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# OFFSHORE WIND ENERGY, SAGARMALA, AND THE BLUE ECONOMY


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## The SAGARMALA Project and Predicted Energy-Requirements

Launched in 2015, the SAGARMALA Project (SP) is a contemporary, mega undertaking of the Government of India (GoI) that is aimed at 'port-led' comprehensive and holistic development of the country as a whole. Its stated vision is to *"reduce logistics cost[s] for both domestic and EXIM cargo with minimal infrastructure investment"*.[1] The four principal pillars of the project are: (1) port modernisation, (2) port connectivity, (3) port-led industrialisation, and (4) coastal-community development. The first three pillars and the thrust-lines along which they are developed are almost entirely focussed upon one or another facet of 'ports'. The follow-through mechanisms in respect of these three pillars all seek to improve efficiency and productivity (recognising, of course, that these are not synonymous terms). The more these factors of efficiency and productivity are aligned to the UN Sustainable Development Goals (SDGs), the 'bluer' the Indian economy will become.[2]

Port modernisation entails incorporation of emerging technologies related to "Industry 4.0" such as Internet of Things, 5G, digitalisation of port infrastructure, etc., while port-connectivity encompass the multi-modal transportation of goods, involving the creation or enhancement of rail, road, pipeline and inland waterway networks. New (Greenfield) ports and improvements in connectivity attract new investment and fuel the growth of industrial clusters to support all three models relevant to port-led industrialisation, viz., the energy-based model, the materials-based model, and, the export-oriented discrete-manufacturing model.[3] The existence and growth of these clusters, in turn, leads to the migration of people to coastal areas in search of employment and better opportunities. Irrespective of the which of the three models of port-led industrialisation is predominant, the clusters themselves require substantial inputs of energy in one or another form. Consequently, it is fairly common to find thermal power plants and petrochemical complexes being located in coastal areas due to the proximity of the port, which ensures easy access to raw materials such as coal, natural gas, and crude oil that are typically transported by ships.

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[1] Ministry of Shipping, Government of India, SAGARMALA National perspective Plan, April 2016, p. http://sagarmala.gov.in/sites/default/files/5457695312te1.pdf

[2] The Blue Economy is defined by *The World Bank* as the *"sustainable use of ocean resources for economic growth, improved livelihood and jobs and ocean ecosystem health."* https://www.worldbank.org/en/news/infographic/2017/06/06/blue-economy

[3] *Supra* 1, SAGARMALA National perspective Plan, p 12-23.

India, being one of the biggest consumers of energy resources, is also the third biggest polluter in the world and contributes significantly to greenhouse gas (GHG) emissions. Around 98 per cent[4] of the country's transportation sector and over 60 per cent of electricity production[5] is dependent on fossil fuels. For a lower-middle-income country that is highly vulnerable to the impacts of climate change and with a per capita GDP of approximately USD 2000[6], reduction in greenhouse gas (GHG) emissions must be an integral part of any major development plans. This is especially relevant in the context of development in coastal areas which are likely to face the brunt of climate change in the form of sea-level rise and increasing extreme-weather events, such as cyclones and tidal floods. While on the one hand, the SAGARMALA project aspires to reduce carbon emissions by an estimated 12.5 million tonnes (MT) annually,[7] ironically, the project also envisages cheaper transportation of coal through coastal shipping and the development of thermal power plants and petrochemical refinery projects in its planned industrial-corridors such as the Vizag-Chennai Industrial Corridor (VCIC). In order to be sustainable and reduce India's long-term carbon emissions, there is a need to incorporate provisions to facilitate clean, renewable energy in the SAGARMALA doctrine. In addition, the carbon footprint of ports is either explicitly or implicitly related to cargo-handling operations, exhaust from ships, power plants providing energy for ports, harbour crafts, rail locomotives, trucks, etc.[8] This article establishes reasons for exploring Offshore Wind Energy (OffWE) to power the SAGARMALA vision. The authors advocate the use of OffWE, particularly in the vicinity of India's minor and upcoming ports. OffWE has the potential to power ports, shore-based industry, coastal communities as well as the tourism sector, and, thereby, further India's endeavour to transition to Blue Economy. The article concludes by discussing the key challenges both in terms of practicality and policy in the wider adoption of OffWE in India.

**India's Ambitious Climate Targets**

In progressing a global strategy to mitigate climate change, the 2015 Paris Agreement mandated the member States of the United Nations Framework Convention on Climate Change (UNFCCC) to provide individual proposals to reduce their GHG emissions through 'Intended Nationally Determined Contributions' (INDCs). India intends to reduce its 'emissions intensity' (emissions per unit GDP) by 33-35 per cent from the 2005 levels, and to produce 40 per cent of cumulative power

