Bharat Cleantech Manufacturing Platform: Wind Indigenisation Pathways

Accelerating an Aatmanirbhar, Green and Viksit Bharat

bharat CLIMATE FORUM

Council for International Economic Understanding

mec+

Dalberg

As India rapidly moves towards meeting its NDCs, indigenisation of cleantech manufacturing is critical for an *Aatmanirbhar* and *Viksit Bharat*

India has national targets and projections across renewable energy and e-mobility for 2030…

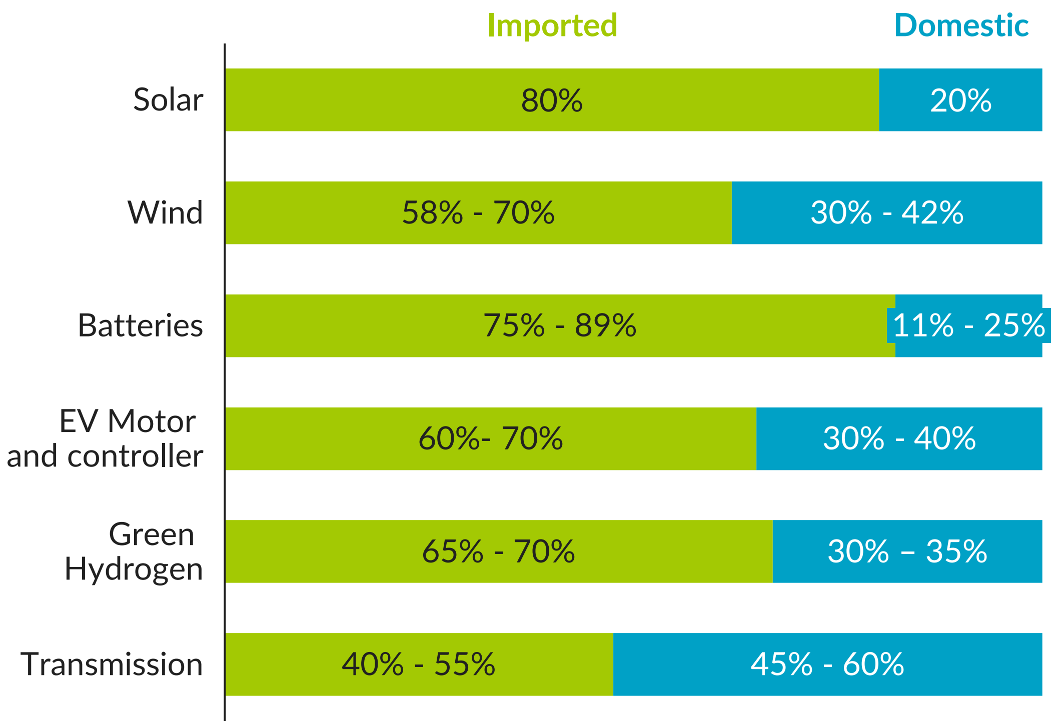
300 GW Solar *installed capacity*[1]

30% EV *sales penetration*[2]

100 GW Wind *installed capacity*[3]

5 MTPA Green Hydrogen *production*[4]

… but cleantech supply chains are heavily import-dependent and need to be indigenised for an Aatmanirbhar Bharat



Cleantech manufacturing import dependence across the value chain, 2023

Source: (1) MNRE; Solar capacity projection extrapolated from CEA's 2032 Solar capacity projections, assuming linear growth in capacity; (2) NITI Aayog ; (3) ET ; (4) MNRE - NGHM; MNRE, Ministry of Power; Economics Times; BNEF's installed and announced capacity; IEA, India – World Energy Investment 2024 – Analysis; NITI, India's Power Sector | Capacity & Generation Mix; PIB, India's Ethanol Push: A Path to Energy Security, CEEW, Strengthen India's Clean supply chain, 2024; Bain, India Electric Vehicle Report, 2023; Policy circle; Economist Impact, Scaling clean energy: financing and transition strategies for India's sustainable future

The Platform could support the National Manufacturing Mission to target at least 50% indigenisation of cleantech manufacturing value chains by 2030 enabling net-zero ambition with indigenous production

The Platform's potential to accelerate development of incremental indigenous capacity can be observed across sectors

Sector-wise goals

	Solar	Wind	BESS	E-mobility	Green Hydrogen	Transmission
Installed capacity						
2030 targets	300 GW[1]	100 GW[2]	230-240 GWh[3]	30@30[4]	5 MTPA[6]	648,190[7] ckm
% value chain indigenisation*						
Current levels (est.)	~20%	~35%	~20%	~35%[5]	~35%	~55%
2030 target (Proposed)	~50%	~60%	~45%	~50%	~60%	~70%

May decline due to shifting and unstable demand of domestic components amid intensified global competition

Note: *Indigenisation is domestic value contribution across cleantech value chain from raw materials to end production for all components; : (1) MNRE; (2) ET; (3) Estimated requirements under National Electricity Plan (NEP) 2023 of CEA; (4) NITI Aayog ; (5) For EV Motors and controllers; (6) MNRE - NGHM (7) 2032 target from National Electricity Plan Volume II – Transmission of CEA

Source: MNRE, Ministry of Power; Economics Times; BNEF's installed and announced capacity; IEA, India – World Energy Investment 2024 – Analysis; NITI, India's Power Sector | Capacity & Generation Mix; PIB, India's Ethanol Push: A Path to Energy Security, NEP 2023 of CEA; EV Reporter, India's electric vehicle supply chain landscape | An overview, 2024

A detailed strategy and action plan for the focus sectors would be developed to achieve these goals and objectives and build the cleantech indigenisation pathways for these sectors

Sector-wise gaps would be identified and addressed with all stakeholders across each cross-cutting theme in alignment with the National Manufacturing Mission

Enablers:
Policy recommendations; Trade partnerships; Public and private stakeholder recommendations; Demand and supply drivers; Leveraging AI for Climate and cleantech manufacturing

Sectors

- Solar
- Wind
- BESS
- E-mobility
- Green Hydrogen
- Transmission

Cross-cutting themes

Demand & Market Architecture	*Drive demand and adoption of output, incl.* ***Quality Control Orders (QCOs)***
R&D & Product Innovation	*Drive technology sharing, adoption and indigenous R&D*
Upstream Raw Materials & Critical Inputs	*Streamline raw material sourcing (e.g. critical rare earth elements; bio-energy feedstock etc.)*
Capital Equipment & Infrastructure	*Address machinery sourcing & infrastructure requirements (e.g., grid connectivity)*
Talent & Workforce	*Bridge skilling gaps for specialised and non-specialised workforce*
Financing & Taxation	*Identify financial instruments and mechanisms to reduce the funding gap* *Identify levers to improve* ***Ease of Doing Business*** *to attract investments*

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SECTION ONE

CURRENT WIND LANDSCAPE IN INDIA

India's installed wind capacity has grown at 8% CAGR over 2014-2025 with targets to triple installed capacity to 140 GW by 2030; recent efforts have also focused on increasing domestic manufacturing

