# Tamil Nadu Offshore Wind Manufacturing Supply Chain Investment Study

Report

February 2025

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Ocean Energy Pathway fast-tracks the development of a sustainable, high ambition, global offshore wind sector, as part of a thriving blue economy. As a not-for-profit organisation, Ocean Energy Pathway delivers expert, independent technical assistance to governments and stakeholders and works with policymakers, industry, conservation leaders, and other stakeholders to build strategies to sustainable scale for the sector. Ocean Energy Pathway is scaling in over ten markets and over the last year has launched operations in Brazil, India, Japan, the Philippines, and South Korea.

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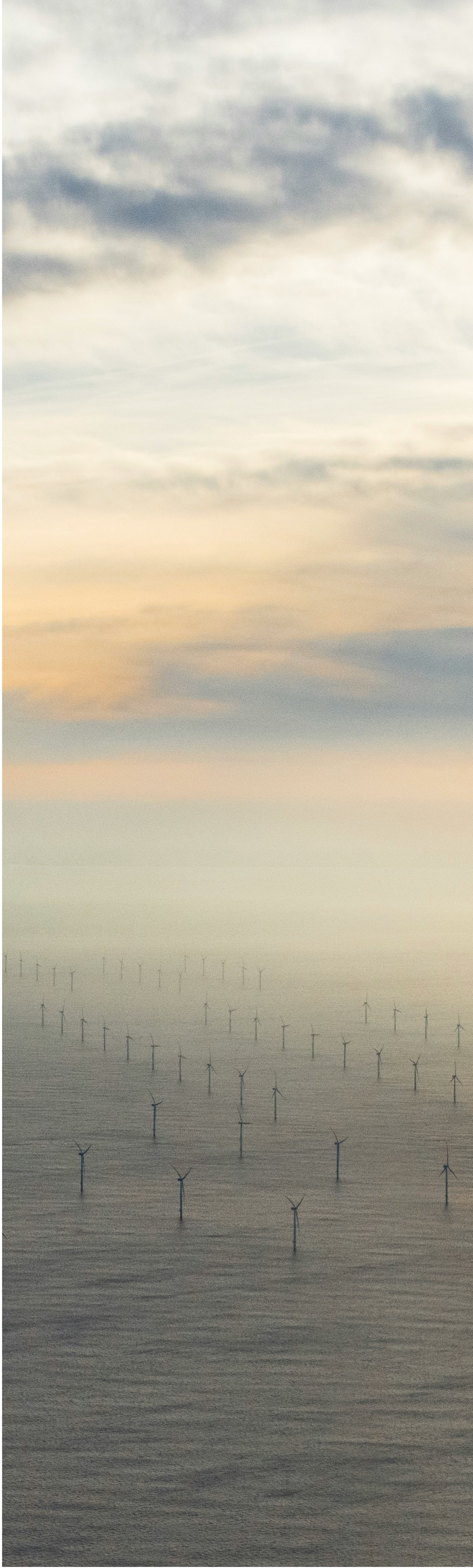

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# Foreword

# 1 Foreword

Over the past several years, governments around the world have made the green energy transition a key mandate to ensure climate goals of the Paris Agreement are kept alive. The COP28 agreement to triple renewable energy by 2030 marked a pivotal milestone in global climate action, gaining momentum as a crucial strategy for mitigating climate change. Notably, progress to date to address climate change has been too slow and nations were urged, and committed to, prioritising the reduction of fossil fuel consumption while accelerating climate action through the development of renewable energy sources such as solar and wind power.

As the 5$^{th}$ largest economy in the world, India has taken responsibility for its own climate action plan and has set ambitious targets to help tackle climate change, these include:

- Reach 500 GW non-fossil energy capacity by 2030;
- Ensure 50 percent of its energy requirements are from renewable energy by 2030;
- Reduce the total projected carbon emissions by one billion tonnes from 2022 to 2030;
- Reduce the carbon intensity of the economy by 45 percent by 2030, over 2005 levels; and
- Achieve the target of net zero emissions by 2070.

With 91 GW of fixed offshore wind potential along the Indian coastline, offshore wind will play a significant role in realising India's green energy future (The Wold Bank, 2021). Momentum to date has however been muted and further policy certainty is required to unlock the ambitious growth scenario of more than 37 GW in offshore wind installations by 2030. These installations will not only deliver green energy to India, but as this report demonstrates, will also promote the development of an offshore wind manufacturing supply chain which in turn will help stimulate the local economy and create thousands of new jobs.

To help fast track the development of offshore wind, the Ministry of New and Renewable Energy (MNRE) published a revised offshore wind strategy (September 2023) which introduces a flexible framework for project development. This approach facilitates varied development models, accommodating both government and private sector roles in expanding offshore wind energy. It encompasses government-led bids for sites pre-assessed by the National Institute of Wind Energy (NIWE) or other government entities, with financial support for predetermined tariffs. Additionally, it allows for developer-initiated projects, either through exclusive seabed rights or independent site identification within the EEZ, without central financial assistance. With some delay, the first offshore wind tender of 4 GW capacity off the coast of Tamil Nadu was launched in February 2024. This however received reservations from both the India Offshore Wind Working Group and other industry leaders and as such was placed on hold. A key request from the industry was the inclusion of a financial commitment from the government to assist with high costs associated with early offshore wind projects. In June 2024, the government approved a Viability Gap Funding (VGF) scheme for implementing offshore wind projects (MNRE, 2024). The VGF scheme announced by the Union Cabinet of India for offshore wind energy projects will be a total outlay of INR 74.53 billion. This includes an outlay of INR 68.53 billion for installation and commissioning of 1 GW of offshore wind energy projects (500 MW each off the coast of Gujarat and Tamil Nadu), and INR 6 billion for upgrading two ports to meet logistical requirements for offshore wind energy projects. This VGF scheme is a major step towards implementation of the National Offshore Wind Energy Policy (2015) and will bring renewed interest in offshore wind developments within Tamil Nadu.

As part of India's renewed drive towards offshore wind development, significant investment will be required for supporting the manufacturing supply chain within the offshore wind ecosystem. As such, Ocean Energy Pathway (OEP) and the Global Wind Energy Council (GWEC) have approached COWI to assist in identifying the opportunities and challenges associated with key manufacturing supply chain activities for offshore wind development within the Tamil Nadu region, including related to the socio-economic benefits for Tamil Nadu and India as a whole.

# Executive Summary

# 2 Executive summary

## Introduction

Tamil Nadu has significant onshore wind capability, where the supply chain is well established and encompasses all key manufacturing, assembly, and logistical components. To transfer this capability into offshore wind, the supply chain will need to be developed to cater for larger blades, generators, gearboxes, and primary foundations. Key industry players are reluctant to take this leap into offshore wind and are waiting for further certainty through the successful seabed auction rounds before investing in significant CAPEX projects.

## Objective

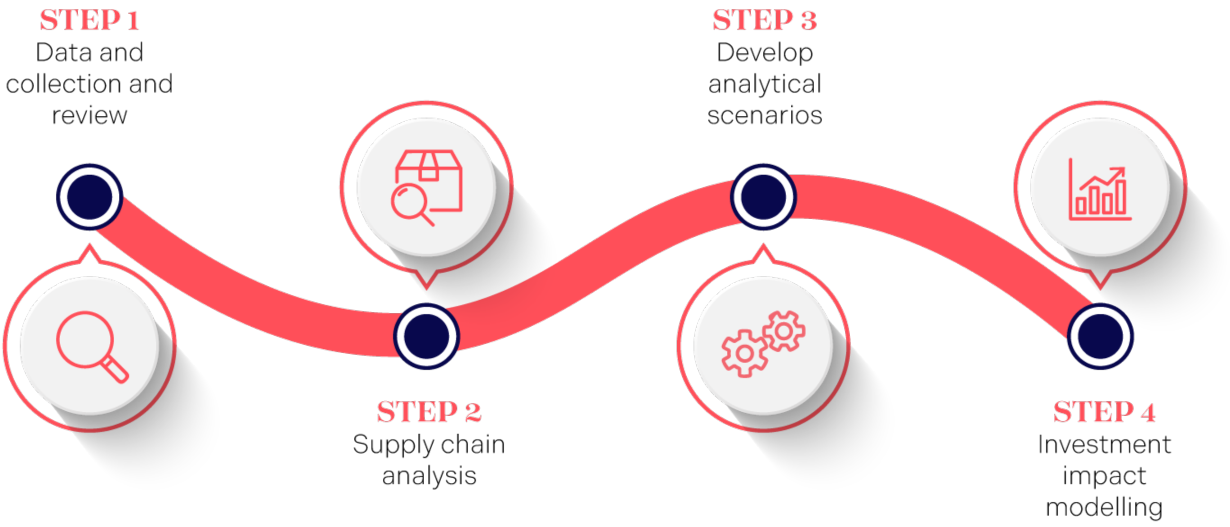
This study aims to help mobilise key decision-makers, which includes government, industry leaders and civil society, to help unlock India's offshore wind potential – specifically for the Tamil Nadu region. Key objectives include the following:

- Establish the current offshore wind supply chain within Tamil Nadu and identify how this can be further developed to accommodate offshore wind.
- Identify possible development scenarios which align with MNRE's 37 GW seabed lease trajectory from 2024 to 2030.
- Quantify the economic effects of investments in offshore wind development for the identified development scenarios, as well as how offshore wind can help reduce $CO_2$ emissions by offsetting fossil fuel heavy power generation.
- Demonstrate the potential socio-economic opportunities available to Tamil Nadu and India as a whole through successful infrastructure investment into the offshore wind supply chain.

This report outlines the manufacturing supply chain for offshore wind development within Tamil Nadu and how investment within this industry may positively impact the region and provide the necessary catalyst to help drive offshore wind within India. Furthermore, study results will show how this investment influences domestic manufacturing content, and the impact on local economic growth and employment, which includes sectoral impacts, trade and export potentials, and spillover effects beyond the state of Tamil Nadu.

## Methodology

To unpack the status of the current offshore wind supply chain within Tamil Nadu, and to evaluate the impact of investment within this industry, the following stepwise process was followed:




**Data Collection and Review:** Several key data nodes were recorded during the initial data screening and stakeholder engagement process to help assess the status quo of the offshore wind market in Tamil Nadu. These data nodes represent a metric which was quantified during the supply chain analysis.

**Supply Chain Analysis:** Identified the status quo and industry activity opportunities in Tamil Nadu, across the offshore wind supply chain. This included manufacturing of components for the offshore wind project lifecycle, development of power, transportation infrastructure and services, assembling services and finally decommissioning and repowering opportunities.

**Analytical Scenarios:** Based on India's offshore wind potential and MNRE's offshore wind seabed lease trajectory from 2024 to 2030, three separate analytical scenarios were identified. The scenarios provided a short term, medium term and long-term development pathway with various sensitivities around development timing, export potential and local content ratios.

**Investment Impact Modelling:** From the analytical development scenarios identified in Step 3, COWI's input/output investment model was used for analysing the employment and economic impacts of offshore wind development within Tamil Nadu.

Refer to section 7 for further information on this studies methodology.

## The Tamil Nadu Supply Chain

Tamil Nadu presents a promising array of industrial activity opportunities within the offshore wind supply chain. These opportunities arise from two distinct effects.

The first is leveraging Tamil Nadu's existing competencies, primarily rooted in its onshore industry, as well as the state's capacity to cater to the offshore oil and gas industry. Key areas include blades, gearboxes, nacelles, and, to an extent, the development of towers.

The second effect is driven by the increasingly viable business case for large-scale manufacturing of offshore components. If Tamil Nadu's industry encounters a sufficiently large demand for offshore wind projects, it could establish new manufacturing units and an accompanying supply chain in a timely manner. This potential growth would not only expand existing onshore wind companies but also attract new companies, enhancing the supply chain, particularly in the areas of towers and offshore foundations.

However, capitalizing on these capacities depends on the realization of the Indian tender trajectory plan for fixed offshore wind energy farms along the Tamil Nadu coastline in South India. Critical to this development are the volume of production and governmental commitments, particularly in establishing production sites with new production lines. Stakeholders are keen on joining the offshore wind supply chain, but uncertainties in the tendering process and timelines remain significant hurdles. Companies await clearer commitments from the government and a defined 2 to 4-year pipeline with off-taker arrangements to solidify their investment plans. Most Tier 1 companies, being international, are prepared to transfer skills to the local workforce in India, anticipating an initial 60% local content in early projects where a local supply chain is established, increasing to 80% as the market matures.

