RESURGENCE OF OFFSHORE WIND

TECHNICAL REPORT ON DEVELOPING INDIA'S OFFSHORE WIND ENERGY SYSTEMS

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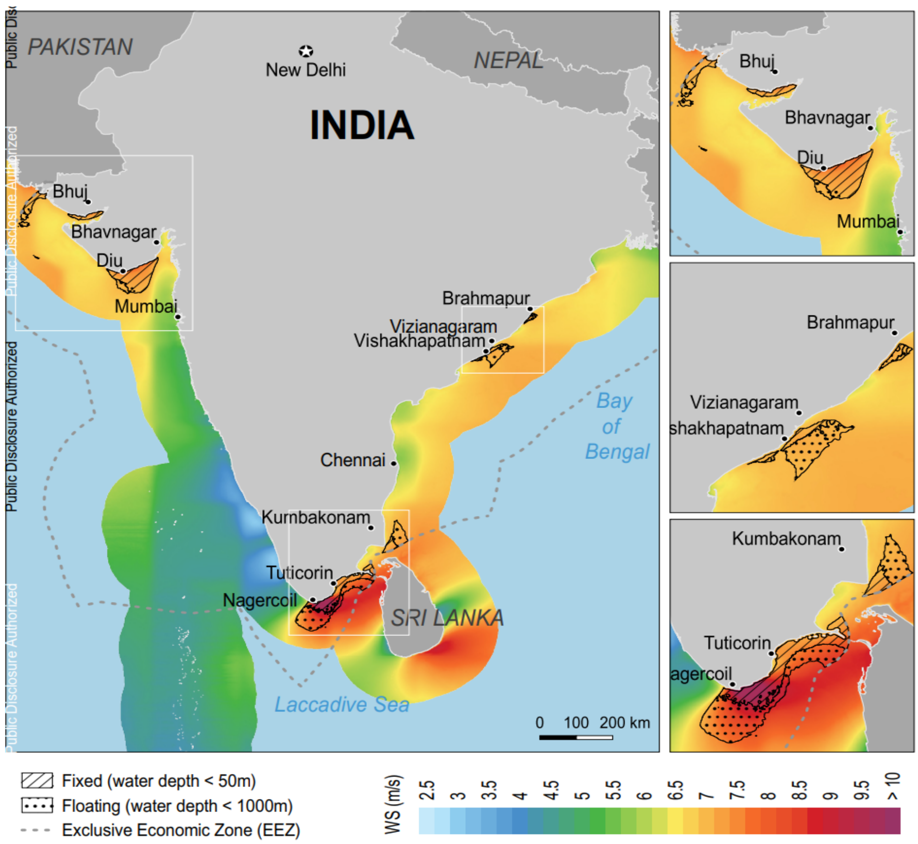
1. Rationale for offshore wind in India

Offshore wind holds promise as an alternative source of energy for a country like India, beset as it is by the lack of usable land and rising difficulty in acquiring land for harnessing energy. Light Detection and Ranging (LiDAR)-based offshore data collection platforms and Wind Atlas help to identify significant potential sites for generating offshore wind energy. It has also been observed by the National Institute of Wind Energy (NIWE) and the World Bank Group that India has an offshore wind capacity of 195 GW. India also has the technical potential of 83 GW floating and 112 GW fixed offshore wind.

Map 1: Offshore wind potential sites along the Indian coast



Source: The World Bank, 2021

With its coastline extending over 7,500 km, India is well suited for the development of offshore wind energy. This abundant, indigenous energy resource offers an opportunity to help out with the following:

- **Improving energy security**: India is heavily reliant on the import of fossil fuels. Its estimated fossil fuel import bill will triple over the next two decades. The uncertainty of future availability and cost of these fuels puts the country at risk from supply constraints and increase in prices. Together with other local renewable energy resources, offshore wind energy can help increase energy independence and resilience, as well as reduce the country's large trade deficit.

- **Lowering greenhouse gas emissions**: Coal-fired power plants account for approximately 96 per cent of India's carbon dioxide emissions from the power sector. The use of low-carbon electricity from offshore wind could allow India to reduce its carbon intensity to less than 45 per cent by 2030.

- **Increasing renewable energy supply**: Although renewable energy installation is increasing, its overall share in India's generation mix was just 9.2 per cent in 2019. As per the National Statement delivered at the 26th session of the Conference of the Parties (CoP), India enhanced the target to meet 50 per cent of its energy requirements from renewable energy and increase its non-fossil energy capacity to 500 GW by 2030. As per the Ministry of New and Renewable Energy (MNRE)'s 2030 target, offshore wind could contribute approximately 30 GW of new generation capacity.

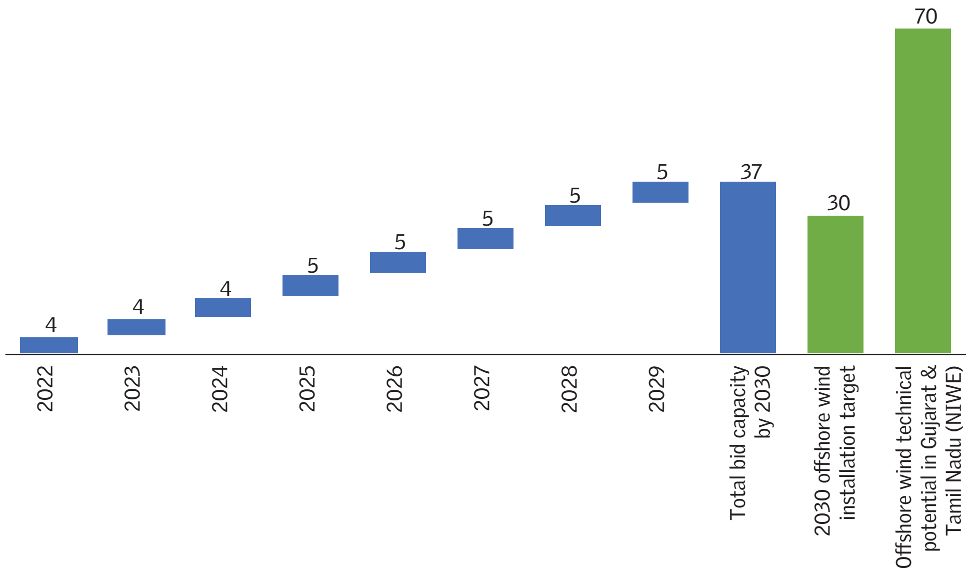
- **Reducing demand for land use**: With over 54 per cent of the population employed in agriculture, land in India is a precious resource. The large-scale development of onshore wind energy is likely to compete for Class I wind sites and cause conflicts in some areas. By meticulously using marine areas, offshore wind could help control the rising demand for land use.

- **Benefitting the economy**: Offshore wind development could create local jobs, catalyse industrial growth in the supply chain, spur upgradation, aid in the expansion of port and grid infrastructure, and increase inward investment.

One-third of the world's electricity is produced in India, and the country is the fourth largest consumer of electricity. Its demand is predicted to grow between 6–7 per cent every year over the next decade, and a shortfall of around 47 GW is expected between 2022 and 2027, according to estimates by India's Central Electricity Authority (CEA).

This allows offshore wind to take a prominent role in India's energy transition. Government initiatives like 24*7 Power for All, Make in India, Atmanirbhar Bharat (Self-reliant India) and the National Mission for Enhanced Energy Efficiency aim to create safe and secure low carbon energy systems which in turn require a large-scale reliable renewable energy supply. As a clean, affordable, scalable, and sustainable indigenous resource, offshore wind can become an important pillar for India to meet its power demand and achieve the goal of wider strategic energy self-sufficiency.

Graph 1: Planned bid trajectory of India (GW)



Source: GWEC | Global Offshore Wind Report 2022

In line with its intended Nationally Determined Contributions (NDCs), India has pledged that by 2030, 50 per cent of installed capacity for power generation will comprise of non-fossil fuel-based energy sources and its emissions intensity will decrease by 45 per cent compared to 2005 levels. It seems likely that this target will be achieved as renewable energy already accounts for 29 per cent (116 GW) of installed power capacity, of which 10 per cent (41 GW) is onshore wind capacity. According to CSE's observations, India achieved 25 per cent of emission intensity reduction of gross domestic product between 2005 and 2016, and is on track to achieve more than 40 per cent reduction by 2030.

India announced a 1 GW Expression of Interest in 2018 in Gujarat, although the tender could not be conducted due to a mismatch of pricing expectations. The government is now exploring multiple pathways to kick start the offshore wind sector in India, including near-shore development, demonstration projects and decentralized development.