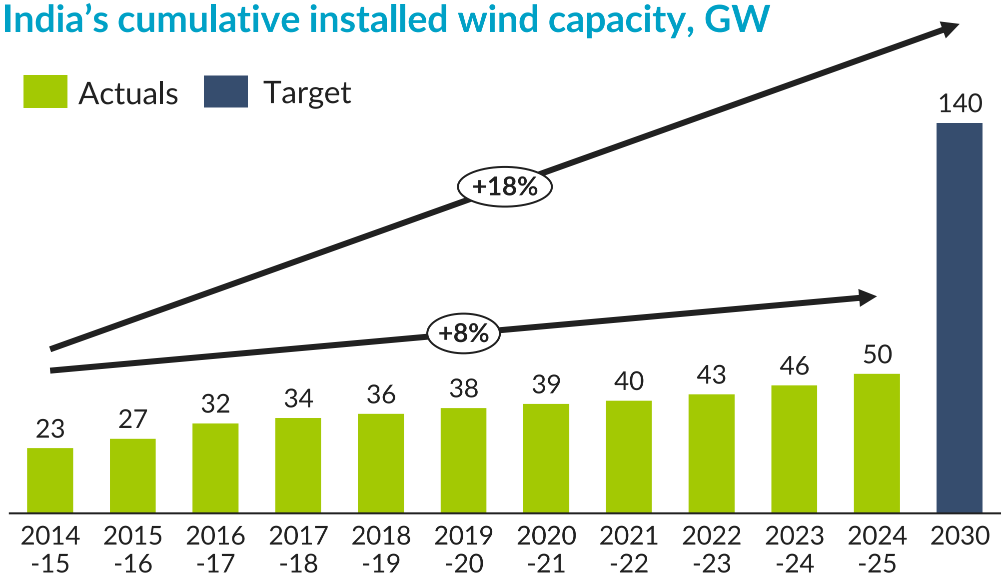
Wind deployment growth drivers

- **Supportive government policies** like ISTS charge waiver, annual wind tenders, RPO etc.
- Strong domestic ecosystem **(4th largest globally, with 50 GW installed; ~34,600 people employed),** enables scale up and supports growth
- Recent policy shifts could impact this demand growth such as:
    - **Rise in India's LCOE for wind** (INR 2.8-3.3/kWh in 2020 - INR 3.3-3.8/kWh in 2024) owing to rise in steel prices
    - **Higher DISCOM charges on RE** [1] (INR 3.4 -3.7/kWh) vs thermal (INR 2.9/kWh)
- Potential to accelerate further by addressing **PPA signing delays**

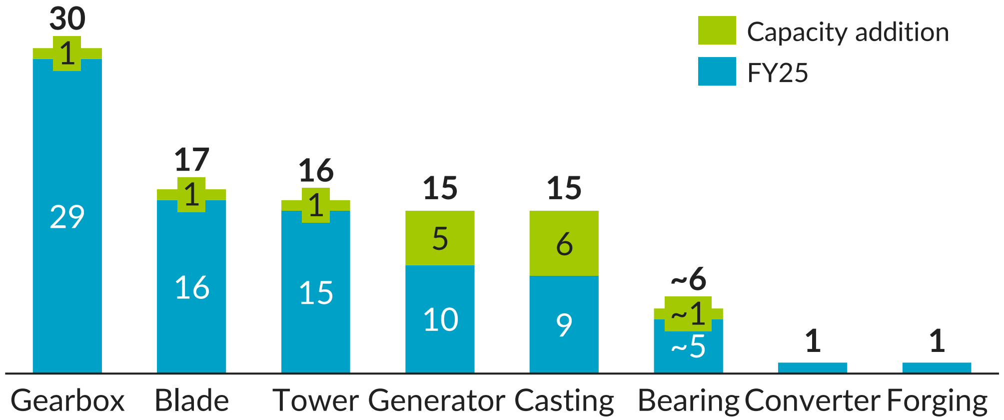
Domestic manufacturing landscape

- **Fiscal and non-fiscal policies** aim to cut manufacturing costs and boost innovation & scalability in RE manufacturing sector
    - **ALMM (Wind)** certification ensures quality WTGs; **100% excise duty exemption** & **CCDC** support imports/localisation
- **Government** expresses interest in taking initiatives for **localisation**
    - **NITI Aayog** proposes **60% domestic content** (by cost) in WTGs.
    - Draft **ALMM (Wind) amendments mandate disclosure** of specs, vendors & local sourcing of key components (with limited import exemptions)

India's cumulative installed wind capacity, GW



WTG component manufacturing existing v/s forecast, GW

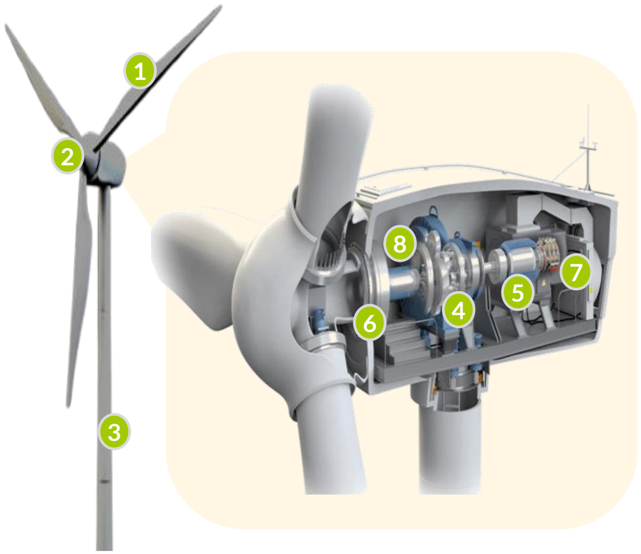


Note: RPO – Renewable Purchase Obligation; LCOE- Levelized Cost of Energy , Total Wind capacity as of 31Mar'25 is 50 GW ; Source: ISTS waiver; Wind RPO; Tariff bidding update;, India Wind Outlook, News Articles IEA. MEC+ analysis

Wind Energy | Major components break-up of a wind turbine generator (WTG)

A WTG has been analyzed at the assembly level by breaking into 3 parts, with 8 critical components that make up for 82% of the WTG value are further examined at the system and raw material level to estimate the level of indigenisation

Wind Turbine Supply Chain Breakdown



Assembly Level	System Level	Value Addition
Rotor Assembly	① *Blade*	*26%*
	② *Castings*[a]	*6%*
Tower Assembly	③ *Tower*	*22%*
Nacelle Assembly	④ *Gearbox*	*13%*
	⑤ *Generator*	*4%*
	⑥ *Bearings*[b]	*6%*
	⑦ *Converter*	*3%*
	⑧ *Forgings*[c]	*2%*
Others[d]	*Miscellaneous*	*18%*

Existing level of indigenisation as of **FY25**

35-40%

Target level of indigenisation by **2030**

55-60%

Note: a Includes hub and mainframe b Bearings include main bearing, blade bearing and yaw bearing. c forgings primarily includes main shaft; d Other components comprising of approx. 18% of the cost includes yaw system, transformer, mechanical brakes, castings and misc. components like cables and sensors
Source: Wind reports. MEC+ Analysis

Wind Energy | Targeted government interventions have accelerated WTG component manufacturing, increasing production capacity from 12 GW in 2022 to 20 GW in 2024

However, further capacity expansion would be required to achieve a minimum of 60% indigenisation by 2030 – this could be enabled through strong fiscal and non-fiscal incentives across the value chain

Manufacturing policy landscape

Fiscal and non-fiscal government policies aiming to reduce manufacturing costs, promote innovation, and enhance scalability in India's wind manufacturing sector

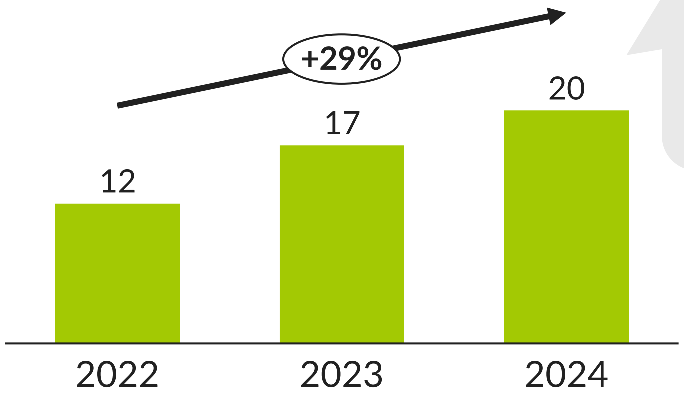
- **ALMM (Wind) type certification** mandated for wind turbines and components ensures only certified, high-quality products are manufactured and deployed
- **100% excise duty exemption** on key wind turbine parts and **CCDC for subcomponent imports** reduces production cost, and supports local assembly

Going forward, government is expressing interest & continuing to take initiatives