For this, it is crucial for Tamil Nadu to be a first mover in establishing necessary infrastructure, including port expansions and upland development. This infrastructure should be made available to offshore manufacturers and their supply chain partners in a way that is attractive and respectful of the industry's business cases.

## Analytical Development Scenarios

Three separate development scenarios were investigated together with a variety of sensitivity tests to assess the socio-economic impact of offshore wind development within the Tamil Nadu region. Note that these were developed considering India’s offshore wind potential and MNRE’s 37 GW seabed lease trajectory from 2024 to 2030. The development scenarios included the following:

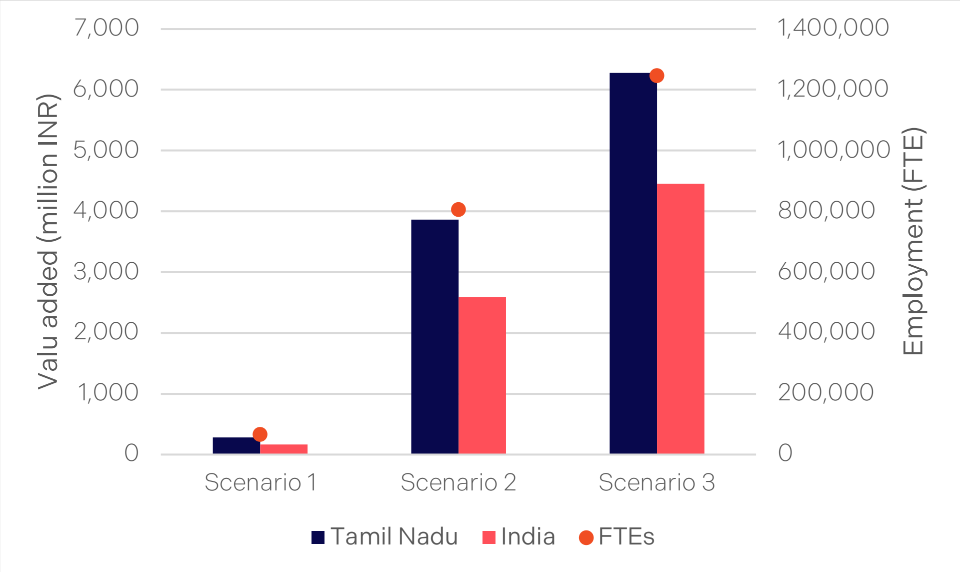
- Short-term business as usual (BAU) scenario: 4 GW tendered and fully commissioned by 2030
- Mid-term scenario: Indian government target of tendering 37 GW by 2030
- Long-term scenario: Indian wind potential of 91 GW tendered until 2040

Sensitivity analyses included the effects of delays in project execution, as well as the extent of local content and how this influences the investment impact. Refer to Section 4 for a more detailed breakdown of the analytical development scenarios considered in this study.

## Investment impacts

Realizing these opportunities could significantly impact Tamil Nadu's economy. The extent of growth in the state of Tamil Nadu varies, ranging between 280 and 6,280 billion INR (2.6 and 85.3 billion EUR) for the time period of 2025-2040, depending on the demand and the future scenario that unfolds. As Figure 2-1 shows, the total impact is larger when taking spillover effects into the local and national economy into account.

*Figure 2-1: Economic growth in Tamil Nadu and India over the period 2024-2040 for three development scenarios*




Short-term Business as Usual: If 4 GW of offshore wind is tendered and installed as announced in February 2024 (as per the study's scenario 1), including 500 MW under a viability gap funding scheme, and no new government policies are implemented to boost local manufacturing of components, the impact on the manufacturing industry will be minimal. The tendered amount would only be sufficient to provide services for offshore installation. However, once 4 GW of offshore wind is deployed, Tamil Nadu companies are well-positioned to handle operations and maintenance activities.

In this scenario, total economic growth in India equates to 450 billion INR (5 billion EUR). Employment will increase with a total of 66,000 Full Time Equivalents (FTE). This represents the accumulated impact on employment over the duration of the scenario and is estimated based on economic activity in different sectors related to the various components in the supply chain. This includes infrastructure, manufacturing, installation and operations.

The implementation of 4 GW in Tamil Nadu will however trigger an import effect on the trade balance, totalling 28 billion INR (0.3 billion EUR). This is due to the developing offshore wind supply chain in Tamil Nadu, which results in the import of almost all offshore wind components and expertise. This is expected to change once additional GW of offshore wind is installed.

The investments will contribute to a displacement of 6 to 14 million tonnes of $CO_2$ emissions per year, depending on whether offshore wind replaces natural gas or coal in the energy production.

Mid-term with government targets: If the entire governmental objective in initiating the implementation of 37 GW offshore wind by 2030 (as the study's scenario 2) is implemented, the prospects are dramatically enhanced. This is due to the comparative advantages of Tamil Nadu's business case to other states, which includes increased wind speeds, shallower seabed depths, and close proximity to industrial hubs. This ultimately results in lower levelized costs for offshore wind. Furthermore, a 30% export of locally produced wind turbine components are included due to the local supply chain gaining sufficient scale.

Total economic growth in India is forecasted to 6,500 billion INR (72 billion EUR) for this scenario. The forecast for the midterm targets scenario is based on the assumptions that financial incentives are made available by the government to bridge the utility cost gap, either on the energy consumer or the producer's side. Initially, components for the first projects are imported. As ports and local manufacturing facilities are established, most of the projects are supplied with local components.

The number of additional employment will reach a total of 805,000 FTE.

Implementing the governmental targets as in scenario 2a, the trade balance is estimated to change with a net-import of rounded 620 billion INR (7 billion EUR). The export of manufacturing and construction activities in scenario 2b, leads to an overall trade surplus of to around 100 billion INR (1 billion EUR).

The mid-term scenario, including the export effect, will contribute to a displacement of around 59 to 130 million tonnes of $CO_2$ emissions per year, depending on whether natural gas or coal is displaced in energy production.

<u>Long term realisation of India's full offshore potential</u>: In the long term, if India realizes its full offshore wind potential, the additional impact on the Tamil Nadu supply chain, in comparison to the mid-term scenario, may be somewhat limited. This is primarily because the offshore wind potentials along the Tamil Nadu coastline are likely to be exploited during the mid-term implementation (scenario 2). The increase in sea transportation costs could reach a point where it's no longer viable to engage Tamil Nadu manufacturers. As a result, Tamil Nadu's production for other inland destinations along the Gujarat coastline and similar areas would be limited to where the state has developed extra comparative advantages, due to economies of scale achieved in meeting the 2030 governmental target.

A total economic growth of 10,700 billion INR (119 billion EUR) is forecasted for this scenario in India. The number of additional employment will reach a total of 1,250,000 FTE.

India's trade balance will be negatively affected if the full wind potential is installed. In the long term it results in an import effect at around 1,180 billion INR (13 billion EUR). If the export of manufacturing and construction activities is included, the overall net import will be reduced to 460 billion INR (5 billion EUR).

The long-term scenario, including the export effect, will contribute to a yearly displacement of around 99 to 217 million tonnes of $CO_2$ emissions by 2040, depending on whether natural gas or coal is displaced in energy production.

## Recommendations

To fully unlock and harness the identified economic potential of Tamil Nadu, strategic and substantial investments are imperative. The investments should extend beyond the mere development of offshore wind sites; they need to contribute to the development of the entire manufacturing supply chain of the offshore wind ecosystem. Implementing a robust investment strategy is crucial in this regard. Such a strategy should be designed to yield extensive socio-economic impacts, benefiting not only Tamil Nadu but catalysing a broader positive impact across India as a whole. The headlines for the five identified key recommendations for action are as follows:

- **Recommendation 1:** Establish a clear pipeline for offshore wind development to attract OEMs to invest in new production facilities within Tamil Nadu. Without a government commitment to sufficient local offshore wind projects in the next few years, investors are lacking an essential prerequisite to enter the market.

- **Recommendation 2:** Create financial incentives for investors to accelerate the offshore wind supply chain in Tamil Nadu. With financial risks, investors are hesitant to commit to large local investments.

- **Recommendation 3:** Government commitment through establishing a clear institutional framework to make it easier to do business in Tamil Nadu. By defining clear guidelines, regulations, processes and responsibilities, the sector becomes more attractive to business and investors.

- **Recommendation 4:** Guaranteeing publicly provided supporting infrastructure to create stable business conditions. Without port expansions, upland development and transmission infrastructure manufacturing facilities and offshore wind projects cannot be established.

- **Recommendation 5:** Clearly define Local Content Requirements (LCR) which support local offshore wind development to make sure that the full potential of a Tamil Nadu supply chain can be harnessed.

# Tamil Nadu Offshore Wind Supply Chain: Status and Opportunities

# 3 Tamil Nadu Offshore Wind Supply Chain: Status and Opportunities

Tamil Nadu's manufacturing industry and connected supply chain in products and services is built to both serve the region’s demand for onshore wind projects as well as exporting components abroad. A designated supply chain for larger wind turbines for offshore use (12 – 15 MW) does not exist. Therefore, this analysis identifies the opportunities for Tamil Nadu to transfer its existing competences to meet the demand for offshore wind components. The analysis relies on estimating the capacity for transferring and expanding the production line of the existing onshore industry, as well as oil and gas and telecommunication, into the offshore wind sector. Furthermore, the analysis will estimate the capacity for Tamil Nadu to attract new manufacturing units required for the upcoming offshore wind sector in India.

This chapter identifies the industry activity opportunities in Tamil Nadu, across the offshore wind supply chain. This includes manufacturing of components for the offshore wind project lifecycle, including production of turbines, foundation and tower fabrication, development of power, transportation infrastructure and services, assembling services and finally decommissioning and repowering opportunities.

## 3.1 Status Quo of the Supply Chain in Tamil Nadu

Currently, several local and international companies are present in the onshore wind turbine supply chain in Tamil Nadu. Tamil Nadu is reported to stand for 18.3 GW manufacturing capacity, corresponding to 46% of India’s total capacity (Kabirdoss, 2023). Tamil Nadu has a large manufacturing ecosystem compared to other states in India and has the largest number of small and medium sized enterprises. For the current manufacturing facilities of wind turbines in Tamil Nadu, stakeholders report that approximately 80% is local content, meaning solely achieved by the Tamil Nadu economy and labour force.

Even though a large amount of Tier 1 and Tier 2 production takes place in Tamil Nadu, cheaper alternatives from abroad are an essential part of the supply chain. Stakeholders reported that the high-quality steel used in the Indian wind turbine manufacturing industry is largely imported. World market prices determine where the raw material can be sourced at the lowest cost and India is not always competitive with respect to other major players e.g. China. In addition, the Indian steel industry is largely focused on the automobile manufacturing sector, which has been a more reliable off-taker. Other largely imported components include castings. India imports 50% of castings required for domestic wind installations and 90% of castings required for local gearbox manufacturing from China (mec+, 2023).

The existing production facilities span across the entire supply chain for both the onshore wind components and smaller offshore wind components respectively. Around 30 – 40 % of the produced components such as wind turbines and blades are exported for both onshore and offshore wind projects abroad via Tuticorin port.

In addition to the many manufacturing hubs, Tamil Nadu has a large workforce with a significant number of engineering colleges and universities providing skilled labour for the existing supply chain. This abundance of skilled labour within Tamil Nadu is another positive enabler for the establishment of the local offshore wind industry within the region.

## 3.2 Transition to an offshore supply chain

Many of the large global offshore wind developers, suppliers and Operation and Maintenance (O&M) companies have previously diversified to the offshore wind sector by transferring their skills, experience and capabilities from the oil and gas industry (e.g. Orsted, previously Dong Energy). India has a well-established and functioning oil and gas sector where key players like ONGC and Reliance have experience in developing large-scale global energy projects offshore, or along the coastline. These include projects that require the fabrication, storage, transportation, and installation of large jacket foundations. Jackets foundations may be required for some of the new offshore wind sites identified in Tamil Nadu dependent on geological characteristics. If however jackets are not necessary, the skills developed and methods used for jacket foundations are transferable to other offshore wind foundation types.

Offshore wind turbines and foundations differ from onshore wind turbines in several ways. The sizes of all components are significantly larger in the offshore segment. It is assumed, that wind turbines with a capacity of 12 - 15 MW are relevant for offshore wind in Tamil Nadu. Therefore, an entirely new manufacturing ecosystem in port-side facilities will be required, as logistical challenges of transporting big components make it impossible to use road transport. Furthermore, the required split of raw materials is different compared to onshore wind. Whereas the largest material input in terms of mass per MW is concrete (72%), and thereafter steel (24%) for onshore wind farms, it is primarily steel (90%) for offshore wind farms, which will impact the supply chain in Tier 2 and Tier 3.

