gentler seabed slopes that are more conducive to offshore installations; however, this region is exposed to frequent cyclones and extreme weather events. These conditions introduce additional risks related to structural integrity, operational durability, insurance coverage and long-term operations and maintenance. Collectively, such location-specific physical and environmental factors contribute to uncertainty in asset performance, lifecycle costs and project bankability, reinforcing the perception of offshore renewable projects as higher-risk relative to onshore alternatives.

The challenges outlined in this chapter demonstrate that India's offshore renewable energy transition is deeply complex. These challenges offer the foundation for designing a resilient, investable and globally competitive offshore renewable energy ecosystem. Each challenge, whether regulatory, technical, financial, environmental, or socio-economic, represents an opportunity to build institutional capability, spur industrial growth and attract global investment.





CHAPTER 08



Strategic recommendations for building India's offshore renewable energy ecosystem

India stands at a pivotal moment as it seeks to transform its maritime domain into a powerful engine of clean energy, economic growth, global competitiveness and community-centered development. With NIWE having identified 16 high-potential offshore wind zones in Tamil Nadu and Gujarat , and MoPSW already executing major capacity expansions across all 12 major ports , the structural foundation for an offshore renewable revolution is emerging. However, to unlock the scale needed for India to transition to an offshore-based sustainable and clean energy hub, the country must adopt a coordinated, multi-sectoral and investment-friendly strategy. The following integrated recommendations articulate a holistic roadmap.

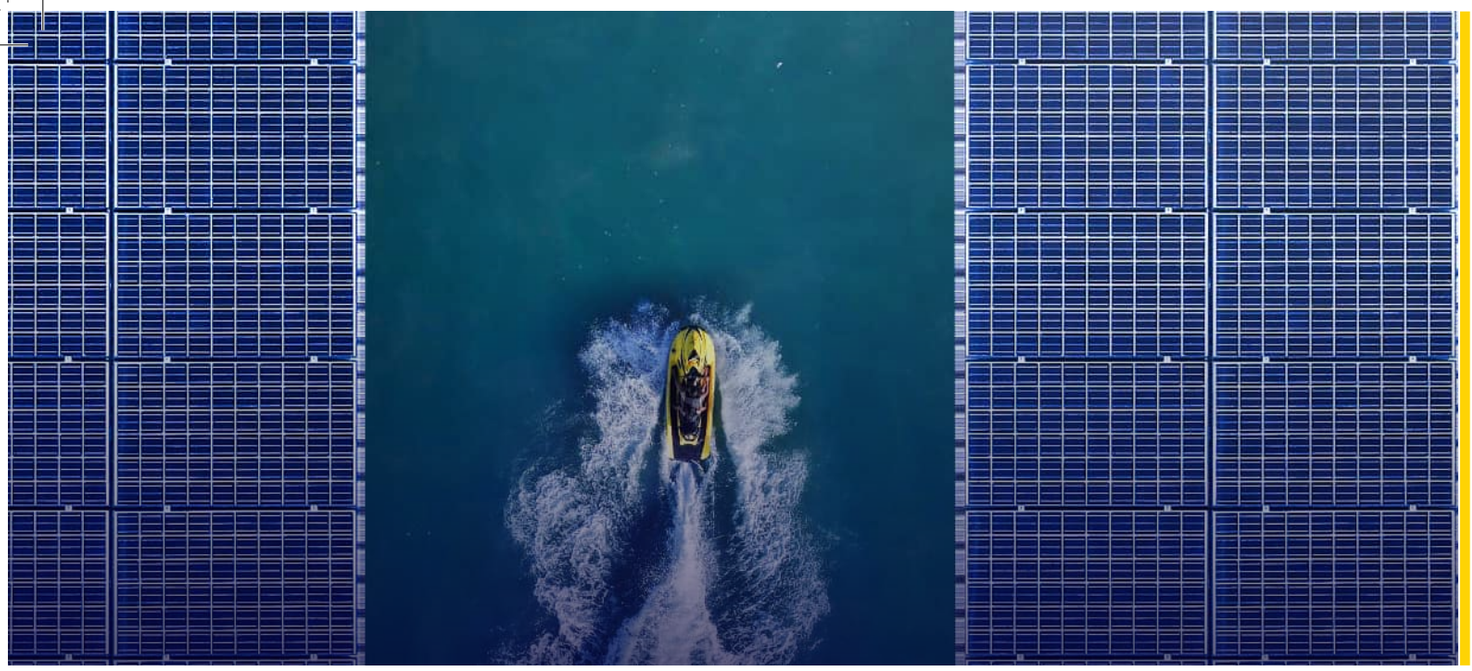
India's offshore renewable energy framework is supported by three complementary policy models that balance public support with private-sector initiative. Model A, the VGF-backed option, enables early-sector acceleration by reducing financial risk and allowing developers to commission projects within four years under a predetermined tariff or viability funding requirement. Model B promotes full private-sector development by granting developers a five-year lease exclusivity period to justify self-financed surveys, project development and flexible power offtake arrangements. Model C encourages innovation and competitive site identification by allowing developers to select and study their own sites at full commercial risk while securing a First Right of refusal in subsequent bidding. Together, these models create a diversified pathway for scaling offshore renewable energy through a blend of government facilitation and private-sector capability. To operationalize and optimize outcomes from these models, India needs to adopt the following solutions to strengthen the offshore renewable energy ecosystem.