- NITI Aayog has proposed to **mandate a 60% cost percentage of locally manufactured components** in WTG, aiming deeper localisation
- Draft amendments to the ALMM (Wind) Listing require manufacturers to disclose key technical specifications and domestic vendors, and **mandate local procurement of towers, blades, gearboxes, and generators**, with only limited import exemptions—further strengthening the domestic wind manufacturing ecosystem

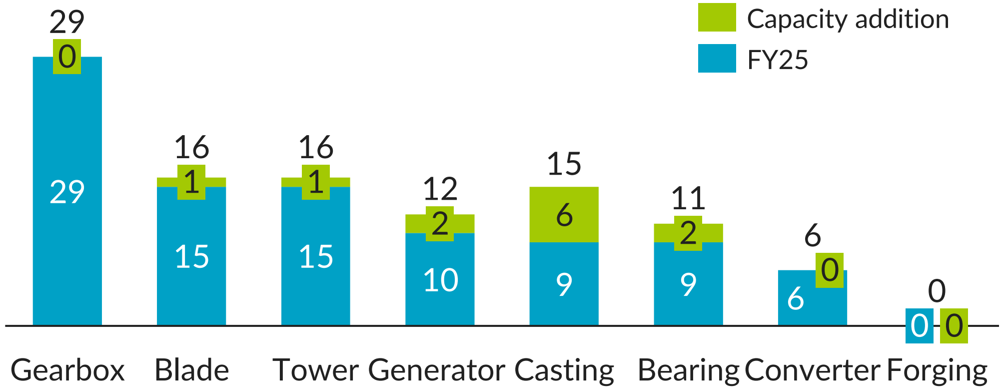
Government policies have propelled **domestic manufacturing of WTG components** (despite halt in manufacturing during COVID 19) as production capacity grew by **CAGR 29%** from **2022** to **2024**

Nacelle assembly capacity addition, GW



~8 GW manufacturing capacity addition in last 3 years

WTG component manufacturing existing v/s forecast, GW



Note:ALMM (Wind) Approved List of Models and Manufacturers (Wind); FDI: Foreign Direct Investment; CCDC: Concessional Custom Duty Certificate

Source:GWEC; MNRE; NITI Ayog; NIWE Domestic Nacelle Mandate; News articles; MEC+ analysis

There are several opportunities that could be captured through wind value chain manufacturing indigenisation

USD 8-11 Bn

Annual domestic wind market potential by 2030

USD 8-9.8 Bn

Cumulative import bill savings 2025-30

Up to 32,000 jobs[1]

Across wind manufacturing value chain by 2030

USD 7-7.5 Bn

Annual export wind market potential by 2030

INR 13,500-20,700 Cr

Financing gap closure for wind indigenisation pathway by 2030

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(1) Refers to incremental jobs required in the Wind manufacturing sector; Source: MEC+, Dalberg's analysis; RMI, India at 2047; Bloomberg NEF, Energy Transition Investment trend, 2024

SECTION TWO

WIND INDIGENISATION PATHWAYS FOR INDIA

The wind indigenisation pathways have been built on two demand scenarios – conservative and optimistic – to identify potential pathways and key enablers to achieve 60% indigenisation for wind value chain by 2030

	CONSERVATIVE SCENARIO	OPTIMISTIC SCENARIO
Scenario criteria		
1 Government policy landscape	Upswing in tender activity, RAP targets to be met up top states	RAP targets to be met by all states, grid augmentation at current pace
2 C&I wind installations	Expected to increase from current levels	Acceleration expected as corporates adopt cost-competitive hybrid power to achieve net-zero emissions and RE100 targets by 2030
3 Export growth	US/Europe/ME & Africa : Existing share of 15% in global exports to these countries to be maintained	US/Europe : Existing share of 15% in global exports to these countries to be maintained ME & Africa : Increase in total share considered
2030 annual demand for turbines , GW	**14 GW**	**18 GW**
Incremental capex investment required for 60% indigenisation by 2030, INR Cr	**INR 13,500 – 14,500 Cr[1]**	**INR 19,700 – 20,700 Cr[1]**
Total government support needed till 2030, INR Cr	**INR 10,100 Cr**	**INR 12,400 Cr**
Potential import bill savings (2025-2030), INR Cr	**INR 68,800 Cr**	**INR 84,300 Cr**

Detailed in Annex

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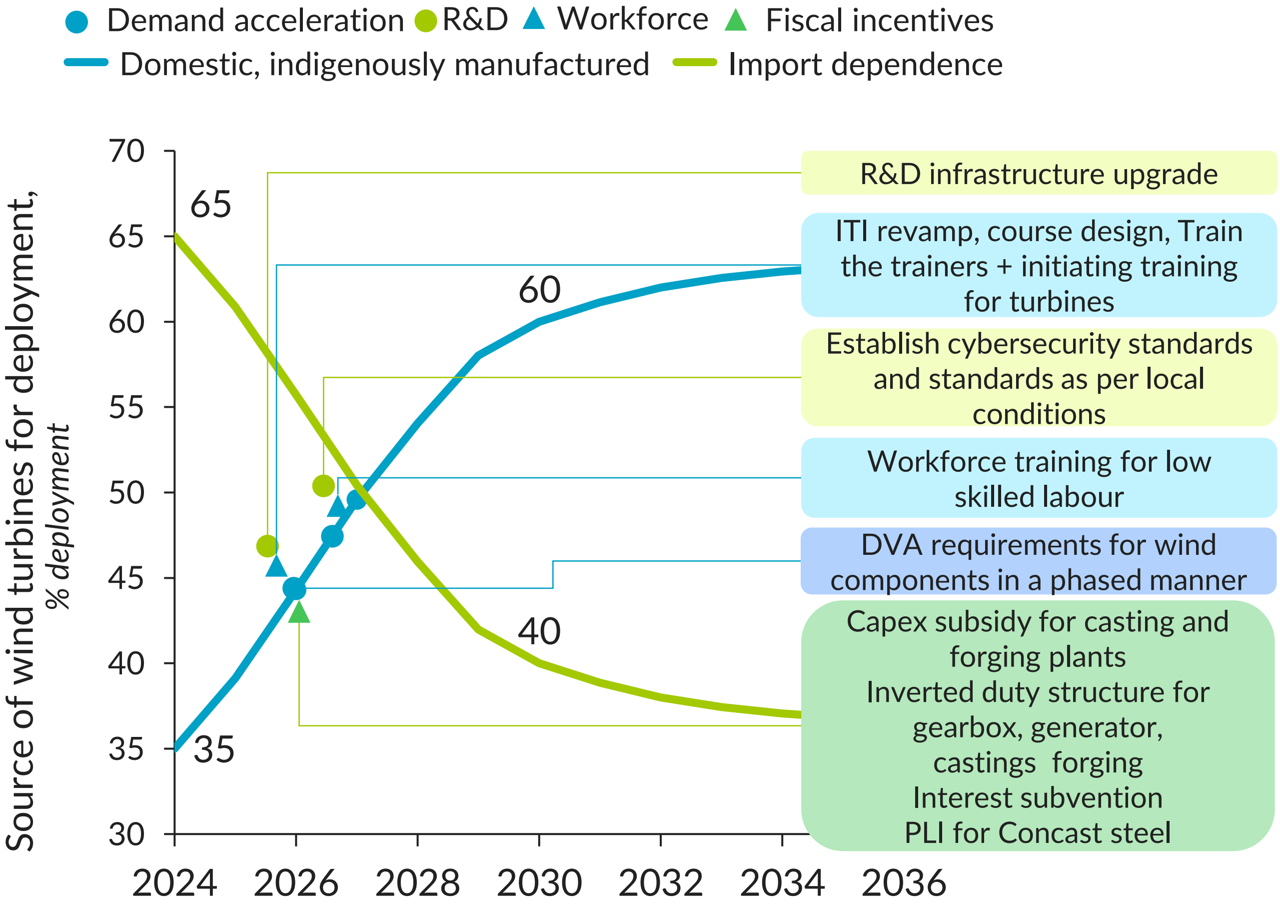
(1) Does not include input side capex subsidies