Stakeholders report high interest in entering the offshore wind supply chain, however, the largest challenge reported is the uncertainty around the tendering process and associated timelines. It is understood that companies are waiting for larger commitment and direction from the government before they commit to any substantial investment into the offshore wind sector. As such, establishing targets for offshore wind establishment are not considered enough, and a clear pipeline with off-taker arrangements over medium term (2 to 4 years) and long term (>10 years) horizons will be a necessary prerequisite to consider the business case. The Indian government has taken onboard these concerns and have since approved Viability Gap Funding (VGF) to install and commission 1 GW of offshore wind energy projects off the coastline of Gujarat (500 MW) and Tamil Nadu (500 MW). Furthermore, funding has been made available for the upgrading of two ports to meet logistic requirements. The Indian Government hope that the VGF will provide a catalyst for development of the local offshore wind market and supply chain and ensure better market participation for the offshore wind tender of 4 GW capacity off the coast of Tamil Nadu which was originally launched in February 2024. It is expected that the Tamil Nadu 4 GW tender will gain renewed traction, while the VGF tenders for harnessing potential off the coasts of Gujarat and Tamil Nadu will enable price discovery.

As most Tier 1 companies are international and have production facilities for larger offshore wind turbines in other countries, they report that the necessary capabilities can be transferred to upskill the local work force when required. Leading OEMs report that they expect that the local content will be lower, around 60% for the first few developments, and thereafter will increase to 80% once the Indian market starts to mature.

The status quo of the supply chain is based on closely related industries and is summarized in Table 3-1 together with the various components which make-up an offshore wind farm.

*Table 3-1: Overview of potentials regarding the supply chain for offshore wind*

| Category | Examples of local companies with capacity | Experience from closely related sectors | Offshore experience in TN | Production facility establishment* | Market size for initiation** | TIER 2 local share | TIER 3 local share |
|---|---|---|---|---|---|---|---|
| Blades | Suzlon, Vestas, Simens Energy, Envision, Senvion India, Nordex | High | None | 2-4 years | 20 GW | High | Medium |
| Towers | Suzlon, Nordex, Velmurugan<br>Toolfab Engineering, Barakath, Altec Fabricators, Jay Engineering, Anand Engineering, Batliboy<br>Patel Alloy steel Ltd | High | None | 2-4 years | 5 GW | High | Low |
| Nacelles, hereunder gearboxes | Siemens Energy, Suzlon, Vestas , ZF Wind Power, Nordex, NGC, Winergy | High | Low | 2-4 years | 10 GW | High | Medium |
| Foundations | L&T, Suzlon | Medium | Low | 2-4 years | 5 GW | Low | Low |
| Offshore substations | L&T hydrocarbon, Scheider Electric and Siemens Energy | High | None | 2-4 years | 20 GW | Low | Low |
| Export cables | None | Low | None | 2-4 years | 30 GW | High | Low |
| Array cables | None | Low | None | 1-2 years | 5 GW | High | Low |
| Vessels | L&T, Katupalli shipyard | Medium | None | 5–10 years | - | Low | Low |
| Port infrastructure | Tuticorin and Vizhinjam | Low | Low | 2-4 years | 1 GW | NA | NA |

Note: The table includes the main components in the manufacturing supply chain and there will be other parts of the supply chain such as services which are further described below. (*) The establishing time is independent of the production capacity. (**) The thresholds for the volume of market size refers to an order requirement of an amount within a reliable time frame of approximately up to 15 years.

Note, that one of the leading OEMs, Siemens Energy, as per May 2024, is exploring options, including partnerships and/or announced plans to sell its Indian wind business to concentrate on its core markets in Europe and the US. Therefore, it is to be expected that other companies will take over their market share.

The following chapters outline the status quo of the supply chain for the individual components and possibilities for a transition into the offshore wind supply chain.

## 3.3 Blades

A blade manufacturing industry in India has a solid foundation in onshore wind technology but faces challenges in scaling up to meet the specific demands of the burgeoning offshore wind sector. Addressing these challenges requires strategic investments, market development, and capability enhancements, particularly in manufacturing logistics and operational expertise.

The manufacturing of the blades is predominantly made from fiberglass and epoxy resin. Manufacturing these large, aerodynamically efficient structures requires advanced technical capabilities. Offshore wind turbine blades are reaching up to 105m in length for 12MW turbines, and potentially up to 115m for 15MW turbines. Due to their size, these blades necessitate independent manufacturing facilities at ports, as road transportation is unfeasible.

The current manufacturing landscape includes in-house manufactured blades in Vestas, Suzlon, Siemens Energy, Envision, Senvion and Nordex, which dominate the onshore blade manufacturing market in Tamil Nadu. Most of these also possess offshore wind projects in their global portfolios. The existing facilities in Tamil Nadu produce blades for onshore turbines, but new investments in port-side facilities are needed for the transportation of the larger blades required for offshore turbines. Tamil Nadu dominates the manufacturing of the total India blade production. Other companies include LM Wind Power, which also has a large production plant for blades in Bangalore and exports 70 % of the manufactured blades (mec+, 2023).

Establishing a new blade manufacturing facility demands significant investment. The facility is likely to utilize the existing supply chain for onshore wind turbines in Tamil Nadu, which can supply the necessary input materials for manufacturing, that are partly imported. The decision to set up local manufacturing facilities hinges on the strength of the domestic market. Opportunities of a market demand of more than 20 GW are essential for the viability of investing into new production facilities. Given the right investments, the current experience in exporting to the global market is likely to leverage a similar, parallel future export market for offshore blades. Critical port infrastructure and availability of long-term port production areas near Tuticorin Port are however closely related to the potential for establishing new facilities.

While the manufacturing companies have the technical know-how for blade manufacturing, there is a perceived gap in installation and maintenance capabilities, especially for offshore settings. Upgrading skills and integrating digital technologies in operations and maintenance (O&M) are seen as essential.

## 3.4 Towers

Steel is the primary material for manufacturing the offshore towers and represents 80% of the total tower costs. While India's steel industry has the experience and diversity to cater to the onshore wind market, scaling up for offshore wind requires significant upgrades in manufacturing capabilities, investments in port-side production facilities, and strategic collaborations between domestic manufacturers and global OEMs.

The annual onshore wind capacity addition in Tamil Nadu reduced after the implementation of the reverse auction mechanism in the country. This has resulted in the reduction of the number of Tamil Nadu tower suppliers to only 7 Tier 1 manufacturers today, including Nordex with a global offshore wind experience. However, only the producer Suzlon is believed to meet the diameter requirements for offshore wind projects up to 6 MW. No facility has the capacity to produce towers with a larger diameter. For offshore wind, a diameter of 8 to 10 meters is necessary for 12 MW to 15 MW turbines. Because of the dimensions, new offshore facilities must be situated near the port, due to transportation impracticalities via road. The investment for such a facility is estimated to be around INR 250 crores (mec+, 2023).

Besides the Tier 1 manufacturers, Tier 2 supply chain include Jay Engineering, Anand Engineering, Batliboy, Patel Alloy steel Ltd, none of which have offshore wind experiences.

Significant investments are needed for the manufacturers of towers, to supply towers with a larger diameter required for offshore wind turbines (above 6m). Companies are willing to invest, if space at ports can be secured and sufficient demand of at least 2 GW a year is guaranteed. While most of the production line can be manufactured within Tamil Nadu, the manufacturing of steel in the quality needed for towers is currently not part of the Tier 3 supply chain in neither Tamil Nadu nor India, but is imported. Stakeholders report that they do not expect this to change even if the demand increases.

## 3.5 Nacelles

Current Indian facilities are unsuitable for large offshore nacelle assembly due to size and portside requirements. Initial offshore wind projects are likely to use imported nacelles due to underutilization concerns of a new local production facility.

While there is a strong logic for localizing nacelle assembly and production of sub-components in India, the decision is hindered by financial and technical challenges, market uncertainties, and the need for clear government policy and infrastructure support. The assembly process involves system design, component assembly, and functional testing. Most technology and supply chains are currently based in Europe, with Western manufacturers leading in the Indian market.

Siemens Energy, Suzlon, Vestas, and Nordex have nacelle manufacturing and assembly facilities for onshore wind projects in Tamil Nadu. Other facilities outside Tamil Nadu are also active in wind turbine nacelle assembly in India. While some have capabilities for turbines up to 3.6 MW, others are preparing to supply higher-rated models. Major players like SGRE, Vestas, and Adani are notable for their high-rated turbines and facilities.

For gearboxes which are components of the nacelle, several manufacturers exist in Tamil Nadu today such as ZF Wind Power, NGC and Winergy. They partly produce for the global offshore wind market, however, not in the sizes required for 15 MW turbines.

A new portside assembly facility involves significant investment (INR 1500-3000 crores (mec+, 2023)). The industry would require a steady market size of 2-4 GW per year to justify local assembly facility investment. Besides the inland demand, the manufacturers of nacelles are likely to reach this requirement quickly by replicating their current success in the global onshore market, striving for similar export ratios for offshore than the onshore market.

## 3.6 Foundations

Foundations like monopiles and jackets are central to offshore wind projects. Monopiles, dominant due to simpler design and cost-effectiveness, are large cylindrical structures requiring advanced manufacturing processes. Jackets are used in specific seabed conditions and are less material-intensive but more complex and costly to produce.

No companies in India produce sufficiently large steel structures, that could be adapted for monopile offshore foundations, which is the most common foundation for offshore wind projects due to its cost-effectiveness. However, a jacket-foundation manufacturing unit for offshore oil and gas projects already exists in Tamil Nadu, which could be adapted for offshore wind projects. Others have shown interest, however, without having initiated specific investments. Larsen and Toubro (L&T), Essar Projects, Bharati Shipyard, Cochin Shipyard, and EEW have been identified as prospective companies that could venture into this space1.

Significant investment may need to establish port-side facilities for monopile and jackets manufacturing. This requires a demand for at least 5 GW for the investments to emerge. Jacket foundation facilities, on the other hand, may only need minimal investment to adapt existing capabilities for offshore wind.

## 3.7 Substations

Offshore substations are used to connect offshore energy production facilities to the onshore electrical grid. Offshore substations comprise transformers, reactors, switchgear, and power electronics, housed within a topside structure designed to withstand marine conditions. The latter, housing the electrical equipment, requires fabrication capabilities that can handle weights ranging up to 20,000 tonnes, depending on the chosen HVAC or HVDC system. The stations are essential for minimizing transmission losses and providing grid protection.

Tamil Nadu and India have extensive experience in offshore platforms within the Oil & Gas sector, which is synergistic with offshore wind substation fabrication. In Tamil Nadu, these include L&T Hydrocarbon, Siemens Energy and Schneider Electric. Given upgrading existing yards for substation topside manufacturing would require substantial investment, they are well-positioned to undertake such projects, given their existing facilities and installation capabilities. Others such as GE, Hitachi Energy, Essar Projects, and JSW Energy have facilities/expertise in other states that may be leveraged for manufacture substation topsides..

The business case for upgrading facilities can be challenging due to the low product demand of one or two substations per offshore wind project. Additionally, wind farms are reliant on the substations not having any down time as they are critical infrastructure for transmitting the produced electricity. Hence, project developers might only want to go with manufacturers with strong experience within the sector. For initial projects, it is assumed that substations will be imported.

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[1] https://www.gwec.net/wp-content/uploads/vip/Fowind-study-report_29-06-2016_pages_JWG-update_v2.pdf

Developing capabilities for designing and integrating complex topside structures and electrical systems is crucial. Collaborations with experienced global players and investments in R&D are essential for local companies to bridge capability gaps.

## 3.8 Array and export cables

The cable manufacturing industry for offshore wind farms in India involves the production of inter-array and export cables, each with distinct technical specifications and manufacturing challenges. Inter-array cables connect turbines to the offshore substation, while export cables link the offshore substation to the onshore grid.

Out of 16 major cable manufacturers in India, none are situated in Tamil Nadu. Of these manufacturers, 8 have the capabilities to supply subsea inter-array cables, due to their current experience within the O&G as well as telecommunication sectors (mec+, 2023). Because of this experience, the manufacturers are likely to initiate their investments as early as when the offshore market demand is increasing to 5 GW. With an expanding global market demand for offshore array cables, the local cable industry is likely, besides meeting inland demand, to enter this market as well. Through this experience opportunities exist for local companies in cable installation and maintenance. The risk of expanding the current capacity to the offshore wind sector is assumed to be low.