A **Strengthening governance:**

A unified governance architecture is fundamental to accelerating India's offshore renewable transition. The creation of a National Offshore Energy Authority, modeled after the UK Crown Estate, would consolidate seabed leasing, single-window permitting, environmental regulation and marine spatial planning (MSP). Unified governance can reduce project lead times by 30% to 40%, as demonstrated in mature offshore markets such as Denmark and the Netherlands. India's NIWE Models A–C provide a strong policy foundation, which needs to be coupled with streamlined execution, faster licensing timelines and predictable market signals. The national authority would be empowered to better map the high and perennial renewable resource potential along with high-potential geographies, collaborating with the state and central governments, and devising region-specific programs to accelerate and operationalize the ecosystem.

B **Adopting a technology-prioritized and location-specific development pathway for marine renewable energy:**

To enable efficient and phased development of India's marine renewable energy (RE) sector, a technology-prioritized and location-specific approach is essential. Commercially mature technologies such as offshore wind and floating solar should be advanced as anchor investments to establish shared offshore infrastructure, regulatory clarity and market confidence, while simultaneously serving as platforms for integrating emerging technologies such as tidal, wave and OTEC. Deployment strategies should be aligned with regional resource characteristics: tidal energy along the Gujarat coast and deltaic regions, OTEC in near-equatorial and island waters, wave energy along the western coastline, and scalable offshore wind and floating solar along suitable coastal zones. Promoting integrated, hybrid offshore energy systems that combine complementary marine resources can address seasonal variability, improve capacity utilization and enhance supply reliability. Such a structured and geographically informed framework provides investors with clarity on technology pathways, risk mitigation through hybridization and predictable infrastructure development, thereby strengthening project bankability and accelerating private sector participation in India's offshore renewable energy transition.



C **Low-cost solutions or cost-effective technology**

Promoting low-cost solutions and cost-effective technologies is essential to accelerate the development of offshore renewable energy in India. Given the high capital intensity and early-stage nature of offshore projects, reducing costs across the project lifecycle from technology selection and manufacturing to installation, grid integration and operations is critical for improving project viability and attracting private investment.

D **Market design, investment frameworks and financial mechanisms:**

India's offshore renewable energy ambitions require a unified financial and infrastructure strategy that lowers risk, mobilizes capital and builds long-term capability. India should extend mechanisms such as viability gap funding, Green Hydrogen Mission mode programs, sovereign-backed guarantees, blended finance, contract for difference (CfD) and infrastructure investment trust (InvIT) frameworks to improve bankability and reduce the cost of capital. Parallel investments in a dedicated offshore transmission grid, upgraded ports, domestic vessels, marine data systems, MSP frameworks and decommissioning rules will streamline permitting and strengthen investor confidence. Cross-ministerial convergence, for example, deploying OTEC for desalination with the Jal Shakti Department, can unlock multi-sector benefits. These integrated measures will de-risk early projects, attract global capital and establish India as a competitive offshore renewable energy hub.