[4] International Energy Agency, "India 2020: Energy Policy Review" 2020, https://webstore.iea.org/download/direct/2933?fileName=India_2020-Policy_Energy_Review.pdf
[5] Central Electricity Authority, 2020, "All India Installed Capacity (in MW) of Power Stations as on 30 April 2020" http://www.cea.nic.in/reports/monthly/installedcapacity/2020/installed_capacity-04.pdf
[6] "India per capita GDP," *CEIC Data*, https://www.ceicdata.com/en/indicator/india/gdp-per-capita
[7] "Vision," SAGARMALA, *Ministry of Shipping, Government of India*, (assessed 18 August 2020). http://sagarmala.gov.in/about-sagarmala/vision
[8] "Why does global clean ports matter?", *UN Environment Programme*. https://www.unenvironment.org/explore-topics/transport/what-we-do/global-clean-ports/why-does-global-clean-ports-matter

from non-fossil fuel based energy resources by 2030.[9] In its movement towards this goal, India aims to achieve 175 gigawatts (GW) of clean energy capacity by 2022, of which 100 GW would be of solar energy and 60 GW of wind energy.[10] The long-term targets that have been set by India are the production of 450 GW from renewables by the year 2030, with 300 GW exclusively from solar and 140 GW from wind power.[11] These targets have also been motivated by the UN SDG #7, which aims to provide affordable, reliable, sustainable, and clean energy for all. These targets are highly ambitious and India may well fall short of achieving them due to various reasons. As on 30 April 2020, 87 GW of renewable capacity addition had been achieved with the share of Solar being 35 GW and that of Onshore Wind Energy (OnWE) being 37 GW. Insofar as solar photovoltaics are concerned, due to the lack of indigenous manufacturing, India is primarily dependent on cheap imports from China. The heightened tensions between the two nations along the Himalayan frontier could lead to increases in import costs and customs duties.[12] The ensuing section discusses in detail the challenges associated with solar and OnWE adoption in India.

**Challenges Associated with Conventional Onshore Wind and Solar Energy**

India's energy demand is persistently increasing with the primary energy demand reaching 906 million tonnes of oil equivalent (MTOE) in 2019.[13] According to the NITI Aayog, India's energy demand will double by 2040 and the electricity demand, specifically, will increase three-fold.[14] Current trends show great momentum towards expansion of renewable energy capacity in India, driven primarily by solar and wind capacity addition. Solar photovoltaics development has gained momentum and offers wide investment opportunities in India. According to the International Energy Agency (IEA), India's investment in solar energy, in 2018, was greater than all fossil-fuel sources of electricity generation, put together.[15] The creation of the International Solar Alliance (ISA), led jointly by India and France, is a prime example of Prime Minister Modi's resolve as far as solar energy capacity augmentation is concerned. The ISA is headquartered at Gurugram in

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[9] "India's Intended Nationally Determined Contributions: Working towards Climate Justice", United Nations Framework Convention on Climate Change (UNFCCC). https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf

[10] PTI, "India's Renewable Energy Capacity Crosses Mark" RK Singh in *The Economic Times*, 16 July 2020. https://economictimes.indiatimes.com/industry/energy/power/indias-renewable-energy-capacity-crosses-80gw-mark-r-k-singh/articleshow/70244364.cms?from=mdr

[11] Government of India, Ministry of Power, Central Electricity Authority (CEA), "Draft Report on Optimal Generation Capacity Mix for 2029-2030", February 2019, http://cea.nic.in/reports/others/planning/irp/Optimal_generation_mix_report.pdf

[12] Abhinav Singh, "Solar Companies' Dependence on China may prove to be a Challenge", *The Week*, 25 June 2020. https://www.theweek.in/news/biz-tech/2020/06/25/solar-companies-dependence-on-china-may-prove-to-be-a-challenge.html#:~:text=Indian%20solar%20companies%20are%20highly,pricing%20compared%20to%20domestic%20manufactures.

[13] National Statistical Office, *Energy Statistics 2020 (27th Edition)*, Ministry of Statistics and Programme Implementation, Government of India. http://www.mospi.gov.in/sites/default/files/publication_reports/ES_2020_240420m.pdf

[14] *India 2020 - Energy Policy Review*, International Energy Agency (IEA). https://niti.gov.in/sites/default/files/2020-01/IEA-India%202020-In-depth-EnergyPolicy_0.pdf

[15] *Ibid*

Haryana, while the National Institute of Solar Energy (NISE) will be devoted towards its research and development which is also situated in Gurugram, Haryana.[16]

India has some of the world's largest solar installations. With a capacity of 2245 megawatts (MW), the Bhadla Solar Park, located in Rajasthan, is the world's second largest solar power station.[17] The world's largest single-location solar power plant with a capacity of 648 MW is located in the state of Tamil Nadu. Other large solar power plants in India are the Kamuthi Solar Power Project (648 MW), the Charanka Solar Park (600 MW), the Sakri Solar Plant (150 MW), and, the Welspun Solar MP Project (151 MW), in the states of Rajasthan, Gujarat, Maharashtra, and Madhya Pradesh, respectively.[18]