None of the 16 manufacturers has experience with the production of subsea cables, which can be used as export cables. Globally, only a few companies have this expertise, and three out of the 16 manufacturers present in India have the capabilities internationally. An investment into port-side production facilities only occurs when there are long-term agreements with off-takers of these cables. These companies are reported not so see any investment opportunity in local manufacturing in India in the coming years. Initial volumes for export cables in the Indian market are likely to be met through imports and India is expected to explore international partnerships for inviting investments in this sphere.

## 3.9 Vessels

The offshore wind farm industry heavily relies on specialized vessels for installation, maintenance, and operational activities. Various lifting vessels are needed for installing turbines, foundations, and substations, with specifications depending on the weight, size, and deck space of the components. monopile and jacket foundations, often heavier than turbines, necessitate vessels with higher crane capacities. Repurposed jack-up vessels from the oil and gas industry are often used if they meet the required specifications. Heavy lift vessels like shear leg, heavy lift jack-up, or semisubmersible vessels are used, depending on the weight of the substation.

Although India has some capabilities for offshore wind farm vessel operations, there are gaps, especially in turbine and cable installation vessels. However, international vessels can be contracted for installation, reducing the necessity for Indian-flagged vessels. Local capabilities are more critical for operations and maintenance activities in the long run.

No significant investments have been made specifically for offshore wind projects in India, and today about 13 vessel operators exist in India, with experience from other sectors including oil and gas, telecom, and marine works. Only L&T (situated in Tamil Nadu) and Afcons are expected to have suitable vessels for foundation and substation installation and O&M work.

The industry is poised for growth, with international collaboration and investment in local capabilities being key factors. L&T has commissioned facilities to build offshore platforms, drilling rigs and FPSOs (floating production, storage and offloading unit), besides a minor port which can handle container ships. Katupalli Shipyard in Tamil Nadu is capable and planning to build offshore rig vessels, which will also be for the international market. Close to Tamil Nadu the largest shipbuilding and maintenance facility in India (Cochin Shipyard) together with the Hindustan Shipyard, which is equipped for retrofitting specialized vessels, can become part of the supply chain capacity.

Stakeholders however report that they do not see any offshore vessel manufacturing in Tamil Nadu's shipyards. Firstly, other shipyards on the Indian West coast have larger capabilities. Secondly, developers of offshore wind farms are likely to either hire vessels, including the crew, or use their own fleet during the installation phase. This is a common occurrence that is observable for existing offshore wind projects

## 3.10 Port infrastructure

Although the ports of Tuticorin and Vizhinjam have been identified as suitable for offshore wind terminals development, the existing capacity cannot serve as future hubs for manufacturing of offshore wind components, transport and installation. Tuticorin is foreseen to have the highest capacity as it is already shipping off a large part of the exported onshore wind components from the Tamil Nadu producers, as well as jacket foundations for offshore oil and gas. Besides Tuticorin and Vizhinjam, several other ports in Tamil Nadu have been identified as being suitable for O&M of offshore wind farms.

For Tuticorin to be used for shipping off offshore components directly to local projects, or export abroad, will require large investments over the next few years. This includes extensive dredging to ensure adequate draft requirements for storage and load-out operations; seabed strengthening to support vessel jack-up legs; a new heavy-duty quay; storage and fabrication facilities; as well as accompanying furniture and lifting equipment. These elements have an estimated cost of INR 9.65 billion and construction is expected to take 30 months (DEA, COWI, 2023).

In addition to the port infrastructure, stakeholders report that they are looking at production sites around the Tuticorin port, however, information about concrete investment plans has not been shared publicly.

## 3.11 Transmission infrastructure

In addition to subsea cables to transfer the generated electricity from the wind turbines to the onshore grid, substantial onshore grid upgrades will be necessary. The infrastructure needs to be reinforced and upgraded to accommodate the increase electricity flow, including constructing new high-voltage substations and transmission lines. New converter stations and grid integration systems will be necessary to connect the offshore wind parts to the electricity grid.

The Ministry of New & Renewable Energy has given the go-ahead for the implementation of Phase-II of the Green Energy Corridor project in Tamil Nadu. The ambitious project aims to set up transmission lines to facilitating the evacuation of renewable energy power with a capacity of approximately 4,000 MW in the state. A government grant will cover 33% of the total cost (MNRE, 2023).

As this infrastructure investment will cater to the increasing energy production from solar and onshore wind power, further investments will be needed to integrate the electricity production from new offshore wind installations. As per the Ministry of Power, a transmission system for 10 GW offshore wind in Gujarat and Tamil Nadu is estimated to cost 280 billion INR until 2030 (GWEC, 2023).

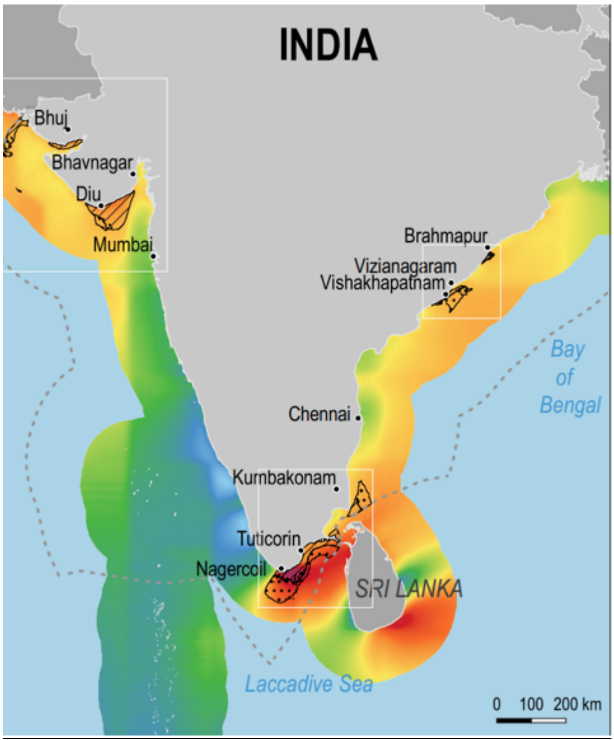
# Business Development Scenarios

# 4 Business Development Scenarios

## 4.1 Introduction

Three main scenarios are developed to assess the possible impacts on the local offshore wind supply chain in Tamil Nadu. The scenarios are based on the potential for offshore wind in India, which is 174 GW according to the 2021 mapping by the World Bank (see Figure 4-1), of which fixed offshore wind is estimated to 91 GW, the remainder being floating foundation.

*Figure 4-1: Offshore wind potential in India*




*Source: ESMAP (The Wold Bank, 2021)*

It is assumed, that floating offshore wind turbines are not technologically mature to be part of the tenders outlined in the scenarios, which have a time frame of up to 2040. The offshore potential for fixed foundation turbines is 91 GW, where 35 GW is identified off the coast of Tamil Nadu, 36 GW in Gujarat, also reported by MNRE (MNRE, 2023), leaving 20 GW potential for other coastal regions (e.g. as per World Bank mapping in Andhra Pradesh or Odisha), see Table 4-1.

*Table 4-1: Distribution of Indian offshore wind potential for turbines with fixed foundation (GW)*

| Tamil Nadu | Gujarat | other |
|---|---|---|
| 35 | 36 | 20 |

*Source: Offshore Wind Potential from ESMAP (The Wold Bank, 2021)*

## 4.2 Identified Scenarios

### 4.2.1 General

Three separate development scenarios were identified for this study and are based on public tenders of different sizes and time frames, see and Table 4-2. In addition to the baseline scenarios identified, the influence of exports was incorporated when suitable scale was reached by the various suppliers based on OW demand trajectories.

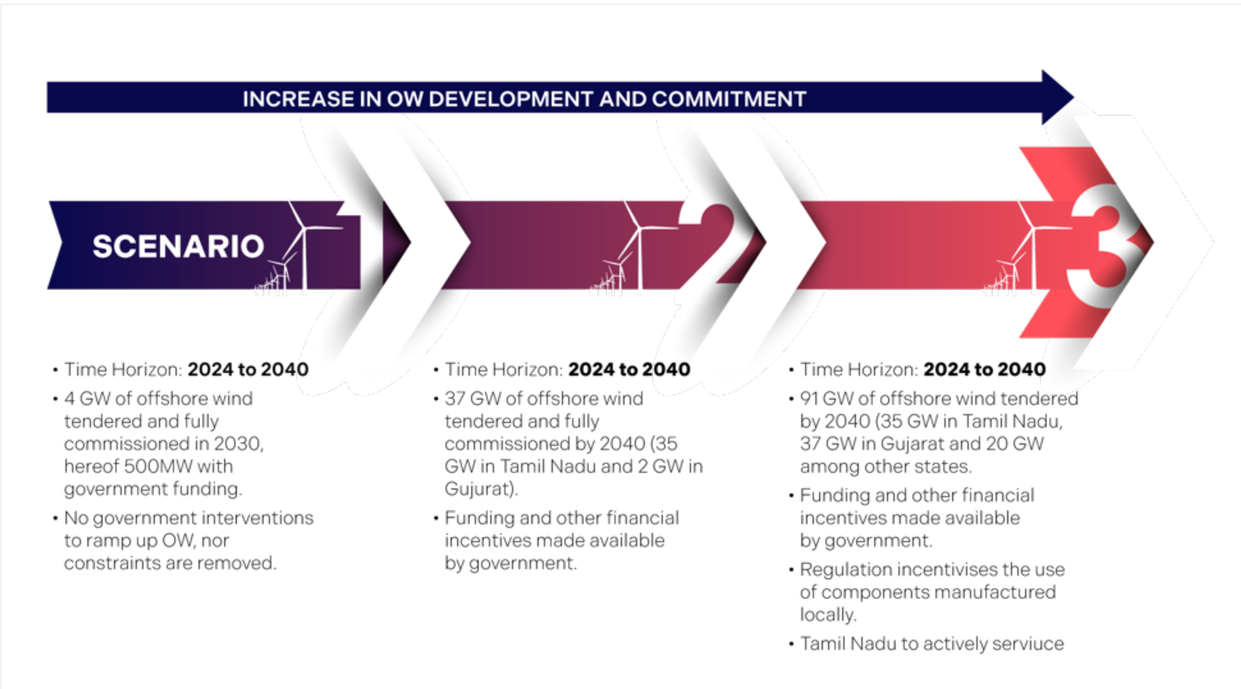
The identified scenarios include the following:

**Scenario 1:** Short-term Business As Usual (BAU) scenario: 4GW tendered in Tamil Nadu and fully commissioned by 2030.

**Scenario 2:** Mid-term scenario: Indian government target of tendering 37 GW by 2030.
a) Tamil Nadu supply chain impact, based on inland offshore wind demand only
b) Tamil Nadu supply chain impact, based on inland demand and global export

**Scenario 3:** Long-term scenario: Indian wind potential of 91 GW tendered until 2040.
a) Tamil Nadu supply chain impact, based on inland offshore wind demand only
b) Tamil Nadu supply chain impact, based on inland demand and global export

*Figure 4-2: Business development scenarios for Offshore Wind*



The three scenario trajectories shown in Table 4-2 illustrate the planned public auction trajectories of offshore wind tenders, following the latest announcements of the Ministry of New and Renewable Energy.

The timeline for the investment impact for the Tamil Nadu manufacturing supply chain of the tendered projects will start being realised after the auction and upon contract signature of each project. Each project will follow a similar full project cycle, which includes site surveys, manufacturing and construction and is forecasted to take 5 to 7 years to complete.

*Table 4-2: Public tender trajectories for offshore wind in India (GW)*

| Tender year | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| 2024 | 4 | 4.5 | 4.5 |
| 2025 | - | 3.5 | 3.5 |
| 2026 | - | 7 | 7 |
| 2027 | - | 7 | 7 |
| 2028 | - | 5 | 5 |
| 2029 | - | 5 | 5 |
| 2030 | - | 5 | 5 |
| 2031 – 40 | - | - | 54 |
| **TOTAL** | **4** | **37** | **91** |

For the export scenarios in 2b and 3b, only components for established facilities will be exported, meaning that there is no incentive to establish additional manufacturing only targeted towards export.

### 4.2.2 Sensitivity Tests

For all scenarios two sensitivity analyses is conducted:

- Sensitivity to a project development delay. Estimated as a delay of three years lag in developing offshore projects after the tendering year.
- Sensitivity to a level of local content (produced in Tamil Nadu). Estimated as a change of plus/minus 10% in local content.

