Confederation of Indian Industry

RENEWABLE ENERGY MANUFACTURING

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Summary

Wind Manufacturing Sector

Wind manufacturing sector examines the current state and challenges of India's wind turbine manufacturing sector, emphasizing the need to strengthen domestic manufacturing to support India's goal of reaching 100 GW of wind power capacity by 2030. It explains that wind turbines are mainly composed of three assemblies towers, blades, and nacelles with these and related components accounting for about 80% of the turbine's total cost. Structurally large components such as towers and blades, which together make up roughly 45% of the cost, are mostly produced domestically due to existing manufacturing capacity. However, critical nacelle components including gearboxes, generators, bearings, converters, castings, and forgings remain significantly dependent on imports, particularly from China.

Capacity Building of National Institute of Wind Energy (NIWE)

Wind equipment proposes strengthening institutional coordination, capacity building, and testing infrastructure to support India's long-term onshore and offshore wind energy goals. It recommends establishing a structured mechanism for regular engagement between NIWE, relevant ministries and agencies, regulators, and industry stakeholders to enable timely information exchange and early resolution of policy and implementation challenges. The paper also calls for a long-term capacity-building and institutional development plan for NIWE aligned with national wind and offshore roadmaps. Additionally, it proposes a phased upgrade of NIWE's testing and certification infrastructure to match evolving turbine technologies, support domestic R&D, and enhance India's global competitiveness.

Elevating India's Wind Turbine Exports for Global Markets (Aligned with Make in India for the World)

Elevating India's Wind Turbine Exports for Global Markets The white paper explains that India's wind energy sector is at a turning point where it can transition from mainly serving the domestic market to becoming a global export hub for wind turbines and components. India has rapidly expanded its wind turbine manufacturing capacity to about 20 GW per year, but 20-55% of this capacity remains underutilized, as domestic installations are expected to remain around 7-8 GW annually.

Facilitating Wind Repowering in India

Wind Repowering explains that India has a large opportunity to boost wind power generation by repowering old, sub-MW wind turbines installed in prime wind corridors with modern multi-MW machines. Repowering can deliver over 1.5 higher generations from the same land while improving grid and land-use efficiency. Although Ministry of New and Renewable Energy estimates about 25 GW of repowering potential, progress is slow due to turbine availability gaps, weak grid infrastructure, fragmented state policies, and financing challenges. The report recommends a National Repowering Mission, uniform repowering rules across states, and faster certification of high-turbulence turbines. It also stresses the need for grid upgrades and targeted financial incentives to make repowering bankable and scalable.

Solar Manufacturing

Solar Manufacturing proposes calibrated trade-remedial measures against dumping of key solar ancillary products, with strong anti-circumvention safeguards, alongside the development of cluster-based integrated solar manufacturing parks to lower costs and enable synergies. It recommends aligning the PLI scheme with export and domestic content objectives by prioritising advanced technologies, upstream integration, and restoring the full five-year incentive window. The paper also calls for a structured industry–regulator feedback mechanism to resolve regulatory bottlenecks, periodic reviews of trade barriers (including BCD) to balance protection and competitiveness, and a targeted export promotion strategy supported by trade diplomacy, simplified compliance, trade finance, and competitive project financing.

Balance of Materials

Balance of Materials proposes a dedicated policy framework for Solar Balance of Materials (BoM) aligned with ALMM/ALCM, DCR, and PLI schemes, with clear domestic content and value-addition targets. It recommends rationalising customs duties to remove inverted duty structures, especially for copper interconnects and busbars, and establishing a structured industry–regulator feedback mechanism to resolve regulatory bottlenecks. The paper also calls for periodic, consultative tariff reviews for BoM components, phased introduction of QCOs for critical items in line with domestic capacity and granting priority sector status to Solar BoM manufacturing to enable access to concessional, long-tenure finance.

1

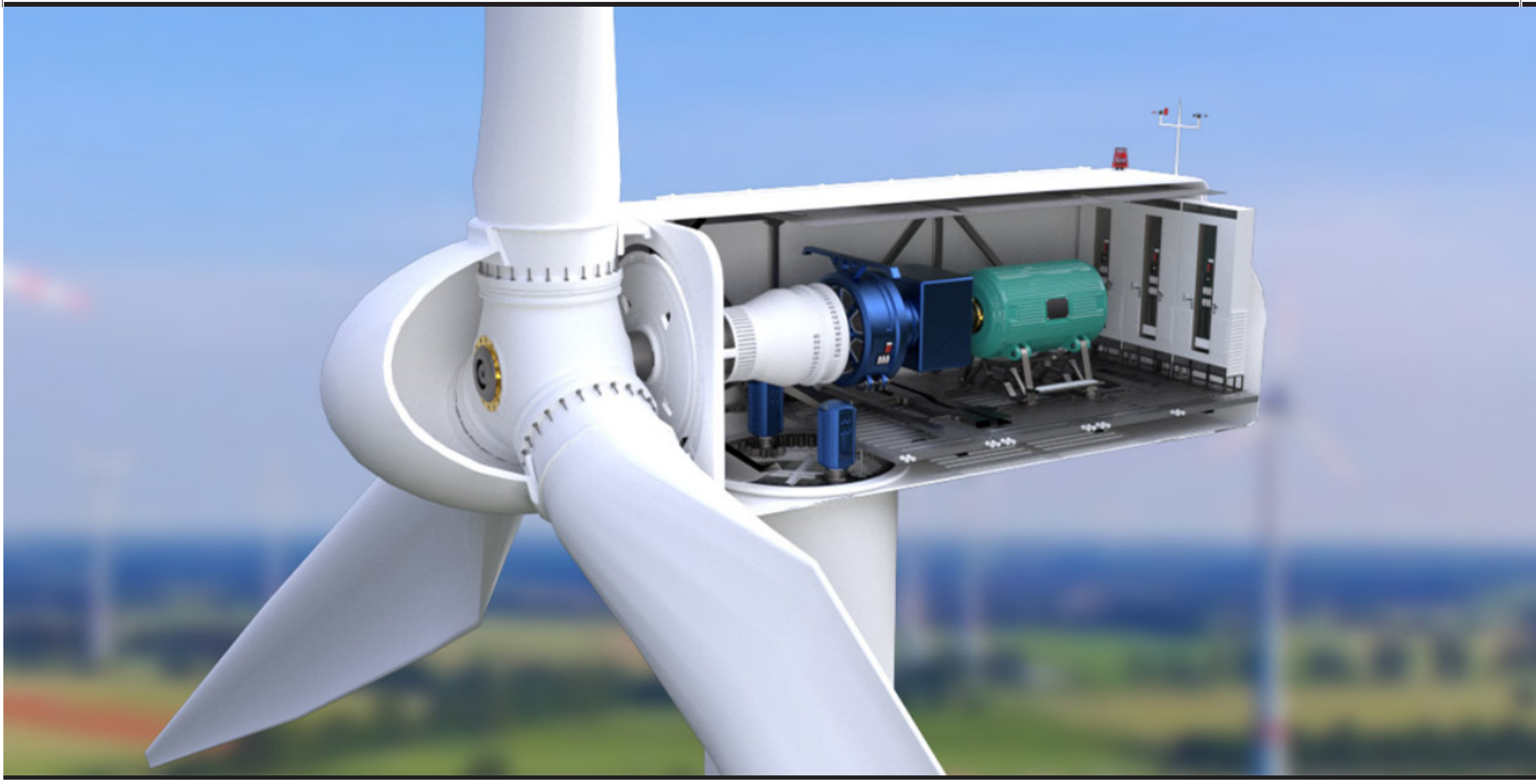
Wind Manufacturing Sector

Wind Manufacturing Sector

Background:

India's ambition to accelerate wind energy deployment and achieve 100 GW installations by 2030 rests heavily on strengthening its domestic manufacturing ecosystem. The wind supply chain is structured around three major assemblies, nacelle, tower, and blades, with associated components together accounting for 80% of turbine costs. Structurally heavy components such as towers and blades, which alone make up ~45% of turbine costs, are largely procured domestically, supported by established local capacity. However, nacelle internals that include gearboxes, generators, bearings, converters, castings, and forgings remain substantially import dependent.

While domestic manufacturing capacity exists across all critical components, except for large forgings where it is absent and special bearings where it is constrained, its utilization remains uneven. Combining installed turbine data with export figures indicates that in FY24, 20–50% of capacity remained underutilized, with some diverted to other industrial sectors.



The underutilization is driven by two key factors:

i. inherent cost disadvantages against imports and

ii. capability gaps in select critical components.

On the cost front, domestic manufacturing of components is typically 20–30% more expensive than Chinese imports. Stakeholder interactions reveal that this gap persists due to India's smaller demand base relative to China, limiting economies of scale, alongside restricted access to critical raw materials, capability gaps in high-precision manufacturing, and the lack of targeted financial incentives. Even after factoring in duties and logistics, landed imports remain around 10-15% cheaper than local sourcing. This component-level cost disadvantage reflects at the turbine level, where turbines with higher domestic content are priced at INR 3.8–5.2 crore per MW, compared to INR 3.6-4.3 crore per MW for import-reliant configurations, resulting in an overall cost differential of 5–20%.

On the capability front, India's wind manufacturing capacity is largely anchored in legacy 3-4 MW designs, leading to a mismatch with the global and domestic shift toward 4 MW+ platforms.

This cost gap can be narrowed by interventions across four themes:

- Scale Efficiencies
- Technology upgradation
- Structural component cost optimization
- Nacelle assembly cost reduction

Wind supply chain:

Wind energy supply chain is inherently complex and capital-intensive, requiring integration of a wide range of advanced components and systems. A wind turbine is structured around three major assemblies, tower, blade, and nacelle, along with miscellaneous components that support overall operation.

Towers and blades are structurally large components which, through their size, influences the energy capture. Together, they contribute nearly 45 % of the total turbine cost. The nacelle serves as the central hub of the turbine, housing high-value mechanical and electrical systems. Key components include gearbox, generator, special bearings, power electronics, large castings, and large forgings. These six components represent the technological backbone of the supply chain and account for 35% of the turbine cost. The miscellaneous category comprises motor and brakes for yaw and pitch systems, mechanical brake, transformer, nacelle assembly, cables, sensors, and other ancillary equipment. While essential for smooth operation, these components together account for remaining 20% of the total turbine cost.

Achieving cost-effective and resilient domestic manufacturing therefore depends on the localization of eight critical components including tower, blade, and nacelle assemblies, These Eight critical components drive 80% of wind turbine cost, making them central to assessing India's wind supply chain.

Procurement landscape

While structurally heavy components are sourced domestically, critical nacelle components remain partially import-dependent.

Based on the procurement analysis of eight critical wind turbine components show a clear divide between structurally heavy components and nacelle internals. Towers and blades are primarily sourced domestically, supported by established manufacturing capabilities and minimal import reliance. In contrast, nacelle internals remain partially dependent on imports.

In FY25, around 60 percent of demand for gearboxes, castings, and power electronics was met through imports, while generators relied on imports for about 40 percent of requirements. Bearings and forgings are entirely imported at this stage, with 90 percent and 100 percent dependence respectively.

Drivers of import dependence

India's wind manufacturing base is sizeable, with 10–30 GW capacity across components, yet 20–50% remains underutilized.

India today has a sizeable wind manufacturing base, with an estimated 10–30 GW of annual capacity across towers, blades, nacelles, gearboxes, generators, and other key components. This ecosystem, supported by both domestic and global OEMs, is theoretically capable of serving India's installation targets and even contributing to exports. Despite steady domestic demand of 4-5 GW for WTGs & expected to increase to 8-10 GW by 2030, the actual offtake across components has not been sufficient to fully absorb available manufacturing potential.

Notably, there are two exceptions where capacity itself is a binding constraint: special bearings and large forgings. While main bearing manufacturing is well established in India, as their large size and high logistics costs make domestic production the preferred option for OEMs, manufacturing of pitch and yaw bearings is only a recent development and remains limited. On the forging side, India lacks dedicated facilities for large open-die forgings required to produce main shafts for turbines above 2.5 MW. The small capacity that does exist is commercially unviable due to unfavourable unit economics and uncertain demand, which has deterred further investment.

Thus, while India has built a robust assembly and component manufacturing ecosystem, much of it remains underutilized. Two factors drive this: (i) inherent cost disadvantages against imports and (ii) capability gaps in select critical components.

Cost differential

A closer comparison of component costs reveals a clear differential between domestically manufactured components and their imported counterparts. This comparison was drawn using trade price data for imports from China and exports from India, adjusted for manufacturer margins, duties, and logistics, and further validated through discussions with OEMs and suppliers. Chinese component prices often reflect export-linked incentives and aggressive pricing strategies, which inherently influence the observed cost gap.

At the landed cost stage, import prices increase with duties, taxes, and logistics, which narrows but does not fully offset the gap. The residual landed cost differential largely stems from India's continued dependence on imported raw materials, higher financing costs, and fragmented domestic supplier networks, all of which add to the manufacturing premium of locally assembled components.

Recommendations:

Addressing the existing cost differential of 5–20% is critical to reducing import reliance and unlocking the potential of India's underutilized manufacturing base. While cost competitiveness is the primary driver, capability-linked capacity upgrades are also essential to ensure domestic production aligns with higher-rated turbine platforms and next-generation WTG designs. Thus, the interventions to bridge these gaps are organized across four themes, spanning across the turbine and component levels

WTG-Level Enablers:

Theme A: Scale efficiencies – Doubling of annual installation scale to 8–10 GW will unlock economies of scale, improve utilization of manufacturing capacity, and lower overhead costs, thereby reducing the overall cost of turbines.

Theme B: Technology upgradation – Transition to higher-rated turbine platforms facilitates greater efficiencies through improved energy yields and optimized designs. Higher capacity turbines reduce CAPEX per MW and are supported by targeted R&D interventions.

Component-Level Levers

Theme C: Structural component cost optimization – Contribute around 45% of turbine costs, mainly towers and blades, are already procured domestically. The opportunity lies in further driving down costs through better material cost efficiency.

Theme D: Nacelle assembly cost reduction - Contributing around 35% of total WTG costs, nacelle internals remain significantly import-dependent due to a 10-30% cost differential with global suppliers. Achieving cost parity requires a calibrated duty realignment aligned with domestic manufacturing maturity, complemented by targeted incentives to strengthen local manufacturing, particularly in castings and forgings, which together account for nearly 60% of nacelle internal costs.

Collectively, these four intervention themes can narrow the cost differential by 15-18%, leaving a modest residual gap of up to 7%.

Bridging this cost gap is essential for India to build a globally competitive wind manufacturing base and achieve its 100 GW target. Timely interventions and coordinated investments will determine whether India emerges as a cost-efficient hub or remains import dependent

As discussed above, existing 5-20% cost differential can be bridged through interventions across four themes: scale efficiencies, technological upgrades, structural component cost optimization and nacelle assembly cost reduction. These interventions, supported by targeted budget allocations, focus on enabling scale execution, driving technology upgradation, aligning duty structures to boost domestic sourcing and supply chain depth, and supporting manufacturing CAPEX reimbursement schemes. The following Table summarizes the proposed measures across turbine-level and component-level themes, along with their expected impact on cost reduction.

Table: Summary of proposed interventions and cost reductions

Theme	Intervention			Impact	
		Description	Level	Description	Cost Differential Reduction
Natural Trajectory					
A. Scale Efficiencies	A1	Doubling of scale from 5 GW to 10 GW	WTG	Reduces per-MW Cost through overheads reduction and improves economics through higher scale	8%
Proposed Trajectory					
B. Tech-nological Upgradation	B1	R&D grants and 150% tax holiday for drivetrains and blade testing facility	WTG	Facilitate shift to higher rated turbines by shortening development cycles, improves product reliability and long-term cost reduction	4%
	B2	Upgrading testing and certification ecosystem	WTG	Ensures certification standards are aligned with India-specific operating conditions while building local testing and validation capacity	

Theme	Intervention			Impact	
		Description	Level	Description	Cost Differential Reduction
C. Structural Component Cost Reduction	C1	Duty Structure Revision (Tower and Blade)	Component	Lowers raw material cost for domestic manufacturers, narrowing the net cost gap	2%
D. Nacelle Assembly Cost Reduction	D1	Duty Structure Revision (Nacelle Components)	Component	Disincentivizes imports of finished nacelle components and subcomponents	2%
	D2	CAPEX upgradation grant	Component	Enable capacity upgrades in casting and forging, decoupled from demand uncertainty	1%
	D3	5% interest subvention on working capital cost	Component	Lowers effective financing cost across working capital requirement	0.2%
	D4	BIS guidelines adjustment	Component	Prevents a 25–30% forging raw-material cost jump from forced sourcing in Europe	-

The proposed interventions across four areas will require an overall investment of INR 2,650 crore, split into INR 2250 Cr as a one-time cost and INR 400 Cr in a phased manner until FY2030.