India could achieve 60% indigenisation on wind manufacturing by 2030 across the value chain from component level to raw material through focused interventions, fiscal and non-fiscal incentives

Wind Indigenisation Pathway



R&D infrastructure upgrade

ITI revamp, course design, Train the trainers + initiating training for turbines

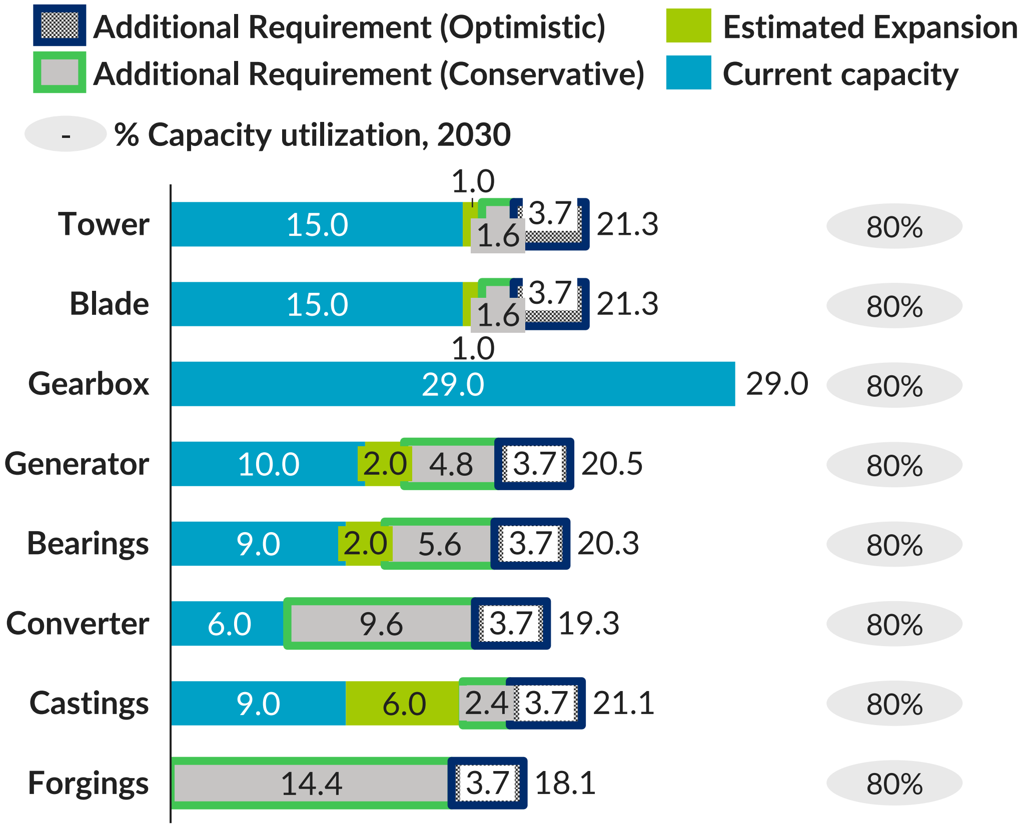
Establish cybersecurity standards and standards as per local conditions

Workforce training for low skilled labour

DVA requirements for wind components in a phased manner

Capex subsidy for casting and forging plants
Inverted duty structure for gearbox, generator, castings forging
Interest subvention
PLI for Concast steel

Manufacturing capacity required to achieve 60% indigenisation, 2030, GW[2]



Detailed in Annex

Source: : NITI Aayog, mec+ analysis

Demand acceleration interventions such as align inverted duty structure to fuel indigenous manufacturing across the value chain, while investment in R&D and upstream raw materials could drive self-reliance

Demand & Market Architecture

- Adjust **inverted duty structures to create domestic pricing competitiveness** of sub-system level components
- **Policy to attract global suppliers** of components who are not currently present in India to set-up manufacturing facilities in India

Overall **Government** fiscal incentives required:

INR 350-400 Cr

R&D & Product Innovation

- **Develop shared R&D labs**[1] for R&D on **10-20 wind initiatives**
- Focus on **developing standards and testing simulations as per local conditions**
- Establish **cybersecurity standards for wind turbines** and development of requisite tools for implementation
- Ensure **quality standards for raw material** and subcomponents are aligned across the industry

Overall **Government** investment :

INR 450-500 Cr

Upstream Raw Materials & Critical Inputs

- **Total PLI required: ~5,000 Cr** to drive cost competitiveness for S355 concast steel
- **Incremental investment** for improving existing and developing additional manufacturing facilities: **10,000-15,000 Cr** for S355 concast steel
- R&D in early-stage on **recycling and reusing turbine components** like tower, shafts, bearings etc. to **enable closed-loop circular use** and reduce imports

Overall **Government** investment required:

INR 5,000 Cr

Detailed in Annex: *Demand Acceleration*; *R&D Ecosystem*; *Upstream Raw Materials*

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(1) Potentially set up by MNRE/ANRF;

Fiscal incentives combined with public-private partnerships for R&D and workforce skilling could accelerate indigenisation at cost-competitive prices for integrated wind turbine manufacturing in India

Capital Equipment & Infrastructure

- **Build Casting and Forging capabilities** in India to remove dependency on foreign countries
- Inverted duty structure supports import of **finished casting product (7.5% duty), instead of raw materials (15% duty)**

Incremental capex investment required:

INR 13,500-20,700 Cr

Talent & Workforce

- **Incentivize joint R&D projects in partnerships with industry**; establish wind energy centers of excellence in technical universities
- **Co-develop training curricula** with OEMs and suppliers
- Align industrial and skill policies to **support local wind manufacturing**
- Establish **national certification frameworks** aligned with global wind industry standards.

Overall **Government** investment (5% of ITI upgradation budget):

INR 2,580-3,100 Cr

Financing & Taxation

- Driving **additional investment for capacity expansion** of Casting, Forging and bearing
- **Targeted input subsidies** on capex, interest subvention to improve cost competitiveness for Indian wind turbines of **INR 1,521-3,120 Cr** till 2030
- Proposed import duty waivers on key raw materials with **potential tax revenue impact of INR 206-241 Cr**

Overall **Government** fiscal incentives required:

INR 1,727-3,361 Cr

*Achieving **60% indigenisation** across the wind value chain requires **INR 10,100-12,400 Cr** total government investment by 2030 and could result in **INR 68,800-84,300 Cr** of total import bill savings.*

Detailed in Annex: *Capex and Infra*; *Workforce*; *Financing*

Dalberg

Increasing wind value chain indigenisation to 60% could support cumulative import savings of USD 8-9.8 Bn (INR 68,800-84,300 Cr) by 2030 for domestic manufacturing

Wind deployment imports could increase from ~USD 5.6-6 Bn in 2025 to USD 7.8-9.8 Bn by 2030 without increased indigenisation beyond current and announced capacities across the wind value chain

Key insights

Comparison of cumulative import bill savings of USD 8-9.8 Bn till 2030:

Legend: 🟢 Potential Savings/Income 🔵 Cost/Investment

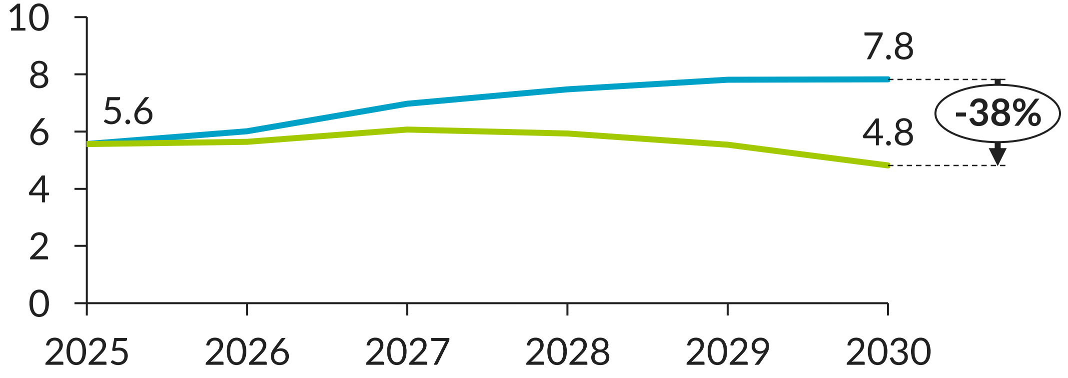
Import savings comparison	Cumulative impact 2025-2030, USD Bn	
Cumulative import bill savings	USD 8-9.8 Bn	🟢
Cumulative capex investment required for 60% indigenisation	USD 3.3-5 Bn	🔵
Government investment / fiscal incentive support	USD 1.2-1.4 Bn	🔵