- During 2019–20, the government signed the 3-year Indo-Danish Strategic Sector Cooperation on offshore wind, which will include studies of the expected cost of generation of offshore wind through the "Financial modelling of offshore wind in India" initiative.
- National Institute of Wind Energy (NIWE) has identified sites for near-shore development in Gujarat and Tamil Nadu. Currently, it is in the process of securing the necessary approvals. A technology demonstration site in Tamil Nadu's Dhanushkodi for exploring various turbine and foundation designs suitable for India is also being contemplated.
- Concurrently, NIWE installed two additional LiDARs in Gujarat and Tamil Nadu in September 2021; MNRE is considering increasing the pace of development in Tamil Nadu due to the superior wind quality in the state.

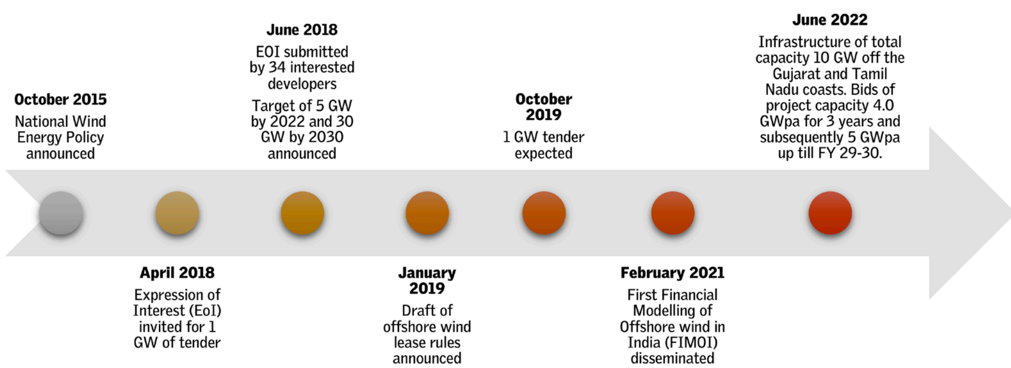
There is a need to accelerate the growth of wind and other renewable energy sources if the government's 2030 target of 500 GW of non-fossil energy capacity has to be reached. As India's power demand is forecast to rapidly expand over the next 20 years, this will provide a critical source of clean and secure green power—requiring the addition of 'a power system the size of the European Union (EU) to what [India] has now,' according to the International Energy Agency (IEA).

2. India's offshore wind development status

Exploratory phase: 2010–19

In India, discussions on offshore wind began in 2010 when the National Institute of Wind Energy (NIWE) invited leading offshore wind technology suppliers for technical advice. This led to the initiation of two promising projects: Facilitating Offshore Wind in India or FOWIND (2013–18); and First Offshore Wind Project of India or FOWPI (2016–19).

Figure 1: Timeline of government initiatives for offshore wind



Source: CSE analysis

FOWIND conducted studies focused on Gujarat and Tamil Nadu. An area of 12 nautical miles off the coast was mapped to identify 16 offshore wind zones. It was during this project that the Government of India came up with the National Offshore Wind Policy in 2015 to provide a legal framework for the development of the offshore wind sector in the country, with the Ministry of New and Renewable Energy (MNRE) and National Institute of Wind Energy (NIWE) taking on the roles of Nodal Ministry and Agency, respectively.

India's first commercial talks around offshore wind economics began during the FOWPI project conducted by a COWI-led consortium. This was supported by the EU, which assisted up to the pre-FID (Financial Investment Decision) stage and provided capacity-building for Indian stakeholders. This resulted in an Expression of Interest (EOI) issued by NIWE in 2018 for a 1 GW project in Gujarat. Geotechnical analysis was conducted in 2018 and 2019 using data derived from the only LiDAR in the Gulf of Khambhat zone in India, which was commissioned in November 2017. Interestingly, this analysis emphasized the stronger windy zones of Tamil Nadu and shifted attention away from Gujarat. Going forward, further studies and analyses to identify bankable offshore wind sites to renew interest from investors and developers are required.

Leading multinational and domestic companies responded enthusiastically to the EOI. However, in the absence of a financial support scheme and high capital expenditure (CAPEX), the EOI has been unable to progress since 2018. In mid-2019, MNRE applied for US $900 million viability gap funding (VGF) to the Ministry of Finance to support the construction of the first 1 GW project in Gujarat.

Financial Modelling of Offshore Wind Farms in India (FIMOI), 2019–2021, involves the collaboration of MNRE, NIWE and the Danish Energy Agency (DEA). This project aims to assist the Indian government in developing the Indian offshore wind market. A series of consultations with stakeholders, including National Research Development Corporation (NRDC) and Organisation for Economic Co-operation and Development (OECD), have highlighted key issues, along with three priorities for attaining short- to medium-term (till 2030) development of offshore wind in India:

- **Clarity on contracts** such as clarifications on Power Purchase Agreement (PPA) conditions and sanctity, off-taker risk, tariff regime, revenue support and pipeline development
- **Regulatory conditions** for technical standards, import duties, local content requirement and local taxation
- **Infrastructure development** like ports, yards and transmission lines

India established bilateral agreements and inter-governmental cooperation with European countries in December 2013 to develop offshore wind markets and related technical capabilities. The first offshore wind farm in Denmark was installed as part of a bilateral agreement signed in 2019 and reaffirmed with the creation of a green strategic partnership in September 2020. Furthermore, there have been local collaborations, including the signing of a Memorandum of Understanding (MoU) between the Oil and Natural Gas Corporation (ONGC) and the National Thermal Power Corporation (NTPC) to explore further opportunities for the offshore wind sector. Tata Power Renewable Energy and Germany-based RWE Renewables have also signed MoUs for the development of offshore wind projects.

Overall, the Indian government has shown interest in developing an offshore wind market and has taken steps in this direction. However, these efforts will need to be intensified in order to meet the decarbonization targets.

MNRE held a consultation with the industry in March 2022 concerning its discussion paper entitled *Establishment of Offshore Wind Energy Projects to achieve a target of 30 GW by 2030*. The ministry proposed various models for holistic development.

Additionally, developing green hydrogen from offshore wind has the potential to create high value jobs, with a significant proportion of those jobs likely to be located in remote, rural or coastal communities near offshore wind resources. Workers can use these opportunities to redeploy and develop skills gained in the oil and gas industry, in accordance with the principles of Just Transition.

HYDROGEN FOR GERMANY'S ENERGY TRANSITION

Germany, along with the rest of the European Union member states, has committed itself to reducing its greenhouse gas emissions by 2050, based on the targets agreed upon under the Paris Agreement. For Germany to become greenhouse gas neutral and meet its international obligations under the Paris Agreement, it must decarbonize its energy supply. Hydrogen has been cited as a key element in the country's energy transition. In June 2020, the Federal Government of Germany announced its National Hydrogen Strategy (NHS) that commits to establishing 5 GW of hydrogen production capacity by 2030.

Offshore wind is seen as an attractive renewable technology to produce green hydrogen. The offshore wind to hydrogen framework is being developed further to ensure that investments achieve payback. Potential adjustments that are being discussed include the designation of additional areas that can be used for offshore production of hydrogen, investment in necessary infrastructure, and the potential for additional rounds of auction.

As part of the National Hydrogen Strategy, the federal government has highlighted measures that will be taken to facilitate demand for hydrogen within the targeted sectors. In the industrial sector, the government intends to incentivize the transition to green hydrogen by providing funding for investments in electrolysers.

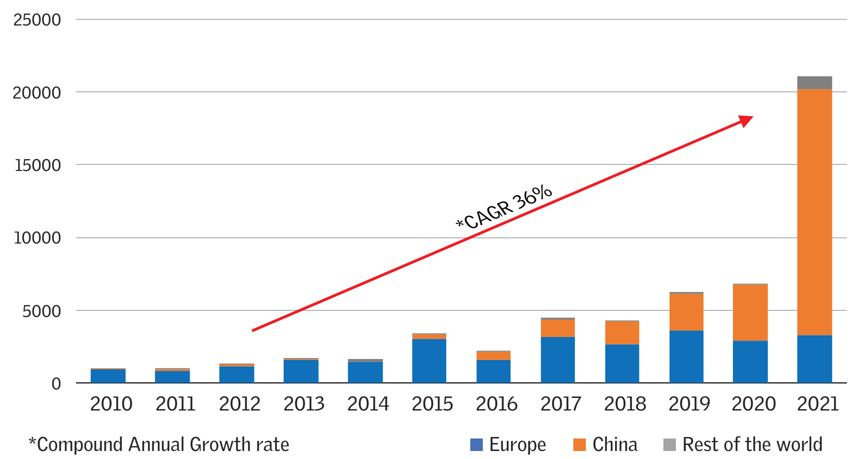
In addition, a new pilot programme for Carbon Contracts for Difference (CCfD) will be set up. Under this scheme, the government guarantees to support the differential between the actual costs of avoiding emissions—or a project-related, contractually defined carbon price per avoided quantity of greenhouse gas emissions—and the ETS prices for the construction and operation of decarbonization technologies to achieve greenhouse gas neutrality.