In terms of OnWE development, India's installed capacity is an impressive 37.5 GW, making the country the fourth largest producer of OnWE power in the world after China, the USA, and Germany.[19] Yet, there is scope for growth as OnWE constitutes just 10 per cent of India's total installed electricity generation capacity. The GoI is, therefore, providing several incentives in developing wind parks/farms. Amongst the more prominent and larger OnWE parks in India are Tamil Nadu's Muppandal Wind Farm (1500 MW), Rajasthan's Jaisalmer Wind Park (1064 MW), and, Maharashtra's three mega wind-parks in Brahmanvel (528 MW), Dhalgaon (278 MW), and, Vankusawade (259 MW).[20]

Even though the thrust towards expansion of solar and OnWE is proceeding apace, there are, nevertheless, a few major challenges which impede an expedited and expanded adoption of OnWE. First, both solar and OnWE are highly land intensive. According to a 2017 report by The Energy and Resources Institute (TERI) entitled, "*Addressing Land Issues for Utility Scale Renewable Energy Deployment in India*", around 1,50,000 hectares of land is needed for 50 GW of solar and 30 GW of OnWE production, which translates to 3000 hectares per GW for solar and 5000 hectares per GW for wind energy.[21] In a densely populated country such as India, land is a highly-prized commodity and land-acquisition is, consequently, a major hurdle for the expansion of solar and OnWE parks to cater to the country's rising demand. This paucity of land further leads to improper land-

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[16] Gautam Raina and Sunanda Sinha, "Outlook on the Indian Scenario of Solar Energy Strategies: Policies and Challenges," *Energy Strategy Reviews Volume 24* (April, 2019): 331-341 https://reader.elsevier.com/reader/sd/pii/S2211467X1930032X?token=A88AA5ACF416A5168E1F971D83944B939A743C02DCB704BAFC8A7417A6784F5922529CA017626548950BC5C798210237

[17] ENS Economic Bureau, "Explained: How Does Rewa Solar Power Plant Match up to Similar Plants in India and Abroad", 12 July 2020, https://indianexpress.com/article/explained/rewa-solar-power-plant-madhya-pradesh-features-components-explained-6500673/

[18] Dr APV Appa Rao et al, "Solar Energy in India - Present and Future," *International Journal of Engineering Science Invention (IJESI)*: 06 - 11. http://www.ijesi.org/papers/Conf.1802(ICMEEP)/Vol-2/2.%2006-11.pdf

[19] "Profiling the Top Five Wind Farms Operating in India," *NS Energy*. https://www.nsenergybusiness.com/features/top-wind-power-farms-india/

[20] *Ibid*

[21] Amit Kumar and Sapan Thapar, "Addressing Land Issues for Utility Scale Renewable Energy Deployment in India", TERI School of Advanced Studies, New Delhi, 2017), https://shaktifoundation.in/wp-content/uploads/2018/01/Study-Report-Addressing-Land-Issues-for-Utility-Scale-Renewable-Energy-Deployment-in-India.pdf

management practices by OnWE farms, causing large scale erosion and landslides that causes rubble to flow into the fertile farmlands and river systems, causing significant environmental degradation.[22] Another major problem associated with solar and wind energy is the issue of intermittency. Solar energy, for instance, is available only during daylight hours, implying that an electricity-grid operator has to adjust its 'day-ahead', 'hour-ahead', and 'real-time operating' procedures.[23] This leads directly to the challenge of storing electricity that is produced from renewable sources. The storage of electricity remains a significant issue as batteries tend to become bulky with increasing storage capacity and are, therefore, cumbersome to handle, require considerable maintenance, and, need frequent replacement.[24]

OnWE farms also face several issues such as spatial-crowding caused by the erection of urban structures in the vicinity, which affect the speed and pattern of the wind, and lower the efficiency of the farms. The best locations for OnWE and solar-energy development are remote, sparsely-populated areas, but such areas often lie within one or another protected-area network, such as the Western Ghats, in Maharashtra.[25] This brings them into conflict with environmental law and increases the cost of production.

It is in this context that ocean-based renewable energy can play a crucial role in not just reducing the dependence on fossil-fuel-generated power, but also, in avoiding the challenges associated with onshore renewable energy sources. Among the various ocean renewable energy resources, Offshore Wind Energy (OffWE) offers a particularly promising solution due to the technological maturity that it has achieved over the past couple of decades. OffWE is a unique case as it is considered an Ocean Renewable Energy Resource (ORER), even though its functioning mechanism is dependent on the kinetic energy of wind blowing over oceanic areas, rather than being generated by the ocean itself.

**Harnessing OffWE Potential in India's Coastal Areas**

In order to realise the SAGARMALA vision while significantly 'blueing' India's economy, it is essential for India to develop MARPOL-compliant non-major ports that adopt high and modern standards of functional efficiency. In the Financial Year 2019-20, between 01 April and 31 December 2019, India's twelve major ports handled a total cargo traffic of 704.82 million tonnes

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22 "Offshore Wind Power vs. Onshore Wind Power," *Indian Environment Portal.* http://www.indiaenvironmentportal.org.in/content/375793/offshore-wind-power-vs-onshore-wind-power/

23 Robert Fares, "Renewable Energy Intermittency Explained: Challenges, Solutions and Opportunities," Scientific American, https://blogs.scientificamerican.com/plugged-in/renewable-energy-intermittency-explained-challenges-solutions-and-opportunities/