Import bill savings resulting from 60% Indigenisation of the wind value chain outmatch the investment required

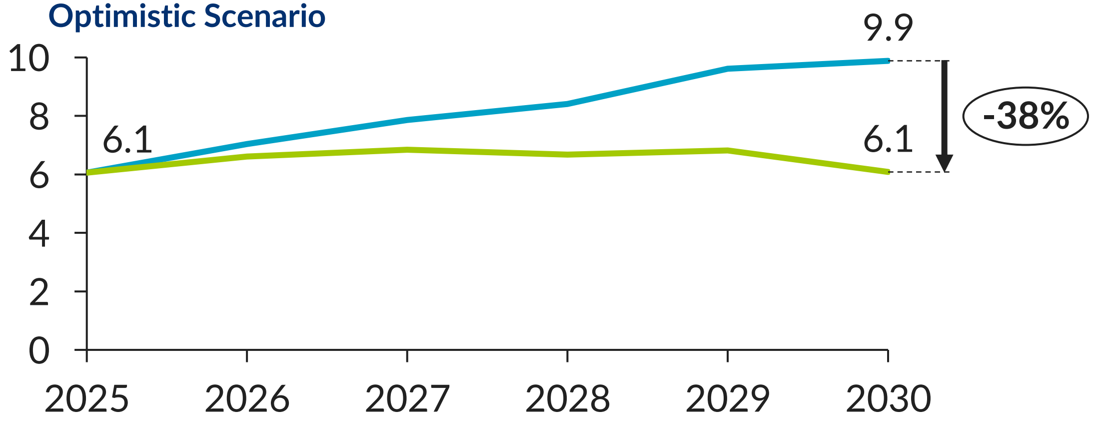
Expected annual import for wind turbines, USD Bn

Existing indigenisation — 60% indigenization

Conservative Scenario



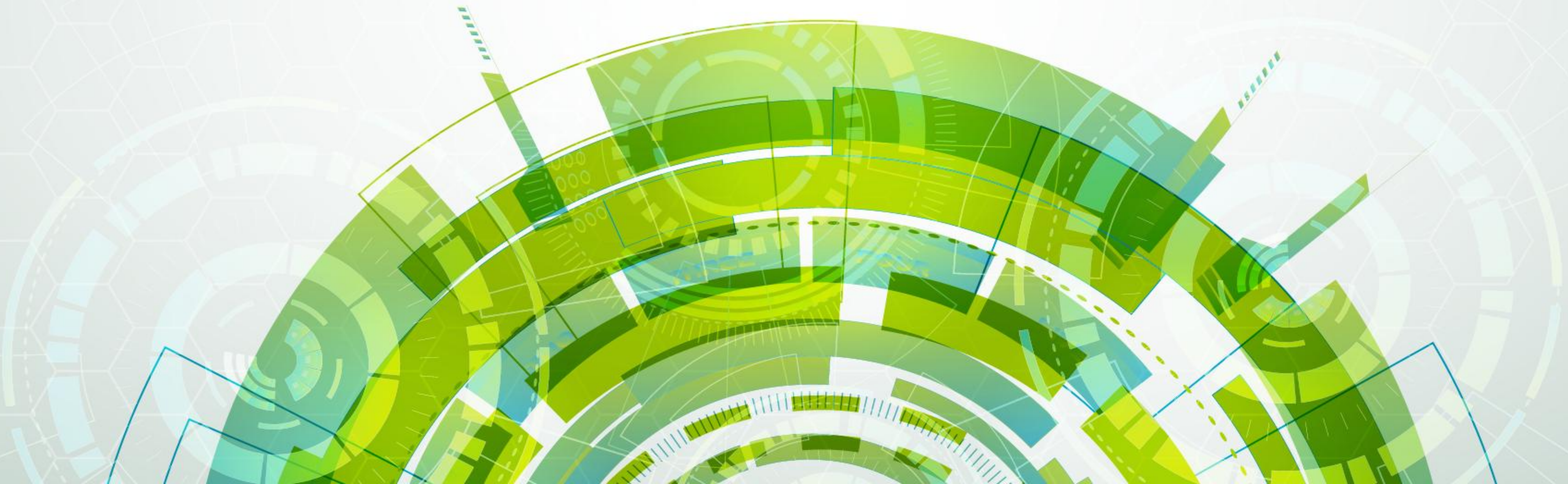
Optimistic Scenario



Sources: EXIM bank database, Fortune India, Economic Times

SECTION TWO, SUB-SECTION A

WIND INDIGENISATION PATHWAYS FOR INDIA: DETAILED BY CROSS-CUTTING THEMES

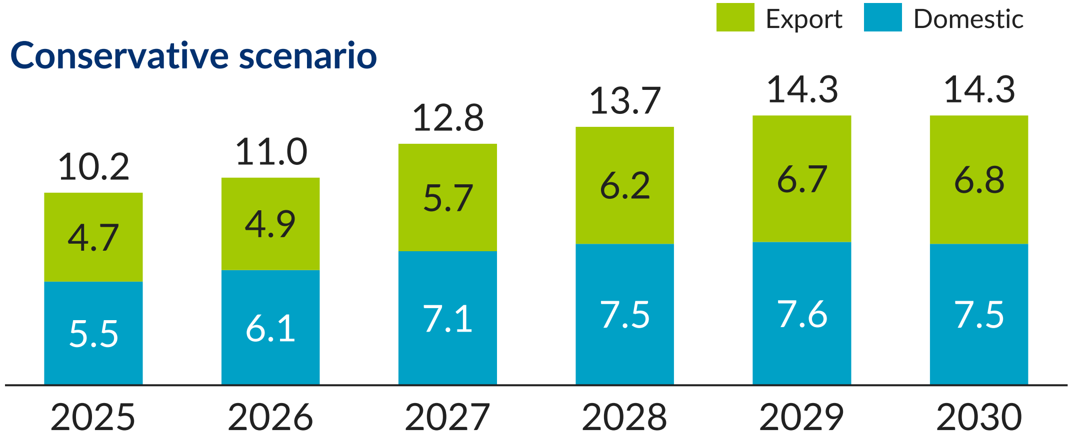


1 **Demand |** Policy interventions such as local content requirement, duty structures alignment along with policies to attract global suppliers of components could drive WTG components demand to meet 14 – 18 GW 2030 goal

While the demand for WTGs are driven by both domestic and export driven factors, policy interventions across the value chain can support supply to meet this demand along with required indigenisation levels

Wind Domestic and Export demand 2026-2030, GW

Conservative scenario



Optimistic scenario

Key policy interventions

- **Value chain demand driver**: Boost local manufacturing to support indigenisation goals
    - Develop and implement across **components local content requirement roadmap** in a **phased** manner
    - Align duty structures to **create domestic pricing competitiveness** of sub-system level components
    - Policy to attract global suppliers of components who are not currently present in India to **set-up manufacturing facilities in India**
- **Deployment driver**: Support the downstream implementation of wind at right capacity
    - **40% share of C&I segment to remain robust** due to grid tariffs and increasing sustainability efforts
    - **Target Export across MEA and APAC** to cater to the extensive supply gap across majority of the components
    - **Align duty structures** to create domestic pricing competitiveness of sub-system level components by investing ~