E **Integrated marine spatial planning, environmental safeguards and community collaborations:**

Offshore renewable growth must coexist with India's diverse maritime users, including fishers, shipping corridors, naval security zones and coastal tourism. MSP will assist in identifying low-conflict development zones. NIWE's preliminary resource mapping across Tamil Nadu and Gujarat provides an excellent starting point and shall be strengthened through multi-season biodiversity surveys and navigational assessments.

F **International cooperation for technology transfer and funding opportunities:**

India should actively collaborate with global offshore renewable energy leaders to accelerate technology transfer, secure low-cost financing and advance pilot-scale demonstrations. Partnerships with countries experienced in offshore wind, floating systems, tidal, wave and OTEC can help India access proven engineering models, safety standards and specialized vessels while avoiding early-stage deployment risks. Bilateral and multilateral cooperation through joint pilot projects, co-funded research programs, concessional climate finance and OEM manufacturing partnerships will strengthen India's institutional and technological readiness. Such collaboration will also enhance supply-chain resilience, deepen domestic capabilities and position India as a regional hub for offshore renewable deployment across the Indo-Pacific.

G **Green bonds and blue bonds for offshore renewable energy financing:**

India should strategically deploy green and blue bonds to attract private capital and global climate finance for offshore renewable energy. Green bonds can finance offshore wind, offshore solar and hydrogen-linked infrastructure, while blue bonds can support marine-based technologies such as OTEC, tidal and wave systems. These instruments appeal to institutional investors and high-emitting countries seeking credible decarbonization investments. By establishing transparent project pipelines, robust ESG standards and sovereign-backed guarantees, India can issue investment-grade bonds that lower financing costs and mobilize large-scale capital. Expanding these thematic bonds will strengthen India's offshore renewable energy ecosystem and accelerate its transition to a blue-green energy economy.

H Socio-economic and environmental sustainability interventions:

For the complex socio-economic context of India, any sector that aims to be successful and sustainable in the long-term requires buy-in from all stakeholders, especially the local community. India must adopt community benefit sharing and fisheries co-management approaches commonly used in Scotland, Denmark and South Korea. This may include revenue-sharing funds, compensation for fishing disruption, local employment quotas and collaborative monitoring. Such mechanisms not only secure social licenses but also align coastal development with national clean-energy goals.

Similarly, environmental sustainability should be embedded through a National Marine Biodiversity Observatory Network (NMBON) similar to global Marine Biodiversity Observatory Network (MBON) , which comprises scientists, resource managers and end-users who share data and observations to monitor changes in marine biodiversity and ecosystem functions, cumulative impact assessments and adaptive ESIA standards aligned with global practice such as Scotland's robust marine monitoring protocols. Transparent ecological baselines reduce litigation, enhance community trust and allow faster approvals.

I Accelerated port modernization, vessel capability and logistics infrastructure:

Leveraging the momentum of India's Maritime Vision 2030, India can develop dedicated offshore renewable energy hubs on the lines of those in Esbjerg (Denmark) and Taichung (Taiwan), equipped with marshaling yards, heavy-lift cranes, deep drafts and integrated hydrogen storage/export capabilities. Simultaneously, India must catalyze domestic shipbuilding for installation vessels, SOVs, cable-laying ships and floating platform deployment vessels, reducing dependence on foreign fleets, which increase project timelines and capex. A targeted vessel subsidy program or shipyard revival package can mirror South Korea's successful offshore vessel strategy. Modernizing ports for multi-utility use, such as energy, hydrogen export, manufacturing clusters and logistics, will not only accelerate offshore renewable energy deployment but also strengthen coastal industries and reduce offshore project costs.