3. Global offshore wind market status

Offshore wind is considered to be an important pillar of the world's future energy mix and investment in this technology is increasing worldwide.

The expiry of Feed-in-Tariffs (FiTs) for offshore wind at the end of 2021 led to an exponential increase in new offshore installations in China in order to lock in the premium offshore wind Feed-in-Tariff (0.75–0.85 RMB/kWh) for 20 years and avoid price competition (and price cuts) with coal.

Graph 2: Addition of offshore wind capacity in global market (MW)



Source: GWEC, 2022

The EU has helped develop wind power technology owing to ambitious policies and investments. European companies have invaluable experience since they spearheaded the offshore wind sector with the first offshore wind farm installed in Vindeby, Denmark in 1991. With around 16 GW of grid-connected capacity by mid-2022, the EU is leading in offshore wind deployment. It is currently a global leader in the manufacturing of key wind turbine components and in the foundations and cables industry. Approximately 50 per cent of the active companies in the wind sector (onshore and offshore) are headquartered in the EU.

In November 2020, the European Commission published a new EU strategy on offshore renewable energy under the European Green Deal. The strategy proposes two targets for increasing Europe's offshore wind capacity

1. From 16 GW of installed capacity to at least 60 GW by 2030 and;
2. From 16 GW of installed capacity to 300 GW by 2050.

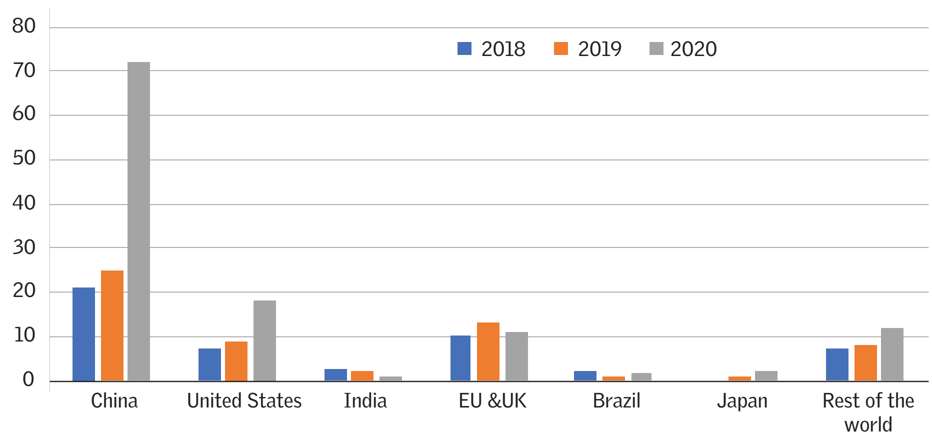
The global offshore market grew by 36 per cent per year in the last decade. Total installations increased to approximately 56 GW (accounting for nearly 7 per cent of total global wind capacity at the end of 2021).

Europe was the largest regional offshore wind market at the end of 2021 with a share of 50.4 per cent of total cumulative global offshore installations, 18 per cent lower than the previous year. UK had been leading in total installations but was overthrown by China by the end of 2021. Germany, Netherlands and Denmark are the other top-five international leaders in offshore wind energy. The sharp drop in Europe's market share is primarily due to the remarkable growth of the offshore sectors in China and Vietnam in 2021.

As the world's second largest regional market, Asia is trailing behind Europe by less than 1 per cent in cumulative installations. China is the largest market in the region, followed by Vietnam, Taiwan, South Korea and Japan. Outside Europe and Asia, North America had 42 MW offshore wind in operation as of the end of 2021 at the Block Island wind farm located in the US. In terms of floating wind installations, 57.1 MW was installed in 2021, of which 48 MW was in the UK, 5.5 MW in China and 3.6 MW in Norway.

In 2021, 21.1 GW of offshore wind energy reached grid connections worldwide, three times more than in 2020, setting a record in the offshore wind industry. Of the 21.1 GW in new offshore installations, 80 per cent was contributed by China.

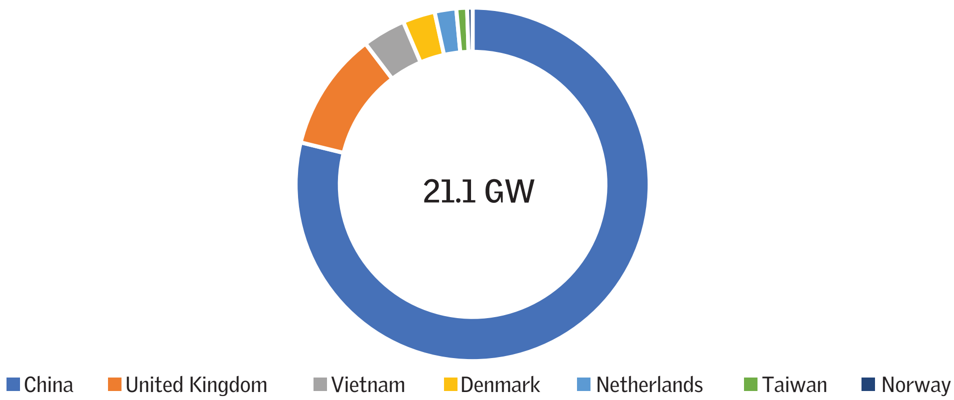
Graph 3: Global annual additions to wind capacity, 2018–2020



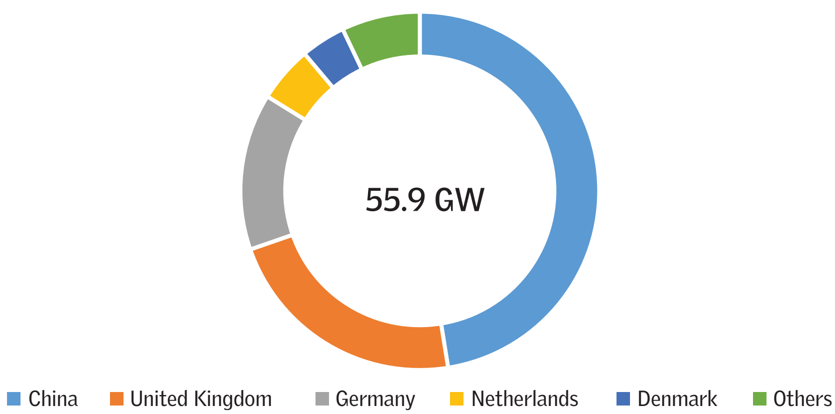
Source: IEA, 2021

This makes 2021 the fourth year that China has led the world in new offshore wind installations. The UK had a record year in 2021 with more than 2.3 GW reaching grid connection; however, it lost its title as the world's largest offshore wind market in total installations to China. Coming in second for new installations in Europe is Denmark with 605 MW commissioned last year, followed by Netherlands (392 MW) at third.

Graph 4: Global offshore wind installations by market (2021)



Graph 5: Market share of global offshore wind installations



Source: GWEC | Global Offshore Wind Report, June 2022

India's stand in the global wind market

Estimation of offshore wind energy potential in India is carried out by NIWE, which is assisted by various multilateral agencies. Preliminary estimates suggest that good potential for this sector exists off the Gujarat and Tamil Nadu coasts. Eight zones in Gujarat and Tamil Nadu have been identified as potential zones for development of offshore wind energy projects through techno-commercial analysis and preliminary resource assessment based on satellite data and available data from other sources.

DRAFT TENDER DOCUMENT FOR SEA-BED LEASING FOR OFFSHORE WIND IN INDIA

The Government of India kicked off plans for offshore wind in India by releasing a consultation paper to call for bids to lease 870 sq. km seabed area near the southern tip of the country off the coast of Tamil Nadu. The blocks are at a depth of 20–50 m and 10–39 km from the coast. The indicative capacity for project installation is 4 GW (with assumed capacity of 4.5 MW per sq km).

The seabed leases are to be awarded for a period of five years and can be extended by a period of two years. They are indicated to be awarded before March 2023, which might be a bit ambitious considering that India does not have any offshore development and developers will need time to understand the risks.