24 "What's the Best Battery," Battery University, https://batteryuniversity.com/learn/archive/whats_the_best_battery

25 "Offshore wind power vs. Onshore wind power," *Indian Environment Portal.* http://www.indiaenvironmentportal.org.in/content/375793/offshore-wind-power-vs-onshore-wind-power/

(MT), while the 200-odd non-major ones handled 447.21 MT.[26] The 12 major ports in India can handle a combined capacity of 1524.91 MT, which translates into a current capacity-utilisation of less than 50%.[27] This results from a combination of factors — lack of adequate infrastructure, inefficient operations at berths, slow rates of loading and unloading cargo, poor movement of logistics, etc., especially in the non-major ports.[28]

In any attempt to enhance capacity-utilisation, power supply is a major issue that needs to be addressed. The availability of continuous, stable, and reliable electricity in ports, is essential not only for port operations themselves, but also for providing external power to ships at the port's berths. Electric power for all twelve of India's major ports already has a significant contribution from solar and wind power facilities. This, however, is far from being the case with the non-major ports. In addition, with MARPOL regulations now in force, and with the drive towards reducing carbon emissions from berthed ships, ports are now being urged to provide shore-generated power to ships berthed alongside the various wharves, jetties, and piers in the various terminals of the port. This provision of shore-based supply is termed "cold ironing".[29] As a consequence of these MARPOL-induced measures and the genuine desire to 'blue' the ports by aiming for an eventual state of carbon-neutrality, there is a pressing need to equip these ports with power generated from renewables, which will, of course, require the setting-up of more solar and OnWE facilities. However, as discussed previously, there are several impediments — including land usage and intermittency — to the adoption these land-based renewable-energy technologies and facilities. This is where OffWE can be pursued and integrated into SAGARMALA.

India's long coastline has immense potential for OffWE. According to a study conducted by the National Institute of Wind Energy (NIWE), the potential of all forms of wind energy in India is around 302 GW at 100-metre hub height (i.e., the distance from the turbine platform to the rotor of an installed wind turbine). That said, issues with OnWE, as discussed earlier, preclude this potential from being fully realised. Encouragingly, however, according to the Ministry of New and Renewable Energy (MNRE), OffWE potential is an estimated 127 GW. Of this potential, as much as 70 GW can be exploited off the coasts of Gujarat and Tamil Nadu, alone.[30] The 'Facilitating Offshore Wind in India' (FOWIND) project — an 'Indo-European Cooperation on Renewable Energy' programme[31] — has identified Gujarat and Tamil Nadu as the most feasible locations for

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26 "Shipping Industry & Ports in India," India Brand Equity Foundation, https://www.ibef.org/industry/ports-india-shipping.aspx#:~:text=In%20FY20%2C%20major%20ports%20in,annum%20(MTPA)%20in%20FY19P.

27 P Manoj, "Cargo Volumes at Major Ports up 0.8% to 704.63 MT in FY 20," The Hindu Business Line, 03 April, 2020, https://www.thehindubusinessline.com/economy/logistics/cargo-volumes-at-major-ports-up-08-to-70463-mt-in-fy20/article31250168.ece

28 S Islam and TL Olsen, "Factors Affecting Seaport Capacity: Managerial Implications for a Simulation Framework", 2013, https://www.asor.org.au/conferences/asor2013/J3/islam.pdf

29 MARPOL Annex VI, "Onshore Power Supply", International Maritime Organisation, October 2012, http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Circ.794.pdf

30 Anshul Joshi, "India Identifies Offshore Wind Energy Potential of 70,000 MW along Gujarat, TN Coasts", ET Energy World, 02 January 2020, https://energy.economictimes.indiatimes.com/news/renewable/india-identifies-offshore-wind-energy-potential-of-70000-mw-along-gujarat-tn-coasts/73072580

31 Global Wind Energy Council (GWEC) website, https://gwec.net/members-area-market-intelligence/fowind/

future OffWE development.[32] The OffWE development potential is underexplored in India and requires serious consideration, duly supported by financial investment. Brijesh Lohia, Managing Director of the Ocean Group is of the view that,

> "*India offers great potential for developing offshore renewable energy and government has accorded due priority to attract investment in this area. The power generated will feed the coastal activity and also contribute to the national grid.*"[33]

In June 2018, guided by the FOWIND report, the MNRE set mid-term and long-term targets for OffWE. The plan is to install a capacity of 5 GW by 2022, and 30 GW by 2030. OffWE has several benefits over OnWE as the wind farms are situated at sea and, hence, do not have to compete with urban coastal agglomerations for space. The open ocean provides, in principle, a large amount of area, for big wind-turbine installations and, therefore, the scope of expansion is tremendous. Since there is no obstruction to wind at sea, the quality of wind is better for energy production. Also, its remote location, far from populated areas makes it less intrusive than OnWE.[34] It is, however, important to note that at the present state of development of engineering technology, the cost of OffWE in India is higher than that of onshore installations — about Rs 7-9 per unit compared to OnWE which costs Rs 2.8-2.9 per unit.[35] However, as mentioned before, OnWE installation projects typically have to go through a strenuous process due to the paucity of land and other logistical issues related to community impacts. OffWE — even though it is high on capital investment — can be developed on a large scale that will provide long-term energy-security to the non-major ports and, as the infrastructure is put into place, and with additional capacity, as also with the advance of engineering technology, the costs will inevitably come down, particularly in the long-run.[36]