J Building a future-ready transmission and hydrogen integration network:

India must adopt a cluster-based offshore transmission strategy, combining shared export cables, offshore substations and HVDC corridors, following the multi-country grid approach. With the Central Electricity Authority (CEA) estimating offshore transmission costs at ~INR28.1 million/MW (CEA) , pooled infrastructure can dramatically lower per-MW evacuation costs and eliminate stranded projects. Offshore renewables also present a unique opportunity to anchor green hydrogen production. Co-locating offshore wind with coastal hydrogen hubs, electrolysis, desalination systems and hydrogen pipelines can transform India into a green fuel export center for the Indo-Pacific. The intervention can align with the new governance framework for integrated planning between PGCIL, MoPSW, NTPC Green and state maritime boards to realize this opportunity.

K Local manufacturing, technology pilots and R&D deployment:

India can leverage offshore renewable energy as a catalyst for industrial growth by establishing offshore manufacturing zones in coastal states, supported by incentives for turbines, floating foundations, subsea cables and offshore substations. Taiwan's localization model, which grew domestic offshore wind manufacturing from <10% to >60% in eight years, provides critical lessons. Localization will support both the service and manufacturing industries domestically and export potential in the long run. India needs national technology demonstration projects on floating wind farms, OTEC pilots, and wave/tidal demonstrators to validate systems under India's complex monsoonal and cyclone conditions. Long-term metocean buoys and open-access oceanographic datasets will reduce uncertainties and attract global OEMs. OTEC pilots in Lakshadweep and large-scale energy-storage battery system pilots in Andaman will support creating proof of concepts (PoCs) and replicable, as well as bankable, models for the Indian context.

L De-risking or blended funds mechanism:

This can play a critical role in accelerating offshore renewable energy development in India. Offshore renewable energy projects involve high upfront capital costs, technology risks and uncertainties related to marine conditions, regulatory approvals and long project timelines. Creating dedicated de-risking or blended finance mechanisms can reduce financial and operational risks for private investors. Government participation through viability gap funding helps build investor confidence and lowers the cost of capital. This approach would increase private-sector participation and enable faster project implementation for offshore renewable projects. Over time, this would support large-scale deployment, technology maturation and cost reduction, while strengthening the offshore renewable energy ecosystem.

M International collaboration for the transfer of technology (TOT):

This is essential to support the cost-effective development of offshore renewable energy in India. Several countries have successfully used this approach, for example, China , which partnered with European offshore wind technology providers in the early stages, enabling rapid localization of manufacturing and significant cost reductions in offshore wind deployment. By adopting proven technologies and adapting them to local conditions, countries can avoid high initial R&D costs and reduce

project risks. Structured international collaboration for TOT can help access mature, low-cost offshore renewable technologies while building domestic manufacturing and technical capacity. This approach will accelerate deployment timelines, lower project costs and strengthen indigenous capabilities, creating a sustainable offshore renewable energy ecosystem.

N Development of indigenous technology with an indigenous value chain:

The value chain is critical for building a resilient and sustainable offshore renewable energy sector. Developing home-grown technologies supported by local manufacturing and supply networks can reduce dependence on imports, lower long-term project costs, and improve supply security. An indigenous value chain also enables better adaptation of technologies to Indian marine conditions while creating skilled jobs and strengthening domestic industry. This approach will enhance technology self-reliance, improve project viability, and support long-term scale-up of offshore renewable energy.

O Government to incentivize R&D and piloting in PPP mode:

This can significantly accelerate offshore renewable energy development. Offshore technologies are capital intensive and involve high technical and operational risks, which often limit private-sector participation at the early stages. Government support in the form of grants, co-funding, or risk-sharing mechanisms can encourage private players to invest in innovation and pilot projects. Such an approach enables real-world testing of technologies, reduces uncertainty, and helps bridge the gap between research and commercial deployment. Over time, PPP-based R&D and piloting can lead to cost reduction, technology validation and faster scaling of offshore renewable energy.

P Safety, skill development and O&M ecosystem modernization:

A high-performing offshore sector requires a strong human capital foundation. India must launch a National Offshore Skills Mission aligned with the Global Wind Organization (GWO) standards, establishing training centers at major ports for technician certification, safety drills, vessel operation training and underwater works. As offshore capacity scales, India will require a sophisticated O&M services ecosystem with specialized vessels, remote diagnostics, marine robotics and predictive maintenance systems. Global experience shows that high-quality O&M reduces downtime by up to 15% to 20%, significantly improving project economics. This mission can generate thousands of skilled jobs and strengthen India's coastal economies.