### 4.2.3 Prerequisites to Development

Upstream and downstream public and private infrastructure investments in Tamil Nadu, including road and ports, are prerequisites for all scenarios. They are assumed to be in place before the manufacturing industry units are fully established, and ahead of the commencement of construction activities for first offshore wind project in Tamil Nadu. Firstly, port infrastructure has to be in place for port-side manufacturing facilities to be in operation and local offshore installation projects to take place. Secondly, transmission infrastructure has to be built so power from installed capacity can be retrieved and distributed. It is assumed that the new power generation is additional to existing power and not substituting power from e.g. existing fossil sources.

## 4.3 Scenario 1 – Short-term Business as Usual

The short-term scenario is based on the revised strategy paper from 26th of September 2023 by MNRE (MNRE, 2023), and the press release from 2nd of February 2024 (MNRE, 2024), where 4 GW offshore wind are tendered off the coast of Tamil Nadu in 2024. In February 2024, the government approved a viability gap funding scheme for implementing offshore wind projects, hereof 500 MW in Tamil Nadu and 500 MW in Gujarat (MNRE, 2024).

The scenario is based on the current manufacturing capacity in Tamil Nadu (see chapter 3). Therefore, most components will be imported. The tendered amount of 4 GW is not sufficient to provide a viable business case for manufacturing many components locally. In fact, only services for the installation and deployment and maintenance operations are foreseen (see Table 4-3).

Assumptions:

- There are no special policy schemes or interventions put in place to speed up Tamil Nadu engagement, except for a viability gap funding scheme for 500 MW (MNRE, 2024). Other regulatory or market constraints are not eased for India to ramp-up its wind capacity.
- There will be sufficient demand to develop the port of Tuticorin to serve as port for assembly and installation of the 4 GW capacity along Tamil Nadu's coast. The required infrastructure and available locations for the manufacturing units, including a sufficient transmission infrastructure, is assumed to be timely in place.

*Table 4-3: Offshore wind supply chain presence in Scenario 1*

| Business | Manufacturing / service in TN |
|---|---|
| Blades | No |
| Towers | No |
| Nacelles | No |
| Foundations | No |
| Offshore substations | No |
| Array cables | No |
| Export cables | No |
| Installation | Partially (20%) |
| O&M | Yes |
| Port infrastructure | Necessary prerequisite |
| Grid infrastructure | Expansion required |

## 4.4 Scenario 2 – Mid-term with government targets

By 2030, 37 GW of offshore wind is tendered in India following the planned auction trajectory, as outlined in the revised strategy paper from 26th of September 2023 by MNRE2. In Model-A, 0.5 GW will be tendered in Gujarat with financial assistance from the government. These capacities are assumed to be established. The 14 GW that are announced to be tendered under Model-B and 22 GW under Model-C are not specified geographically, except the 4 GW tendered in Tamil Nadu by February 2024.

Assumptions:

- Wind conditions are better in Tamil Nadu than Gujarat and the levelized cost of energy is much higher in Gujarat. Therefore, it is assumed that most wind turbines are established in Tamil Nadu. As outlined by MNRE, Tamil Nadu has a potential of 35 GW of fixed offshore wind. Hence, it is assumed that 35 GW will be installed in Tamil Nadu and the remaining 2 GW in Gujarat.
- After reconstructing and improvement works, the maximal installation capacity in Tuticorin port is 4 GW/year. To be able to install larger capacities in some years as outlined in Table 4-2, a second installation port in Tamil Nadu is assumed to be developed prior to the project implementation. This could for example be the port of Vizhinjam.
- Before the local businesses in Tamil Nadu are established, and required manufacturing units are constructed, an initial import of most components is assumed. Due to the large volumes to be tendered to reach the government targets, it is assumed that local manufacturing is expanded stepwise for most turbine manufacturing components, as depicted in Table 4-4. The threshold for a viable business case of establishing local manufacturing of export cables of 30 GW is not reached, as cables for the first projects are imported.
- Funding, or other financial incentives, are made available by the government to bridge the gap between actual tariff and power purchase tariff by designated entity, which will ensure the economic feasibility of installing the full potential in Tamil Nadu.

Scenario 2b includes an estimated 30% export of wind turbine components manufactured in Tamil Nadu, which is based on current export volumes of local manufacturers. It is assumed that manufactured components such as nacelles and blades will be exported to meet the growing offshore turbine demand in Asia and globally. The shipping capacity required for this export is assumed to be independent of the ports' project installation capacity.

[2] https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/09/202309271030958532.pdf

*Table 4-4: Offshore wind supply chain presence in Scenario 2*

| Business | Manufacturing / service in TN | TN export opportunity |
|---|---|---|
| Blades | Yes | 30 – 40% |
| Towers | Yes | |
| Nacelles | Yes | 30 – 40% |
| Foundations | Yes | |
| Offshore substations | Yes | |
| Array cables | Yes | |
| Export cables | No | |
| Installation | Yes | |
| O&M | Yes | |
| Port infrastructure | Necessary prerequisite | |
| Grid infrastructure | Expansion required | |

## 4.5 Scenario 3 – Long-term Indian wind potential

Scenario 3 includes the volumes from scenario 2 of 37 GW tendered in India until 2030. Additionally, further offshore potentials in India are added, based on the mapping by the World Bank (The Wold Bank, 2021). As the potential for offshore wind in Tamil Nadu is already exhausted in scenario 2, this scenario looks at the possibilities for Tamil Nadu as a manufacturing hub delivering components to offshore wind projects in other states in India.

Of the full offshore wind potential for fixed foundation turbines, 35 GW are tendered in Tamil Nadu, 36 GW are tendered in Gujarat, and 20 GW are tendered along the coast of other states, e.g. Andhra Pradesh and Odisha.

Assumptions:

- Funding, or other financial incentives, are made available by the government to bridge the gap between actual tariff and power purchase tariff by designated entity, which will ensure the economic feasibility of installing the full offshore wind potential for fixed foundations in India.
- Regulation incentivises the use of components manufactured in India compared to import. Hence offshore projects in Gujarat and on the east coast will source wind components from Tamil Nadu, where local production is not available.
- Due to large volumes in Gujarat and other coastal states, local manufacturing will be feasible for components with a low GW-order requirement which would be costly to ship from Tamil Nadu such as towers and foundations. As Tamil Nadu has an established manufacturing hub from the first Indian offshore wind projects, the state has a comparative advantage of

manufacturing blades, nacelles, offshore substations and export cables. As such, these components are assumed to be produced in Tamil Nadu and shipped to the other states.

Scenario 3b includes an estimated 30% export of wind turbine components manufactured in Tamil Nadu, which is based on current export volumes of local manufacturers. It is assumed that manufactured components such as nacelles, blades and export cables will be exported to meet the growing offshore turbine demand in Asia and globally. The shipping capacity required for this export is assumed to be independent of the ports' project installation capacity.

*Table 4-5: Offshore wind supply chain presence in Scenario 3*

| Business | Manufacturing / service in TN | TN manufacturing / service used in other Indian states | TN export opportunity |
|---|---|---|---|
| Blades | Yes | Yes | 30 – 40% |
| Towers | Yes | No | |
| Nacelles | Yes | Yes | 30 – 40% |
| Foundations | Yes | No | |
| Offshore substations | Yes | Yes | |
| Array cables | Yes | No | |
| Export cables | Yes | Yes | 30 – 40% |
| Installation | Yes | Partially | |
| O&M | Yes | No | |
| Port infrastructure | Necessary prerequisite | - | |
| Grid infrastructure | Expansion required | - | |

# Investment Impacts

# 5 Investment Impacts

The investments into offshore wind and the supply chain in Tamil Nadu are measured from 2025 to 2040 for the different scenarios. There are both impacts from the construction phase, spanning over building port and transmission infrastructure, manufacturing facilities for offshore wind components and the installation of offshore wind projects in Tamil Nadu as well as the operational phase, where there will be ongoing operations and maintenance of the installed offshore turbines. The methodology is described in section 7.

## 5.1 Impacts on the economy

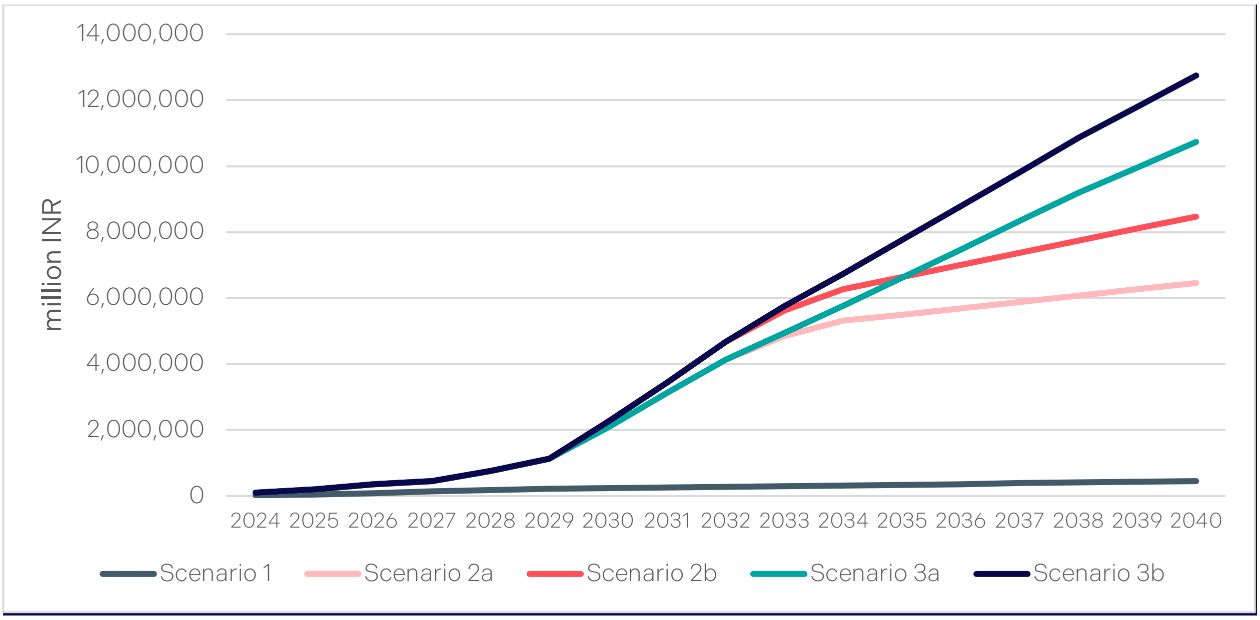
The investment impact on the economy is measured as value added to GDP. There are both direct impacts in Tamil Nadu as well as indirect spillover effects in India as a whole. These effects are consolidated in Figure 5-1, which visualizes the accumulated economic impact across all scenarios over time.

In scenario 1, due to the low project volume of 4 GW, the economic impact in both Tamil Nadu and India, although still beneficial, will be less substantial than for Scenario 2 and 3. From the total direct investments, only 29% will be disseminated locally in Tamil Nadu. This outcome is primarily because the offshore wind supply chain will only be partially established, and most of the components will be imported. Initially, Tamil Nadu will experience economic benefits from the development and construction of necessary port infrastructure, as well as from conducting surveys and site development for the offshore wind projects. After the construction of ports and transmission, Tamil Nadu's primary involvement will be in operation and maintenance activities.

Scenario 2 examines the economic impact of achieving the governmental tendering targets until 2030. Here, the value added to the Indian GDP sees a significant rise post-2029, coinciding with the gradual expansion of the local manufacturing supply chain for most offshore wind farm components. However, this increase changes to a lower level of impact after 2032, as the focus shifts from installation to operation and maintenance services. The local content in Tamil Nadu is estimated to be 56% of direct investments.

Scenario 3 follows a similar development path to Scenario 2 up until 2032. Post-2032, the local impact continues to grow at a similar rate as observed between 2029 and 2032 and local manufacturing continues to produce components for other Indian states. Additionally, Scenario 3 projects a higher export impact, reflecting an increase in international demand in the subsequent decades. Here, the local content is estimated to be 60% of the supply chain and infrastructure investments.

*Figure 5-1: Accumulated value added to Indian GDP over time for each scenario, direct and indirect effects*




*Source: Modelling results (see section 7 for methodology)*

The direct impact on the economy of Tamil Nadu for the construction phase is shown in Table 5-1, divided into the main economic sectors. Apart from scenario 1, where no local manufacturing of components takes place, the largest impact is expected to be in the manufacturing sector for the remaining scenarios, followed by construction.