The process outlined envisages the award of the bids will be through a two-stage single bid process. The developers will be required to submit a technical bid and a financial bid. The technical bid will have 70 per cent weightage and the financial bid will have 30 per cent weightage. The ministry will only entertain bids of companies/consortiums who have experience in onshore wind in India, offshore wind globally and net worth of more than Rs 250 billion or US $3 billion. Those who qualify will be scored on the basis of 14 parameters ranging from experience, to plans, track records and financial evaluation. The criteria laid out are defined objectively but can be expected to be contested by developers.

Nevertheless, the scores obtained will be normalized and added to the score received for the quote of lease fee. This weighted average blended score will be used to declare the winners. The list of criteria indicates that the government aims to invite experienced and capable offshore wind players to enter into consortium with onshore wind developers in India to jointly develop the projects.

The winners will need to pay the fee as per their bids until the start of construction, i.e., only for the survey. During construction and operation of the farm, the lease fee will revert to the base price of Rs 1 lakh per sq. km (US $1,300) to keep the cost of electricity competitive. Those who wish to continue and construct the plant after the surveys, will sign a concession agreement for 35 years inclusive of construction and decommissioning.

The main concern for developers will be the timelines for bids as the commercial and infrastructural risks are not fully mapped. Commercially, the power offtake will be to corporates or can be sold via exchange and will be the sole responsibility of the developer who wins the block. The government will not be taking any responsibility for power offtake. No subsidy on CAPEX or preferential tariff is envisaged for this particular round. However, incentives available to onshore wind are extended to offshore wind. Additionally, provision of power infrastructure, REC with multipliers, carbon credits, and waiver of transmission charges will be provided as and when they are made available by the Government of India. These are more generous than what is provided for onshore renewables being sold to third parties, but will still lead to higher priced power. The government is banking on the requirement of large steel, cement and other heavy industry companies in India to use this power as a substitute of fossil fuels.

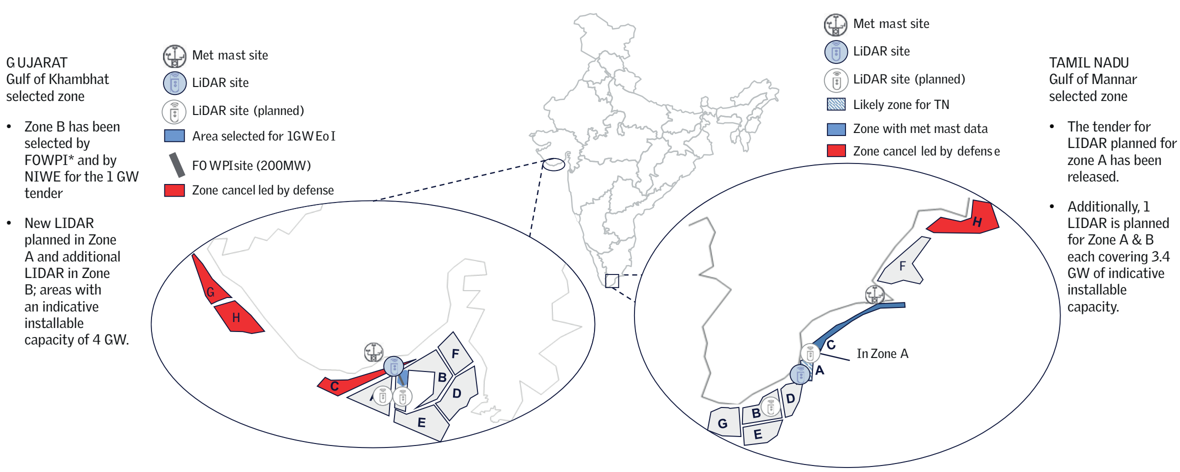
Additionally, a point that will probably trigger industry demand to provide more time for bid submissions is the requirement that all the infrastructure needed for assembly of WTG, port facilities for storage and coordination of installation and commissioning will need to be done by the developer. Since India does not have any offshore wind development and the ports themselves have done little preparation so far, this will take a bit more time than provided for.

The first offshore wind installation in India was at Dhanushkodi, Tamil Nadu. Ambitious targets were set by the Indian government in 2018: to install 5 GW offshore wind by 2022 and 30 GW by 2030. Concrete steps to achieve these targets were taken by announcing a 1 GW Expression of Interest (EOI) for a prospective project off the Gujarat coast in the Gulf of Khambhat. Forty participants responded to the EOI, including major offshore wind players. For a 1 GW offshore project in Gujarat, LiDAR measurements and geotechnical/geophysical investigations have been completed, and preliminary permits have been secured. Moreover, PPAs have been signed with the Gujarat State Distribution Company (GUVNL) and viability gap funding is currently under review with the Ministry of Finance for one-time capital expenditure support subsidy.

Further, assessments by NIWE, excluding the areas in consultation with various line ministries/organizations, suggest that 36 GW of offshore wind energy potential exists off the coast of Gujarat and 35 GW off the coast of Tamil Nadu. The sites are to be studied and classified as those approved by defence authorities, and put forth to invite investors (through Expressions of Interest).

The government aims to take advantage of the decreasing global tariff trend by installing offshore wind capacity at a fast pace. This may give confidence to both national and global project developers, along with financing institutions, in the Indian market.

Figure 2: Identified zones off Gujarat and Tamil Nadu coast (2016)



Note: *FOWPI: A 200 MW site in zone B that was being developed by COWI India along with Windforce Management Services since Dec'15; Funded by European Union
Source: FOWIND Pre-feasibility Study for GJ; FOWPI; MEC+analysis

4. National policy and regulatory framework

The *National Offshore Wind Energy Policy 2015* is targeted at exploring and encouraging deployment of Offshore Wind farms (OWFs) in the Exclusive Economic Zones (EEZ) of the country, including those under Public Private Partnerships. The Central Government is responsible for the promotion of investment in energy infrastructure, spatial planning and management of maritime renewable energy resources in the EEZ through suitable incentives. Ultimately, energy security has to be achieved by reducing carbon emissions and increasing the deployment of indigenous offshore wind energy technologies, thereby also promoting research and development in the offshore wind energy sector.

A critical benefit of developing offshore wind energy is the generation of employment opportunities for skilled manpower. It will also facilitate the development of Project Engineering, Procurement, and Construction (EPC) with regard to offshore wind industry, coupled with the need to develop coastal infrastructure and supply chain to support heavy construction and fabrication work, as well as operation and maintenance activities.

MNRE is responsible for the overall monitoring of offshore wind development in the country, co-ordination with other ministries/departments, issuing guidelines/directives, and oversee the working of and provide necessary support to the NIWE for smooth functioning.

Renewable Energy Catapult and NIWE have announced a Joint Declaration of Intent (JDI) to establish a 5-year collaboration programme to support India's and UK's offshore wind industry. Under the MoU between India and Denmark, a knowledge hub called the Centre of Excellence for Offshore Wind and Renewable Energy was launched in September 2021 for the adoption of a comprehensive and coherent approach for cost-effective offshore wind power, in order to mobilize significant investment. An initial report in May 2022 estimated that the lowest possible levelized cost of energy (LCoE) by 2025 and 2030 could be in the range of Rs 11.2–7.4/kWh and Rs 7.8–5.2/kWh, respectively.

In June 2022, the MNRE discussed the requirements for building transmission and evacuation infrastructure for offshore wind projects of total capacity 10 GW off the coasts of Gujarat and Tamil Nadu. They also decided to invite bids equivalent to project capacities of 4 GW per year for three years starting in the current fiscal year 2022–23 for the development of the coastlines of Tamil Nadu and Gujarat; and subsequently to start inviting bids for project capacities of 5 GW every year for a period of five years i.e., up till FY 2029–30.

As shown in the table below, the offshore wind sites in the state of Gujarat are more mature and are in a better position to participate in tenders than the Tamil Nadu offshore wind sites.