Q Cybersecurity, physical security and resilient infrastructure:

India shall invest in adopting operational technology and information technology and other digital projects under public- private partnership cybersecurity protocols tailored to offshore infrastructure, like Norway's National Cyber Security Centre and the US Coast Guard's maritime cybersecurity directives. A joint maritime security framework integrating the navy, coast guard and port authorities shall be developed to safeguard subsea cables, offshore platforms, hydrogen pipelines and control systems. As offshore energy becomes part of India's critical national infrastructure, resilient cybersecurity systems will be essential for maintaining investor trust and preventing systemic disruptions.

R Circularity, decommissioning standards and long-term asset stewardship:

India should implement mandatory decommissioning bonds and recycling mandates similar to the UK's offshore petroleum regulator's decommissioning framework. This enables developers to plan for end-of-life costs upfront, preventing environmental liabilities. Offshore blade and foundation recycling facilities can develop into a new circular-economy industry, supporting green jobs and reducing waste. With 30–40 GW of offshore assets expected by 2040, lifecycle standards will be crucial for sustainable growth, investor confidence, and environmental protection.

S Dissemination of technologies and market information:

To enable informed participation by industry and investors in emerging marine and offshore renewable technologies, the government should proactively disseminate technology, resource and project-readiness information through structured national and international platforms. Regular dissemination of validated technical data, pilot outcomes and future opportunity pipelines will help reduce information asymmetry and perceived investment risk. This can be achieved through dedicated sessions at sectoral events such as ESTIC, international energy and blue economy forums, investor roadshows and digital knowledge portals led by nodal ministries and research institutions. Timely and transparent communication of both current capabilities and future development pathways will enhance market awareness, support private sector confidence and facilitate early-stage partnerships and investment decisions.

By integrating governance reforms, advanced marine planning, world-class port and transmission infrastructure, strong community partnerships, robust financing mechanisms, circularity and a skilled workforce, India can unlock its full offshore renewable energy potential. These multi-utility recommendations support not only the energy transition goals but also India's aspirations to become a global offshore energy hub, driving investment, sustainable coastal development, industrial growth and long-term energy security.

CHAPTER 09



Conclusion

India now stands at a decisive moment in its clean-energy and blue economy trajectory, where unlocking the offshore renewable energy potential of its vast coastline and EEZ is no longer a technological aspiration but a national imperative for energy security, climate leadership and sustainable coastal development.

As this white paper demonstrates, offshore renewables ranging from wind, solar and OTEC to wave, tidal and salinity-gradient systems offer India an unparalleled opportunity to diversify its energy mix, reduce dependence on imported fuels, relieve land pressure, decarbonize marine and industrial sectors and catalyze the next generation of blue-economy industries. The expansion of offshore renewable energy is intrinsically linked to India's broader ocean agenda, strengthening climate resilience, improving maritime infrastructure, promoting sustainable fisheries, enabling green shipping, expanding coastal livelihoods and advancing cutting-edge marine science.

India's offshore renewable energy opportunity has reached a moment where vision must translate into execution. The convergence of demonstrated pilots, centrally sponsored support and growing institutional readiness calls for immediate, coordinated action by all stakeholders. Central ministries and state governments must jointly establish a unified governance and marine spatial planning framework, fast-track regulatory clearances and align port, grid and coastal infrastructure investments with offshore renewable deployment plans. Scientific institutions such as NIOT, NIWE, INCOIS and NCCR must accelerate resource assessments, environmental baselines, and technology validation to de-risk scale-up and guide evidence-based policymaking.

Financial institutions, multilateral partners and climate funds are urged to mobilize blended finance, concessional capital and risk-mitigation instruments to unlock the anticipated INR30 lakh crore investment envelopes over the next decade. Private developers, OEMs, shipyards, ports and EPC players must collaborate to localize supply chains, build offshore construction and O&M capabilities, and anchor India's emergence as a competitive offshore renewable manufacturing and services hub. Equally critical is the active participation of coastal states, port authorities and coastal communities to enable benefit-sharing, skill development and livelihood creation to be embedded in project design.