The inclusion of OffWE deployment within the various projects under SAGARMALA can greatly facilitate GoI's efforts towards modernisation, industrialisation, and infrastructural development of ports. With the immense potential of OffWE thanks to the presence of abundant OffWE resources in the nation, this renewable can cater to the power requirements of new installations and development activities in coastal areas. The powering of ports and related activities from such installations will significantly reduce the carbon footprint and 'blue' India's port-led developmental

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[32] Dr K. Balaraman et al, "India's Wind Potential Atlas at 120 m AGL", National Institute of Wind Energy, Ministry of New and Renewable Energy, Government of India, 2019, https://niwe.res.in/assets/Docu/India's_Wind_Potential_Atlas_at_120m_agl.pdf

[33] PTI, "SAGARMALA Project to boost GDP by 2 per cent: Ocean Group," The Economic Times, 19 July 2017, https://economictimes.indiatimes.com/industry/transportation/shipping-/-transport/sagarmala-project-to-boost-gdp-by-2-per-cent-ocean-group/articleshow/59669259.cms?from=mdr

[34] M Dolores Esteban et al, "Why Offshore Wind Energy?", Renewable Energy 36 (Issue 2), February 2011: 444-450, https://www.sciencedirect.com/science/article/abs/pii/S0960148110003332

[35] Jyoti Gulia and Shilpi Jain, "Offshore Wind Energy in India - the Territory Ready to be Explored", JM Research and Analysis, https://jmkresearch.com/wp-content/uploads/2019/10/Offshore-Wind-Energy-in-India_JMK-Research.pdf

[36] *Ibid*


**Figure 1:** The corridors envisaged under the SAGARMALA Project as well as select major and non-major ports of India. **Source:** Rajras.in, https://www.rajras.in/index.php/sagarmala-program-port-led-

efforts to boost the country's economy. Figure 1 displays India's major ports and some select non-major ports, along with the proposed coastal corridors under the SAGARMALA mega-project.

As has already been mentioned, a major pillar of the SAGARMALA vision involves port modernisation. This, *inter alia*, involves automation of several port-processes and this, in turn, requires a substantial amount of dedicated power, and uninterrupted power supply.[37] Further, the ongoing process of digitalisation of Indian ports and the incorporation of 'Industry 4.0' to lift the county's port sector to 'Port 4.0' standards, a whole slew of contemporary and near-future practices would be required, all of which will require dedicated, stable and uninterrupted power supply.[38] This is what OffWE will be able to provide.

[37] "SAGARMALA — Building Gateways of Growth", Ministry of Shipping, Government of India, 2016, http://sagarmala.gov.in/sites/default/files/5457695312te1.pdf

[38] "Inducing Digitalisation in Indian Maritime Sector," SAGARMALA, http://sagarmala.gov.in/sites/default/files/INDUCING%20DIGITALISATION%20IN%20INDIAN%20MARITIME%20SECTOR%20%281%29-converted.pdf

**Powering Ancillary Industry and Coastal Community Development with OffWE**

It would be recalled from the preceding paragraphs that the third pillar of the SAGARMALA mega-project concentrates on port-led industrialisation, along three focal-models — energy, materials, and discrete-manufacturing. The locations of industries are 'clustered' such that they are in the vicinity of ports (both, 'major' as well as 'non-major' ones) in order to facilitate movement-of and access-to cargo. These clusters, collectively termed Coastal Economic Zones (CEZs), also synergise with the planned industrial corridors such as the Delhi-Mumbai Industrial Corridor (DMIC), the Visakhapatnam-Chennai Industrial Corridor (VCIC), etc.[39] The one factor that is glaringly common in all three models of port-led industrialisation is that the industries that are sought to be 'clustered' are all highly electricity-intensive. Hence, OffWE will be able to assist in significant manner by supplying energy for the development of CEZs, as also providing electricity for the functioning of optimal utilisation of the ports themselves.[40] This will have the cascading effect of attracting not only large firms but also a whole host of ancillary industries that provide raw materials to the former, as also to the ports themselves, bringing with them technology, capital, job opportunities, and links to global value and supply chains.[41] The linkage of non-major ports to industrial units — both powered by OffWE — will result in expedited development of the coastal regions, while at the same time moving in the direction of eventually achieving net-zero carbon emissions.