Table 1: Comparison between the progress in offshore wind sector in Tamil Nadu and Gujarat

Category	Gujarat	Tamil Nadu
LiDAR	One LiDAR commissioned at Zone B in Nov 2017; Two are proposed for zones A and B	No LiDAR installed; Three are proposed for zones A, B and C
Avg. wind speed	~7.63 m/a @100m HH as per 6-month LiDAR Data for Zone B	NIWE's 100 m guyed mast installed at Rameshwaram shows 8.62 m/s average wind speed @100m HH and WPD of 603 W/m^2 @50 m a.g.l.
Geotechnical condition	Extensive weak clay or soft soil layers (~9m) found in zones A and B; challenging and costly for foundation design and need customization	Better than Gujarat site, soil profiles for Zone A indicate significant spatial variation in the southern Tamil Nadu offshore region; ranging from weak/loose sands/clays to strong cemented sand
Infrastructure and logistics	Pipavav port is large and lively with high vessel availability and storage facility in the region but needs to be optimized for offshore wind	Ports are relatively smaller in size; need significant modification to be ready for installation of offshore wind farms
Coastal area	Rich in biodiversity and has fishing communities up to 10 km off the coast; Rapid Environmental Impact Assessment (EIA) is done; however, detailed EIA for overall impact analysis is required	Strong tradition of fishing communities in coastal areas; precise geopolitical, EIA and social acceptance study is required
Tender or other activity	EoI invited for Zone B nearest to Pipavav port in Gulf of Khambhat. Rapid EIA, and geotechnical and geophysical analysis have been done.	No tender has been floated till date; the plan is to award first project of 300–500 MW capacity in zone B. The first National Offshore Research & Testing Facility will be established on 75 acres of land allocated to NIWE

Source: GWEC, 2021

5. Benefits and challenges of offshore wind

High efficiency output and clean energy resilience

Offshore wind has a higher capacity and a more consistent output (a turbine in 15-mph wind can generate twice as much energy as a turbine in 12-mph wind) than other variable renewable energy sources. In contrast to onshore wind turbines (around 2–3 MW), offshore wind turbines are larger (between 5 and 10 MW). Further, absence of any obstruction in the sea offers much better quality of wind and its steady conversion to electrical energy.

Although offshore turbines are more expensive because of the need for stronger structures and foundations in marine environments, the desired tariffs can be obtained because of the higher efficiencies of these turbines after the development of the ecosystem.

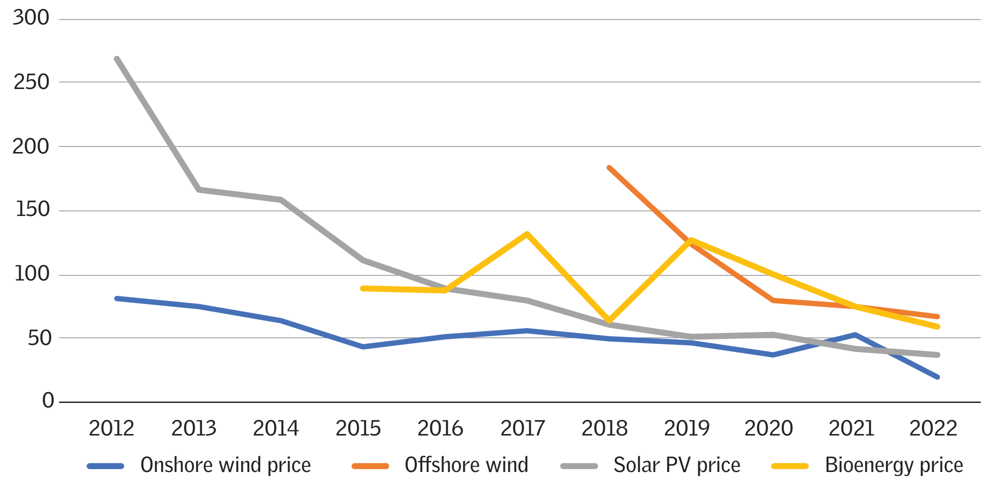
Seismic vulnerability of Gujarat offshore wind farms

The Gujarat zone is in a seismically active area due to its special location near two plate boundaries. Therefore, all developments in this area will need to be designed to withstand seismic activity with attention being paid to the liquefaction risk of the underlying sand strata, particularly for areas of the site overlain by a soft, thin layer of clay.

Economic and execution feasibility

Tariffs for solar and onshore wind in India are lower than those for conventional or other renewable sources. Since the initial cost of offshore wind is higher due to heavy component costs, there is resistance from the government to invest in this technology. High capital cost leads to higher tariffs when compared to present onshore wind rates, which makes consumers resistant to adopting this. It is anticipated that offshore wind tariffs in India will range from Rs 7–9 per unit, compared with the prevailing rate of Rs 2.8–2.9 per unit for onshore wind. A decision on viability gap funding (VGF) support for the first offshore wind project from the Ministry of Finance was delayed in light of the pandemic, but should be accelerated to send out a positive signal in the market. As a result of technological advancement and optimization of OWF processes and components, the cost of producing offshore energy has decreased. The timely execution of an offshore wind farm right from its feasibility study phase to commissioning requires skilled project management over a period of seven to nine years.

Graph 6: Global trend of decreasing offshore wind price (USD/MWh)



Source: IEA, 2022

A drop in the cost of offshore wind energy, especially in mature European markets, and a favourable strike price for offshore wind compared to electricity generated from nuclear power plants, makes it 37 per cent cheaper than nuclear energy. This also prevents energy consumers from being locked in exceptionally long-term cost commitments while the plant is operating for even centuries thereafter.

In terms of financing, an increasing number of developed markets are inching towards competitive auctions and are likely to experience more market-based mechanisms enforced by the government to support its future growth. These moves create challenges for individual or small project developers to secure attractive long-term finance in European markets where revenues depend on overall energy production and the prevailing price of electricity in the market.

The difficulty of obtaining low-cost financing and insurance is even greater in most emerging markets. As offshore wind projects expand into deeper waters and into regions in East Asia with frequent typhoons and earthquake prone seabeds, the project becomes riskier and an additional engineering challenge is posed. The initial costs of financing are still very high and thus, significant support will be needed through low-cost public funds, along with stable regulatory mechanisms, to leverage private investment.

Stiff competition in the renewable energy market

The nascent offshore wind industry has to face the issue of cost differentials between offshore wind and other renewable technologies. In India, recent auctions have made solar PV and onshore wind competitive with thermal power generation. Thus, offshore wind technology has to overcome the challenges posed by the steep cost reductions achieved by these emerging markets.

Lack of efficient supply chain

During its initial phase, a key bottleneck for the offshore wind industry was the lack of a dedicated supply chain, which meant that developers had to depend on the onshore wind and fossil fuel industries. However, with increasing competition across most areas of the supply chain, the situation has improved. Only a few region-specific market concerns still remain. It should be noted that variation of any parameters (size, location, connection point, etc.) can have an impact on the design of the system, and therefore this should not be considered as a 'blueprint' for the design of offshore wind grid connections in India.

Socio-environmental implications

With over 4,000 commissioned offshore turbines globally, the sector has a better understanding of environmental impacts such as threat to birds, fish, marine mammals and bats due to collision, displacement from breeding or nesting areas, disruption of migration corridors, barrier/avoidance effects on movement, acoustic and electromagnetic disturbances, changes in food supply, and habitat degradation. Some studies have also shown that species are more abundant and species assemblages more diverse in areas with offshore wind farms. As a positive impact, wind farms could contribute to high marine growth in warm nutrient-rich waters, but the possibility of microbiologically induced corrosion must also be considered. Offshore wind development primarily affects local fishing communities and those who reside near these developments, owing to visual intrusion and noise pollution. Shipping routes may also be affected and there is increased competition with other sectors for space in the waters.

Technological requirements

There is uncertainty associated with inefficient and largely inaccessible bankable offshore wind data and studies based on GIS data. The identification of specific areas for offshore wind development and the mapping of exclusion zones and areas for other ocean uses (shipping lanes, defence areas, fishing areas, ecologically protected areas, oil exploration, mineral extraction and dredging regions, submarine communication cables, coastal tourism, etc.) has not happened properly, which has led to significant delays in the consenting process. After LiDARs are installed under MNRE and NIWE's current measurement campaign, a 12-month hatching period will be required to identify bankable offshore wind project sites.

Skill gaps and job opportunities

- Offshore wind is likely to create direct employment and inward investment opportunities, which will exceed the public support required at an early stage many times over. Currently, however, these job creation and investment benefits have not been evaluated in the cost-benefit analysis undertaken, and they must be articulated and presented to the appropriate ministries.
- The Offshore Wind Industry Council (OWIC) has published its Skills Intelligence Model Report. By 2026, the number of offshore wind jobs is expected to almost triple from 26,000 to 70,000.
- Skill Council for Green Jobs has been set up to educate and train people in skills required for participating in green jobs involved in the wind energy sector.