2

Capacity Building of National Institute of Wind Energy (NIWE)

Capacity Building of National Institute of Wind Energy (NIWE)

The demand for wind turbines in India is underpinned by a robust and expanding market, driven by ambitious national energy transition goals. The Government of India has set a target of achieving 500 GW of non-fossil fuel-based energy capacity by 2030, with wind power being a cornerstone of this strategy. The total installed wind power capacity in the country currently stands at approximately 53.9 GW, with annual capacity additions fluctuating in the range of 4 to 5 GW in recent years. The projected demand to meet the 2030 targets necessitates a significant acceleration in annual installations, creating a substantial and sustained order pipeline for wind equipment manufacturers.

National Institute of Wind Energy (NIWE) is a key Indian institution supporting the wind sector to meet the 2030 targets primarily by providing resource assessment, testing and certification, research and development, and human resource development. NIWE is an autonomous research and development institution under the Ministry of New and Renewable Energy (MNRE), Government of India.

Industry stakeholders increasingly expect NIWE to function as the central technical authority for wind energy, providing guidance on standards, testing, certification, and best practices.

The total installed wind power capacity in the country currently stands at approximately **53.9 GW**, with annual capacity additions fluctuating in the range of **4 to 5 GW** in recent years.

Stakeholder feedback from wind equipment manufacturers highlights the need for NIWE to be more proactive, to attract and retain professionals with advanced and contemporary skillsets, to develop and operate prototype testing facilities, and to prepare technical standards and guidelines that can be followed by all original equipment manufacturers (OEMs) and other sector participants.

NIWE was established in 1989 to serve as the technical focal point for wind energy development in the country. The key divisions at NIWE are as follows: (a) Research and Development (R&D), (b) Certification and Information Technology, (c) Testing and Standards & Regulation, (d) Skill Development & Training, and (e) Wind Resource Assessment. NIWE also has a Wind Turbine Test Station (WTTS) situated at Katyahar which is supported by DANIDA, government of Denmark . These activities provide a strong foundation, but the pace of technology evolution, growing project sizes, and increasing expectations regarding quality, reliability, grid integration, and safety point to the need for significant capacity enhancement.

A structured capacity building initiative is therefore required to enable NIWE to effectively serve as the technical voice for the Indian wind sector and to support policymakers, regulators, utilities, project developers, OEMs, financial institutions, and state nodal agencies.

Key challenges and possible solutions to support capacity building initiatives for NIWE

1. Limited institutional mandate for proactive sector leadership

NIWE was established as the national nodal agency for wind energy under the MNRE, with a primary focus on resource assessment, testing, certification, and research and development. Over time, the wind sector has evolved rapidly, with larger turbine ratings, complex grid integration requirements, hybrid projects, repowering, offshore wind, and increasing expectations from industry and states. However, NIWE's present mandate, internal processes, and resource allocation are largely aligned with a traditional role of a technical support institution, rather than that of an agile, proactive sector leader and "technical voice" for wind energy in India. This has resulted in the following challenges:

- Limited institutional mechanisms for regular, structured engagement with industry, state agencies, power system operators, and academia on emerging technical and regulatory issues.
- Absence of a formal mechanism for NIWE to issue technical advisories or guidance notes that are systematically adopted across central and state agencies, grid operators, and financial institutions.
- Fragmentation of technical responsibilities across multiple entities (for example, BIS for standards, CEA for grid codes, state agencies for approvals) leads to gaps and overlaps. NIWE's role as a central technical reference body for wind is not uniformly recognized/ operationalized.
- Slow response to new technology trends (such as very large rotor diameters, modular blades, digital monitoring systems, new control technologies, and offshore wind). Offshore wind-related capabilities are in nascent stages despite imminent project development timelines.

Comparable institutions such as the National Renewable Energy Laboratory (NREL) in the United States, the Technical University of Denmark (DTU) Wind Energy Department, and the Fraunhofer Institute for Wind Energy Systems (IWES) in Germany, maintain dedicated technology foresight functions and proactive industry engagement mechanisms. The illustrative solutions for the above challenges are as follows:

- Revision and formal notification of NIWE's mandate by MNRE to clearly recognize NIWE as the central technical authority for wind energy, with responsibilities covering standards and guidelines, prototype testing, technical due diligence, and advisory support for onshore, offshore, hybrid, and repowering projects.
- Allocation of dedicated budgetary support and performance-linked targets for proactive technical studies, scenario analyses, position papers, and technology briefs to inform policy and regulatory decisions.
- Creation of formal consultative platforms under NIWE (for example, standing technical committees and industry advisory councils) covering turbine technology, grid integration, standards and certification, offshore wind, repowering, and digitalisation.
- Structured coordination mechanisms between NIWE, MNRE, CEA, GRID-India, state nodal agencies, and SERCs for regular technical inputs on regulations, codes, and guidelines.
- Establishment of a national wind knowledge portal managed by NIWE, providing authoritative technical information, model guidelines, and updates on standards and best practices.

2. Professionals with specialized skillsets are required to lead NIWE efforts

Rapid technological advancements in wind turbine design and project development require highly specialized expertise in aerodynamics, structural dynamics, materials science, power electronics, control systems, condition monitoring, digital twins, offshore engineering, and grid integration. The need for professionals with specialized skillsets is described as follows:

- Increasing rotor diameters and higher hub heights demand advanced knowledge of aerodynamic load modelling, wake effects, and turbulence intensity to optimize annual energy production while maintaining structural safety.
- Complex structural configurations such as taller tubular towers, hybrid (concrete–steel) towers, and larger foundations require specialized competence in fatigue analysis, vibration control, and life-cycle structural reliability assessment.
- The use of new materials, including high-performance composites for blades, advanced steels for towers, and improved grouting and concreting solutions for foundations, necessitates expertise in material selection, failure mechanisms, recyclability, and compliance with Indian and international standards.
- Sophisticated power electronics (PE) systems in modern wind turbines, including full converters and doubly fed induction generators, require specialized skills in PE converter design, harmonic mitigation, fault ride-through capability, and compliance with Central Electricity Authority (CEA) and Central Electricity Regulatory Commission (CERC) grid code requirements.
- Condition monitoring and predictive maintenance systems based on vibration analysis, oil analysis, thermal imaging, and advanced data analytics require professionals skilled in sensor technology, signal processing, machine learning, and interpretation of health indicators for critical components such as gearboxes, bearings, generators, and blades.

Rapid technological advancements in wind turbine design and project development require highly specialized expertise in aerodynamics, structural dynamics, materials science, power electronics, control systems, condition monitoring, digital twins, offshore engineering, and grid integration.

- Offshore and near-offshore wind development, as promoted under Government of India initiatives for offshore wind in identified zones off Gujarat and Tamil Nadu, requires specialized offshore engineering skills in met-ocean assessment, geotechnical investigation, foundation and substructure design, marine operations, corrosion protection, and health, safety, and environment (HSE) management in offshore conditions.
- System-level planning for hybrid projects and wind–solar–storage configurations, guided by central policies on hybrid and energy storage, necessitates specialized skills in techno-economic optimisation, energy storage, power flow management, and compliance with relevant regulatory and market mechanisms.
- Integration of advanced forecasting tools for wind generation, mandated for scheduling and deviation settlement under CERC and State Electricity Regulatory Commission regulations, requires expertise in numerical weather prediction models, statistical post-processing, and continuous performance evaluation.
- Environmental and social impact assessment for large wind projects, particularly in ecologically sensitive and coastal areas, requires professionals skilled in regulatory compliance, biodiversity assessments, noise and shadow flicker analysis, stakeholder consultation, and preparation of mitigation and management plans.
- Financial structuring and risk assessment for wind projects, in line with evolving central policies, competitive bidding guidelines, and green finance frameworks, demand specialized expertise in tariff modelling, bankability assessment, contract structuring, and evaluation of policy and regulatory risks.
- Development of skilled manpower at technician, supervisory, and managerial levels, aligned with national skilling initiatives for the renewable energy sector, requires dedicated training professionals for curriculum design, training delivery, certification, and continuous upskilling in line with emerging technologies and safety standards.
- Specialized expertise is required to address vulnerabilities in Supervisory Control and Data Acquisition (SCADA) systems and to guide Original Equipment Manufacturers (OEM) to ensure that data collection servers and software updates comply with the cybersecurity protocols.

The illustrative solutions to meet the above requirements for specialized professionals are as follows:

- Formulation of a long-term capacity building plan for NIWE, aligned with national wind deployment targets, offshore wind plans, and the evolving technology landscape.
- Introduction of flexible recruitment policies approved by MNRE and relevant ministries to enable lateral hiring of domain experts from industry, research organizations, and universities at competitive remuneration.
- Creation of specialized technical positions and centers within NIWE (e.g., Blade Technology Centre, Power Electronics and Control Centre, Offshore Technology Cell, Digital and Data Analytics Unit) with clearly defined skill requirements and career progression pathways.

- Systematic partnerships with IITs, NITs, IISc, CSIR laboratories, and leading global wind research institutions for joint research, staff exchanges, visiting scientist posts, and co-supervised doctoral work.
- Establishment of mandatory continuing education programmes, including certification courses, online training, and participation in international standards committees (IEC, IEA Wind, etc.), supported by dedicated training budgets.
- Creation of a structured international exposure programme enabling NIWE professionals to work with global testing laboratories, certification bodies, and research institutions through short-term attachments and exchanges.

3. Need for prototype testing and certification infrastructure

The growth of domestic wind turbine manufacturing and the increasing size and complexity of turbines have created the need for comprehensive prototype testing, component-level testing, and type certification services within India. The key challenges are as follows:

- Limited capacity for full-scale prototype testing of new turbine models, especially high-capacity machines (3 MW and above), hybrid configurations, and turbines designed for low wind regimes.
- Insufficient specialized testing infrastructure for blades, gearboxes, generators, power converters, control systems, and nacelle components that meets current international standards.
- Constraints in test bench availability, instrumentation, data acquisition systems, and environmental simulation capabilities for accelerated life testing and extreme condition assessments.
- Dependence on foreign testing and certification bodies for certain high-end tests and type certifications, resulting in higher costs, longer timelines, and reduced strategic autonomy.
- Limited support for early-stage prototype testing and validation by start-ups, MSMEs, and research institutions working on innovative technologies, including small wind and distributed applications.

The illustrative solutions for the above challenges are as follows:

- Preparation of a phased national plan for augmenting NIWE's testing infrastructure, aligned with projected turbine size trends, offshore wind development timelines, and domestic R&D needs.
- Establishment of state-of-the-art prototype test facilities at NIWE, including large-scale blade test rigs, drivetrain and gearbox test benches, power electronics and converter test labs, and integrated nacelle test facilities designed to accommodate next-generation turbine sizes.
- Creation of dedicated facilities for environmental and accelerated testing (corrosion, fatigue, temperature, humidity, and vibration) to simulate Indian site conditions including coastal, high-humidity, dusty, and high-temperature environments.
- Development of dedicated support schemes under MNRE for subsidized access to NIWE test facilities by domestic manufacturers, start-ups, and academic institutions, especially for early-stage technology validation.
- Integration of prototype testing facilities with digital data platforms that allow secure sharing of anonymized test results, performance benchmarks, and reliability statistics to support wider sector learning.

Illustrative timeline for implementation of solutions

The above challenges need to be addressed in timely manner for supporting the capacity building initiatives for NIWE. The key solutions are categorized by (a) solutions that need to implement immediately, (b) solutions that should be implemented within medium term (2~3 years), and (c) solutions that should be implemented within long term (5~10 years). The illustrative timeline for implementing such solutions is given in the table below:

SN	Timeline	Solutions block
1	Immediate (0~ 1 year)	• Revision and formal notification of NIWE's mandate by MNRE to clearly recognize NIWE as the central technical authority for wind energy, with responsibilities covering standards and guidelines, prototype testing, technical due diligence, and advisory support for onshore, offshore, hybrid, and repowering projects. • Allocation of dedicated budgetary support and performance-linked targets for proactive technical studies, scenario analyses, position papers, and technology briefs to inform policy and regulatory decisions • Structured coordination mechanisms between NIWE, MNRE, CEA, GRID-India, state nodal agencies, and SERCs for regular technical inputs on regulations, codes, and guidelines. • Creation of specialized technical positions and centers within NIWE (e.g., Blade Technology Centre, Power Electronics and Control Centre, Offshore Technology Cell, Digital and Data Analytics Unit) with clearly defined skill requirements and career progression pathways. • Systematic partnerships with IITs, NITs, IISc, CSIR laboratories, and leading global wind research institutions for joint research, staff exchanges, visiting scientist posts, and co-supervised doctoral work.

SN	Timeline	Solutions block
2	Medium Term (2~ 3 year)	• Creation of formal consultative platforms under NIWE (for example, standing technical committees and industry advisory councils) covering turbine technology, grid integration, standards and certification, offshore wind, repowering, and digitalisation. • Establishment of a national wind knowledge portal managed by NIWE, providing authoritative technical information, model guidelines, and updates on standards and best practices • Establishment of mandatory continuing education programmes, including certification courses, online training, and participation in international standards committees (IEC, IEA Wind, etc.), supported by dedicated training budgets. • Creation of a structured international exposure programme enabling NIWE professionals to work with global testing laboratories, certification bodies, and research institutions through short-term attachments and exchanges • Creation of dedicated facilities for environmental and accelerated testing (corrosion, fatigue, temperature, humidity, and vibration) to simulate Indian site conditions including coastal, high-humidity, dusty, and high-temperature environments.
3	Long Term (5 ~ 10 year)	• Establishment of state-of-the-art prototype test facilities at NIWE, including large-scale blade test rigs, drivetrain and gearbox test benches, power electronics and converter test labs, and integrated nacelle test facilities designed to accommodate next-generation turbine sizes. • Development of dedicated support schemes under MNRE for subsidized access to NIWE test facilities by domestic manufacturers, start-ups, and academic institutions, especially for early-stage technology validation. • Integration of prototype testing facilities with digital data platforms that allow secure sharing of anonymized test results, performance benchmarks, and reliability statistics to support wider sector learning.

Proposed actions:

- Propose structured mechanisms for interactions between NIWE, key industry stakeholders (OEMs, EPCs, O&M service providers, financial instructions, investors) and government ministries/ departments (MNRE, CEA, GRID-India, state nodal agencies, and SERCs). The structured mechanism would enable regular interactions between industry, government agencies, and research institute and help the relevant stakeholders keep posted with latest developments in technology, financial mechanisms, policies, and regulations. The regular interactions would also help in understanding challenges faced by stakeholders and help resolve challenges in a manner that is suitable for ensuring sustainable wind sector development in India.
- Propose long-term capacity building development plan for NIWE, aligned with national wind deployment targets, offshore wind plans, and the evolving technology landscape
- Recommend a phased national plan for augmenting NIWE's testing infrastructure, aligned with projected turbine size trends, offshore wind development timelines, and domestic R&D needs.

3

Elevating India's Wind Turbine Exports for Global Markets (Aligned with Make in India for the World)

Elevating India's Wind Turbine Exports for Global Markets (Aligned with Make in India for the World)

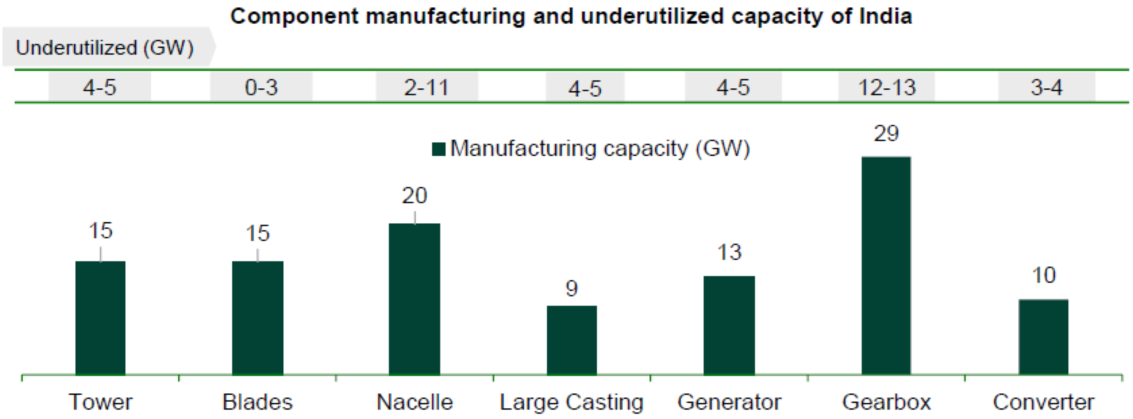
With **20–55%** underutilization across key components and domestic installations projected at **~7–8 GW** annually over the medium term, exports must become a core growth engine rather than a peripheral opportunity-oriented.