Global technology leaders and research partners are invited to engage through structured PPPs, joint ventures and knowledge partnerships to accelerate innovation across offshore wind, OTEC, wave, tidal, floating solar and green hydrogen value chains. With decisive leadership, coordinated investment and inclusive implementation, India can convert its offshore domain into a cornerstone of energy security, climate leadership and sustainable blue-economy growth. The opportunity is clear; the foundation is laid, and the time to act collectively is now.

List of abbreviations

- A&N : Andaman and Nicobar
- BU : Billion Units
- CEA : Central Electricity Authority
- CFD / CfD : Contracts for Difference
- COP : Conference of Parties
- CSIR : Council of Scientific & Industrial Research
- DISCOM : Distribution Company
- DP : Dynamic Positioning (for vessels)
- EEZ : Exclusive Economic Zone
- ESIA : Environmental & Social Impact Assessment
- ESG : Environmental, Social and Governance
- GWh / GWp : Gigawatt-hour / Gigawatt-peak
- GHG : Greenhouse Gas
- GWO : Global Wind Organization
- H : Hydrogen
- HVDC: High Voltage Direct Current
- IMO : International Maritime Organization
- INCOIS : Indian National Centre for Ocean Information Services
- IRA (US) : Inflation Reduction Act
- LCOE : Levelized Cost of Energy
- LiDAR : Light Detection and Ranging
- LTTD : Low Temperature Thermal Desalination
- MoEFCC : Ministry of Environment, Forest and Climate Change
- MoES : Ministry of Earth Sciences
- MNRE : Ministry of New and Renewable Energy
- MoPSW : Ministry of Ports, Shipping & Waterways
- MW / GW : Megawatt / Gigawatt
- NCCR: National Centre for Coastal Research
- NIOT : National Institute of Ocean Technology
- NIWE : National Institute of Wind Energy
- NISE : National Institute of Solar Energy
- NDC : Nationally Determined Contribution
- OTEC : Ocean Thermal Energy Conversion
- OEM : Original Equipment Manufacturer
- O&M : Operations and Maintenance
- PPP : Public-Private Partnership
- PLI : Production-Linked Incentive
- PPA : Power Purchase Agreement
- PRO : Pressure Retarded Osmosis
- PV : Photovoltaic
- RE : Renewable Energy
- RPO : Renewable Purchase Obligation
- RED : Reverse Electrodialysis
- RAM : Regulated Asset Model
- SOV : Service Operation Vessel
- SDG : Sustainable Development Goal
- TAFE : Technical and Further Education (Australia)
- TWH : Terawatt-hour
- UNFCCC : United Nations Framework Convention on Climate Change
- UNCLOS : United Nations Convention on the Law of the Sea
- VGF : Viability Gap Funding
- WEC : Wave Energy Converter



Contact us

Cdr. (Dr.) P. K. Srivastava (Retd.)
Scientist G,
Ministry of Earth Sciences
Email: Srivastava.pks@gov.in

Rakesh K Mishra
Partner,
Business Consulting, GPS
Email: rakesh.k.mishra@in.ey.com
Ph: +91 9910022353

Bhavna Rathee
Director,
Business Consulting, GPS
Email: bhavna.rathee@in.ey.com
Ph: +91 9971998789

Avinash Kumar
Senior Manager,
Business Consulting, GPS
Email: Avinash.Kumar6@in.ey.com
Ph: +91 7667744281

Priya Tayde
Manager,
Business Consulting, GPS
Email: Priya.Tayde@in.ey.com
Ph: +91 8007117142

Acknowledgements

Core team

Vice Admiral Saroj Kumar Jha (Retd.)
Advisor, EY

Dr. Anil Kumar Vijayan,
Scientist F,
Ministry of Earth Science (MoES)

Dr. Anil Kumar,
Scientist E,
Ministry of New and Renewable Energy (MNRE)

Dr. Mangala K R,
Scientist D,
Ministry of Earth Science (MoES)

Mr. Ambuj Nayan
Vice President,
G-Tech Infrastructure Pvt. Ltd.