Figure 3: Classification of regions based on availability of human capital and skill gaps

CATEGORY 1	CATEGORY 2	CATEGORY 3	CATEGORY 4
Low Risk Plenty of talent in local markets. Very little or no offshore wind competence required.	**Moderate Risk** Some challenges viewed on a national scale, offshore wind competence can be achieved within 12 months.	**High Risk** Limited talent internationally, offshore wind competence takes up to three years.	**Very High Risk** Hard to fill on an international basis, offshore wind competence takes more than three years.

Source: Taylor Hopkins

- A joint survey by Earth Scotland, Greenpeace and Platform found that more than 75 per cent of offshore oil and gas workers would move between sectors, with half of them stating their first choice would be a switch to wind energy.
- Traditional engineering, technical and project management skills will continue to be in demand in the offshore wind sector
- Re-skilling, apprenticeships and training programmes can play a huge part in encouraging more women and ethnic minorities into the industry.

6. Key factors for successful development of offshore wind in an emerging market

Favourable policy framework and regulatory support

The MNRE in collaboration with relevant state authorities, should identify dedicated offshore wind development zones within exclusive economic zones. Further, for their 'first of its kind projects' in India, regulators must ensure measures are taken to safeguard them against losses from curtailment by the state or regional grid operators.

NIWE has agreed to provide a 'Single Window Clearance' system for all necessary approvals and permits. It is imperative that this facility include all relevant aspects, including environmental clearances and onshore power evacuation approvals. There is no doubt that this is a key component of the supporting regulatory ecosystem, as it is expected that many ministries and regulatory bodies would have to participate, both at the state and national levels, in order to obtain the necessary project clearances. Given the initial cost of early offshore wind projects, these wind farms should be granted the "Must Run" status. Also, NIWE must work towards ensuring effective collaboration between involved/affected parties during the planning stages to minimize execution challenges later.

A mismatch in priorities at the Central and State levels has led to a slowdown of offshore wind development. As seen in the US, China, Brazil and other markets, local states often have a particular interest in offshore wind and experience friction at the national level. Strong cooperation between different levels of government is vital for the achievement of national targets and coordination of activity around the highest potential sites to build investor confidence.

Financial support via international and regional collaborations

The government can seek collaborations and partnerships with the European Investment Bank, which has a history of significant lending to offshore wind projects in Europe over the last decade. There are also institutions like the KfW, which has a programme for offshore wind projects, and other sister development banks which provide low-cost funds for offshore wind projects. The State Bank of India recently availed US $625 million facility from the World Bank for the promotion of the grid-connected rooftop solar project. A similar thing could be done for offshore wind projects. The Ministry could also consider ensuring that a Feed-in-Tariff with mandatory procurement by the DISCOMs is available to offshore wind projects.

The industry had recommendations for the design of this tariff regime. Offshore wind tariff could be structured in a way that considers the specific nature of each project. Tariff bands may be built considering the depth of the water, distance from the shore, the capital cost involved, etc. This would be similar to onshore wind policy developed by states where tariff is determined based on wind power density, capital cost of installation, operation and maintenance cost, etc. Tariff could also be differentiated based on project size and should be worked out based on a 'Front Loaded' payment method, wherein instead of having a constant tariff level over the complete duration of support, the tariff structure could pay higher tariff for the early years of a project, with a tapering out of the tariff towards the end of the tariff agreement period. This can help to reduce financing cost without increasing the total sum of financial support for early offshore wind projects.

Offshore wind farms are capital investment-intensive owing to their relatively novel nature. Therefore, an initial high cost of energy is inevitable. Financial viability of the projects can be improved by securing public sector loans and government-supported special projects. Additionally, in accordance with the high investment needs for offshore projects, priority payments from DISCOMs must be ensured.

Revamping onshore grids for offshore power evacuation

State governments are responsible for reducing risk of offshore wind projects by improving the existing onshore grid infrastructure. This is done by floating concurrent tenders for connection of offshore plants to the onshore grid. A review of the current grid-code should be done to assess the need for a separate grid code. Modifications, specifically for offshore wind, should be initiated by MNRE in collaboration with the Central Transmission Utility. Future grid code modifications should be reviewed in light of the specific characteristics and the quantum of power from offshore wind farms and the capacity addition envisaged under long-term plans for the offshore sector. There is also a need for state and central agencies to clarify the compliance boundary for offshore wind farms under each grid code requirement, as applicable. Underwater/seabed power evacuation infrastructure needs to be developed and an offshore substation has to be set up under the responsibility of the Power Grid Corporation of India Limited (PGCIL). Training of PGCIL personnel should be done in key offshore countries such as the UK, Germany, Denmark and Netherlands as underwater/seabed power evacuation and cabling expertise is currently unavailable in India. National Clean Energy Fund allocation could be utilized for investments in the relevant transmission sector improvements.

Infrastructural development

Offshore wind project delivery can be boosted by the government by developing ports, as the current port infrastructure in India could be a limiting factor. Public specialist companies like ONGC could be tasked with developing operational and human resource competency for offshore wind projects. A government directive to this effect would greatly expedite the collaboration between ONGC, its suppliers and offshore project developers. Ensuring a transparent system for acquiring approvals along with related information through dedicated online portals that are regularly updated will also be beneficial. Operation and maintenance (O&M) costs of offshore wind facilities have declined by 45 per cent globally in the last 10 years. Several steps may be taken to reduce O&M costs even further, including resource sharing between facilities, minimizing transportation and installation distance, and executing scheduled maintenance.

7. Transmission infrastructure

One of the most distinguishing features of offshore wind farms as compared to other more established renewable energy sources is that they need a dedicated offshore electricity transmission infrastructure. The regulatory model for the connection of offshore wind farms to the main onshore grid network is critical for investment incentives in offshore technology because it governs the distribution of costs and risks between project developers, network operators and other stakeholders.

It is vital to develop transmission infrastructure for connection of and power evacuation from offshore wind farms within a fixed timeframe. Regulatory models of delivery and ownership of offshore transmission assets that best suit Indian power system conditions (as discussed in the *Grid Integration Study for Offshore Wind Farm Development in Gujarat and Tamil Nadu*, GWEC) have a significant bearing on the cost and feasibility of projects. There is also a need to grow local capability in the planning, design and delivery of offshore transmission systems amongst key power sector stakeholders and capture learning from more mature offshore wind markets in Europe through dialogue between utilities.

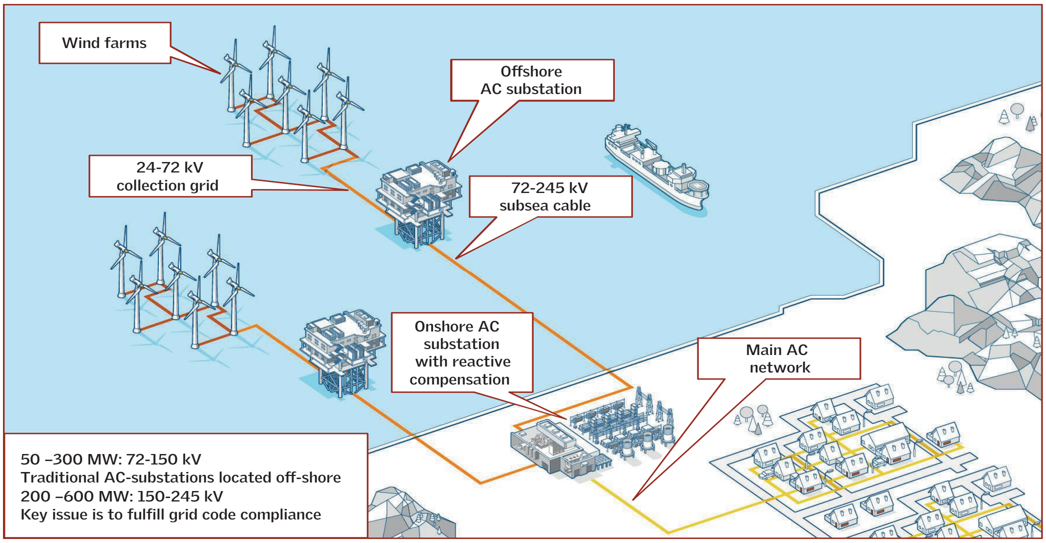
The report discusses briefly three major regulatory models for delivering and owning offshore transmission assets based on the experience of project development in Europe.

- Generator model: Project developer builds and owns the offshore grid connection; lowers risk of stranded wind farms;
- TSO model: The Transmission System Operator (TSO) is responsible for delivery and ownership of the offshore grid connection; allows for coordinated development;
- Third-party model: Tender is taken out to select third-parties to perform these functions; de-risks projects and allows for specialization.