India's wind energy sector stands at a strategic inflection point, transitioning from a domestic oriented market to a globally relevant manufacturing and export hub. Over the last three years, India has rapidly expanded its wind turbine generator (WTG) manufacturing capacity to ~20 GW per annum, while simultaneously building deep capabilities across the component value chain.

With 20–55% underutilization across key components and domestic installations projected at ~7–8 GW annually over the medium term, exports must become a core growth engine rather than a peripheral opportunity-oriented. Annual global wind installations are projected to rise steadily to ~160 GW by 2030. Meanwhile, global supply chains are being reconfigured as developers and OEMs diversify manufacturing footprints beyond China, strengthening the opportunity for India to position itself as a cost competitive and scalable export base for wind turbines and components.

Key Enablers

India currently has 20–55% unutilized manufacturing capacity across key wind turbine components, including towers, blades, nacelles, large castings, generators, gearboxes, and converters. This indicates that India possesses adequate manufacturing capacity to meet domestic demand while also being well positioned to expand its role as a competitive exporter in the global wind energy market.



Source: GWEC India outlook 2025

India is well positioned to emerge as a global export hub for wind turbine generators (WTGs) and components due to a confluence of structural, policy, and market-driven factors. Key reasons are outlined below.

A. Strong and Underutilized Manufacturing Base

India has developed a comprehensive domestic manufacturing ecosystem across major WTG components including blades, towers, gearboxes, generators, castings, and converters with 20–55% surplus capacity. This underutilization provides immediate headroom to scale exports without significant incremental capital investment, enabling competitive pricing and faster delivery timelines.

B. Cost Competitiveness and Scale Advantages

Lower labour and operating costs, improving manufacturing efficiencies, and large-scale production facilities allow Indian manufacturers to offer cost-effective solutions compared to European peers facing higher energy and labour costs. This cost advantage is particularly attractive for price-sensitive emerging markets and for global OEMs seeking to optimize supply chains.

C. Policy-Driven Manufacturing Depth

Government initiatives such as the ALMM framework for wind and proposed local content requirements have strengthened domestic supply chains and encouraged technology localization. These policies have improved quality, reliability, and depth of manufacturing, creating export-ready capabilities aligned with global standards.

D. Strategic "China+1" Supply Chain Positioning

As global markets seek to diversify supply chains away from overdependence on China, India is increasingly viewed as a credible alternative. Its geopolitical stability, large industrial base, and growing trade linkages position it favourably as a "China+1" manufacturing destination for global wind OEMs.

E. Proximity to High-Growth Wind Markets

India's geographic location provides logistical advantages for supplying fast-growing wind markets in Southeast Asia, the Middle East, Africa, and Australia, while also serving European markets facing domestic capacity constraints. This enhances India's role as a regional and intercontinental export hub.

F. Expanding Technology and Quality Capabilities

Indian manufacturers are steadily moving up the value chain, supported by technology partnerships, global certifications, and increasing compliance with ESG and bankability requirements. This enhances acceptance of Indian-made WTGs and components in international markets.

With surplus capacity, competitive costs, strong policy backing, and shifting global supply-chain preferences, India is structurally positioned to evolve from a large domestic wind market into a globally significant export hub for wind turbines and components. The opportunity lies in converting manufacturing depth into sustained export-led growth through targeted market access and global partnerships.

Positioning India as a global export hub:

Positioning India as a global export hub drives multiple strategic, economic, and sectoral benefits for the wind energy ecosystem. Key drivers and outcomes include:

A. Export-led growth and capacity utilization:

Enables absorption of surplus WTG and component manufacturing capacity, improving plant utilization, operating leverage, and return on capital for OEMs and suppliers.

B. Global supply-chain diversification:

Strengthens India's role as a "China+1" manufacturing destination, offering global OEMs and developers a reliable, geopolitically stable alternative sourcing base.

C. Cost competitiveness and price stability:

Leverages India's structural cost advantages to supply price-competitive turbines and components to cost-sensitive emerging markets and supply-constrained mature markets.

D. Industrial and employment growth:

Scaling Wind installations to ~8 GW could create around 153,000 jobs, while achieving ~15 GW per year has the potential to generate nearly 307,000 jobs annually highlighting the strong employment multiplier of wind sector (source: GWEC 2025)

E. Technology upgradation and value-chain advancement:

Encourages technology transfers, global partnerships, and movement up the value chain from component manufacturing to system integration, services, and O&M.

F. Foreign exchange earnings and trade balance improvement:

India's wind sector is increasingly emerging as a global export hub for blades, nacelles, and gearboxes, serving markets in Europe, the United States, and the Asia-Pacific. This momentum is reinforced by strong investor confidence, with foreign direct investment (FDI) inflows into the renewable energy sector exceeding USD 6.1 billion (source: MEA)

G. Long-term sector resilience:

Reduces dependence on cyclical domestic tender volumes by diversifying demand sources, enhancing the long-term stability of India's wind manufacturing ecosystem.

Global OEM Landscape: A Market Defined by Scale and State Support

The global wind turbine market has undergone a decisive shift over the past five years. Chinese manufacturers now dominate global installations, driven by a combination of massive domestic demand, state backed financing, vertically integrated supply chains, and accelerated innovation cycles. The top Chinese OEMs collectively account for a substantial share of global installed capacity, reshaping competitive dynamics worldwide.

Key structural signal: the global market is no longer technology led alone; it is scale, finance, and ecosystem driven. OEM competitiveness increasingly hinges on the ability to bundle turbines with financing, EPC, logistics, and long term service not just equipment supply.

India's Relative Position: Cost Competitive, but Strategically Constrained

Indian wind turbine manufacturers occupy a narrow but real competitive window. Turbine prices from India are meaningfully lower than those from the United States and Europe, and only moderately higher than Chinese offerings. This positions India as a credible mid cost alternative for markets seeking diversification without compromising baseline quality. However, this advantage remains fragile and context dependent.

- China Vs India
- Europe/US: materially higher than Indian benchmarks

Implication: India is cost competitive against the West but structurally disadvantaged versus China, particularly in price sensitive emerging markets where financing and delivery certainty outweigh marginal quality differentiation.

Key Barriers for India OEMs

- Cost competition
- R&D
- Financial Support

India's path to becoming a global wind export hub will be shaped less by manufacturing capacity and more by its ability to overcome non-manufacturing constraints. Cost competitiveness provides a necessary foundation, but global success depends on closing gaps in technology scale up, international financing, and after sales credibility. The opportunity exists but it is

conditional, selective, and execution intensive, requiring focused strategic interventions rather than broad based export aspirations.

Strategies for Price Competitiveness

Price competitiveness is the primary gating factor for India's wind turbine and component exports. Winning export tenders increasingly depends on total landed cost factory gate price plus taxes, logistics, financing, working capital intensity, and supply chain reliability.

Price Competitiveness Is a Policy Outcome, Not Just an OEM Outcome

Wind manufacturing is capital intensive and exposed to embedded taxes and cash flow frictions particularly GST on civil works, non creditable services, constraints in capital goods credit refunds, and delayed GST refunds. These factors raise effective costs and reduce bid flexibility in international tenders.

Central Policy Support: Strong Signals, Uneven Translation to Export Economics

Onshore wind lacks comparable central manufacturing/export incentives, weakening demand visibility and constraining export dedicated scaling decisions.

Financing: The Decisive Lever in Export Win Rates (Often More Than Price)

Export success is frequently determined by access to long tenor buyer side finance and guarantees. India's enabling instruments support execution but do not substitute for a dedicated wind export finance facility that offers buyers' credit, long tenor project finance, and (where required) local currency options.

Table: Policy and finance levers—what reduces landed cost vs. what increases win rate

Lever	Mechanism (illustrative)	Primary effect
Export-linked manufacturing incentive	Incentive tied to export output / FOB value	Lowers factory-gate cost. Improves bid price
Wind export finance facility	Buyers' credit; long-tenor project finance	Makes projects bankable. Improves win-rate
Project Development Fund (PDF)	Catalytic early-stage capital and deliver an integrated "India Inc." wind export package	Catalytic funding enabling scalable, competitive Indian wind exports
Cash-flow support	Faster GST refunds; embedded-tax relief	Improves liquidity. Improves pricing flexibility
Market development	Demonstrations + certification support	Reduces buyer risk premium. Supports acceptance
Supply-chain support	Supplier parks near ports; input/power support	Lowers structural costs. Stabilises competitiveness
ECA-Backed Payment Deferral Facility	100% sovereign guarantee on export receivables; allowing Indian OEMs to offer deferred payment terms	Enables Indian OEMs to offer deferred payments and significantly boost global wind-tender competitiveness.

Recommendations:

While India has built a strong wind manufacturing base and a track record of demand side deployment support, its current policy framework does not adequately address the needs of export-oriented wind turbine manufacturing. Global leaders in wind exports such as Denmark, Germany, China, and the United States have complemented domestic deployment with targeted production incentives, export linked financing, and buyer side risk mitigation mechanisms to actively create and sustain overseas demand for domestically manufactured turbines and components. In contrast, Indian wind OEMs continue to face higher factory gate costs, limited access to long tenor export finance, and constrained ability to compete in emerging and frontier markets where concessional financing is often decisive.

To bridge these gaps and convert India's manufacturing capabilities into a durable export advantage, a focused package of export linked fiscal, financial, and market development measures is required. Such interventions would improve cost competitiveness, unlock scale, reduce market entry risks, and position India as a reliable long-term supplier in the global wind turbine value chain.

Recommendation 1: Establishment of an Export Linked Wind Manufacturing Incentive (ELWMI)

India currently lacks a manufacturing side incentive linked explicitly to wind exports, unlike solar or global peers such as Denmark and China. Wind turbine exports are highly price sensitive,

even marginal cost disadvantages at the factory gate can decisively affect international tenders. Introduction of a centrally administered export linked fiscal incentive for wind turbine and component manufacturers would directly offset higher input, logistics, and compliance costs faced by Indian OEMs in overseas markets. The incentives may be structured as Production linked incentive for exports (₹/MW or % of FOB export value) for 5 – 7 years, or Turnover linked incentive for 5 – 7 years applicable only to exports outside India.

This incentive will be available for Indian wind turbine OEMs and component manufacturers (blades, towers, nacelles, drivetrains, key sub systems). This will be eligible only for exports outside India, ensuring the incentive drives global market expansion. Both large OEMs and export-oriented Tier 1 suppliers will be benefited from this incentive.

Expected outcomes:

a) Lowers effective manufacturing costs for exported turbines and components.

b) Improves bid competitiveness in international tenders, particularly in emerging markets.

c) Encourages OEMs to scale export dedicated production lines and invest in advanced turbine platforms.

d) Creates predictable export volumes, supporting employment and localization depth.

Recommendation 2: Creating an Indian Wind Export Finance Facility (IWEFF)

Competing wind exporting countries routinely provide long tenor, concessional buyer side financing, which in many wind project tenders is more decisive than turbine price alone.

Indian OEMs, however, lack systematic access to buyer's credit, long term non-recourse project finance, and local currency lending mechanisms for exports. In the absence of such financing support, Indian firms are largely confined to self-financed transactions or a narrow set of markets with readily available commercial funding, limiting their ability to scale and compete globally.

To address this, a dedicated wind export financing window may be created under EXIM Bank of India, or A new vertical co managed with SIDBI / NIIF / IREDA

This may offer various incentives:

I. Buyer's credit for foreign wind projects procuring Indian turbines.

II. Supplier's credit to Indian OEMs executing export EPC contracts.

III. Long tenor project finance (15 – 20 years) aligned to wind cash flows.

IV. Local currency lending options in selecting emerging markets.

Incentives	Beneficiary
Buyer's credit	• Foreign wind project developers, utilities, and independent power producers (IPPs) undertaking onshore or offshore wind projects outside India. • Projects that procure wind turbines, major components, or EPC services from Indian manufacturers • Both state owned and private developers in emerging and frontier markets where access to long tenor commercial finance is limited
Supplier's credit	• Indian wind turbine OEMs and EPC contractors executing turnkey or supply and install wind projects abroad. • Indian manufacturers supplying turbines, blades, towers, nacelles, and balance of plant equipment under export contracts. • OEM led consortiums or joint ventures responsible for delivery, installation, and commissioning in foreign markets.
Long tenor project finance	• Foreign special purpose vehicles (SPVs) set up for wind power projects using Indian supplied turbines. • Project developers whose revenue streams are governed by long term power purchase agreements (PPAs) or regulated tariffs. • Projects in markets where commercial banks cannot provide long tenor or non-recourse financing aligned with wind project lifecycles.
Local currency lending options	• Foreign wind project developers and utilities operating in emerging and developing economies with currency volatility risk. • Projects procuring Indian turbines where local currency revenues are mismatched with hard currency debt. • Indian OEMs and EPC contractors whose export contracts are denominated partly or fully in local currencies.

Expected outcome:

a) Expands addressable export markets for Indian wind manufacturers.

b) Anchors Indian turbines in overseas projects by making projects bankable.

c) Reduces capital cost for foreign buyers, increasing preference for Indian suppliers.

d) Positions India alongside established wind export finance providers globally

Recommendation 3: Establish a Project Development Fund (PDF) for Wind Exports

Indian wind developers face significant barriers in initiating overseas project due to the high upfront capital requirements and elevated risks associated with early-stage developments. Activities such as feasibility study, regulatory clearances, site identification, stakeholder alignment, off-taker credit risk, land and community issues, currency volatility, and local counterparty constraints in unfamiliar markets, demands substantial investments with uncertain outcomes, often discouraging both developers and financers. As a result, many potentially viable projects fail to advance beyond the conceptual stage, limiting India's ability to establish a strong pipeline of bankable wind export opportunities.

To address this issue, a Indian government-backed Project Development Fund may be created, dedicated to supporting Indian OEM-led wind and renewable projects in priority international markets.

I. Provide catalytic equity and early-stage risk cover to help Indian developers secure initial project traction in partner countries.

II. Recycle capital once projects are de-risked, enabling continuous deployment without long-term fiscal burden.

III. Create Bundled "India Inc." offer. i.e. Indian OEM turbines + Indian EPC + Indian O&M + Indian capital (PDF equity + Exim buyer's credit). Will help compete head-on with Chinese "package" (technology + EPC + state bank finance).

Global Parallel: This mirrors blended-finance structures such as AREF and the Climate Finance Partnership, where public/DFI anchor capital de-risks early projects and mobilizes large-scale commercial investment.

This may be implemented by:

- Identifying target geographies where India has FTAs, strategic relations, or EXIM lines of credit to leverage existing diplomatic and sovereign frameworks.
- Inclusion of domestic content thresholds (e.g., 100% Indian turbines, Towers, and Balance of Plant systems) to anchor export volumes.
- Introduction of caps by country, off-taker type, and technology mix to manage exposure and diversify risk.

This incentive will benefit the following:

a) Indian Wind OEMs & Manufacturers: Gain assured export demand for turbines and components, improving scale, utilization, and global competitiveness.

b) Indian Developers & EPC Companies: Access early-stage capital and risk support, enabling entry into overseas markets and faster project origination, stage capital, and risk support, enabling entry into overseas markets and faster project origination.

c) Indian O&M and Service Providers: Secure long term international service contracts, building recurring export revenues and global track records, term international service contracts, building recurring export revenues and global track records.

d) Indian Financial Institutions: Benefit from a pipeline of de-risked, bankable projects that crowd in commercial finance and reduce development risk.

Expected outcome

The establishment of a Project Development Fund is expected to unlock a scalable pipeline of bankable wind projects led by Indian companies in priority international markets. By reducing early-stage development risk and providing catalytic capital, the fund would enable faster project origination, crowd in commercial financing, and strengthen India's ability to offer integrated, competitive renewable energy export packages. Over time, recycled capital would ensure sustained project deployment with limited fiscal burden, while supporting export growth for Indian manufacturers, developers, and service providers and reinforcing India's position as a trusted global partner in clean energy development.-stage development risk and providing catalytic capital, the fund would enable faster project origination, crowd in commercial financing, and strengthen India's ability to offer integrated, competitive renewable energy export packages. Over time, recycled capital would ensure sustained project deployment with limited fiscal burden, while supporting export growth for Indian manufacturers, developers, and service providers and reinforcing India's position as a trusted global partner in clean energy development.

Recommendation 4: Export Linked Tax Incentives & Cash Flow Support

Exporters often face significant working capital stress caused by delayed GST refunds and the inability to recover embedded taxes, which ties up liquidity that could otherwise be used for production and expansion. At the same time, high costs related to mandatory certifications, overseas marketing efforts, and technical adaptation to meet foreign market standards are insufficiently supported under existing schemes, placing an additional financial burden on firms. These combined cash flow constraints particularly affect mid-sized exporters, limiting their capacity to scale operations, enter new markets, and compete effectively in global value chains.