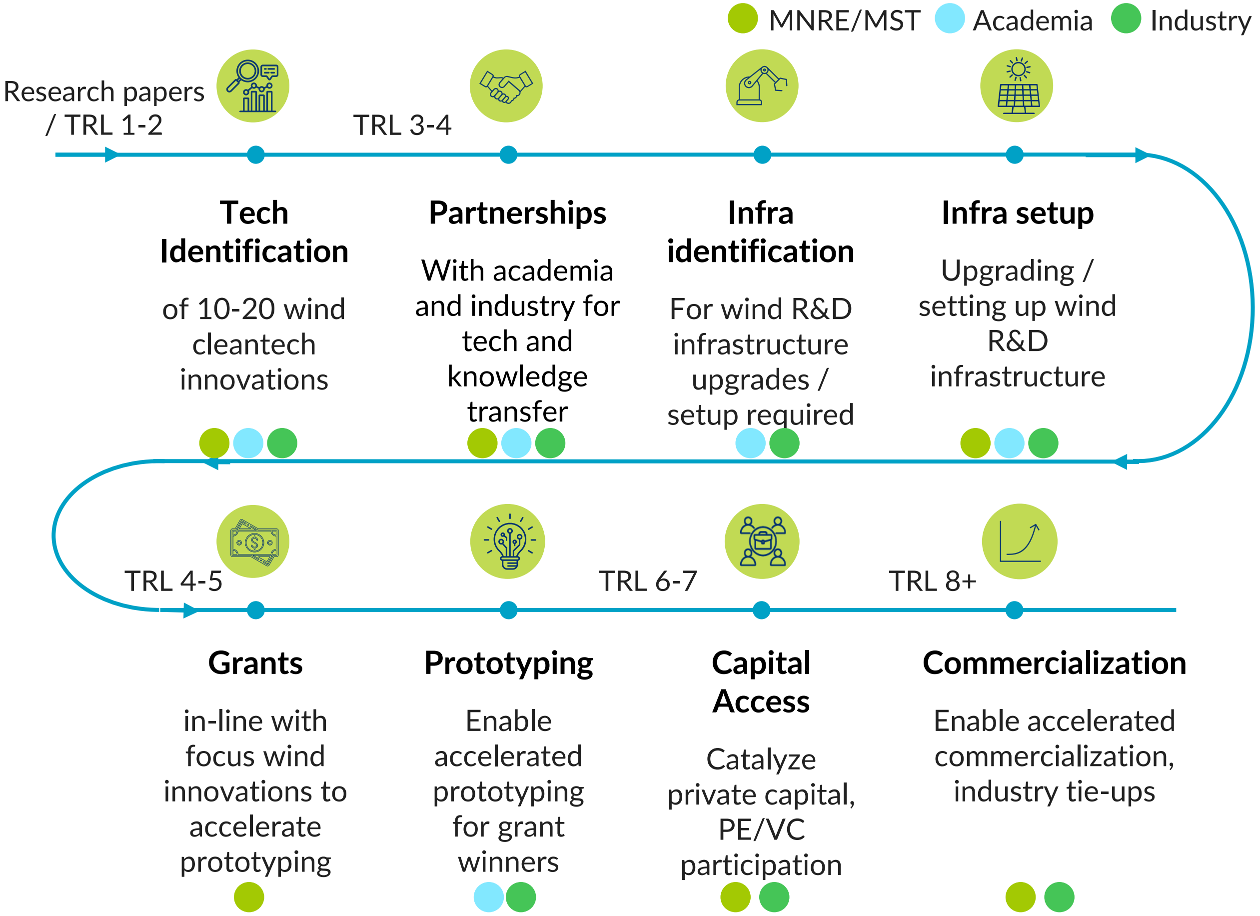
Note: APAC excludes India and China
Source: GWEC 2025 report, mec+ analysis

Detailed in Annex

2 **R&D** | Build a collaborative R&D ecosystem with industry-academia-government collaboration to support prototyping to commercialization for 10-20 wind initiatives

The R&D ecosystem would require industry and academia participation and shared investment of INR 450-500 Cr on infrastructure investment to fuel R&D and innovation for wind initiatives

Steps for wind R&D acceleration



Tech Identification

of 10-20 wind cleantech innovations

🟡 🔵 🟢

Partnerships

With academia and industry for tech and knowledge transfer

🟡 🔵 🟢

Infra identification

For wind R&D infrastructure upgrades / setup required

🔵 🟢

Infra setup

Upgrading / setting up wind R&D infrastructure

🟡 🔵 🟢

Grants

in-line with focus wind innovations to accelerate prototyping

🟡

Prototyping

Enable accelerated prototyping for grant winners

🔵 🟢

Capital Access

Catalyze private capital, PE/VC participation

🟡 🟢

Commercialization

Enable accelerated commercialization, industry tie-ups

🟡 🟢

Key insights on R&D ecosystem development

- **MNRE and ANRF could set up a Core Working Group** with industry-academia-government representation **to lead efforts on** infrastructure set up, grants, private participation[1]
- **Industry participation crucial** from beginning to identify the right, focus 10-20 innovations where industry could support commercialisation
- **INR 450-500 Cr** total wind **R&D infrastructure** requirement
- **Open-access, shared R&D labs** to be set up across HEIs, public and private sector[3] focusing on **select, high-quality labs** maximising resource efficiency and public-private collaboration
- **Focus on developing standards and testing simulations as per local conditions**
- Establish **cybersecurity standards for wind turbines** and ensure the development of requisite tools for implementation
- Ensure **quality standards for raw material** (Concast steel) and subcomponents are aligned across the industry

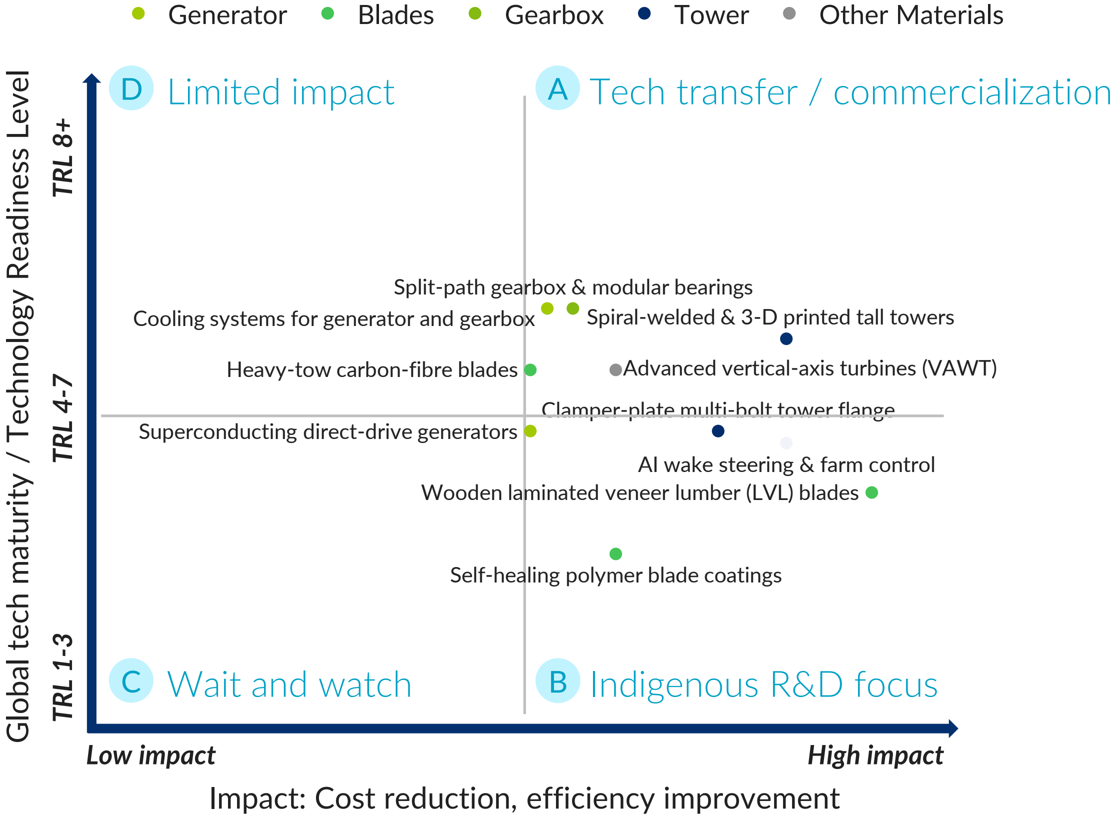
Detailed in Annex: ***Steps***; ***Infrastructure***; ***Funding***