In India, a hybrid of the generator and TSO model is the preferred way. In the hybrid model, the offshore grid connection is built by the developer and subsequently transferred to the TSO.

Such decisions have a significant bearing on the cost and feasibility of projects. These affect how local capability will grow in planning, design and delivery of offshore transmission systems amongst key industry stakeholders.

Figure 4: High voltage AC electrical layout



Source: ABB 2016; Feng Li, Wind ISI, CNABB

Table 2 : Advantages and disadvantages of the three models

Regulatory model	Advantages	Disadvantages
Generator model	• The offshore wind farm owner has an incentive to build reliable and cost efficient connections to maximize profit margins. • Experienced developers are well placed to manage the development risks and ensure that operational risks associated with the grid connection life time are also minimized. • The grid connection operation and maintenance (O&M) can be integrated with the offshore wind farm O&M to reduce costs. • End-of-life decommissioning will be combined with wind farm decommissioning, potentially reducing costs. • No offshore interface with the TSO, all offshore assets are owned by the developer and there is no need to segregate wind farm and grid connection assets offshore (interface is onshore).	• Places a large cost burden on the wind farm owner. • In the EU under the Third Energy Package legislation, a generation license holder cannot own a transmission license and hence cannot own transmission assets. Once the transmission assets have been constructed, the developer must sell them to a transmission license holder.

Regulatory model	Advantages	Disadvantages
TSO model	• Potentially can reduce the cost burden on the developer if the connection cost is paid for through use of system charges, rather than as an upfront charge • The TSO can centrally plan the full network and may have the opportunity to integrate the offshore wind farm grid connection within another strategic network development such as an offshore interconnection or network reinforcement. Multiple offshore wind farms located in close proximity will also benefit from central planning. • In the EU, the TSO model ensures compliance with the Third Energy Package, hence there is no requirement for the sale of transmission assets after construction. • TSO with substantial offshore grid plans can drive supply chain efficiency savings due to the scale of procurement.	• Potentially places a cost burden on the TSO if the connection cost is paid for through use of system charges and there is financing risk where numerous connections are executed simultaneously by the same party. • TSO is a natural monopoly, the development of reliable and cost efficient connections is dependent on the regulatory regime and regulatory oversight. • TSOs with limited offshore network may not be as well placed as the developer to manage risks and ensure that operational risks associated with the grid connection life time are minimized. • Development, construction and operational risks reside with the TSO. TSO will require suitable regulatory incentives to minimize risks while maintaining cost efficiency. • It may be the TSO or the electricity customers who bear the risk of stranded grid connection. • Wind farm and TSO assets may need to be segregated offshore due to an offshore interface with the TSO.
Third party model	• Reduces the cost burden on the developer and the TSO. • Typically, a third-party model would introduce competition and downward pressure on grid connection costs compared with the TSO model. • Adds a new market opportunity for businesses. • Provides an opportunity for investors looking for longer term investments, ex. pension funds. • Brings new investment into the energy supply industry. • Can introduce parties which specialize in financing and O&M of offshore grid assets. • In the EU, it ensures compliance with the Third Energy Package.	• Adds complexity to the electricity regulatory regime and the governance arrangements, codes and standards required. • Increased risk of third-party business failures impacting the electricity industry. • There may be a requirement to reduce third party risks to incentivize investment. • Compared with the Generator model, this transfers certain cost risks from the wind farm developer/owner to the electricity consumer. • Requires the establishment of a competitive O&M service provision market. • Adds additional party interfaces compared with the other two models. • Introduces the need for a competitive tender process to award the Offshore Transmission Owners (OFTO) license.

Source: FOWIND Consortium, 2017

There is not a simple single solution to the development and operation of offshore transmission networks. However, this issue must be clearly laid down in the policy for offshore wind farm developments in India. This is because it determines the cost and risks borne by many different stakeholders. Initially, the OFTO model may not be appropriate due to additional complexities of conducting separate auctions. Additionally, a hybrid model could be adopted where construction of offshore transmission network is followed by handing it over to the TSO.

8. Levelized Cost of Energy

The Financial Modelling of Offshore Wind in India (FIMOI) initiative was launched within the Centre of Excellence for Offshore Wind and Renewable Energy, established under the India Denmark Energy Partnership programme. It is based on a government-to-government partnership between the Indian Ministry of New and Renewable Energy (MNRE), the National Institute of Wind Energy (NIWE) and the Danish Energy Agency (DEA) under the Ministry of Climate, Energy and Utilities.

Considering that offshore wind projects have not yet been constructed in India, there is an inherent difficulty in estimating costs. Moreover, extensive investor dialogue with Indian and international stakeholders contributed to developing Levelized Cost of Energy (LCoE) estimations specific to India.

It is important to note that the findings of the FIMOI 2 report are based on a full-scope offshore wind project, which includes offshore substations, export cables, and onshore electrical infrastructure. A variety of countries have adopted different approaches to split the risk between private project developers and the government in relation to the provision of infrastructure. A decision is currently being made by the Government of India regarding the scope of offshore wind projects in the country and the interface between the developers and owners of transmission systems.

LCoE estimations in the FIMOI report and subsequent calculation of subsidy levels are based on the most basic LCoE calculation, which do not take into account VAT, duties, PPA design or other economic incentives. As can be seen from the numbers, Tamil Nadu and Gujarat show a rapid decline in LCoE from 2020 to 2025, followed by a further reduction of 30 per cent from 2025 to 2030.

There is a potential for Tamil Nadu to have the lowest cost of energy, with a LCoE that could be as low as Rs 7.4/kWh in 2025 and Rs 5.2/kWh in 2030. A LCoE of Rs 11.2/kWh is expected in Gujarat in 2025, and of Rs 7.8/kWh in 2030.

Table 3 : Basic LCoE (Rs/kWh, real-21)

	2020	2025	2030
Tamil Nadu Zone B	10.3	7.4	5.2
Gujarat	14.4	11.2	7.8

Source: FIMOI version 2, April 2022

It is important to note that there are still many uncertainties associated with the offshore wind market, supply chain, and project development in India, which contribute to a level of LCoE that is higher than that expected in Europe. It is anticipated that these uncertainties will be minimized as offshore wind development takes off in India and that the LCoE will be able to approach European levels at a faster pace. Since many components of the first offshore wind projects in India will most likely be imported, including skilled offshore specific labour, the Rs/USD exchange rate will have a significant impact on the LCoE.

On the basis of the LCoE levels, subsidies have been estimated either as investment subsidies or as per unit generation-based incentives (GBI).

Table 4: Government support to reach target LCoE of Rs 3.5/kWh and Rs 7/kWh

Target LCOE		**3.5 Rs/kWh**		**7 Rs/kWh**	
Subsidy type	**Site**	**Gujarat**	**Tamil Nadu Zone B**	**Gujarat**	**Tamil Nadu Zone B**
GBI (real-21)	Per unit (Rs/kWh)	7.7	3.9	4.2	0.43
	Annual GBI (bn Rs)	20.2	15.5	10.9	1.7
	NPV (bn Rs)	170	130.8	92.3	14.2
	Subsidy (bn Rs)	191.6	147.6	104.1	9.24
Investment subsidy (real-21)	NPV (bn Rs)	155.2	119.5	84.3	7.5

Source: FIMOI version 2, April 2022

In order to achieve a target LCOE of Rs 3.5/kWh for a 1,000 MW offshore wind project, the GBI per unit subsidy could be down to Rs 3.9/kWh or NPV of Rs 130.8 billion. Full scope means the developer owns the entire infrastructure between the wind turbines and the offshore substation, export cables to the connection point on land with an onshore substation. As subsidy levels are influenced by the LCoE levels of offshore wind projects, the subsidy levels for Gujarat with a tariff of Rs 7.7/kWh or NPV of Rs 170 billion would be higher. The net present value of the total subsidy suggests that investment subsidies are the most cost-effective option. However, the Government of India will be required to make a much smaller financial commitment up front under GBI. In addition to de-risking the project, the LCoE or subsidy level is heavily influenced by securing a revenue stream for the project. According to the table above, the subsidy levels are based on a basic LCoE without taking into account VAT and duties. It is likely that viability funding would increase if these standards were applied to offshore wind projects.

During the process of developing the terms and conditions of a PPA/subsidy scheme, several parameters need to be considered and weighed. Future technology developments, CAPEX and OPEX costs, and financing costs are subject to inherent uncertainties.