To address this issue, fiscal measures that directly improve exporter's cash flow may be introduced:

- Refund of embedded taxes & duties on exported wind turbines
- Accelerated GST refunds (within 15 – 30 days) for renewable equipment exporters on quarterly basis.
- Allow weighted deduction for export related R&D, certification, and market development expenses.

This incentive will benefit the following:

- Indian wind turbine OEMs and component manufacturers exporting complete turbines or major components such as blades, towers, nacelles, generators, and power electronics.
- Export oriented Tier 1 and Tier 2 suppliers engaged in manufacturing and supply of wind specific equipment and sub systems for international markets.
- Renewable energy equipment exporters incurring unrecovered embedded taxes, duties, and GST while supplying wind equipment outside India.
- Indian manufacturers and engineering entities undertaking export related R&D, international certification, grid code compliance, product customization, and overseas market development for wind turbines and components.
- MSME and mid-sized firms integrated into wind export value chains, for whom accelerated GST refunds and tax deductions materially improve liquidity and ability to scale exports.

Expected Outcome:

a) Improves liquidity and reduces cost of capital for exporters.

b) Shortens cash conversion cycles, enabling higher export throughput.

c) Encourages sustained investment in export-oriented R&D and compliance.

d) Strengthens participation of domestic suppliers in global wind markets.

Recommendation 5: Launch an India Wind Global Market Development Program

Indian wind turbine and component manufacturers currently have limited visibility and a weak demonstration footprint in international markets, making it harder to build credibility with foreign utilities and project developers. High upfront costs associated with compliance with country specific grid codes, and market entry requirements act as significant non price barriers, particularly for first time exporters. In contrast, global competitors actively leverage government backed demonstration projects abroad to showcase performance, reduce buyer risk, and create sustained demand pull, placing Indian manufacturers at a structural disadvantage without similar support mechanisms.

To address this issue, the following initiatives should be undertaken:

- Government backed wind export promotion missions.
- Co funded demonstration wind projects abroad using Indian turbines.
- Support for international certifications and country specific grid codes

The support will be targeted at Indian wind energy manufacturers and exporters across the value chain, with a focus on firms that have demonstrated technical capability but face entry barriers in global markets. This includes:

- Indian wind turbine manufacturers (OEMs) and component suppliers (such as blades, gearboxes, generators, towers, and power electronics) seeking to expand exports.
- Mid-sized and emerging exporters, for whom certification, overseas demonstration, and compliance costs are a significant constraint.
- Consortia of manufacturers, EPC companies, and developers participating in government backed export promotion missions and co funded demonstration wind projects abroad.
- Manufacturers targeting new or strategic markets, who require support for international certifications, country specific grid code compliance, and market entry approvals.

The mechanism may also extend facilitative support to industry associations and export promotion bodies acting on behalf of eligible firms, to jointly organize missions, demonstrations, and certification initiatives that benefit the broader Indian wind manufacturing ecosystem.

Expected outcome:

a) Builds international confidence in Indian wind technology.

b) Accelerates acceptance of Indian turbines by overseas financiers and utilities.

c) Reduces market entry time and risk for exporters.

d) Establishes India as a credible long term wind technology supplier.

Recommendation 6: Strategic Input & Supply Chain Support

Key inputs such as steel, castings, and composite materials constitute a significant share of overall wind turbine costs, making manufacturers highly sensitive to input pricing and supply conditions. High energy intensity in manufacturing processes, combined with elevated domestic power tariffs and rising logistics expenses, erodes the export competitiveness of Indian wind equipment. Additionally, the fragmentation of supplier locations and the lack of adequate port adjacent manufacturing and storage infrastructure increase delivery timelines and execution risk, further weakening the ability of Indian firms to reliably serve global markets.

To address this issue, targeted support should be provided for:

- Steel, castings, and composites used in wind exports.
- Preferential power tariffs for export-oriented manufacturing
- Anchor supplier parks near ports with plug and play infrastructure.

Expected outcome:

a) Reduces structural cost disadvantages at the input and energy level.

b) Improves predictability and efficiency in export logistics.

c) Enables scale manufacturing through integrated supplier parks.

d) Strengthens India's end to end wind export value chain.

Recommendation 7: Launch an ECA Backed Payment Deferral Facility

The wind sector faces persistent challenges related to high upfront capital requirements, limited access to affordable long tenure financing, and weak payment security mechanisms in many international markets. These issues restrict Indian OEMs from offering competitive commercial terms such as deferred payments, which global developers increasingly expect in utility scale and IPP tenders. -tenor financing, and weak payment security mechanisms in many

international markets. These issues restrict Indian OEMs from offering competitive commercial terms such as deferred payments, which global developers increasingly expect in utility-scale and IPP tenders.

To directly address this bottle neck, ECGC (or a dedicated Export Credit Agency window) may be enabled to provide a 100% sovereign guarantee on export receivables, allowing Indian OEMs to offer deferred payment terms to global buyers.

Global Precedent: Vestas successfully used ECA backed deferral structures in markets such as Australia, winning major projects by easing upfront capital burdens for buyers. A similar Indian mechanism would unlock high value tenders for domestic OEMs.

This incentive will benefit the following:

- Indian OEMs – They can offer competitive deferred payment terms and win more global wind tenders.
- International wind project developers – Benefit from improved cash-flow and better project IRRs due to reduced upfront capital needs.
- Exporting Indian supply chain (towers, blades, nacelles, components) – Gains from higher export volumes enabled by stronger OEM order pipelines.
- Financiers and lenders – Receive greater payment security due to sovereign backed guarantees, backed guarantees.

Expected outcome:

a) Enables Indian OEMs to offer 2–3 year deferred payments after project commissioning.

b) Makes projects more attractive by improving bankability for global developers.

c) Enhance project IRRs by reducing upfront capital burden on buyers.

d) Help developers operating in cash flow constrained markets. -flow-constrained markets.

e) Boosts India's competitiveness in IPP and utility scale wind tenders worldwide. -scale wind tenders worldwide.

f) Aligns Indian OEM offerings with global best practices used by competitors like Vestas.

g) Opens access to larger, high value international wind tenders, value international wind tenders.

Recommended Enhancements for Schemes: RoDTEP and Duty Drawback on Imported Inputs for Exports

India's export-oriented tax framework integrates customs duties, GST, and targeted incentive schemes under FTP 2023 to enhance manufacturing competitiveness. For wind turbine manufacturers, which are capital-intensive and dependent on imported components, this policy ecosystem is critical. Customs duty impacts are mitigated through mechanisms such as Duty Drawback, RoDTEP, Advance Authorization, DFIA, EPCG, and bonded regimes including

MOOWR. In parallel, GST rationalization efforts seek to reduce structural distortions affecting SEZs and EOUs. At the state level, support is reinforced through capital subsidies, tax exemptions, production-linked incentives, and access to export finance and concessional credit.

However, several challenges persist, including embedded taxes on civil works and capital goods, delays in GST refunds, and declining remission rates under RoDTEP and Duty Drawback. Addressing these gaps will be critical to unlocking cost efficiency, scale, and global competitiveness for India's wind energy manufacturing sector.

4

Facilitating Wind Repowering in India

Facilitating Wind Repowering in India

Executive summary

India's wind sector is entering a modernization decade. A large share of the installed fleet comprises older, sub-megawatt turbines with lower hub heights and smaller rotors—often deployed on the country's best wind corridors but delivering suboptimal output compared with modern technology.

Repowering refers to the replacement of such old, small turbines with modern multi-MW class machines, resulting in:

- Unlock >1.5 times higher generation from the same site
- Optimize land and grid utilization.
- Enable modern O&M practices and digital monitoring.

Ministry of New and Renewable Energy (MNRE) estimates ~25.4 GW of repowering-eligible capacity (largely turbines below 2 MW), representing a market opportunity of >1.50 lakh crore.

The National Repowering & Life Extension Policy (Dec 2023) notified to accelerate the implementation of repowering.

Despite the market size and policy intent, repowering progress remains constrained by three structural bottlenecks: (1) shortage of certified turbines suited for high-turbulence Category A sites (TI 0.16), (2) inadequate evacuation and grid infrastructure—especially legacy 11 kV systems in old wind clusters, (3) lack of uniform repowering policy framework across states and incentives and (4) financing and transaction frictions stemming from repowering-specific costs and fragmented asset ownership.

Ministry of New and Renewable Energy (MNRE) estimates **~25.4 GW of** repowering-eligible capacity (largely turbines below **2 MW**), representing a market opportunity of **>1.50 lakh crore.**

This white paper synthesizes the National Repowering Mission framework actionable view of where the repowering opportunity is, what is blocking it, and what an integrated solution framework looks like across manufacturing/turbines, evacuation infrastructure, and finance/policy harmonization.

1. India's repowering opportunity

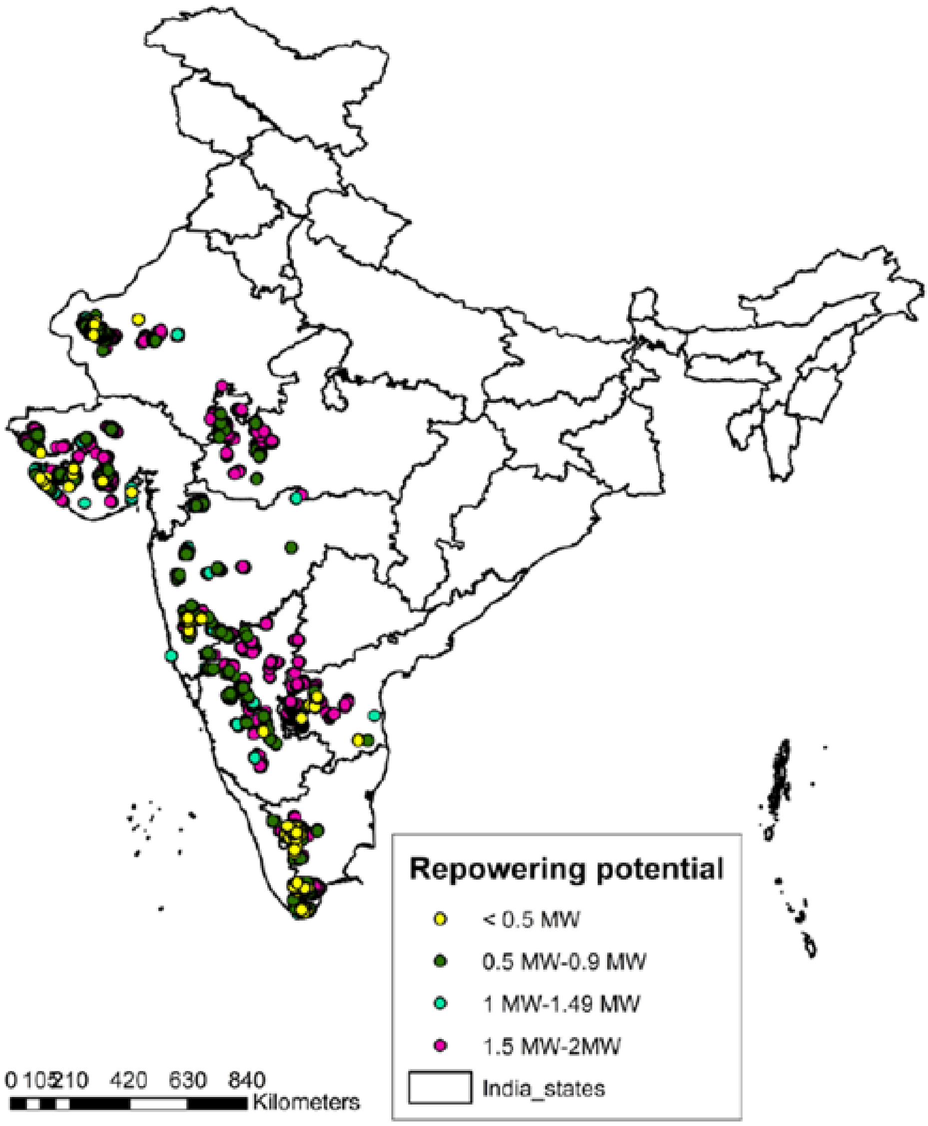
1.1 Repowering Potential

Preliminary data reveals that Tamil Nadu's 8,810 old turbines include 3,865 units below 0.5 MW and 4,127 in the 0.5–2 MW range. Similarly, Maharashtra has 3,275 aging turbines (3.18 GW), Karnataka hosts 2,440 machines (3.03 GW), and Rajasthan contains 2,655 turbines (2.88 GW). Even states with smaller wind footprints, such as Andhra Pradesh and Kerala, present viable repowering opportunities.

MNRE: Statewise Repowering Potential as Identified by the NIWE

States	Total Capacity below 0.5 MW	Total Capacity between 0.5-1 MW	Total Capacity between 1-1.5 MW	Total Capacity between 1.5-2 MW	Total Capacity below 2 MW
Tamil Nadu	1,181	2,919	1,813	1,473.5	7,387
Maharashtra	243	1,068	1,389	731.4	3,431
Karnataka	0.3	954	652	1,417.1	3,023
Gujarat	51	1,457	1,352	1,805.4	4,665
Rajasthan	39	1,192	788	914.9	2,934
Madhya Pradesh	0	290	260	1,012	1,562
Kerala	0	18	0	10	28
Andhra Pradesh	92	378	195	1,701.2	2,366
Total	**1,606.3**	**8,276**	**6,449**	**9,065.4**	**25,396.7**

Figure 1: MNRE: Statewise Repowering Potential as Identified by the NIWE



Source: National Institute of Wind Energy

1.2 Why repowering is strategically attractive

Older turbines occupy prime wind-rich sites but operate at efficiencies far below contemporary standards. Repowering can unlock latent capacity from the best corridors without incremental land acquisition and can avoid some land/permitting constraints associated with greenfield wind development.

The older turbines often show CUF of ~10–14%, underscoring the upside of deploying modern rotor/hub-height technology and improved controls on the same sites.

Using turbine capex assumptions of Rs 6–7 crore/MW, there is a potential market size of ~INR 1,75,000 crore for repowering.

2. Key challenges associated with repowering

2.1 Lack of WTGs for Class I Category A sites

India's premier wind corridors, including Tamil Nadu's Muppandal and Gujarat's coastal regions, require turbines capable of handling both high wind speeds (~10 m/s) and high turbulence intensity (TI 0.16).

However, the current Revised List of Models and Manufacturers (RLMM) issued by the MNRE offers only six certified models rated for TI 0.16—all of which are under 1 MW capacity and have hub heights below 100 metres. These models are technically inadequate for effective repowering, which requires 2–3 MW turbines with higher hub heights.

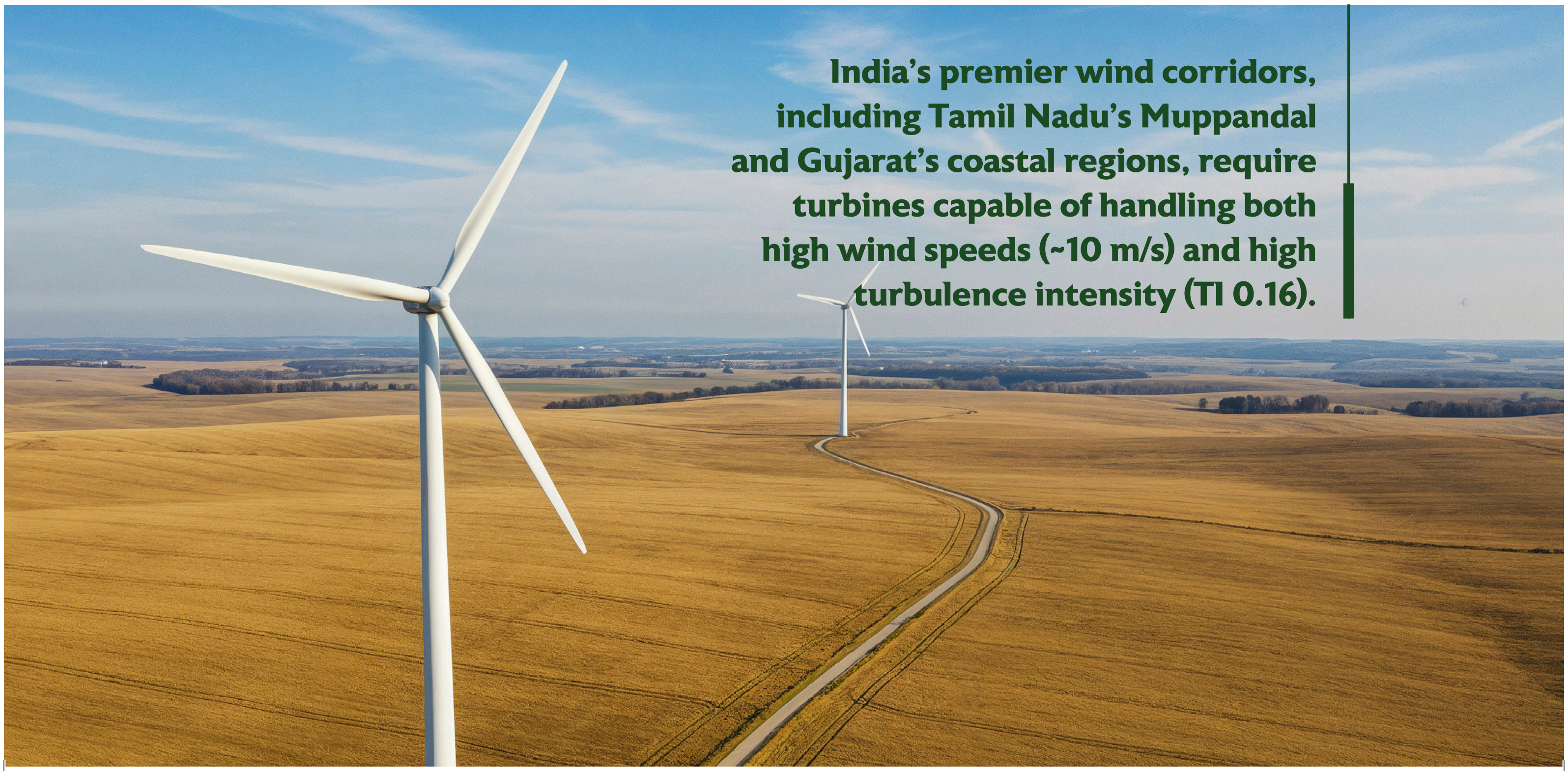
The majority of turbine models offered by the largest OEMs, including Senvion, Envision, Vestas, Suzlon, Siemens Gamesa and Adani are designed for sites with lower turbulence levels (TI 0.12–0.14) and more common globally, rendering the country's best wind corridors effectively unserviceable.