In India, approximately 18 per cent of the population call the 72 coastal districts 'home'. As a result, Coastal Community Development is the fourth pillar of SAGARMALA. This can be undertaken by providing employment opportunities, skill development, and, affordable, stable and uninterrupted electricity. The OffWE industry has the potential to provide these benefits to the population in coastal regions. In the life cycle of an OffWE farm, diverse skills are required in the planning, construction, and maintenance stages. According to Lauran Morton, Director of American Wind Energy Association, "*to build and operate an offshore wind farm requires a diverse workforce of 74 different occupations.*"[42]

This showcases the scope of jobs that can be generated by OffWE deployment. The demand for skilled human resources will naturally lead to skill-development within coastal communities.[43] For instance, in the European Union (EU), it is predicted that by 2030 almost 215,000 people will be

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[39] "SAGARMALA — Building Gateways of Growth", Ministry of Shipping, 2016,

[40] "Focus Now on Port-led Industrialisation: SAGARMALA Development," The Hindu Business Line, 23 September 2019, https://www.thehindubusinessline.com/economy/logistics/focus-now-on-port-led-industrialisation-sagarmala-development/article29487874.ece

[41] Arvind Panagariya, "Jobs, Growth and Coastal Economic Zones," NITI Aayog, https://niti.gov.in/writereaddata/files/document_publication/NITIBlog11_VC.pdf

[42] Bob Woods, "US has Only One Offshore Wind Energy Farm, but a $70 billion Market is on the Way," CNBC, 15 December 2019, https://www.cnbc.com/2019/12/13/us-has-only-one-offshore-wind-farm-but-thats-about-to-change.html

[43] Rohit Vivek Gadre and Shruti Shukla, "From Zero to Five GW — Offshore Wind Outlook for Gujarat and Tamil Nadu 2018-2032", Facilitating Offshore Wind in India (FOWIND) and European Union, 2017, https://gwec.net/wp-content/uploads/2017/12/FOWIND_2017_Final_Outlook_2032.pdf

employed in the OffWE sector, exceeding by far the jobs provided by the OnWE farms themselves.[44] Likewise, in India, the OffWE sector would provide extremely substantial employment-opportunities, ranging from the manufacture of wind turbines, their installation and maintenance, to the multiplier-effects in terms of employment in related ancillary industries and the secondary and tertiary jobs (school teachers, health-workers, barbers, tailors, shopkeepers, hardware-suppliers, vehicle-repairers, stationers... the list is endless) that come in the wake of such port-led processes.

A very large number of ancillary industries that are more directly related to the activities of Indian ports — such as fishing, shipbuilding, coastal tourism, etc., are already present. Of these, fishing — as a sector that has sea-going and shore-based segments — is one that is of particular significance to coastal communities, and plays an important role in furthering India's Blue Economy endeavours. However, its products are perishable and require cold storage stocking and warehousing facilities.[45] Right from the time the fish is caught, it needs proper storage and preservation, usually under low temperature. This 'cold-chain' calls for a variety of refrigeration devices and facilities, all of which, once again, consume large amounts of electricity. Depending on their capacity handled and the outside temperature, such cold storage facilities consume between 30 and 50 $kWh/m^3/year$ of electricity.[46] In the absence of captive renewable power, this power has to be drawn from electricity grids fed by traditional, fossil-fuel-run power plants. OffWE, if installed so as to feed non-major ports, will be able to provide clean, renewable energy to such facilities.

Sustainable coastal tourism is another sector that will contribute to India's Blue Economy. India's Ministry of Tourism aims to build coastal tourist-circuits so as to enhance the country's attractiveness to Indian and foreign tourists.[47] As coastal tourism is centred upon ports, OffWE will be able to cater to the power requirements of the tourism sector, as well. In addition, with the introduction of coastal ferries, cruises, etc., there is a need to develop new jetties and berths to facilitate the embarkation and disembarkation of tourists, and these, once again, can be entirely powered using OffWE. A well-established tourism sector can provide local employment in the hospitality and service sectors and can also enhance the associated small-scale industries.

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[44] Mehmat Bilgili, Abdulkadir Yasar and Erdogan Simsek, "Offshore Wind Power in Europe and its Comparison with Onshore Counterpart", Renewable and Sustainable Energy Reviews Volume 15 Issue 2, February 2011, 905-915, https://www.sciencedirect.com/science/article/abs/pii/S1364032110003758?via%3Dihub

[45] "Cold Chain & Post Harvest Infrastructure Development - 2022", Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture and Farmers Welfare, Government of India, August 2017, http://mmd.nfdb.gov.in/uploads/site_content/GoI_Action_Plan_2022-Cold_Chain_and_Infrastructure_Development.pdf

[46] Dr N Mukhopadhyay and Raj Gopal Nanda, "A Study on Energy Audit of a Cold Storage," Dr N Mukhopadhyay International Journal of Engineering Research and Applications, Volume 5, Issue 4, (April 2015): 06 - 10. https://www.ijera.com/papers/Vol5_issue4/Part%20-%207/B504070610.pdf

[47] "Coastal Tourism", Ministry of Tourism, Government of India, http://swadeshdarshan.gov.in/index.php?Theme/themeDetail/1

Shipbuilding is another critical industry that demonstrates the technological capabilities of any nation. It is often referred-to as the "Mother Industry"[48] as it supports a very large range of associated ancillary industries. The shipbuilding sector as a whole is very sensitive to uninterrupted power-supply, as any delay in delivery of orders translates into heavy financial losses and, more importantly, loss of the reputation of the concerned shipyard or boatyard. India plans to further its shipbuilding capabilities in terms of both, naval vessels and mercantile ones catering to the transportation of cargo and bulk products. This is especially relevant today with PM Modi's clarion call of "Make in India"[49] and "*Atmanirbhar Bharat*" (Self-Reliant India).[50] Given the emphasis being laid on the expansion of trade along India's national waterways, the demand for a whole slew of new vessels whose shape, form and number is contextualised to the requirements of various connectivity options, often involving multi-modal transportation, will increase significantly. Within this paradigm of growth, the use of OffWE would significantly reduce the shipping industry's overall carbon emissions that are primarily driven by the high energy usage.