Source: Academia and industry experts

2 **R&D |** Focus R&D and innovations across the value chain and required infrastructure could be aligned with industry and academia to ensure commercialization potential and pathways prior to investment mobilization

Potential focus initiatives for wind R&D could be identified basis impact potential and global TRL levels

Focus R&D and innovation initiatives: Wind



India could invest in 10-12 R&D labs to upgrade existing labs, set up new ones, and ensure efficient operations

	DEVELOPMENT LABS	TESTING LABS
Number of labs	**5-6 development labs** *2-3 existing and 2-3 new labs*	**4-5 testing labs** *~4 regional testing labs under 1 central facility*
Cost per lab, INR Cr	**INR 400-450 Cr** *INR 50 Cr/ lab for upgrades; INR 100 Cr/ lab for new setup*	**INR 4-10 Cr** *INR 1-2 Cr for upgrades/ new setup*
Existing labs for upgrade	*IIT Madras*	Central testing facility नीवे NIWE
Machinery needs	• Device fabrication equipment • Coating machines • CNC gear machines	• Material testing equipment • Efficacy testing machines (including blade test rigs, vibration rigs and others)
Manpower and support needs	**Advanced training** for new materials, equipment	• **PPP-led lab management** for maximizing utilization and industry connect • **Market needs assessment** to inform relevant research

Detailed in Annex: Technologies; Infrastructure

Source: MEC Analysis; Stakeholder consultations across wind supply chain,IEA; Mercom India; Energetica India Magazine; Company websites and news reports

Upstream: Raw Materials | India should invest ~INR 5,000 Cr in PLI to improve S355 steel manufacturing capabilities and decrease reliance on imported raw materials

Of the three potential pathways to reduce import dependence for S355 steel, two-thirds of the domestic demand could be met by increased domestic manufacturing capacities by 2030

Pathways for reducing India's raw material import dependance in the wind value chain

Sources of minerals and metals

	2030 Potential	Investment / Enabler
Improving S355 steel manufacturing capability	Total concast S355 steel required by 2030: 8 lakh tonne/year[1]	Incremental investment for improving existing and developing additional manufacturing facilities: ~10,000-15,000 Cr[3] Total PLI required: ~5,000 Cr[2]
Scaling circularity	R&D in early stages, currently low potential for reuse in wind in India	*To be estimated*
Diversifying import partners	Additional imports required to meet balsawood, glassfiber demand and unmet capacity	Leverage bi-lateral, multilateral G2G partnerships with other Steel producers, Glassfiber producers - **Japan**, **South Korea**

Key insights

- India possesses the capability to produce S355 concast steel plates, but low demand and limited scale make domestic supply expensive compared to imported alternatives
- R&D in early-stage on **recycling and reusing turbine components like tower, shafts, bearings etc.** to enable closed-loop circular use and reduce imports
- The domestic demand would still require some imports for glassfiber, balsawood and some S355 steel till the time its localised

Note: (1) Concast steel is ~30% of total turbine weight i.e. 100 tonne/MW (2) PLI is considered as ~25% of CAPEX requirement in order to get breakeven in ~8 years (3) Cost for setting up 1 plant of 1 lakh tonne annual capacity in India taken as ~1,250 Cr; total 8 lakh tonne/year capacity required

Source: MNRE; Ministry of Power; NREF; EU Commission research; Niti Aayog; IJRET; Material Assessment; Mdpi; KTH institute, Sweden; MEC+ analysis

4 **Capital equipment & infrastructure** | India can reduce its capital equipment import dependence by up to ~80% in casting and ~10% in forging by manufacturing select equipment domestically (1/2)

Domestic capacity for capital equipment manufacturing could be built for equipment with cross-sector synergies and economies of scale potential, low tech expertise needs, and low efficiency and cost gaps vs. imported machines

Potential pathways for enhancing India's capital equipment manufacturing:

🟢 High 🟡 Medium 🔴 Low

Pathway criteria	1 **Domestic manufacturing** ***for select, non-specialized wind equipment***	2 **Import** ***highly specialized, advanced wind capital equipment***
Scale Up Capabilities	🟢 **Existing synergies** with adjacent industries (similar machine/ components/ processes like wind)	🔴 No existing synergies
Fix Cost Barriers	🟢 Need **marginal improvements**/ tweaks to existing machines	🔴 China leads in technical expertise; India to face very long lead time to build comparable domestic know-how
Secure Demand	🟡 Potential to attain global competitiveness in tech and cost efficiencies	🔴 Highly tech and cost-efficient Chinese capital equipment; domestic production unlikely to catch up
% Capex contribution	**~80% - casting, ~10% forging** Potential domestic manufacturing for machinery across casting and forging Examples: induction/arc furnace, moulding systems	**~20% - casting, ~90% forging** Continued import dependence for machinery across casting and forging Examples: ring rolling mill, forging presses, CNC machine lines

Source: RE Supply Chain Report, 2024; GWEC Report on global wind energy supply chain; MEC+ analysis

4

Capital equipment & infrastructure | India can reduce its capital equipment import dependence by up to ~80% in casting and ~10% in forging by manufacturing select equipment domestically (2/2)

Domestic capacity for capital equipment manufacturing could be built for equipment with cross-sector synergies and economies of scale potential, low tech expertise needs, and low efficiency and cost gaps vs. imported machines

Potential pathways for enhancing India's capital equipment manufacturing:

🟢 High 🟡 Medium 🔴 Low

1 Domestic manufacturing *for select, specialized wind equipment*

2 Import *highly specialized, advanced wind capital equipment*

Key Benefits

1 — Domestic manufacturing:

- Potential to repurpose and build on **existing capacity**
- Reap benefits of **economies of scale and long term market opportunity**
- Initiate building resilience against foreign supply shocks

2 — Import:

- **Leverage existing foreign capabilities** to procure at effective costs and diversify supplier base
- **Quick access** to capital equipment supports rapid production ramp up

Pathway unlocks

1 — *Identify equipment synergies for wind equipment with other sectors*

- **Synergies with other industries**, e.g., Arc furnace in steel & metallurgy, railways, heavy engineering etc; Moulding equipment in construction equipment, agriculture machinery etc
- **Synergies in same industry for other applications**, e.g., Casting & forging machinery can be used across multiple components of wind turbine (tower, gearbox, generator, bearing)

2 — *Potential to explore partners beyond China for capital equipment sourcing*

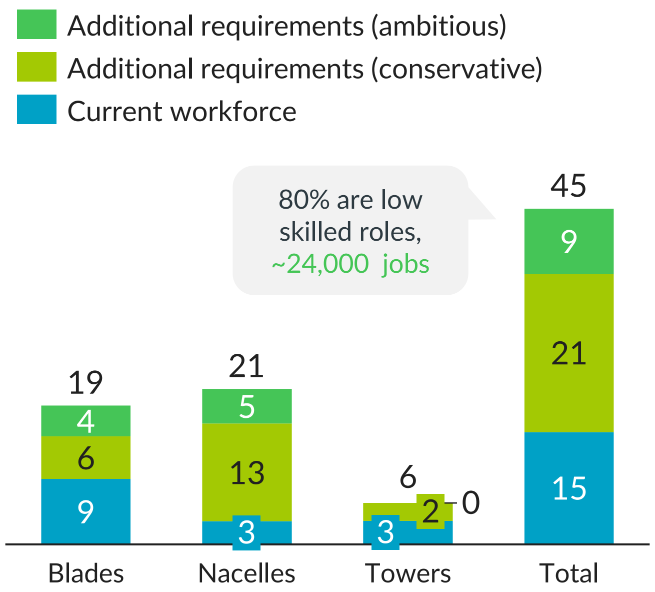
Wind component	Castings	Forging
Existing capacity	Germany, Japan, USA, Italy, South Korea	Germany, Japan, USA, Italy, South Korea