Developing turbines for Category A conditions demands significant R&D, advanced engineering. However, OEMs are hesitant to invest, citing limited global market demand to offset the high development costs.

2.2 Incompatible Evacuation and Transmission system

Majority of aging wind farms are still connected to 11 kV and 33 kV feeders, originally built for small, sub-megawatt turbines. These low-voltage lines cannot efficiently handle the much higher capacities expected from repowered clusters with modern 2–3 MW turbines. The result is technical inadequacy, higher line losses, frequent overloading, and poor power quality, limiting the effective utilization of repowering investments.

Another gap is the lack of modern pooling substations. These act as collection points, consolidating power from multiple turbines before sending it to the main grid. Many older wind clusters lack high-capacity substations at 33–110 kV or 66–220 kV levels. Without these, it's difficult to manage the larger, more variable output of repowered sites or to integrate them smoothly into the wider grid.



Monitoring and control systems are also outdated or missing. Modern wind farms rely on systems like SCADA, smart relays, and voltage controls for real-time monitoring and grid code compliance. These are essential for balancing loads and ensuring reliability, but they are largely absent in older clusters.

2.3 Lack of uniform repowering policy framework across states and incentives

Despite having over 25 GW of repowering potential locked in ageing wind turbines, the lack of consistent policies across key states—Tamil Nadu, Karnataka, Gujarat, and Maharashtra—is limiting investment and slowing the transition towards the national target of 500 GW renewable energy capacity by 2030.

- Tamil Nadu is the only state among the four that has taken concrete steps. In 2024, it introduced dedicated policy for repowering which provides - a nodal agency to streamline approvals, enabling provisions such as banking, wind–solar hybridisation, and continuity of PPAs.
- Karnataka is relying largely on MNRE's 2023 guidelines and not offering state-level incentives/support mechanisms, leaving gaps in infrastructure and financial clarity.
- Gujarat's stance is even more limiting. It permits repowering only for turbines with a capacity of 1 MW or less. There is no state-specific policy, and repowering is treated under general renewable energy guidelines. This creates a lack of clarity and structure—there are no dedicated incentives, no clear project approval mechanisms, and no formal support for grid integration.
- Maharashtra lags the most. Its 2015 renewable energy policy does not mention repowering at all. With no formal guidelines, incentives, or institutional framework, developers are left in the dark about how to proceed. The absence of state policy effectively shuts the door on repowering projects altogether.

Lack of favourable repowering policy results in:

- higher regulatory and contracting risk,
- slower aggregation of small-owner projects into bankable portfolios, and
- higher cost of capital, as lenders struggle to apply standardised assessment frameworks.

2.4 Financing barriers & fragmented asset ownership

Repowering includes cost layers absent from new builds—dismantling, site preparation, and evacuation upgrades. Current financial support mechanisms do not always reflect these repowering-specific needs.

Inadequate banking products: Lenders often treat repowering like greenfield projects, leading to high-cost debt or rejections; banks also struggle to value old turbines/parts as collateral and lack frameworks to assess repowering-specific risks and cash flows.

Fiscal incentive gaps: Removal of incentives such as accelerated depreciation reduced interest from SMEs/individual investors; there are limited targeted fiscal benefits for repowering (e.g., no performance-linked rewards, GST relief, or special tax treatment).

Market access & tariff constraints: Competitive auctions disadvantage small owners (who control much of the repowering-ready fleet); existing PPAs/tariffs are designed for new projects, with limited tailored tariff/contract pathways for repowered assets.

Open access uncertainty: Unpredictable and inconsistent open access charges across states undermine revenue predictability; policy often prioritizes DISCOM protection over stable long-term open access, reducing investor confidence.

3. Integrated solution

3.1 Manufacturing scale-up

- National Institute of Wind Energy (NIWE) must urgently undertake on-site wind measurements at 120m and 140m hub heights across all identified Category A sites. Without this high-resolution data, OEMs face barriers in turbine design, certification, and deployment.
- Certification processes for turbine platforms designed specifically for Class I, high-turbulence conditions should be accelerated to bring more options into the market quickly.
- Production Linked Incentive (PLI) schemes and research grants specifically to support the development of such turbine platforms, the PLI coverage should not stop at OEMs but should also include component and sub-component manufacturers

3.2 Evacuation infrastructure modernization

- Establish coordination mechanisms between MNRE/CEA/state utilities and mandate site-specific load-flow studies and grid upgrade planning for repowering projects, implemented as cluster-level modernization in dense wind belts.
- systematically upgrading feeders to 33 kV or 66 kV, along with strengthening transformers and protection systems.
- A central coordination mechanism involving MNRE, CEA, and State Transmission Utilities must streamline execution.

3.3 Uniform Repowering Rules

In 2022, Ministry of Power notified Green Energy Open Access Rules, which were adopted across India, providing long term certainty on open access framework, in similar lines Repowering rules can also be issued which may include the following to facilitate repowering:

Sr No.	Particulars	Details
1	Eligibility	- All WTGs commissioned prior to Apr 01, 2016, should mandatorily opt of repowering upon completing 20 years of operational life. - For other WEGs, participation is voluntary.
2	Performance Benchmarks	Repowered projects should increase in the annual generation of atleast 1.5 times of existing average generation of last 3 years.
3	PPA continuity rules	The existing contracted energy would be procured at the agreed PPA tariff, for additional generation, the respective SERC to determine the Feed in Tariff and the Generator may have an option to contract the additional generation at the notified Feed in Tariff.
4	Banking	Annual banking without any restriction shall be provided for the entire repowered capacity for a period of 15 years.
5	Hybridisation	Wind repowering projects should be allowed to be converted into wind solar hybrid projects.
6	Exempted Open Access Charges	100% waiver of transmission and wheeling charges for the projects opted for repowering.
7	Single window clearance	Approvals should be managed through a single-window system in each state with a clear 45-day decision period.
8	Project Commissioning timelines	18 -24 months from date of consent from State Nodal Agency

3.4 Financial reform and de-risking

Create a National Repowering Fund to provide capital support and soft loans and incentivize dismantling, infrastructure retrofits, and performance-linked generation gains.

Financial institutions such as IREDA, REC, and PFC should offer concessional loans with interest rate discounts specifically for repowering projects meeting technical criteria for enhanced turbine performance and grid readiness. A 0.25 per cent interest rate concession can significantly lower financing costs and improve project viability.

The fragmented ownership of many old wind farms owned by multiple owners requires innovative approaches that combine several small assets into larger, viable repowering projects. These old wind farms can be repowered by large Renewable IPP under following models.

1. **Full Land Lease Model**
    - Take the entire land on lease for a fixed lease rent from multiple owners.
    - Install and operate new repowered wind turbines.
    - Supply renewable power to different consumers through open access or bilateral arrangements.

2. Joint Development / Group Captive Model

- Joint development of land along with the existing WTG owner under a group captive structure.
- Power supplied to the existing WTG owner (cum consumer) on a group captive basis.
- Land contribution by the consumer can be treated as part of their equity.

3. Revenue-Sharing Lease Model

- Take the entire land on lease for a lease rent.
- Install and operate repowered turbines.
- Supply renewable power to different consumers, while sharing revenue equivalent to the current revenue realized by the existing WTG owner under their existing PPA with the state distribution utility.

4. Recommendations

1. Launch a National Repowering Mission with clearly defined state-wise targets.
2. Constitute a Ministry-led Taskforce comprising MNRE, NIWE, state nodal agencies, OEMs and IPPs.
3. Notify uniform Repowering rules to be adopted across states.
4. Promote repowered wind projects – annual banking, hybridisation, waiver of open access charges etc.
5. Provide financial incentives such as interest subvention and tax breaks.
6. Fast-track multi-MW category A turbines availability via certification pathways and aligned incentives
7. Mandate grid-readiness planning for repowering clusters.
8. Implement single-window approvals with clear timelines.
9. Create model pilot project in Tamil Nadu.

5 Conclusion

India's repowering opportunity is large, concentrated, and strategically valuable. Unlocking requires repowering as a system-wide upgrade: turbines suited for high-turbulence corridors, modern evacuation infrastructure, fit-for-purpose finance and policy harmonization. With coordinated intervention, repowering can unlock higher energy output from India's best wind sites while optimizing land use and accelerating renewable integration.

By replacing old sub-MW machines with modern MW-class turbines, India can:

- Unlock 25–30 GW additional capacity from the same land.
- Unlock >1.5 times higher generation from the same site
- Optimize land and grid utilization
- Reduce imports through domestic manufacturing and O&M localization.
- Contribute to Atmanirbhar Bharat and India's 500 GW RE by 2030 target.

Annexure

1. Case Study

The preliminary and basic potential assessment study in certain key wind installed pockets with certain assumptions on the turbines are carried out with the current annual generation, existing CUF etc. The inference on the prior mentioned study is mentioned below:

- Keelaveranam (TN, 204 WTGs – 250kW, 750kW and 1250kW): CUF improved from 20% to 35% post-repowering.
- Radhapuram (TN): 77 x 400 kW machines repowered into 16 x 2.1 MW. Capacity increased from 31 MW → 33.6 MW, but annual energy production (AEP) more than doubled.
- Devarkulam (TN): 40 WTGs x 250 kW replaced with 6 x 2.1 MW. Capacity 10 MW → 12.6 MW; CUF doubled.

2. Repowering without capacity change:

The existing project capacity remains the same, but the old wind turbines are replaced with new WTG models.

State	Installed wind capacity (GW) ~ (<1.5 WTGs	Total Units (GWh)	Old CUF (%)	New Per WTG (GWh)	New CUF (%)	Total Units (GWh)
Tamil Nadu	5.9	8,269 - 10,337	16–20	5.89–6.44	32–35	16,539 -18,089
Gujarat	2.8	2,943 - 4,415	12–18	5.52–6.07	30–33	7,358 - 8,094
Maharashtra	2.7	2,838 - 4,257	12–18	5.52–5.89	30–32	7,096 - 7,569
Rajasthan	2.0	1,752 - 2,803	10–16	5.15–5.70	28–31	4,906 - 5,431
Karnataka	1.6	1,402 - 2,243	10–16	5.15–5.89	28–32	3,924 - 4,485
Andhra Pradesh	0.8	841 - 1,261	12–18	5.52–5.89	30–32	2,102 - 2,243
Madhya Pradesh	0.6	631 – 946	12–18	5.15–5.52	28–30	1,472 - 1,577

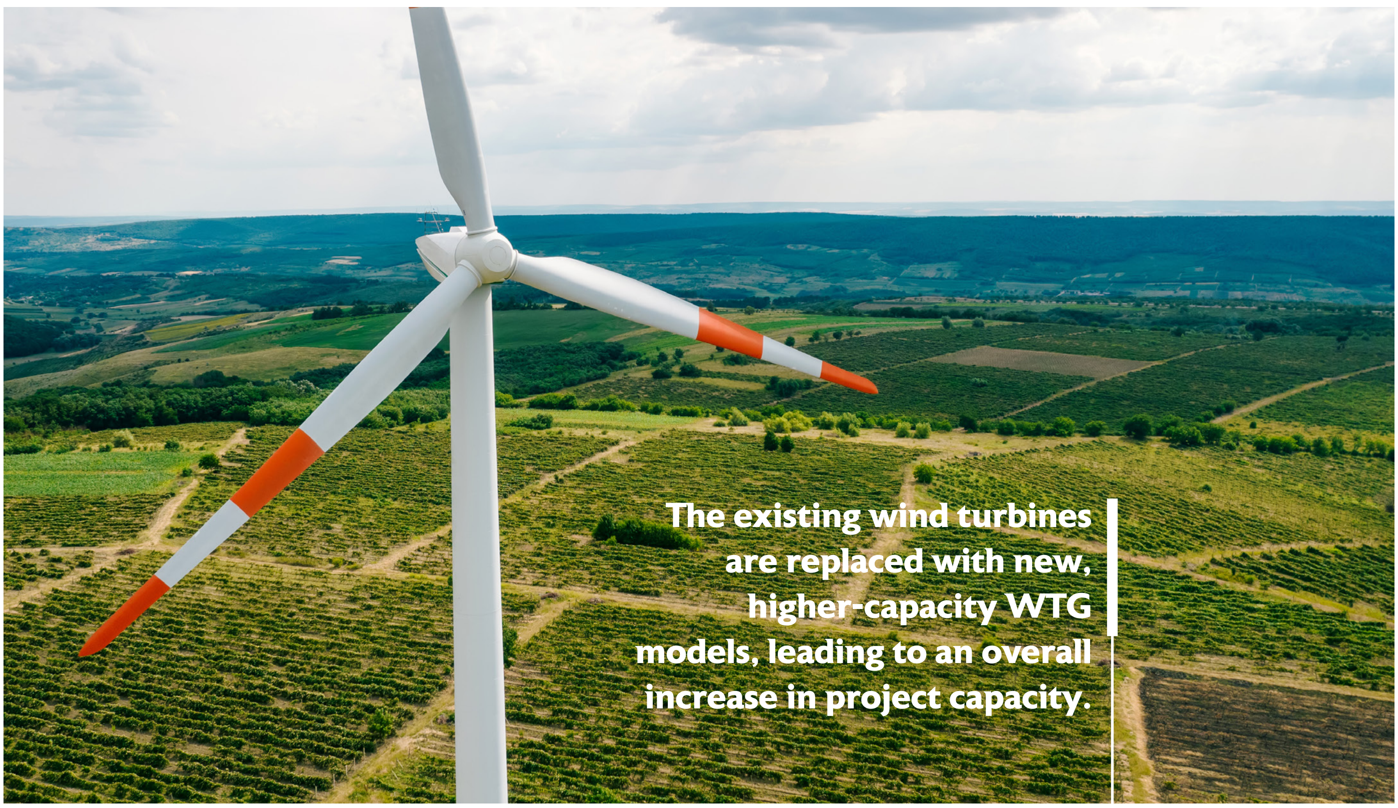
Repowering increases total generation across states by roughly 1.5–3 times

3. Repowering with Capacity Enhancement and Substation Upgrade:

The existing wind turbines are replaced with new, higher-capacity WTG models, leading to an overall increase in project capacity. To handle the enhanced generation, the substation and associated evacuation infrastructure are upgraded, enabling optimal integration of additional power into the grid.

State	Installed wind capacity (GW) ~ (<1.5 WTGs	Total Units (GWh)	Old CUF (%)	New Cap. (~GW)	New Per WTG (GWh)	CUF (%)	Total Units (GWh)
Tamil Nadu	5.9	8,269 – 10,337	16–20	12	5.89 – 6.44	32–35	33,638 – 36,792
Gujarat	2.8	2,943 – 4,415	12–18	8	5.52 – 6.07	30–33	21,024 – 23,126
Maharashtra	2.7	2,838 – 4,257	12–18	6	5.52 – 5.89	30–32	15,768 – 16,819
Rajasthan	2.0	1,752 – 2,803	10–16	4	5.15 – 5.70	28–31	9,811 – 10,862
Karnataka	1.6	1,402 – 2,243	10–16	4	5.15 – 5.89	28–32	9,811 – 11,213
Andhra Pradesh	0.8	841 – 1,261	12–18	2	5.52 – 5.89	30–32	5,256 – 5,606
Madhya Pradesh	0.6	631 – 946	12–18	2	5.15 – 5.52	28–30	4,906 – 5,256

Repowering increases total generation across states by roughly 3–5 times



5

Solar Manufacturing

Solar Manufacturing

Background

India's solar manufacturing ecosystem is undergoing a pivotal transition, shaped by ambitious national targets and evolving global dynamics. The Government of India's commitment to achieve 500 GW of non-fossil fuel capacity by 2030, along with the broader vision of Atmanirbhar Bharat, has placed solar photovoltaic manufacturing at the center of the country's energy and industrial policy. Over the past decade, domestic demand for solar modules has expanded rapidly through utility-scale solar parks, rooftop programmes, PM KUSUM scheme, and emerging applications such as Building Integrated Photo Voltaics (BIPV), floating solar, agrivoltaics and distributed renewable energy.