Table 5: Data sheet with technical and cost data for the baseline estimates of LCoE

	Unit	Gujarat			Tamil Nadu Zone B		
Years of final investment decision		2020	2025	2030	2020	2025	2030
ENERGY/TECHNICAL DATA							
Capacity per turbine	MW	4.2	15	15	8	15	15
Gross capacity factor*	%	38	39	39	54	62	62
Project size	MW	1,000	1,000	1,000	1,000	1,000	1,000
Development time	years	1	1.5	1.5	1	1.5	1.5
Construction time	years	2	2.5	2.5	2	2.5	2.5
Technical lifetime	years	25	27	30	25	27	30
Electrical losses	%	5	5	5	5	5	5
Forced outages and planned outages	%	4	4	4	4	4	4
PROJECT COST DATA							
Nominal investment for developer (real-21)							
Total**	**M Rs/MW**		**207.5**	**146.4**	**243.9**	**207.5**	**146.4**
Of which management							
• Development including surveys**	M Rs/MW	5.7	5.8	4.1	6.8	5.8	4.1
• Project execution	M Rs/MW	2.9	5.4	3.8	6.4	5.4	3.8
Of which equipment							
• Foundation	M Rs/MW	36.6	12.7	9.0	15.0	12.7	9.0
• Wind turbine	M Rs/MW	96.1	93.3	65.8	109.7	93.3	65.8
Of which grid connection							
• Array cables	M Rs/MW	10.0	20.5	14.5	24.1	20.5	14.5
• Export cables	M Rs/MW	26.5	15.5	11.0	18.3	15.5	11.0
• Onshore windfarm substation	M Rs/MW	6.8	5.6	3.9	6.6	5.6	3.9
• Offshore windfarm substation	M Rs/MW	18.2	14.9	10.5	17.5	14.9	10.5
Of which installation	M Rs/MW	47.3	33.7	23.8	39.7	33.7	23.8
Fixed O&M	M Rs/MW/ year	70,27,652	4.64	3.79	7.14	4.64	3.79

Source: FIMOI version 2, April 2022

9. Global policy framework aiding in energy transition

GERMANY

Germany's policy called 'Energiewende' (Energy Transition) has empowered the offshore wind sector so much that the country plans on shutting down all its nuclear reactors by the end of 2022. Furthermore, Germany has also set ambitious renewable energy and emission reduction targets. The latest version of this is contained in the regulation for renewables (Erneuerbare Energien Gesetz, EEG; August 2014) and stipulates:

- 40–45 per cent of electricity generation from renewables by 2025
- 55–60 per cent of electricity generation from renewables by 2035
- 80 per cent of Germany's electricity consumption shall be met by renewable sources by 2050.

The German government has taken a relatively interventionist approach to maximize the benefits of wind energy while seeking to build an industry and create domestic jobs. It is a strategic approach to the power sector by aligning energy policy with industrial policy. Germany has converted its early lead in onshore wind to the offshore wind sector and, currently, most of the dominant players in offshore turbine manufacturing are German (Siemens, Areva and Senvion).

UNITED KINGDOM

Interest in onshore and offshore wind in the UK was primarily driven by legally binding EU 2020 renewable energy targets, which mandate that the UK needs to source over 30 per cent of electricity from renewable sources, up from a very low level at the start of the millennium. The UK has also signed into law the Climate Change Act, which mandates an 80 per cent cut in carbon dioxide emissions by 2050. At the same time, North Sea oil and gas is in long term decline, while around a third of the generating capacity in the UK is expected to go offline over the next decade, increasing concerns around energy security.

DENMARK

The Danish Government had earlier set a 2020 target of 35 per cent of all energy consumption to be supplied from renewable sources (including 50 per cent of electricity from wind) and a 34 per cent reduction in greenhouse gas emissions (relative to 1990). By 2050, the Danes hope to have 100 per cent of their energy supplied from renewable sources. Many leading offshore wind companies are Danish (DONG, Vestas, LM Windpower, Bladt, Ramboll, etc.) or, in the case of Siemens Wind, have Danish roots. This has meant a strong symbiosis between energy and industrial policy.

NETHERLANDS

The Netherlands has set a target of 30 per cent reduction in CO_2 emissions by 2020, compared with 1990, which includes a renewable energy share of 20 per cent in 2020. As part of this, a target has been set to reach 6 GW of onshore wind and 4.4 GW of offshore wind capacity by 2023. The Netherlands has built on its strong marine heritage to develop a strong supply chain in offshore wind, with companies such as Smulders, SIF, VSMC and Van Oord as major contractors and fabricators.

10. Conclusion and recommendations

Problems in the early stages of offshore wind farm development can be addressed only when the uncertainties involving increased capital cost due to elevated risk premiums are resolved. This can be observed in the successful approaches adopted by the Danish government in analysing wind, waves, ocean, and geological conditions with an Environmental Impact Assessment (EIA) of the designated areas.

Maritime Spatial Planning (MSP) is the process of planning and regulating human activities at sea, including shipping, fishing, defence, etc. Additionally, the German framework presents an ideal understanding of how to develop offshore wind farms in tandem with commercial marine activities. After the identification of priority areas for offshore wind farms, locations with good potential for collective grid connections are identified and this is followed by drawing up of Offshore Grid Plans in consultation with other stakeholders. This kind of early engagement and planning by the government has garnered great support from shipping and environmental groups. Reflecting on the cases of delay in Chinese projects due to poor governmental coordination, we understand the importance of issuing regulations clearly demarcating responsibilities for selecting developer bids and agreeing to Feed-in-Tariff (FiT) rates, and also for site approval to oceanic administration agencies. Setting up demonstration projects leads to lower long-term costs and accelerates technology deployment by allowing policymakers and private firms to formulate long-term investment plans based on the outcomes.

Table 6: Barriers in offshore wind energy integration and remedial measures

Barrier	Mitigation	Key stakeholders
No policy exists for delivery and ownership of offshore transmission systems.	Select either generator built or TSO built model for ownership of the first offshore wind projects. Initiate a Central Working Group to frame an enduring national offshore transmission policy.	CEA, CTU, STUs, MoP, MNRE, CEA
No framework exists for offshore transmission network planning.	Initiate a Working Group to evaluate the optimal transmission topology and system planning regime for Gujarat and Tamil Nadu.	CEA, CTU, STUs
There is limited experience in India for the planning, design and construction of offshore transmission systems.	International consultants may fill the gap in the short term. A longer-term roadmap for development of local competencies should be devised.	MNRE, CEA, CTU, STUs

In terms of financing, the high cost of offshore wind has widened the scope of public and private finance. Notable investors in offshore wind are the German KfW, the UK's Green Investment Bank, and the European Investment Bank. These investments have benefited developers with constrained balance sheets as well as brought in new investors.

A strong determined approach is needed to develop the offshore wind market in India, beginning first with a demonstration project and then commercialization. The following recommendations are made according to the conclusions of this study:

1. A visionary policy should be framed, listing out clear objectives of cost reduction and long-term security regarding off-taker risks. This must be done by outlining a 10-year roadmap for procurement and grid infrastructure.
2. Legislation needs to be promptly implemented on the leasing of seabed to developers.
3. Clarity must be provided on the bidding process and timelines for the tender must be released, possibly adopting a "one-stop shop" approach, with the setting of aims for a project pipeline, and conducting research on site-specific technological optimization to encourage investments from leading developers and financing entities.
4. Identification of potential zones for bankable offshore wind projects by widening the government's offshore wind measurement campaign. Advanced detailed site-specific studies should be done.
5. A suitable demonstration project must be started with a support scheme framework. That can provide evidence on economies of scale, capacity factors and technology optimization, and bust myths of high costs.
6. Establishing regular engagement between decision-makers, trade representatives of bilateral countries, local civil institutions and industry, to establish fit-for-purpose infrastructure, supply chains, ports and networks.
7. Strengthening the understanding of the socio-economic benefits of offshore wind at both state and national levels, drawing on case studies and lessons learned from existing offshore wind markets.
8. Alignment of offshore wind strategies between union and state ministries, which will require targeted knowledge-sharing and capacity-building. Building blocks for an offshore wind sector need to be targeted as well.

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India's demand for electricity is predicted to grow between 6 to 7 per cent every year over the next decade. To meet this demand, while meeting its NDC (to have 50 per cent of installed capacity for power generation comprise of non-fossil fuel-based energy sources), there is a need to accelerate the growth of wind and other renewable energy sources.

With its coastline extending over 7,500 km, India is well suited for the development of offshore wind energy. Moreover, it holds promise as an alternative source of energy for a country like India due to the lack of uncultivable land and challenges faced in acquiring land, apart from other bureaucratic hurdles for harnessing energy.. This technical report explores how India can best utilize its offshore wind energy potential.

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