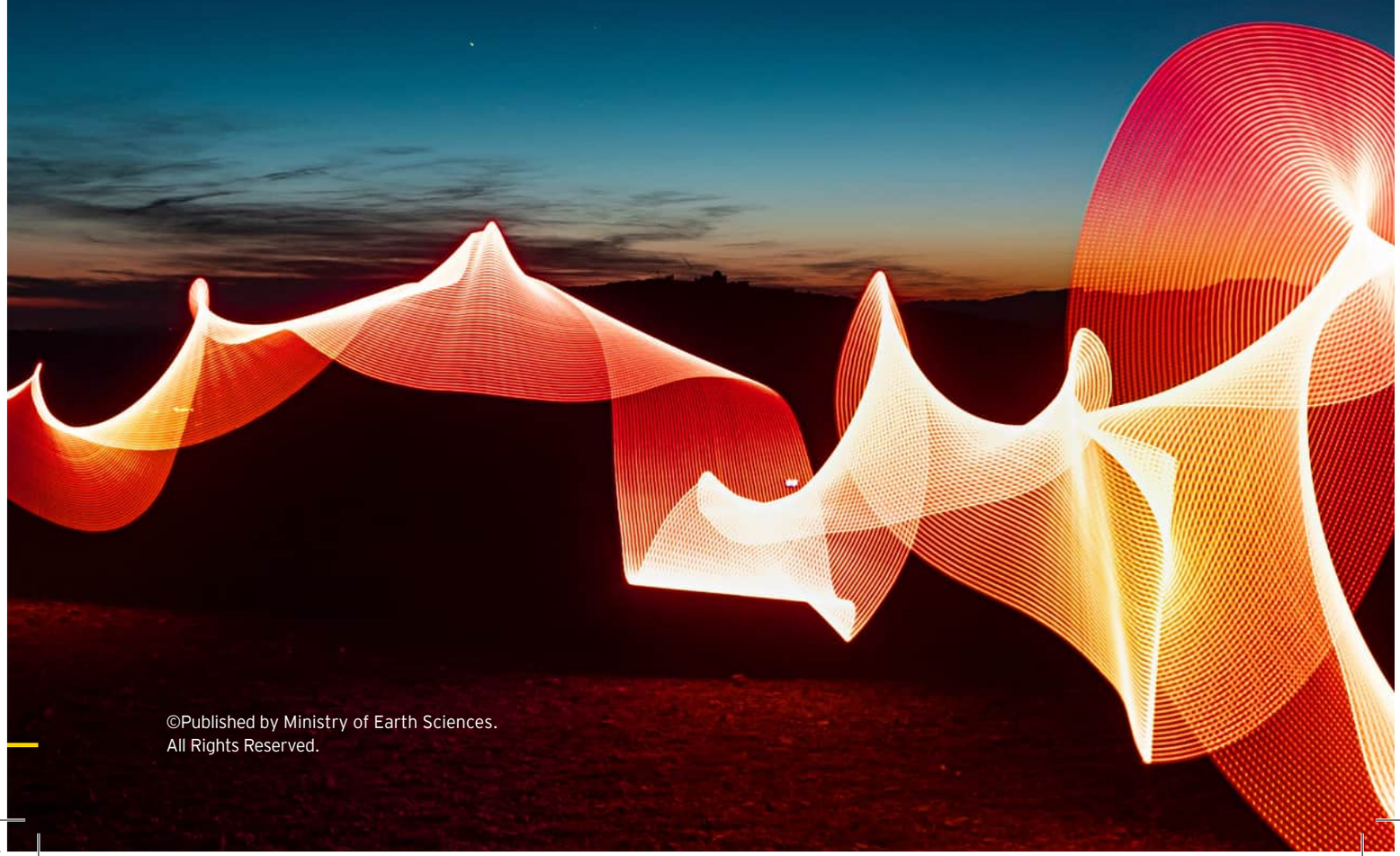
Ms. Reshma Maralkar
Public policy expert,
G-Tech Infrastructure Pvt. Ltd.

Editorial

Sushmita Yadav

Design

Sneha Arora



©Published by Ministry of Earth Sciences.
All Rights Reserved.