*Table 5-1: Value added from construction phase, direct impact in Tamil Nadu for 2025-2040 (M INR & M EUR)*

| *In M INR* | Scenario 1 | Scenario 2a | Scenario 2b | Scenario 3a | Scenario 3b |
|---|---|---|---|---|---|
| Manufacturing | 0 | 1,506,000 | 2,544,000 | 3,507,000 | 4,546,000 |
| Construction | 91,000 | 923,000 | 1,014,000 | 1,253,000 | 1,345,000 |
| Transport | 8,000 | 117,000 | 117,000 | 191,000 | 191,000 |
| Services | 35,000 | 280,000 | 280,000 | 288,000 | 288,000 |
| **Total** | **134,000** | **2,826,000** | **3,955,000** | **5,239,000** | **6,370,000** |

| *In M EUR* | Scenario 1 | Scenario 2a | Scenario 2b | Scenario 3a | Scenario 3b |
|---|---|---|---|---|---|
| Manufacturing | 0 | 16,730 | 28,270 | 38,970 | 50,510 |
| Construction | 1,010 | 10,260 | 11,270 | 13,920 | 14,940 |
| Transport | 90 | 1,300 | 1,300 | 2,120 | 2,120 |
| Services | 390 | 3,110 | 3,110 | 3,200 | 3,200 |
| **Total** | **1,490** | **31,400** | **43,950** | **58,210** | **70,770** |

The indirect effects in Tamil Nadu and India as a whole are shown in Table 5-2 and cover Tier 2 and Tier 3 suppliers as well as wider spillovers in the economy by the investments.

*Table 5-2: Value added from construction phase, indirect impact in India for 2025-2040 (M INR & M EUR)*

| *In M INR* | Scenario 1 | Scenario 2a | Scenario 2b | Scenario 3a | Scenario 3b |
|---|---|---|---|---|---|
| Manufacturing | 17,000 | 621,000 | 954,000 | 1,298,000 | 1,632,000 |
| Construction | 2,000 | 123,000 | 197,000 | 270,000 | 343,000 |
| Transport | 0 | 0 | 1,000 | 1,000 | 1,000 |
| Services | 0 | 4,000 | 5,000 | 7,000 | 8,000 |
| Other sectors | 57,000 | 1,191,000 | 1,665,000 | 2,228,000 | 2,702,000 |
| **Total** | **76,000** | **1,939,000** | **2,822,000** | **3,804,000** | **4,686,000** |

| *In M EUR* | Scenario 1 | Scenario 2a | Scenario 2b | Scenario 3a | Scenario 3b |
|---|---|---|---|---|---|
| Manufacturing | 190 | 6,900 | 10,600 | 14,420 | 18,130 |
| Construction | 20 | 1,370 | 2,190 | 3,000 | 3,810 |
| Transport | 0 | 0 | 10 | 10 | 10 |
| Services | 0 | 40 | 60 | 80 | 90 |
| Other sectors | 630 | 13,230 | 18,500 | 24,760 | 30,020 |
| **Total** | **840** | **21,540** | **31,360** | **42,270** | **52,070** |

Additionally, to the construction and manufacturing phase, there will be impacts from operations and maintenance of the installed offshore wind capacity in Tamil Nadu. The values in Table 5-3 are averages for the analysed period of 2025 to 2040, however, the yearly impact is larger when only looking at years when the capacities are fully installed. The effects are expected to continue far into the future, as the wind farms will be repowered and electricity production continues.

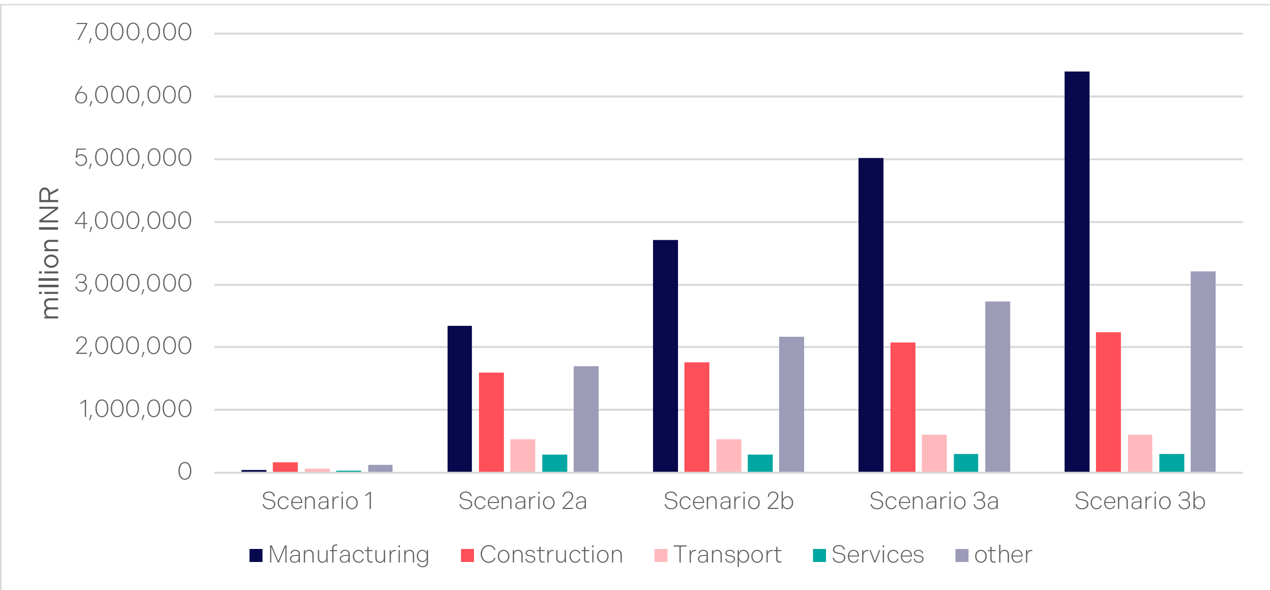
*Table 5-3: Value added from operations and maintenance, average yearly effects in 2025-2040 (M INR/year & M EUR/year)*

| *In M INR/year* | Scenario 1 | Scenario 2a | Scenario 2b | Scenario 3a | Scenario 3b |
|---|---|---|---|---|---|
| Direct effects in Tamil Nadu | 8,700 | 61,300 | 61,300 | 61,300 | 61,300 |
| Indirect effects in India | 5,400 | 38,100 | 38,100 | 38,100 | 38,100 |

| *In M EUR/year* | Scenario 1 | Scenario 2a | Scenario 2b | Scenario 3a | Scenario 3b |
|---|---|---|---|---|---|
| Direct effects in Tamil Nadu | 100 | 680 | 680 | 680 | 680 |
| Indirect effects in India | 60 | 420 | 420 | 420 | 420 |

The total value added from the construction and operations phases is aggregated in Figure 5-2. The share of value added from the manufacturing sector increases in scenario 3 relative to the others as the main increase in economic activity comes from the manufacturing of components which are shipped to other states. Similarly, the export of components contributes to the growth in manufacturing.

*Figure 5-2: Total value added by sector for India as a whole in the time period 2024-2040 (M INR)*




*Source: Modelling results (see section 7 for methodology)*

Synergies with Gujarat are only expected to materialise in Scenario 3, as Tamil Nadu has a comparative advantage of having established a competitive manufacturing sector and can supply Gujarat with selected turbine components if prices can compete with imports from other countries. However, due to high transportation costs and large offshore capacities identified in Gujarat, it is expected that the state can build some of its own offshore wind supply chain, given adequate political support.

Finally, the robustness of the results is analysed in three sensitivity analyses. The results are reported as percentage deviations in the economic impact compared to the main results, see Table 5-4.

The main impact effects are estimated based on the assumption that the first GW are tendered from 2024 onwards with a time period of 5 years until the capacity is commissioned. However, a delay in the period from tender to commission is not unrealistic. A sensitivity analysis with a 3-year delay will cause different effects in the construction phase depending on the scenario. In scenario 1, a decrease in the economic impact is due to efficiency gains over time, which lowers the investment needs and thereby the economic value added. In scenario 2, the delay gives extra time for the port infrastructure and manufacturing facilities to be completed in order to supply the first projects with components, which are otherwise imported - thereby increasing the economic impact. As a delay will push part of operation and maintenance activities beyond the cutoff point of this study (2040), there is a decrease in the impact from this particular phase for all scenarios. The effects of this decrease will be higher for this phase than for the construction phase. This is the same for scenario 3, where less components will be manufactured in the construction phase and thereby decrease the impact therein.

The two other sensitivities are adjusting the expected local share for all components in the supply chain, looking at an increase and decrease in the local content of 10%. The negative and positive impact on value added to the Tamil Nadu economy is higher for scenarios 2 and 3, as more activities are taking place in Tamil Nadu itself. For scenario 1 an increase in local content does not influence the value added as the only activities taking place in the construction phase are supporting infrastructure activities, which are already fully local.

*Table 5-4: Sensitivity analysis by scenario (pct. change of value added compared to main results)*

| | 3-year delay | | 10% decrease in local share | 10% increase in local share |
|---|---|---|---|---|
| | Construction phase | Operation and maintenance phase | Construction phase | Construction phase |
| Scenario 1 | -11.6% | -27.3% | -10.0% | 0.0% |
| Scenario 2a | 8.8% | -33.9% | -13.0% | 9.5% |
| Scenario 2b | 1.0% | -33.9% | -12.8% | 10.3% |
| Scenario 3a | -14.9% | -33.9% | -13.3% | 11.4% |
| Scenario 3b | -15.6% | -33.9% | -13.1% | 11.6% |

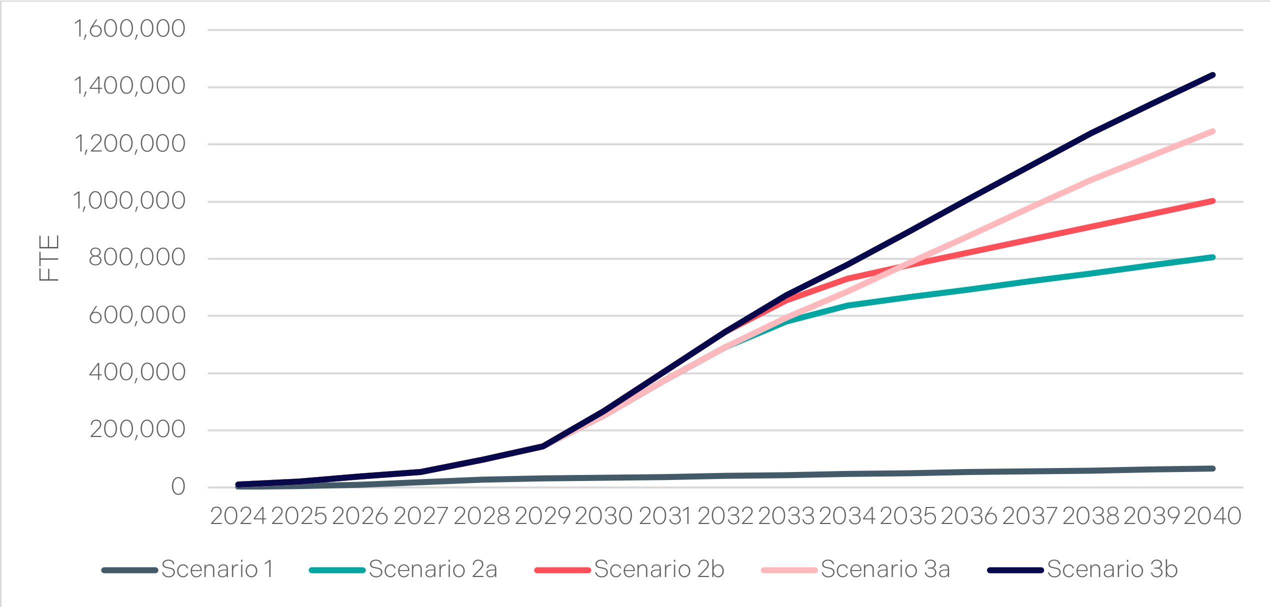
## 5.2 Employment

Investments in the local offshore wind supply chain have large potential to create local employment. Jobs are created when the supporting infrastructure such as ports and transmission lines are constructed by the local labour force. When it comes to the manufacturing sector, there is an initial delay in local employment as facilities have to be established and the staff trained. In scenarios 2 and 3, where there is a large amount of local offshore wind projects, most components can be manufactured locally boosting the local employment. In scenario 1, the weaker business case for local manufacturing leads to importing components, reducing the potential for job creation in Tamil Nadu. For the installation of the offshore wind farms, part of the service will be conducted by international experts. However, operation and maintenance activities will mostly be conducted by the local labour force, generating jobs over many years as the wind farms are maintained and ultimately repowered.