## Challenges and the Way Ahead

For all that, there is no gainsaying that the India's path to developing OffWE is strewn with several foundational challenges which include, amongst others, those summarised below.

(a) Even though policies related to OffWE were framed in 2015,[51] no OffWE farm has physically materialised as yet in India. Developing OffWE plants in India will have high capital (installation) costs. This is due, *inter alia*, to the lack of support vessels and port facilities for OffWE installation, the lack local sub-structure manufacturers, and the lack of skilled employees.[52]

(b) Considerable research and data collection mechanisms need to be created so as to make them available along with historical data such as resource maps, bathymetric data, etc., all of which are crucial for determining the location, design, and feasibility of a given OffWE project.[53]

(c) The use of submarine cables for such projects is essential so as to establish integration with shore-based electricity grids. However, submarine cables are much more

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48 S Navaneetha Krishnan, "Prosperous Nation Building Through Shipbuilding": KW Publishers, New Delhi, 2013, https://books.google.co.in/books/about/Prosperous_Nation_Building_Through_Shipb.html?id=VtRsngEACAAJ&redir_esc=y

49 Government of India PM India website, "Make in India", https://www.pmindia.gov.in/en/major_initiatives/make-in-india/

50 "Building Atmanirbhar Bharat and Overcoming COVID-19", National Portal of India, https://www.india.gov.in/spotlight/building-atmanirbhar-bharat-overcoming-covid-19

51 "National Offshore Wind Energy Policy," Ministry of New and Renewable Energy, Government of India https://mnre.gov.in/img/documents/uploads/3debfe9158b643d8a3e06a7a007f2ef9.pdf

52 "Offshore Wind Energy in India — A Territory Ready to be Explored", JMK Research and Analytics, https://jmkresearch.com/offshore-wind-energy-in-india-a-territory-ready-to-be-explored/

53 *Ibid*

expensive compared to normal cables and, therefore, increase the unit cost of electricity produced by an OffWE project.[54]

(d) OffWE development in India should be viewed as a long-term opportunity and be managed efficiently with timely investments. A synergetic approach is accordingly proposed involving the Ministry of New and Renewable Energy, the Ministry of Earth Sciences, the Ministry of Shipping and Ministry of Skill Development and Entrepreneurship. With such political, financial, and social coordination and cooperation, the SP will greatly benefit from OffWE while significantly empowering the Blue Economy of India.

(e) OffWE turbine manufacturing requires technological expertise as well as a local base for production. Given that indigenous capacities and capabilities are in their infancy, it is necessary to seek technology-transfer to support and advance local manufacturing. Relying solely upon foreign suppliers for the finished product is not only a significant burden on the nation's exchequer, such import-dependence is also the antithesis of the 'Make in India' initiative. These imperatives require a horizontal proliferation of awareness and some degree of knowledge, if not expertise, across a number of vertically-specialised organisational structures of the government as well as private industry. The breaking down of these vertical silos and the comfort zones that they have been established over protracted periods of time, will be a challenge of major proportions.

(f) Determining how to minimise the potential threat that each OffWE project might pose to the marine environment in the vicinity of the installation, whether at the construction, operation, or maintenance stages, is another challenge that needs to be addressed squarely. OffWE projects must, therefore, include environmental impact assessments to identify and minimise these impacts.[55]

(g) Given that the OffWE plant will be situated offshore (i.e., in the sea) there are likely to be challenges (each with its own cost-contribution) related to restrictions and limitations in terms of accessibility to a given OffWE site, during its construction, operation and maintenance.[56]

(h) OffWE installations will invariably form part of the nation's critical maritime infrastructure. While India has adequate organisational structures to address the challenges of offshore security, the fact that OffWE farms would be vulnerable to sea-borne attacks

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[54] "Testing Submarine Cables: Why it's a Big Deal", EXFO, 26 November 2018, https://www.exfo.com/en/resources/blog/testing-submarine-cables/

[55] "How do Offshore Wind Farms Affect Ocean Ecosystems?", DW.com, https://www.dw.com/en/how-do-offshore-wind-farms-affect-ocean-ecosystems/a-40969339

[56] Victoria Baagøe-Engels and Jan Stentoft, "Operations and Maintenance Issues in the Offshore Wind Energy Sector: An Explorative Study", International Journal of Energy Sector Management, Volume 10, Issue 2 (June 2016), 245-265, https://doi.org/10.1108/IJESM-04-2015-0012

from malevolent State-sponsored (and other) non-State actors will add to the burden of the Flag Officer Offshore Defence and Advisor to the Government of India (FODAG) who is the designated authority for the defence and security of OffWE projects, in addition to being similarly responsible for the security of offshore oil installations.[57] An attack on an OffWE installation would impose a cascade of downstream economic losses. In addition, as the advantages of Industry 4.0 are incorporated and adopted, the vulnerability to cyberattacks will increase.[58] While such cyber-vulnerability is not unique to OffWE installations, their location and difficulties in physical accessibility certainly add to the challenge.