Due to massive domestic demand, supportive government policies like Production Linked Incentives (PLI) schemes, cost advantages from lower labor costs, and strategic positioning for global supply chain diversification, all supported by improving infrastructure and growing tech integration, India has potential to leverage cost competitiveness to become a global manufacturing hub, while also emphasizing the need for stronger integration into global value chains, improved logistics, and technology upgradation.

At the same time, the solar manufacturing value chain in India remains characterized by critical gaps in upstream and ancillary segments, exposure to import dependence, and policy and regulatory frictions. While domestic module manufacturing capacity has grown significantly, and cell manufacturing capacity is growing rapidly, domestic capability in polysilicon, ingots, wafers, and several balance-of-materials segments is still limited, leading to reliance on imports for key components of solar manufacturing supply chain.

In response to these opportunities and challenges, there is a need to provide a structured industry platform for policy dialogue, evidence-based recommendations, and collaborative problem-solving. This can be achieved by mapping current capacities, identifying critical import dependencies, and assessing supply-chain vulnerabilities across polysilicon, ingots-wafers, cells, modules, and allied industries such as glass, aluminium frames, Ethylene Vinyl Acetate (EVA)/backsheet, inverters, storage, power electronics, and recycling.

The proposed roadmap targets interventions on PLI, Approved List of Models and Manufacturers (ALMM), standards and certification, customs and trade measures, logistics, and land policy, as well as recommending measures for backward integration, raw material security, and preferential financing, particularly for capital-intensive segments such as solar glass, cell, and module manufacturing.

Key challenges and possible solutions for growth of Indian solar manufacturing sector

The advancement of India's solar PV manufacturing sector is supported by strong government initiatives, but at the same time is confronted by critical structural and external challenges. Addressing these challenges requires a combined approach that improves policies, strengthens the supply chain, and promotes independent technology development. Some of the proposed intervention areas can be:

1. Policy Advocacy, Regulatory Refinements, and Incentivization

The existing regulatory framework includes the Production Linked Incentive (PLI) scheme, the Approved List of Models and Manufacturers (ALMM), Basic Customs Duty (BCD), and BIS Certification standards that requires continuous refinement to optimize its impact and competitiveness. The current framework faces challenges such as the noted reduction of PLI benefits, which impacts financial planning for manufacturers, and persistent BIS certification delays arising from evolving standards and older regulatory structures. These challenges are described as follows:

- **Partial and Uncertain Realization of PLI Benefits:**
  - Production Linked Incentive (PLI) realized by manufacturers depend upon their sales volume, base PLI rate, tapering factor, and local value addition. Thus, actual realized PLI by manufacturers is usually lower than the amount that had been envisaged during planning phase. During implementation phase, this lower realization of PLI than expected amount is, affecting project viability for integrated polysilicon–wafer–cell–module lines.
  - Delays in PLI implementation are also observed due to issues related to machinery supply, complexities in obtaining visas for foreign technical staff, and general infrastructure gaps at manufacturing sites.
  - Delays in disbursal and evolving scheme conditions can increase financial risk perception, especially for highly capital-intensive upstream investments.
  - For addressing the delays, extension was granted for two years of deadline under PLI scheme II. However, the PLI would not be available for first two years, with availability being only for last three years. This results in significant PLI amount not being realizable for the manufacturers.
- **ALMM uncertainty about cell and module manufacturing:**
  - the module manufacturing capacity has crossed 200 GW the cell manufacturing capacity as on 01 June 2026 when the ALMM - II went into effect was limited to about 30 GW. Another 50 GW of cells manufacturing capacity is under construction by the end of 2026, but even then the gap between module and cell manufacturing capacity will be such that around half of the 200 GW of installed capacity of modules in India will not find domestic cells supply.
  - The introduction of ASLMM-II list from 01 June 2026 has effectively created a domestic content requirement for most government, open-access and net-metering solar projects, making the use of solar modules manufactured in India with ALMM-listed Indian solar cells mandatory, thereby driving demand for domestic cell manufacturing while restricting reliance on imported cells.
- **Tariff Structure and Trade-Related Distortions (BCD, ADD, CVD)**
  - Basic Customs Duty (BCD) on solar cells and modules was reduced in the Union Budget 2025, coming down from 25% to 20% for cells and 40% to 20% for modules. While this supports domestic manufacturers but adds near-term cost pressure on project developers, leading to stop–start procurement patterns and demand volatility. However, in the proposed Union Budget 2026-27, import of sodium antimonate (used for manufacture of solar glass) is exempt from BCD.
  - Persistent dumping of glass, aluminum frames and encapsulants from certain ASEAN and other jurisdictions, has eroded the competitiveness of domestic ancillary manufacturers.
- **Logistics and Land-Related Bottlenecks**
  - High logistics costs, port bottlenecks, and inadequate multimodal connectivity increase landed costs of imported raw materials and exported finished products.
  - Complex and fragmented land acquisition processes, coupled with variable state-level charges, delay project execution and raise overall project cost.

The Working group deliberated upon the key challenges and key interventions or possible solutions for the above challenges have been tabulated as follows:

- **Fine-tuning PLI and Complementary Fiscal Support**
  - Restore and ring-fence PLI benefits for committed capacities, ensuring stability of scheme parameters for the entire tenure of each sanctioned project.
  - Restore the full 5-year PLI incentive window for all manufacturers to compensate for initial delays.
  - Introduce differentiated PLI or viability gap funding (VGF) for strategic upstream segments such as polysilicon, ingots–wafers and solar glass, which have high technology risk and long payback periods.
- **Streamlining ALMM, BIS and Standardization Regime**
  - **Establish a unified, time-bound approval framework** aligning ALMM, BIS and other applicable quality standards, with clearly defined service-level timelines for certifications, renewals and upgrades to ensure predictability and regulatory efficiency.
  - **Ensure calibrated enforcement of ALMM** to provide a stable and predictable market for domestic solar cell manufacturing. Enforcement timelines should be aligned with existing domestic cell manufacturing capacity and the industry's demonstrated ability to scale up capacity by the notified enforcement date to meet market demand.
  - **Strengthen domestic testing and certification infrastructure** by expanding BIS-recognised laboratories across regions, equipped with advanced testing capabilities for next-generation modules, cells and Balance of System (BoS) components.
  - **Introduce fast-track certification mechanisms** for incremental product upgrades (such as higher wattage modules on the same technology platform) and for components already certified under globally accepted standards, while maintaining stringent quality and performance benchmarks.
  - **Introduce ALMM-III for wafers** from June 2028 in a graduated way over 2-3 years to allow for market readiness to shift to made in India ingots and wafers.
  - **Immediately transition all Solar PV modules from BIS Scheme-II to BIS Scheme-I** and fully integrate ALMM requirements within BIS Scheme-I to streamline regulatory oversight and enhance legal enforceability. This should include mandatory factory audits by BIS officials to ensure manufacturing consistency and prevent the entry of sub-standard or misrepresented products.
- **Balanced Tariff and Trade Measures**
  - Use targeted anti-dumping and anti-circumvention measures for glass, aluminum frames and encapsulants where evidence of dumping exists, while avoiding broad-based duties that increase system costs.
  - Regularly review BCD and other tariff measures in consultation with industry to ensure a calibrated path that nurtures domestic manufacturing without causing abrupt demand disruption.

- **Improved Ecosystem**
  - Develop dedicated renewable energy manufacturing clusters with plug-and-play land, internal roads, common effluent treatment, warehousing and access to ports and railheads.
  - Encourage state governments to create streamlined, single-window systems for land allotment and clearances for solar manufacturing, with standardized lease terms and transparent pricing.

Strengthening Value Chain Integration and Ancillary Manufacturing

The industry's reliance on imports for polysilicon, wafers, and critical ancillary components constitutes a major supply-chain vulnerability. The domestic ancillary manufacturing segment—specifically for items like glass, aluminum frames, and encapsulants—is severely challenged by the persistent dumping of materials from ASEAN countries and related circumvention practices. These challenges are described as follows:

- **Limited Backward Integration and Import Dependence**
  - Domestic capacity remains concentrated at the module and partially at the cell level, with substantial import dependence for polysilicon, ingots–wafers, high-purity gases, specialty chemicals, silver paste, and other critical inputs. On annual basis, as on March 2026 , there was 160+ GW of module manufacturing capacity, 27 GW of cell manufacturing capacity, and only 2 GW of Poly silicon/ wafer/ ingot manufacturing capacity.
  - There is lack of manufacturing capacity for ingot-wafer which is resulting in a deep dependence on China for these intermediate components.
  - Insufficient domestic capacity for solar glass, EVA/POE encapsulants, backsheets, junction boxes and certain power-electronic components undermine supply-chain resilience and cost competitiveness.
- **Raw Material Constraints and Security of Supply**
  - Shortages of key raw materials such as high-quality silica for glass, aluminum, copper, and certain specialty chemicals pose risks for large-scale, integrated manufacturing.
  - Absence of long-term raw material linkages and strategic reserves increases exposure to global price volatility and supply disruptions.
- **Polysilicon and Full Value Chain Gap:**
  - Global production of polysilicon is heavily concentrated, with China controlling 90-93% of the world's polysilicon supply.
  - The risk of global overcapacity and potential price manipulation is significant, impacting the cost structure for Indian manufacturers.
  - India lacks upstream polysilicon production capability, which is the foundational step for a truly indigenous solar value chain.

- **Fragmented Ecosystem and Scale Limitations**
  - Many ancillary manufacturers operate at small or sub-optimal scale, with limited access to capital, technology and reliable offtake agreements.
  - Lack of integrated clusters where glass, frames, junction boxes, EVA, backsheets and other components co locate with cell and module manufacturers results in higher logistics costs and coordination challenges.
- **Battery, BESS & Inverters Import Dependence**
  - The downstream ecosystem for batteries is heavily reliant on imports for Li-ion cells and battery packs.
  - The domestic recycling ecosystem for batteries is currently limited.
  - Imported inverters dominate the market, raising critical cybersecurity and performance concerns.

The illustrative solutions for the above challenges are as follows:

- **Strategic Domestic Content and Procurement Measures**
  - Design long-term framework agreements or assured offtake programs for domestic ancillary manufacturers linked to central and state procurement schemes (utility-scale, rooftop, and distributed applications).
- **Targeted Support for Upstream, Ancillary and Raw Material Industries**
  - Provide a 50% capital subsidy and `3/unit power support for five years for establishing ingot-wafer manufacturing facilities.
  - Offer a 50-60% capital subsidy for polysilicon manufacturing plants, along with `3/unit concessional power for five years to ensure financial viability.
  - Introduce a Production Linked Incentive (PLI) scheme specifically for polysilicon if deemed necessary to ensure viability against global price pressures.
  - Introduce dedicated fiscal incentives (e.g., capital subsidy, interest subvention, accelerated depreciation) and concessional financing for solar glass, encapsulants, backsheets and key raw material facilities, recognizing their capital-intensive nature.
  - Implement preferential financing or special refinance windows for glass manufacturing and other high-capex ancillary plants, including credit guarantees and longer repayment tenures.
- **Cluster-Based Industrial Development**
  - Promote integrated solar manufacturing parks where upstream (polysilicon, ingots–wafers), midstream (cells, modules), and downstream ancillary units co-locate with shared utilities, logistics and testing facilities.
  - Encourage state–center coordination to identify suitable locations near ports and raw-material hubs, and to provide common infrastructure such as gas pipelines, high-quality power, and waste management facilities.

- **Raw Material Linkages and Cross-Sector Coordination**
  - Facilitate long-term supply arrangements and joint ventures between solar manufacturers and producers of aluminum, glass, steel, specialty chemicals and battery materials.
  - Identify and prioritize key minerals and input materials for inclusion under national critical mineral and raw material strategies, with a focus on securing imports through diversified supplier bases and strategic partnerships.
- **Incentivizing Domestic Manufacturing of Storage and Inverters**
  - Increase Basic Customs Duty (BCD) on Li-ion cells from 5% to 40% and on Li-ion packs/Battery Energy Storage Systems (BESS) from 10% to 40% to protect domestic production.
  - Provide a 25-30% capital expenditure (capex) subsidy for the establishment of 75-100 GWh of domestic Li-ion cell manufacturing capacity.
  - Introduce advanced manufacturers lists for batteries and inverters to ensure quality and provide market confidence on the lines of ALMM mechanism.
  - Provide 60% R&D reimbursement and a 10% export subsidy for domestic battery and inverter manufacturers to boost innovation and global competitiveness.

Research, Development, Technology Upgradation and Quality Infrastructure

Maintaining global competitiveness necessitates a continuous transition from technological adoption to technological innovation. The focus must be on promoting R&D and facilitating technology transfer to advance to next-generation solar cell architectures, such as TOPCon and Heterojunction (HJT) cells. R&D associated challenges are described as follows:

- **Limited Domestic R&D and Technology Transfer**
  - R&D efforts are fragmented and often focused on incremental cost reductions rather than fundamental technology advancement in high-efficiency cells (TOPCon, HJT, back-contact), perovskites, tandem cells and advanced modules.
  - Indian manufacturers are usually required to pay royalties/ licensing fees from foreign technology providers/ manufacturers for use of IP for manufacturing modules, cells, etc. due to lack of R&D efforts and subsequent lack of Indian IP for such technologies. This increases complexity of technology transfer for enabling Indian manufacturing, and costs associated with royalties/ licensing affects cost competitiveness in global market.
  - India should establish a mission-driven solar manufacturing R&D programme with sustained public funding, industry – academia collaboration, international linkages, pilot scale manufacturing facilities, and fiscal incentives to accelerate the commercialization of next generation photovoltaic technologies and manufacturing processes.
- **Inadequate Testing, Certification and Reliability Infrastructure**
  - Domestic testing and certification infrastructure is not fully equipped to evaluate next-generation high-wattage, bifacial, large-format modules, or advanced power electronics and storage-integrated systems.

- Absence of comprehensive reliability testing for Indian climatic conditions (high temperature, humidity, dust, and soiling) constrains development of India-specific product designs.

- **Module Quality and Low-Efficiency Module Entry:**
  - The current BIS Scheme II lacks mandatory factory audits, which may lead to the risks of mislabeled or poor-quality modules entering the market. Therefore, migration to BIS Scheme – 1 should be accelerated for solar modules to ensure a manufacturing quality assurance system. Solar PV modules should be migrated from BIS Scheme-I (Compulsory Registration Scheme) to BIS Scheme-II (ISI Mark Scheme), enabling factory based licensing, periodic surveillance and process audits to ensure consistent product quality, improve reliability and enhance the global competitiveness of Indian solar manufacturing.
  - The deployment of low-efficiency modules in government schemes may lead to underperformance of solar projects, which may impact overall yield and investor confidence. India needs to set out the minimum efficiency benchmarks for solar modules which are higher than those mandated by the MNRE in November 2025 which is only 21% from January 2027 whereas the leading Indian solar manufacturers are already manufacturing modules at 23% and above. India needs to raise the benchmark to ensure that it does not become the dumping ground for low efficiency modules discarded in other countries.

- **Insufficient Focus on Process Innovation and Productivity**
  - Many domestic lines are based on imported turnkey equipment with limited in-house capability for process optimisation, yield improvement, automation and digitalisation.
  - Low investment in skill development for advanced manufacturing, equipment maintenance, and data-driven process control reduces operational efficiency.

- **Early-Stage Technologies and Recycling Ecosystem Gaps**
  - Limited experimentation with new materials, such as lead-free or lower-silver pastes, alternative encapsulants, and recyclable module designs, slows the transition towards sustainable manufacturing.
  - End-of-life management, including module recycling and second-life use for components, remains underdeveloped, with unclear economic models and regulatory frameworks.

The illustrative solutions for the above challenges are as follows:

- **National Solar R&D and Innovation Mission**
  - Establish an integrated mission focusing on cell efficiency improvement, cost reduction, reliability enhancement, recycling technologies, and India-specific product adaptation, with clear multi-year funding and measurable targets.
  - Prioritize collaborative R&D programmes that bring together industry, national laboratories, academic institutions and global technology providers for joint development and pilot demonstrations.