The employment impact is measured in Full Time Equivalents (FTE) and is estimated based on the economic activity in different sectors related to the different components in the supply chain, such as infrastructure, manufacturing, installation and operations. Employment impact is estimated based on input/output and employment data of the Indian economy. As the Indian economy as a whole has a large number of small-scale businesses and is more labour than capital intensive compared to European countries, the estimates are adjusted to reflect the productivity in the Indian high-tech sectors. This is assumed to be required by global investors operating in a highly competitive market.

The strongest effects are realised when the local manufacturing sector is established and is producing components for local projects. These effects are more pronounced during the export scenarios. As can be seen in scenarios 2a and 2b (Figure 5-3), the increase in generated employment flattens out when no further wind turbines are manufactured and installed locally. The recorded employment impact is thus only from operations and maintenance activities.

*Figure 5-3: Accumulated impact on employment (FTE) over time for each scenario, direct and indirect effects*




Source: Modelling results (see section 7 for methodology)

The employment effects in Tamil Nadu in the construction and manufacturing phases range between 20,000 and 600,000 FTE depending on the scenario.

*Table 5-5: Employment impact from construction phase, direct impact in Tamil Nadu for time period 2025-2040 (FTE)*

| | Scenario 1 | Scenario 2a | Scenario 2b | Scenario 3a | Scenario 3b |
|---|---|---|---|---|---|
| **Manufacturing** | 0 | 102,000 | 172,000 | 237,000 | 308,000 |
| **Construction** | 17,000 | 171,000 | 188,000 | 233,000 | 250,000 |
| **Transport** | 1,000 | 16,000 | 16,000 | 26,000 | 26,000 |
| **Services** | 2,000 | 16,000 | 16,000 | 17,000 | 17,000 |
| **Total** | **20,000** | **305,000** | **392,000** | **513,000** | **601,000** |

Additionally, there will be employment effects in Tamil Nadu and India as a whole as shown in Table 5-6 covering Tier 2 and Tier 3 suppliers as well as wider spillovers in the economy by the investments.

*Table 5-6: Employment impact from construction phase, indirect impact in India for time period 2025-2040 (FTE)*

| | Scenario 1 | Scenario 2a | Scenario 2b | Scenario 3a | Scenario 3b |
|---|---|---|---|---|---|
| **Manufacturing** | 1,000 | 42,000 | 65,000 | 88,000 | 110,000 |
| **Construction** | 0 | 23,000 | 37,000 | 50,000 | 64,000 |
| **Transport** | 0 | 0 | 0 | 0 | 0 |
| **Services** | 0 | 0 | 0 | 0 | 0 |
| **Other sectors** | 9,000 | 186,000 | 259,000 | 346,000 | 419,000 |
| **Total** | **10,000** | **251,000** | **361,000** | **484,000** | **593,000** |

*Note: A value of 0 indicates that the indirect employment in that sector is below 1,000 FTEs.*

Additional to the construction and manufacturing phase, there will be impacts from operations and maintenance of the installed offshore wind capacity in Tamil Nadu, shown as averages over the period 2025-2040 in Table 5-7.

*Table 5-7: Employment effects from operations and maintenance, average yearly effect in the time period 2025-2040 (FTE/year)*

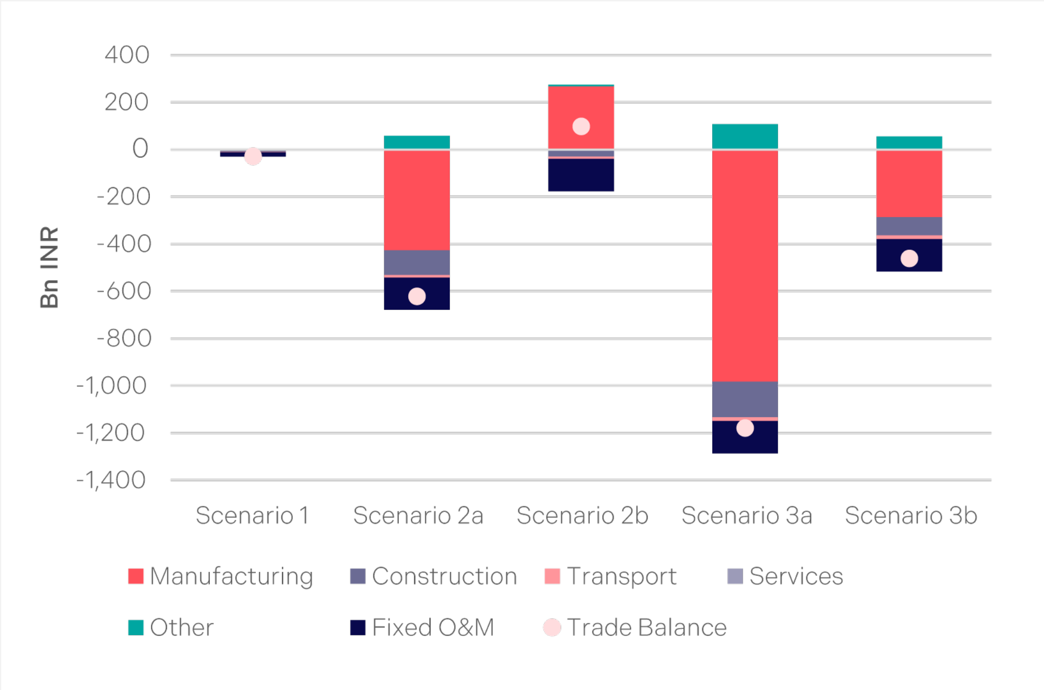
| | Scenario 1 | Scenario 2a | Scenario 2b | Scenario 3a | Scenario 3b |
|---|---|---|---|---|---|
| **Direct effects in Tamil Nadu** | 1,300 | 9,400 | 9,400 | 9,400 | 9,400 |
| **Indirect effects in India** | 700 | 5,200 | 5,200 | 5,200 | 5,200 |

In comparison to other employment indicators in the literature, the estimates in this report are very specific, both to the Indian context as well as due to the methodology. The effects in this report are estimated based on different wind farm components, services and supporting infrastructure related to the supply chain, which can be a broader scope than other estimates reported in the literature. The labour requirement per MW installed capacity can be larger in India, as productivity levels can be lower than in other countries for certain industries. Additionally, large parts of the supply chain can be established locally, which contributes to a higher employment creation ratio compared to countries, where more components or subcomponents and raw materials are imported.

## 5.3 Trade balance

The effect on the trade balance of establishing a local supply chain is contingent upon the activity levels for each scenario. The additional investments in developing the manufacturing offshore industry in Tamil Nadu will exert a negative influence on the trade balance. This is attributable to the nature of activities in Tamil Nadu, which involves importing industry inputs, both complements and supplements, from the Tier 2 and Tier 3 supply chain, particularly within the manufacturing sector, but to a lesser degree also in the construction and transportation sectors.

*Figure 5-4: Trade balance (Export - Import)*




*Source: Modelling results (see section 7 for methodology)*

In scenario 1 the 4 GW in local wind projects triggers a negative trade balance effect, totalling 28 billion INR. For scenarios 2 and 3, there is a large import in the manufacturing sector for parts and subcomponents in Tier 2 and Tier 3, which are not manufactured locally. The export of components to the international market mitigates these import effects.

In scenario 2a, during the mid-term with governmental targets, there is a net import value of 620 billion INR. The export of components manufactured in Tamil Nadu in scenario 2b, dampens the effect and leads to a positive impact on the trade balance of 100 billion INR.

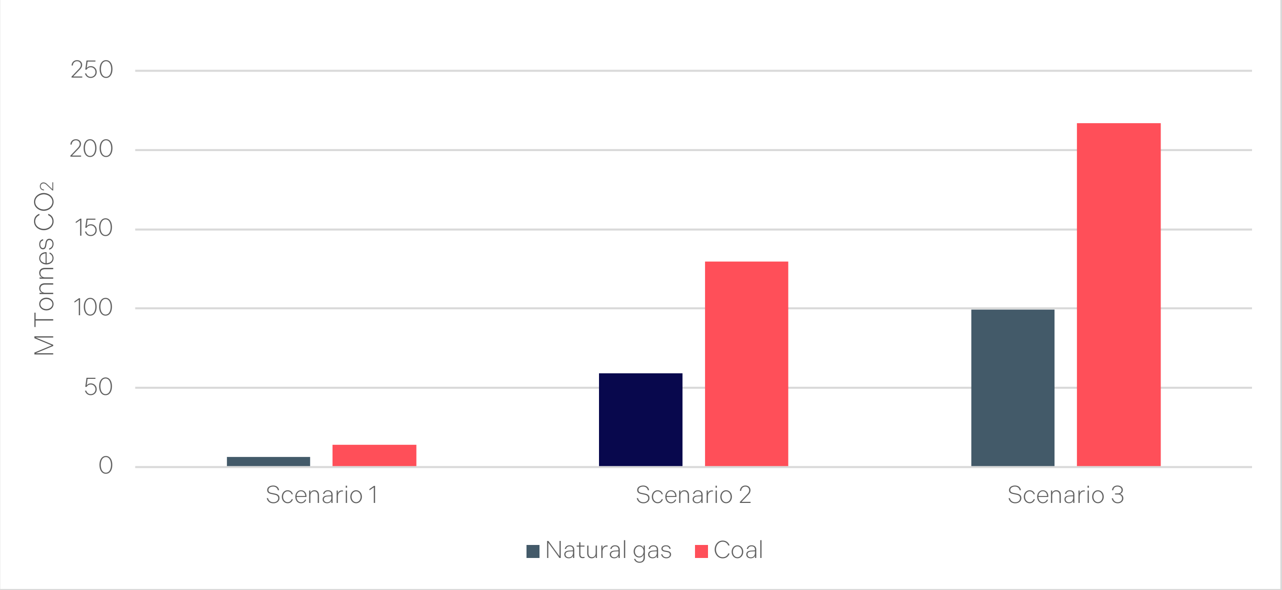
Looking at the long term, in scenario 3a, India's wind potential without equipment exports results in a net import value of 1,180 billion INR, due to the additional imports of the manufacturing sector which is catering to the demand for components from other Indian states. However, in scenario 3b, the export of manufacturing and construction activities dampen the overall net import to 560 billion INR. If a larger export potential can be realised, the negative effect on the trade balance could be offset.

Finally, significant inflows of FDI are expected, as many OEMs are international companies.

## 5.4 Carbon emission displacement

Tamil Nadu's investments in manufacturing and service provision aim to advance the implementation and deployment of renewable energy along the coastline of India. The projects are expected to contribute to a notable reduction in carbon emissions, the magnitude of which depends on the installed capacity, see Figure 5-5 for the variations between the scenarios. The energy production from offshore wind turbines can potentially displace emissions from coal or natural gas by a range of 6 to 14 M tonnes per year in scenario 1. The range is spanning from 99 to 217 M tonnes in scenario 3, where 65 GW are commissioned in India by 2040.

*Figure 5-5: Annual avoided $CO_2$ emissions in India in 2040*




*Source: Own estimates based on (IEA, 2020) (see section 7 for methodology)*

# Recommendations

# 6 Recommendations

To fast track the development of offshore wind, in June of 2022, the Ministry of New and Renewable Energy (MNRE) announced a cumulative 37 GW offshore wind seabed lease tender trajectory for 2022 to 2030, with the goal to add 30 GW of installed offshore wind by 2030. The Ministry's revised offshore wind strategy from September 2023 introduces a flexible framework for project development. This approach facilitates varied development models, accommodating both government and private sector roles in expanding offshore wind energy. It encompasses government-led bids for sites pre-assessed by NIWE or other government entities, with financial support for predetermined tariffs. Additionally, it allows for developer-initiated projects, either through exclusive seabed rights or independent site identification within the EEZ, without central financial assistance.

For Tamil Nadu to realise its economic potential in manufacturing components for meeting India's and global wind targets, significant investment will be required for not only the development of the offshore wind sites, but also the supporting manufacturing supply chain within the offshore wind ecosystem, alongside an investment strategy which will provide socio-economic benefits for not only Tamil Nadu, but for India as a whole.