(i) Being largely located in the tropics, peninsular India is prone to severe cyclonic weather, which could result in damage to installed wind turbines and their associated infrastructure, causing severe interruptions and disruptions to power-supply, thereby imposing significant losses upon the ports and port-fed industries located in coastal areas.

Amidst these challenges, one clear advantage of OffWE is its high value in India's archipelagic island chains — the Lakshadweep Islands off the western coast, and the more distant Andaman & Nicobar Islands off the country's eastern coast. In both these island-chains, electrical energy is currently being provided by localised diesel generators, despite the adverse impact that these fossil-fuel-driven installations have upon the ecosystems and the biodiversity of these ecologically sensitive islands.

While the costs associated with OffWE, at least at the present point in time, are three times greater than those associated with of solar or wind or fossil fuel power, a wide adoption of OffWE yields several advantages, especially over the long run. As technologies mature and become more efficient the 'levelized cost of electricity' will go down and, in a country such as India, with a perennial growth in demand, low tariffs can easily be achieved simply due to the enormous size of the market. In addition, OffWE can play a major role in furthering India's transition to clean (blue) energy in the maritime sector, especially in terms of shipping. Encouragingly, there are already examples that can be emulated. For instance, the use of OffWE for the production of 'green' hydrogen — a clean, zero-carbon-emission alternative fuel (suitable for large cargo ships) — is already being exploited in Hamburg, Germany.[59] Moreover, with the increase of commercial vessels propelled by hydrogen and methane, as well as autonomous electric vehicles, there is increasing scope for development of offshore refuelling infrastructure in the future, which can be carried out using power generated by OffWE.

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[57] Justin H. Leopold-Cohen, "Let Offshore Oil End", Inkstickmedia, 30 June 2020, https://inkstickmedia.com/let-offshore-oil-end/

[58] "Stepping up Cybersecurity in Offshore Wind: How to Protect Against an Unseen Enemy," Technative, https://www.technative.io/stepping-up-cybersecurity-in-offshore-wind-how-to-protect-against-an-unseen-enemy/

[59] Leigh Collings, "Offshore Wind to Power Giant Green-Hydrogen Carbon-Neutral Aviation-Fuel Plant," Recharge, 31 October 2019, https://www.rechargenews.com/transition/offshore-wind-to-power-giant-green-hydrogen-carbon-neutral-aviation-fuel-plant/2-1-696907

The creation of such offshore infrastructure can be leveraged to enhance underwater domain awareness — something that is undoubtedly of interest to the Indian Navy.

Finally, if the technology is mastered with a sufficiently sophisticated indigenous base for production, it can be transformed into a tool for foreign policy and be shared with nations in the Indian Ocean Region (IOR), furthering India's standing as a net provider of security in the region under the twin visions of 'Security and Growth for All in the Region' (SAGAR), as also the 'Indo-Pacific Oceans Initiative' (IPOI).

**Conclusion**

Large developing countries such as India, with their burgeoning populations, are increasingly the hubs of rapid economic growth and development. This growth is propelled primarily by the consumption of energy and, therefore, the demand for energy is constantly on the rise. For maritime nations such as India, this growth encompasses a number of aspects related to her endeavour to transition from a 'brown' economy into a 'blue' one. Consequently, the vision of port-led national development — of which SAGARMALA is a prominent manifestation — cannot afford to neglect or minimise the enormity of its contribution to the 'blueing' of the economy as a whole. While economic growth is crucial, it is critical to incorporate within the chosen growth-model, adaptive and mitigative strategies to reduce or minimise the potentially devastating consequences of climate change. Central to these endeavours is the adoption of clean energy. In India, the drive towards renewable sources of energy has, thus far, been limited to the adoption of solar energy and OnWE. However, limitations such as the unavailability of land, the intermittency of electrical energy generated by renewable sources such as solar and OnWE, the lack of local production capacity capability, etc., remain significant impediments. In order to optimally realise the SAGARMALA vision of port-led development, there is a need to continuously scout for alternative sources of renewable energy. An important one of these alternative sources is OffWE. Owing to their geographic location in the open ocean and the proximity to the coast, OffWE installations can play a major role in powering ports and various ancillary industries including shipbuilding, tourism, fishing, etc. It is, therefore, worthy of serious consideration as an option of choice for India, and can readily supplement the ongoing advocacy for the adoption of 'blue' hydrogen derived from Ocean Renewable Energy Resources — including OffWE.

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