- The government of India should formulate a national strategy to mitigate the impact of China's export restrictions on solar manufacturing technologies by promoting indigenous equipment development, facilitating technology partnerships with trusted countries, and supporting domestic R&D for ingot and wafer manufacturing.
- Formatted: Font color: Auto – There is currently no dedicated ANRF mission (Anusandhan National Research Foundation) specifically focused on solar PV manufacturing technologies. MNRE and ANRF should together create a National Solar PV Technology Mission which could support the next generation silicon technology solar cells as well as wafer, ingot and polysilicon manufacturing technologies.

- **Strengthening Testing, Certification and Metrology Infrastructure**
  - Transition all solar modules to BIS Scheme I, which mandates rigorous factory audits to ensure consistent production quality. Ban the use of low-efficiency modules in all government schemes and procurement.
  - Standardise minimum 22% modules efficacy with immediate effect for all Govt supported projects with no preference to any technology. Launch an Indian "Top Runner"– type programme. Periodic upward revision of minimum efficiency thresholds by every six months. Recognition of higher-efficiency modules in government procurement.
  - Upgrade existing test labs and establish new centres of excellence for solar modules, cells, inverters, storage systems and power electronics, with internationally benchmarked capabilities.
  - Introduce performance and reliability testing protocols tailored to Indian climates, and link government procurement eligibility to these enhanced quality and reliability standards.
- **Support for Technology Upgradation and Process Modernization**
  - Provide fiscal incentives and concessional credit for upgrading manufacturing lines to higher-efficiency technologies (e.g., PERC to TOPCon/HJT) and for adopting advanced automation, AI/ML-based quality inspection, and digital twins for process control.
  - Promote technology-oriented cluster programs that include shared facilities such as pilot lines, demonstration plants and equipment training centres to reduce the cost of technology adoption for smaller firms.
- **Innovation in Sustainable Manufacturing and Recycling**
  - Encourage R&D on low-carbon manufacturing processes, reduced energy intensity, alternative materials with lower environmental impact, and design-for-recycling approaches.
  - Develop an actionable roadmap for end-of-life management, including standards for recycling processes, extended producer responsibility (EPR) frameworks, and supportive fiscal measures for recycling plants and second-use markets.
  - As the capital equipment required for PV module recycling is not available in India, there should be NIL customs duty for import of new equipment for the same.
  - Provide a 30-35% capital expenditure (capex) subsidy for the establishment of PV module recycling plants.

– Storage Responsibility for end-of-life PV modules should be supported through a digital traceability mechanism integrated with CPCB systems and mandatory reporting by authorised recyclers to ensure visibility and accountability.

– EPR requirement for solar module recycling should rest with large developers (projects greater than 20 MW) along with manufacturers as the cost economics of recycling is not positive currently.

– Provide incentives to registered recyclers based on quantum of PV modules waste processed by them. The incentive will help to maintain sustainable operations for recyclers during initial years till high volumes of recycling modules are available.

Illustrative timeline for implementation of solutions

The above challenges need to be addressed in timely manner for supporting the solar manufacturing sector. The key solutions are categorized by (a) solutions that need to implement immediately, (b) solutions that should be implemented within medium term (2~3 years), and (c) solutions that should be implemented within long term (5~10 years). The illustrative timeline for implementing such solutions is given in the table below:

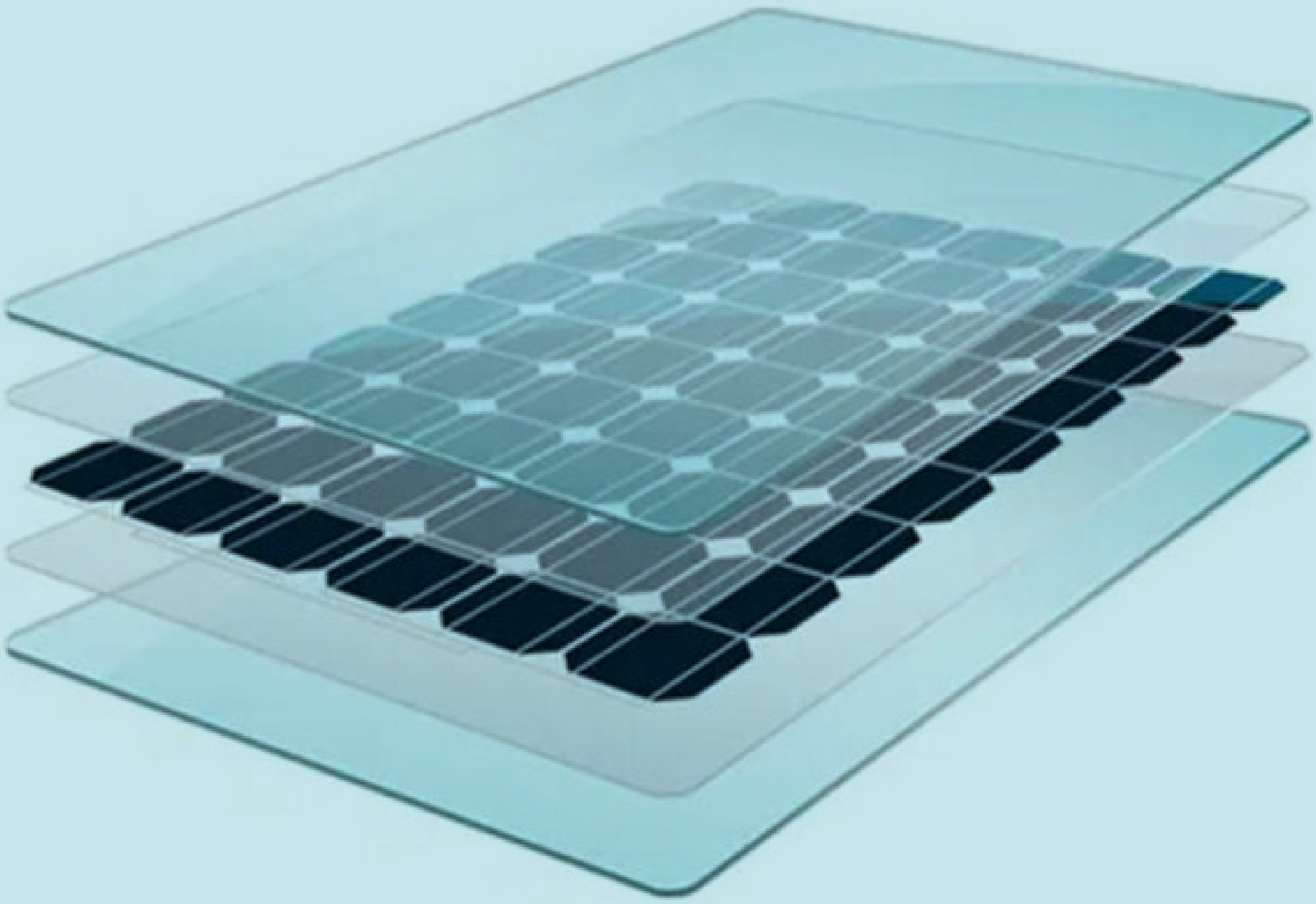
SN	Timeline	Solutions block
1	Immediate (0 ~ 1 year)	• Provide definitive clarity on the timeline for enforcing ALMM. • Initiate the transition of all solar modules to BIS Scheme I, making factory audits mandatory. • Rationalize the Basic Customs Duty (BCD) structure for battery cells, packs, and Battery Energy Storage Systems (BESS) to stimulate domestic production. • Establish a policy for assured market access for domestically produced polysilicon to de-risk initial investments. • Introduce structured feedback mechanism between industry and government ministries/ departments/ regulators to resolve bottlenecks. • Restore the full five-year incentive window for all beneficiaries under the Production Linked Incentive (PLI) scheme to ensure financial viability. • Standardise minimum 22% modules efficacy with immediate effect for all Govt supported projects with no preference to any technology. Launch an Indian "Top Runner"– type programme. Periodic upward revision of minimum efficiency thresholds by every six months. Recognition of higher-efficiency modules in government procurement
2	Medium Term (2~ 3 years)	• Introduce Advanced Manufacturer Lists for batteries and inverters to create a quality-controlled domestic market. • Implement incentives such as R&D reimbursement (up to 60%) and export subsidies (10%) for batteries and inverters. • Provide 50% capital subsidy and concessional power support (e.g., ` 3/unit) for domestic ingot-wafer manufacturing. • Prepare actionable roadmap and supportive fiscal measures for a domestic recycling ecosystem for end-of-life solar modules and batteries.
3	Long Term (3 ~ 6 years)	• Establish National Solar R&D and Innovation Mission for next-generation technologies (e.g., Perovskite, Tandem cells). • Provide 50-60% capital subsidy and concessional power for establishing polysilicon manufacturing plants. • Provide capital expenditure subsidy of 25-30% to facilitate the creation of 75-100 GWh of domestic battery cell manufacturing capacity.

Proposed actions:

- Provide definite clarity and enforce the ALMM List II, effective from June 1, 2026, as per existing MNRE notifications to encourage sectoral investments and manufacturing scale-up.
- We welcome the MNRE notification dated 17th March 2026 regarding the implementation of ALMM for wafers.
- Immediate steps should be taken to prohibit the use of low-efficiency solar modules, particularly in government-supported projects, by standardising minimum 22% modules efficacy, alongside a clearly defined roadmap to progressively enhance module efficiency every six months with no preference to any technology.
- Calibrated trade-remedial measures against continued dumping of key ancillary products such as solar glass, aluminum frames, and encapsulants from ASEAN and other regions, including effective anti-circumvention provisions for routing through non-producing countries.
- Cluster-based development of solar manufacturing parks with integrated facilities for glass, frames, encapsulants, and power-electronics, supported by common infrastructure (testing laboratories, logistics, utilities, waste-treatment). This will enable synergetic development of manufacturing industry while helping to reduce logistics cost for component processing for module manufacturers.
- Recommend alignment of PLI with export objectives and domestic content goals, including additional weight for high-efficiency and advanced technologies (e.g., TOPCon, HJT, bifacial modules) and upstream investments. This can be achieved by recommending changes to tapering factor/ performance matrix in a way that realized PLI is higher for advanced technology manufacturing integrated with upstream manufacturing. The restoration of the full 5-year PLI incentive window is necessary to de-risk investment in long-gestation projects.
- Propose structured feedback mechanism between industry and regulators (MNRE, BIS, other relevant agencies) to systematically identify and resolve regulatory bottlenecks impacting manufacturing timelines and costs. The structured feedback mechanism would enable regular interactions between industry and regulators and help in resolving challenges faced by manufacturers.
- Recommend periodic review of trade barriers, basic customs duties (BCD), and other instruments to balance domestic manufacturing protection, cost to end-consumers, and long-term competitiveness of the value chain. This review should also consider the increase of BCD on Li-ion cells and BESS to promote domestic manufacturing.
- Propose export promotion strategy for solar modules, cells, and balance-of-system components to emerging markets through Memorandum of Understanding (MoU) amongst national governments for facilitating trade through simplification of compliance processes, participation of Indian manufacturers in trade fairs of target countries, establishing regional branches of major Indian banks in target countries for facilitating trade finance, and provide competitive finance for large scale projects in target countries that utilize Indian solar modules and components.

6

Balance of Materials



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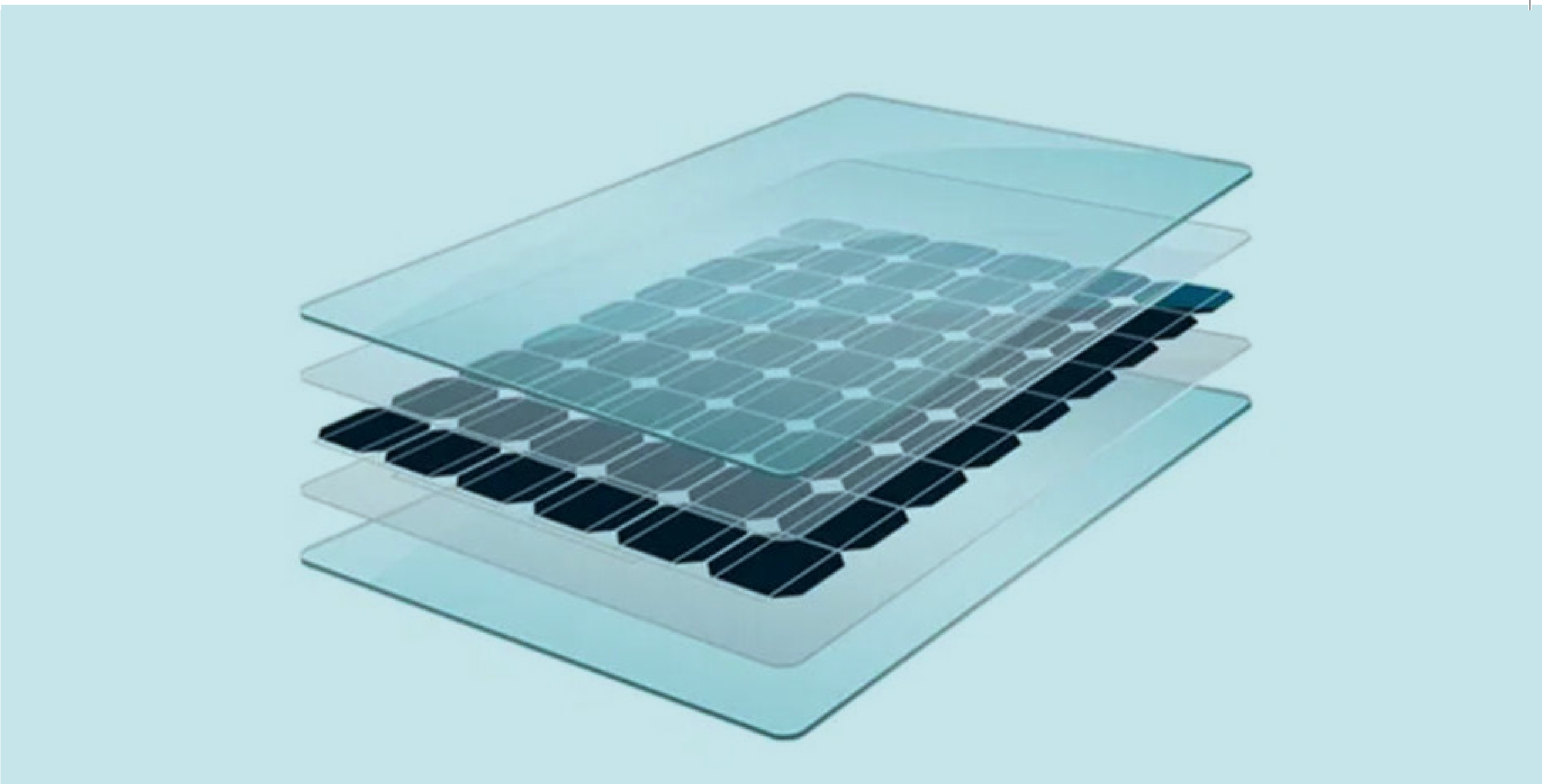
Background

India's solar manufacturing ecosystem is undergoing a pivotal transition, shaped by ambitious national targets and evolving global dynamics. The Government of India's commitment to achieve 500 GW of non-fossil fuel capacity by 2030, along with the broader vision of Atmanirbhar Bharat, has placed solar photovoltaic manufacturing at the center of the country's energy and industrial policy. Over the past decade, domestic demand for solar modules has expanded rapidly through utility-scale solar parks, rooftop programmes, PM KUSUM scheme, and emerging applications such as Building Integrated Photovoltaics (BIPV), floating solar, agrivoltaics and distributed renewable energy.

A key structural shift under way in this context is the movement of the domestic industry from assembly-oriented operations towards deeper, end-to-end manufacturing with higher value addition within India. This transition requires not only scaling up cell and module capacities but also developing a robust domestic ecosystem for the Balance of Materials (BoM) used in PV modules and systems. The overarching philosophy guiding this transition is to progressively localize and manufacture BoM in India, and to limit lower-duty or concessional duty recommendations only to those raw materials and inputs for which there is no domestic capacity, resource availability, or concrete capacity expansion plans. This approach aims to promote sustainable value chain development, reduce import dependence, and enhance India's long-term competitiveness in solar manufacturing.



The Balance of Materials encompasses a wide range of components, that includes but is not limited to solar glass, encapsulants (EVA, EPE, POE), back sheets, aluminum frames, junction boxes, copper interconnects, and sealants. These elements are vital for ensuring the 25-year operational lifecycle required of the assets. Efficiency, cost competitiveness, and the overall environmental footprint of a solar project are directly influenced by the quality and availability of these materials. The development of a strong BoM manufacturing base is therefore essential for ensuring module performance, degradation rates, and project bankability that remain aligned with international benchmarks.