According to stakeholder consultations reported by the OECD and NRDC (OECD, 2022), key barriers for developing a value chain for offshore wind industry in India include uncertainty regarding the policy environment and the future pipelines, the cost of technology imports, domestic manufacturing capacity and high risks for the supply chain due to unclear regulatory conditions and high capital requirements and cost of finance.

There are current incentives to attract investments into the manufacturing sector of Tamil Nadu and India as a whole. Investment promotion subsidies refund part of the investment for companies creating significant local impact and employment. There is no concrete policy for offshore wind manufacturing yet, although it already exists for other areas (e.g. the Production Linked Incentive Scheme (PLI) for the solar industry) (OECD, 2022). Such a policy could lower the financial risks and contribute to attracting more investments into the supply chain.

Often there exists an inbuilt conflict between enforcing strict Local Content Requirements (LCR) and the interest of keeping the Levelized Cost of Energy for wind as low as possible. Such requirements, especially when the industry still lacks maturity, can reduce the business case, and thereby lower the inflow of FDI in offshore wind altogether. Instead, gradually implementing local content may attract local engagement and ensure their business case in the long run, while still attracting necessary FDI from abroad.

Five key recommendations for action are outlined below:

**Recommendation 1: Establish a clear pipeline with sufficient volumes for offshore wind to attract OEMs to invest in new production facilities within Tamil Nadu.**

The size of the tendering volumes creates uncertainty for the potential manufacturers, deterring potential investors. To encourage investment in new production facilities, a clear pipeline with substantial and consistent tender volumes as well as an attractive awarded project pipeline must be established for the short and mid-term time horizon by the responsible authorities. This will provide OEMs with a reliable business case and the confidence to invest in and expand their operations.

Simplifying and making guarantees for the process will also reduce risk and encourage participation. This could be achieved by establishing clear guidelines, transparent timelines, and predictable procedures, making the process more accessible and less daunting for all stakeholders.

**Recommendation 2: Financial incentives for investors to accelerate the offshore wind supply chain in Tamil Nadu.**

High costs and bidding risks are major challenges. A combination of policies is needed to promote local large-scale production and offer incentives that lower the financial risks. An investment promotion strategy such as the PLIs the Government of India has implemented for other sectors should be adopted for the offshore wind manufacturing sector.

By offering competitive tariff rates and subsidies and thereby closing the viable funding gap, as already expressed by Tamil Nadu and Gujarat governments, the initial projects become more financially viable. A guaranteed offtake (e.g. through Power Purchase Agreements and at tariffs that are commensurate with offshore wind LCoE and the then prevailing Average Power Purchase Cost) together with government facilitation of grid connection and transmission infrastructure, will make the state an attractive location for offshore manufacturers and their supply chain partners, respecting and enhancing the industry's business cases. This approach addresses the financial risk concerns and lays the groundwork for a robust offshore wind sector.

Export credits and reduced import duties for raw materials as well as duty waivers for the offshore wind industry as is applicable to the offshore oil and gas industry, should be part of the strategy to secure that Tamil Nadu can offer competitive prices on exported goods. The transition from onshore to offshore wind production offers opportunities that are similar to India's success in exporting onshore wind components, including blades, nacelles and gearboxes. To capitalize on this, Tamil Nadu should build on the experience and make an industry strategy on how to stepwise remove the market barriers to encourage the manufacturers to expand their export markets.

**Recommendation 3: Government commitment through a clear institutional framework.**

There is a need for an institutional framework to link production services and clear offshore wind policies. This institution should define the roles, responsibilities, and milestones for stakeholders such as government agencies, regulatory bodies, and industry players to provide guidance and stability. By defining clear guidelines, regulations, responsibilities and processes, the government can ensure transparency, efficiency, accountability and help in setting industry standards and ensuring compliance, which will attract more businesses and investors to the sector.

**Recommendation 4: Guaranteeing publicly provided supporting infrastructure to create stable business conditions.**

It is crucial for Tamil Nadu to be a first mover in establishing necessary infrastructure, including port expansions, upland development and having grid connections and transmission infrastructure ready for electricity offtake. This infrastructure should be made available to offshore manufacturers and their supply chain partners in a way that is attractive and respectful of the industry's business cases.

For this to happen, there is an urgent need for governmental support in making the manufacturing sites available as soon as possible, and ready for the manufacturing enterprises to meet the demand from offshore wind developers. Active government participation in infrastructure investment, besides financial incentives and regulatory support, is essential to demonstrate commitment to the sector and encourage private sector investment.

**Recommendation 5: Clearly defined Local Content Requirements (LCR) which support local offshore wind development.**

LCRs are important for the development of local manufacturing supply chains for the green energy transition; however, if these policies are too aggressive, they lead to an increase in the cost of renewable energy, impede healthy competition which promotes innovation, and ultimately increase the investment risk profile for OEMs which can slow down the successful implementation of planned offshore wind developments. As such, India should take on a more flexible, non-prescriptive approach when outlining LCR requirements. The following is recommended:

- Tenders should not be leveraged as a tool to enforce unfeasible local content requirements. Instead, in emerging markets such as India, emphasis on bidders' ability to showcase the potential and/or action plan for assisting national priorities such as job creation and investments could be more attractive propositions.
- Agree on an initial, attractive LCR with the industry in due course and gradually increase this as the offshore wind industry matures and the local manufacturing supply chain reaches an appropriate scale; and
- Provide flexibility on LCR requirements for various components, core areas / services within the offshore wind supply chain.

Developers and policy makers should be amenable to the split of where these LCRs are provided, especially for early-stage projects. The above will send a positive message to industry which promote the development of offshore wind in India.

# Methodology

# 7 Methodology

The methodologies for this study include a data collection and mapping of the Tamil Nadu supply chain, scenarios analyses and a modelling of the investment impacts.

## 7.1 Supply chain analysis

To assess Tamil Nadu's key role in India's offshore wind supply chain development, the study included screening, extracting, and mapping existing data and reports relevant to the offshore wind manufacturing supply chain. Subsequently, interviews were conducted with six major manufacturers and one trade organization in Tamil Nadu. The qualitative and quantitative data collected were used to estimate the potential opportunity in the offshore wind manufacturing supply chain in both Tamil Nadu and India. Data encompassed the mapping of company names and industries, capacities in India and Tamil Nadu (presence, number of employees, annual turnover), and source dates and links. After mapping and analysing the companies, the identified data nodes were scored using a three-level system to categorize the data into direct quantitative indicators, strong indirect indicators, and weak indirect indicators.

## 7.2 Analytic scenarios

Three analytic scenarios are selected for the impact assessments, and production pathways from 2024 to 2040. The scenarios are based on stated governmental energy production and carbon emission targets, to estimate the consequential timeline for production levels and energy consumption towards 2040. Priority has been given to the use of local resources and production and are based on identified potential upsides and trade-offs for Tamil Nadu locally, as well as the outlook for India as a whole. To assess the export effects on the economy, separate sub-scenarios (the b-scenarios) have been established, to reflect the aggregated opportunities for Tamil Nadu to supply components and services to neighbouring countries in Sri Lanka, Bangladesh, and other relevant near markets in Southeast Asia, as well as global offshore wind markets such as Europe, USA and Australia.

## 7.3 Modelling the investment impacts

An investment model for analysing the social and economic impacts of offshore wind has been used to identify the impact of the investments in the supply chain on the economy, employment, trade balance and carbon emissions. COWI has used a national input/output model, based on national statistics of the Indian economy.

### A. Value Added

The economic effects of investments in the offshore wind supply chain are quantified for each of the three analytic scenarios. For a given investment, the impact model estimates direct and indirect effects. The direct effect is the increased activity, created by the investment itself. This will include tasks such as development, production, installation and construction work as well as operations and maintenance. The indirect effect stems from the increased procurement of goods and services from suppliers and spans into the Indian economy as a whole. The impacts are reported divided onto several relevant sectors.

The measures of the potential impacts of the domestic manufacturing content and associated supply chains are based on the data identified under the initial data screening of published analyses on local investments potentials in Tamil Nadu, as well as stakeholder interviews and desk research. As part of the work in initialising the model, the various assumptions to be established for the impact calculations were discussed with the GWEC team.

The investment effects of installing offshore wind and establishing a local supply chain in Tamil Nadu are calculated based on the overall components which go into the management, production, installation, operation and maintenance of offshore wind. The cost is based on 15 MW turbines (FIMOI, 2022). The component share of the total CAPEX is highlighted in Table 7-1 below. Note that the operations and maintenance (O&M) is in addition to the CAPEX, and that the shares therefore do not sum to 100%.

*Table 7-1: Investment share by component and phase*

| Component | Investment share |
|---|---|
| Development including surveys | 3% |
| Project execution | 3% |
| Foundation | 6% |
| Wind turbine | 45% |
| Array cables | 10% |
| Export cables onshore & offshore | 8% |
| Onshore windfarm substation | 3% |
| Offshore windfarm substation | 7% |
| Installation | 16% |
| Operations and Maintenance | 3% |

Other investments feeding into the impact estimation model include supporting infrastructure such as ports and transmission. The investment levels for support infrastructures have been identified by using key indicators from available reports (DEA, COWI, 2023; GWEC, 2023) and qualified through the held interviews.

The manufacturing and service provisions for the investments for each component of the supply chain is divided into relevant sectors, where the economic impact and employment are generated. These are primarily:

- *Construction* of manufacturing facilities and supporting infrastructure,
- *Manufacturing* of the components, such as metal structures and electrical equipment,
- *Water transport* and construction during the installation phase,
- Provision of *services* such as consultancy, engineering, technical testing etc.

The input/output model is supplied with the identified data on supply chain investments and the cost of operation divided into individual components of the supply chain. Due to the complexity of producing and installing offshore wind components, each component of the supply chain is linked to the main economic sectors based on COWI's former analyses and experience. For each component, assumptions are made based on the stakeholder engagement and literature on the achievable local content, meaning to which degree construction, manufacturing or services will be conducted by the supply chain and labour force of Tamil Nadu. Using the investments, the model captures and measures the effects into employment and value-added impacts on the Tamil Nadu and the Indian economy at the component and sector level. The model relies on Leontief multipliers, sector-specific production output, and annual employment data by economic activity. Data is sourced from the Asian Development Bank, World Bank, The Indian Department of Census and Statistics, as well as IEA.

The economic impact is calculated as value-added to GDP. Direct effects impact Tamil Nadu's economy, while indirect effects are broader impacts that affects the whole Indian economy. Employment effects are measured in full-time equivalents (FTEs) years, corresponding to one individual working full time for one year.

### B. Employment Effects

Translating the supply chain investments to FTEs is based on employment and input/output data of the entire Indian economy. For the offshore wind supply chain, the estimates are adjusted to reflect the productivity in the Indian high-tech sectors. This is assumed to be required by global investors operating in a highly competitive market. Hence, accurately estimating the number of jobs that can be created in India requires taking these investor demands into account.

When evaluating job creation in the offshore wind industry (e.g. FTE/MW), it is crucial to consider the contrasting contexts of Europe and India. An investment in an offshore wind farm may have the potential to create more jobs in India than in Europe. In the European context, productivity is influenced by well-established infrastructure, advanced technologies, and a high degree of automation. European countries benefit from economies of scale in the offshore wind industry, enabling efficient production processes and higher productivity levels. This, in turn, affects the number of jobs created.

In comparison, the Indian economy as a whole is influenced by a larger number of small-scale businesses, which may have different production dynamics. Access to advanced technologies and the level of automation might vary across different regions in India, potentially impacting productivity levels. As stated above, the estimates for the offshore wind supply chain are adjusted to reflect a higher productivity sector in India.

In comparison to other employment indicators in the literature, the estimates in this report are very specific, both to the Indian context as well as due to the methodology. The effects in this report are estimated based on different wind farm components, services and supporting infrastructure related to the supply chain, which can be a broader scope than other estimates reported in the literature.

### C. Trade Balance

The impact on the state trade balance is estimated based on import and export multipliers in the national input/output model, balanced with the forecast of the identified exports of components for the b- scenarios under scenarios 2 and 3. Note, that the effects on the trade balance only encompass the investments into the local supply chain. Effects from importing equipment for offshore wind projects are not considered.

## D. Climate Impact

The climate impact of investments is estimated as annual avoided $CO_2$ emissions by installing offshore wind instead of fossil energy sources (IEA, 2020). The IEA provides annual $CO_2$ displacement factors of 1.6 to 3.5 million tonnes $CO_2$ per GW installed offshore wind, depending on if it displaces natural gas or coal.

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