The existing and planned domestic capacity for manufacturing key ancillaries is provided on the table below. The data is collected from the industry partners.

Ancillary	Existing Capacity (in GW)	Under construction capacity by March 2027 (in GW)	Total Capacity by March 2027 (In GW)	Further announced capacity March 2028 (in Gw)	Total Capacity by March 2028 (in GW)
Solar Glass	18	33	51	14	65
Encapsulants	50	29	79	44	123
Back-Sheet	28	0	28	0	28
Aluminum Frames	27	58	85	0	85
Junction Box	104	33	137	0	137
Copper Interconnect	43	35	78	45	123
Sealant	27	50	77	0	77

Domestic manufacturing capacity for several ancillary components—including aluminum frames, junction boxes, copper interconnects, and encapsulants—is projected to exceed 50 GW by March 2027. However, actual utilization of this capacity remains modest. This is primarily due to imports from countries such as China, Vietnam, which benefit from direct and indirect subsidies, economies of scale, concessional finance, and other forms of industrial support in their countries of origin.

In response to these opportunities and challenges, there is a need for a structured industry platform that can facilitate policy dialogue, evidence-based recommendations, and collaborative problem-solving focused specifically on BoM and related value chains. Such a platform can support systematic mapping of current and planned domestic capacities, analysis of cost structures and quality benchmarks, identification of critical import dependencies, and assessment of supply-chain vulnerabilities.

The CII Working Group on Balance of Materials is being constituted to serve this role. Its focus is on enabling the transition from assembly to competitive, integrated manufacturing in India by supporting policies and industry actions that deepen domestic value addition in BoM, encourage technology upgradation and scale, and recommend duty calibrations/trade-related measures.

Key challenges and possible solutions for growth of Indian solar balance of material manufacturing sector

The advancement of India's solar balance of material manufacturing sector is supported by government initiatives, but at the same time is confronted by critical structural and external challenges. Addressing these challenges requires a combined approach that improves policies, strengthens the supply chain, and promotes independent technology development. Some of the proposed intervention areas can be:

1. Policy asymmetry between modules and balance of materials

The solar module manufacturing ecosystem has benefited from targeted policy instruments such as the Approved List of Models and Manufacturers (ALMM), Domestic Content Requirement (DCR), and Production Linked Incentive (PLI) schemes. These measures have created predictable demand, improved bankability, and encouraged capacity expansion for cells and modules. In contrast, there is no comparable, structured policy framework for balance of material (BoM) components such as solar glass, encapsulants, back sheets, aluminum frames, junction boxes, copper interconnects, sealants, and other ancillaries. This policy asymmetry has led to several challenges:

- Domestic investments in BoM manufacturing face demand uncertainty and continued competition from low-priced imports, despite the creation of significant local capacities.
- Capacity utilization for several ancillaries remains sub-optimal, resulting in financial stress and delayed new investments.
- The absence of dedicated schemes for ancillaries limits backward integration and weakens the overall competitiveness of the Indian solar manufacturing value chain

The Working group deliberated upon the key challenges and key interventions or possible solutions for the above challenges have been tabulated as follows:

- Designing an ancillary-focused policy framework aligned with existing ALMM/ALCM, DCR, and PLI schemes, with explicit recognition of BoM as a strategic segment.

- Incorporating local value-addition criteria for BoM components in future procurement guidelines of central and state agencies, especially for large-scale and government-supported projects.
- Introducing targeted financial incentives, such as interest rate subvention, viability gap support, or tax deductions on capital expenditure, specifically for BoM manufacturing expansion and technology upgradation.
- Linking any future revisions of ALMM/ALCM and DCR requirements to minimum domestic content thresholds for defined critical ancillaries, with appropriate transition timelines.

2. Tariff structure and inverted duty issues

The current customs duty structure for several BoM components is misaligned with domestic manufacturing objectives. In some cases, finished ancillaries attract lower duties than their raw materials, creating inverted duty structures that discourage domestic value addition. These challenges are explained as follows:

- Tin-coated copper interconnects and busbars, which are reportedly imported under certain HSN classifications with a Basic Customs Duty (BCD) of around 3%, lower than the duty applicable on raw copper used for domestic manufacturing. In principle, the BCD on such value-added copper products should be on par with or higher than the BCD on the raw material to avoid duty inversion. Accordingly, maintaining the BCD on tin-coated copper interconnects and busbars at or above 5% may be considered appropriate.
- Junction boxes imported under generic HSN codes that also cover low-end, non-solar products, enabling lower duty incidence and undercutting specialized domestic producers.
- Solar sealants used for frame and potting applications attracting BCD of 10 percent, which does not adequately offset subsidized and low-priced imports.
- Specific duty concessions provided to certain encapsulants through customs notifications, while other encapsulant types face relatively higher effective duties or administrative barriers.

The illustrative solutions for the above challenges are as follows:

- Introducing dedicated HSN codes for key solar BoM components, including solar photovoltaic junction boxes and copper interconnects (including busbars), with BCD rates calibrated to promote domestic manufacturing while remaining compliant with international trade obligations.
- Correcting inverted duty structures by ensuring that raw materials used by domestic manufacturers do not attract higher customs duties than finished imported ancillaries.
- Gradually increasing BCD for selected ancillaries such as sealants and specialized junction boxes, with clear advance intimation, to allow domestic manufacturers to invest in capacity and technology.

- Undertaking periodic tariff reviews for BoM components through a formal consultative mechanism involving industry, the Directorate General of Trade Remedies (DGTR), and the Ministry of Finance to maintain alignment with evolving global prices, supply risk, and domestic capacity.

3. Regulatory gaps in raw material supply and cost competitiveness

BoM manufacturing depends on a range of critical raw materials, some of which are not produced in India and must be imported. This creates vulnerabilities in cost structure and supply security. Solar glass manufacturing, for instance, depends on sodium antimonate, a critical raw material that is currently not produced domestically and attracts customs duty. Similar dependencies exist for specialty polymers, adhesives, and additives used in encapsulants, back sheets, and sealants. These challenges are explained as follows:

- Higher input costs compared to global competitors, especially where international suppliers benefit from subsidies or concessional energy tariffs.
- Volatility in raw material prices and foreign exchange exposure that erodes margins for domestic manufacturers.
- Constraints on scaling up domestic BoM production in line with the anticipated growth in solar deployment toward 2030 and beyond.

The illustrative solutions for the above challenges are as follows:

- Rationalizing customs duties on critical raw materials that are not manufactured in India, such as sodium antimonate for solar glass production, to reduce input costs and improve competitiveness.
- Promoting domestic production of key raw materials through targeted support, such as inclusion under existing schemes for chemical and specialty materials and offering incentives for import substitution where economically viable.
- Facilitating long-term supply agreements and strategic sourcing arrangements for high-importance raw materials through industry consortia or public–private platforms.

4. Technology and product standardization gaps

The rapid evolution of solar technologies, including larger wafer formats, higher power modules, bifacial designs, and new cell architectures, has direct implications for BoM design and performance. Many domestic BoM manufacturers need to continuously upgrade formulations, designs, and processes to keep pace with international benchmarks and project requirements. At the same time, there is limited formal standardization and certification specific to several BoM components, especially for newer materials and compositions. These challenges are explained as follows:

- Fragmented product specifications across projects and developers, leading to small production runs, higher inventory, and reduced economies of scale.
- Hesitancy among developers to adopt newer domestic BoM products due to concerns about long-term reliability and lack of widely accepted performance data.

- Technology dependence on imported formulations, equipment, and know-how, especially for advanced encapsulants, back sheets, sealants, and high-performance junction boxes.

The illustrative solutions for the above challenges are as follows:

- Developing and notifying Indian standards and technical specifications for key BoM components through the Bureau of Indian Standards (BIS), in consultation with industry, research institutions, and testing laboratories.
- Establishing dedicated testing and certification facilities for BoM components, linked to international qualification standards (such as IEC) and adapted to Indian climatic conditions.
- Supporting collaborative R&D programmes involving industry and academia for advanced BoM materials, including improved encapsulant formulations, high-durability sealants, and high-voltage junction boxes suitable for utility-scale applications.
- Providing fiscal or grant-based support for technology upgradation, pilot lines, and prototyping facilities that help domestic manufacturers validate new BoM technologies.

5. Quality assurance, quality control orders, and enforcement

High-quality BoM is critical to achieving the desired lifetime and performance of solar installations, which are typically expected to operate for 25–30 years. Inadequate quality of glass, encapsulants, sealants, junction boxes, and other components can lead to early degradation, safety risks, and loss of generation. While Quality Control Orders (QCOs) have been applied to solar modules and cells, similar measures for BoM components are either absent or at nascent stages. These challenges are explained as follows:

- Entry of sub-standard imported BoM products that may meet generic standards but are not suited for long-term use in Indian climatic conditions.
- Limited traceability and certification enforcement across the supply chain, especially for small and medium-sized project developers.
- Insufficient advance notice and consultative planning in some sectors in the past, which created uncertainty for both domestic and import-dependent manufacturers.

The illustrative solutions for the above challenges are as follows:

- Implementing QCOs for critical BoM components such as solar glass, encapsulants, junction boxes, and cables, with clear timelines and phased applicability, considering current and planned domestic capacities.
- Aligning QCOs with BIS standards and international technical norms, while specifying performance in Indian environmental conditions (temperature, humidity, UV exposure, dust, and pollution).
- Providing sufficient lead time before enforcement of new QCOs to enable domestic investment, technology adaptation, and clearance of existing inventory.

- Establishing robust enforcement mechanisms at ports, customs, and project sites, including mandatory BIS marking and digital traceability to manufacturers.

6. Financing, investment Risk, and long-term visibility

BoM manufacturing, especially in segments such as solar glass, is capital-intensive and characterized by long asset lifecycles, including complex furnace construction and replacement cycles. Domestic manufacturers require sustained operating cash flows to service debt, provide for depreciation, and finance technology upgrades. These challenges are explained as follows:

- Perceived risk among lenders due to historical volatility in margins and policy changes, including the withdrawal or modification of trade protections.
- Difficulties in securing long-tenure, competitively priced financing for capacity expansion and upgradation.
- Limited use of green finance and sustainable instruments for BoM manufacturing, despite its central role in the renewable energy transition.

The illustrative solutions for the above challenges are as follows:

- Recognizing BoM manufacturing as a priority sector within broader renewable energy manufacturing policy frameworks, thereby facilitating access to concessional or blended finance.
- Encouraging development of finance institutions, green funds, and multilateral agencies to support BoM investments through guarantees, credit enhancement, and long-term lines of credit.
- Linking financial support to performance and sustainability metrics, such as energy efficiency of operations, adoption of renewable energy in manufacturing, and circularity measures.
- Providing stable and predictable policy signals on duties, QCOs, and trade remedies to reduce perceived regulatory risk and improve the bankability of BoM manufacturing projects.

Illustrative timeline for implementation of solutions

The above challenges need to be addressed in timely manner for supporting the solar balance of materials manufacturing sector. The key solutions are categorized by (a) solutions that need to implement immediately, (b) solutions that should be implemented within medium term (2~3 years), and (c) solutions that should be implemented within long term (5~10 years). The illustrative timeline for implementing such solutions is given in the table below:

SN	Timeline	Solutions block
1	Immediate (0~ 1 year)	• Designing an ancillary-focused policy framework aligned with existing ALMM/ALCM, DCR, and PLI schemes, with explicit recognition of BoM as a strategic segment. • Incorporating local value-addition criteria for BoM components in future procurement guidelines of central and state agencies, especially for large-scale and government-supported projects. • Linking any future revisions of ALMM/ALCM and DCR requirements to minimum domestic content thresholds for defined critical ancillaries, with appropriate transition timelines. • Introducing dedicated HSN codes for key solar BoM components, including solar photovoltaic junction boxes and copper interconnects (including busbars), with BCD rates calibrated to promote domestic manufacturing while remaining compliant with international trade obligations. • Correcting inverted duty structures by ensuring that raw materials used by domestic manufacturers do not attract higher customs duties than finished imported ancillaries • Rationalizing customs duties on critical raw materials that are not manufactured in India, such as sodium antimonate for solar glass production, to reduce input costs and improve competitiveness. • Recognizing BoM manufacturing as a priority sector within broader renewable energy manufacturing policy frameworks, thereby facilitating access to concessional or blended finance.
2	Medium Term (2~ 3 year)	• Facilitating long-term supply agreements and strategic sourcing arrangements for high-importance raw materials through industry consortia or public–private platforms • Developing and notifying Indian standards and technical specifications for key BoM components through the Bureau of Indian Standards (BIS), in consultation with industry, research institutions, and testing laboratories. • Establishing dedicated testing and certification facilities for BoM components, linked to international qualification standards (such as IEC) and adapted to Indian climatic conditions. • Implementing QCOs for critical BoM components such as solar glass, encapsulants, junction boxes, and cables, with clear timelines and phased applicability, considering current and planned domestic capacities. • Aligning QCOs with BIS standards and international technical norms, while specifying performance in Indian environmental conditions (temperature, humidity, UV exposure, dust, and pollution). • Providing stable and predictable policy signals on duties, QCOs, and trade remedies to reduce perceived regulatory risk and improve the bankability of BoM manufacturing projects.

SN	Timeline	Solutions block
3	Long Term (5 ~ 10 year)	• Undertaking periodic tariff reviews for BoM components through a formal consultative mechanism involving industry, the Directorate General of Trade Remedies (DGTR), and the Ministry of Finance to maintain alignment with evolving global prices, supply risk, and domestic capacity. • Supporting collaborative R&D programmes involving industry and academia for advanced BoM materials, including improved encapsulant formulations, high-durability sealants, and high-voltage junction boxes suitable for utility-scale applications • Establishing robust enforcement mechanisms at ports, customs, and project sites, including mandatory BIS marking and digital traceability to manufacturers

Proposed actions:

- Propose dedicated policy framework for solar BoM that aligns with ALMM/ALCM, DCR, and PLI, with explicit domestic content and local value-addition targets for key ancillaries.
- Recommend rationalization of customs duties to eliminate inverted duty structures for components such as copper interconnects and busbars, ensuring finished imports do not enjoy lower duties than raw materials.
- Propose structured feedback mechanism between industry and regulators (MNRE, BIS, other relevant agencies) to systematically identify and resolve regulatory bottlenecks impacting manufacturing timelines and costs. The structured feedback mechanism would enable regular interactions between industry and regulators and help in resolving challenges faced by manufacturers.
- Recommend periodic tariff reviews for BoM components through a formal consultative mechanism involving industry, the Directorate General of Trade Remedies (DGTR), and the Ministry of Finance to maintain alignment with evolving global prices, supply risk, and domestic capacity.
- Recommend implementing QCOs for critical BoM components such as solar glass, encapsulants, junction boxes, and cables, with clear timelines and phased applicability, considering current and planned domestic capacities
- Recommend collaborative R&D programmes involving industry and academia for advanced BoM materials, including improved encapsulant formulations, high-durability sealants, and high-voltage junction boxes suitable for utility-scale applications.
- Propose BoM manufacturing to be classified as priority area under green industrial policies which will help to enable access to concessional and long-tenure credit.

Confederation of Indian Industry

The Confederation of Indian Industry (CII) works to create and sustain an environment conducive to the development of India, partnering Industry, Government and civil society through advisory and consultative processes.

CII is a non-government, not-for-profit, industry-led and industry-managed organisation, with over 10,500 members from the private as well as public sectors, including SMEs and MNCs, and an indirect membership of over 365,000 enterprises from 332 national and regional sectoral industry bodies.

For more than 130 years, CII has been engaged in shaping India's development journey and works proactively on transforming Indian Industry's engagement in national development. CII charts change by working closely with the Government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness, and business opportunities for industry through a range of specialised services and strategic global linkages. It also provides a platform for consensus-building and networking on key issues.

Through its dedicated Centres of Excellence and Industry competitiveness initiatives, promotion of innovation and technology adoption, and partnerships for sustainability, CII plays a transformative part in shaping the future of the nation. Extending its agenda beyond business, CII assists industry to identify and execute corporate citizenship programmes across diverse domains, including affirmative action, livelihoods, diversity management, skill development, empowerment of women, and sustainable development, to name a few.

For 2026-27, CII has identified **"Accelerating Competitiveness: Growth, Resilience, Inclusion, Sustainability, Trust"** as its theme, prioritising five key pillars. During the year, CII will align its policy advocacy, institutional initiatives, partnerships, and outreach to support Indian industry in strengthening these five interconnected pillars of competitiveness.

With 70 offices, including 12 Centres of Excellence, in India, and 9 overseas offices in Australia, Egypt, Germany, Indonesia, Singapore, UAE, UK, and USA, as well as institutional partnerships with 255 counterpart organisations in 102 countries, CII serves as a reference point for Indian industry and the international business community.

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