Source: RE Supply Chain Report, 2024; GWEC Report on global wind energy supply chain; MEC+ analysis

5 **Workforce** | India would require an additional 24,000 low skilled workers across wind manufacturing by 2030, who could be trained with 4-5% of ITI upgradation budget

Workforce efforts should target nacelle components—gearboxes, generators, control systems and other nacelle components—where local content lags blades (85% local content) and towers (100% local content)

Current and projected (2030) workforce requirement for wind manufacturing value chain, in '000



Skill level and sources of talent for wind manufacturing

Focus

Ultra-skilled	**R&D and digital Innovation experts** Research labs, PhD/Postgrad, programs, Tier-1 engineering and technical institutes
High-skilled	**Engineers & component specialists** Tier-1 and Tier-2 engineering colleges, lateral hires from automotive/aerospace sector
Low-skilled	**Production line workers** ITIs, vocational training programs

Industry insight

Nacelles components- power electronics

- **Shortage of ultra-skilled workers** for R&D to developing IP-protected converters and controllers. India lacks manufacturing capability for these critical components

Shortage of skilled workers

- Manufacturers report a **severe worker shortage (skilled engineers, technicians)**, forcing them to overspend on talent and reducing overall operational efficiency

Lack of training in institutes

- India's training institutes **lack the capacity and quality** to prepare skilled workers for the wind energy sector. Subpar programs and limited subsidies deepen the shortage of workforce

Total training cost[1]
INR 480-880 Cr

+

Total demo facility investment[2]
INR 2,100-2,220 Cr

Total budget (estimated share of ITI upgradation budget)[3]
INR 2,580-3,100 Cr (~4-5%)

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(1) Training cost for additional low-skill workers required; (2) Assumption: 2–3 ITIs tagged to each manufacturing plant (total 16 plants today; assuming 2 new plants will come up by 2030 making it 18; (3) Cumulative of training cost and demo facility investment

Source: CEEW; Global Wind Workforce outlook; NRDC; IRENA; EU Workforce skill gap; GE 2006; MEC+ Analysis

6 **Financing** | INR 0.29 to 0.43 Lakh Cr would be required during 2025-30 to achieve 60% cost-competitive indigenisation across the wind value chain, build a cohesive R&D ecosystem and train the required workforce

Government funding of INR 10,000-12,400 Cr would be required across demand acceleration, R&D, workforce skilling and subsidies on capex and interest by 2030 to achieve these goals

Theme	Total Funding Required (INR Cr)	Government Funding Required (INR Cr)	Key Activities	Potential outcomes
Demand & Market Architecture	350-400	350-400	EXIM Line of Credit[1] interest subvention for wind turbine export in (Africa)	Boost wind turbine export and reduce risks of dependency on the US and EU as the main export market
R&D & Product Innovation	450-500	450-500	R&D infrastructure: INR 450-500 Cr	Prototyping to commercialization of high-potential 10-20 wind innovation initiatives with industry-academia-government collaboration
Upstream Raw Materials & Critical Inputs	10,000-15,000	5,000	PLI to reduce the cost difference in raw materials, and investment in improving S355 steel manufacturing capability	Increase in local content of towers and gearbox contributing to ~18% of overall turbine DCR
Capital Equipment & Infrastructure	13,500-20,700	Detailed in cost competitiveness below	Invest in capex expansion across the value chain; Support MSMEs to build select casting and forging domestically	Reduce import dependence for casting and forging capabilities where feasible; Ensure accelerated capacity expansion to meet 60% DCR
Talent & Workforce	2,580-3,100	2,580-3,100	Training additional 20,000 low-skilled workers across wind value chain and set up demo training facility at ITIs	Ensuring a stable supply of workers, reducing attrition and lowering training costs for manufacturers
Cost Competitive-ness Ⓐ	1,700-3,400	1,700-3,400	Input subsidies on capex and interest subvention till 2030 and address inverted duty structure leading to potential tax revenue impact of INR 1,727-3,361 Cr	Increased cost competitiveness of domestic wind turbine– potentially bringing within 15% of Chinese landed costs
TOTAL	28,600-43,100	10,100-12,400		

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(1) India announced USD 2 Bn support as LOC for renewable energy development to Africa ;

6A

Cost Competitiveness | INR 1,700-3,400 Cr of targeted capex subsidies and low-cost financing, could improve cost competitiveness for Indian wind turbines at 60% LCR levels

Indigenisation of upstream components, subsidized capex and interest subvention could reduce domestic wind turbine costs by 10% vs. current costs, ensuring no impact on LCOE and cost competitiveness with current landed costs

Current landscape indicate strong need for cost competitiveness

- Current landed costs for Indian wind turbine components are up to 17% higher than Chinese turbine components, with this cost gap potentially widening to 25% if Indian production at 60% LCR (Local Content Ratio) operates without subsidies

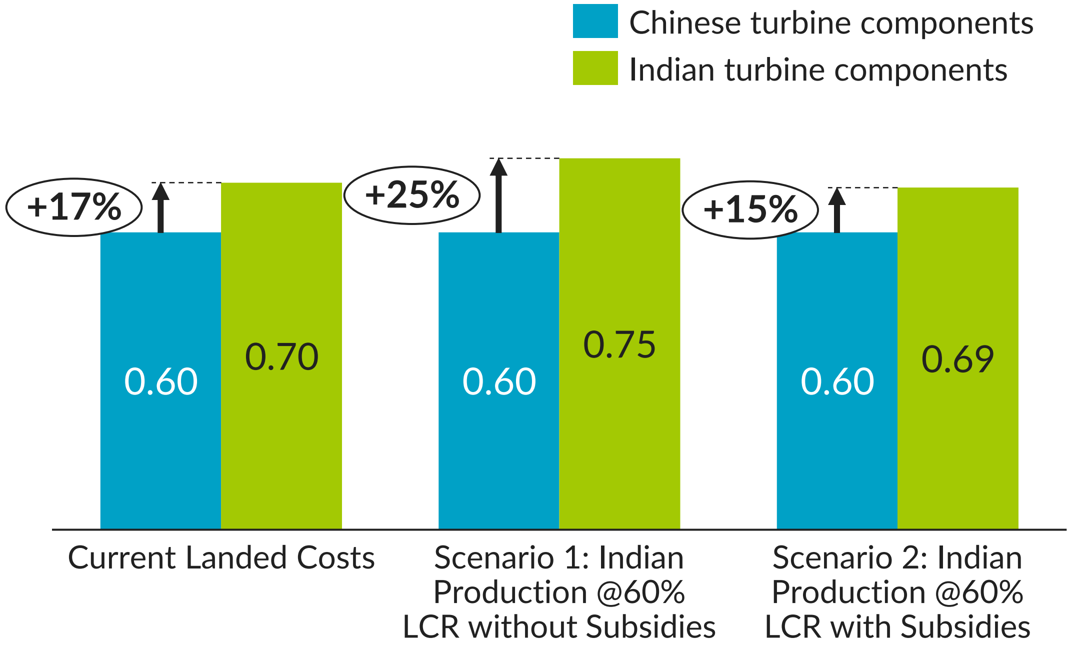
60% indigenisation could increase LCOE by 3-4% (6-8p/kWh), proposed subsidies could keep LCOE flat at current level:

- **Upfront capex subsidy** of **25%** up to **INR 1,225-2,700 Cr**
- **Interest subvention** of **23%** up to **INR 296-420 Cr**

Proposed interventions:

- **Reduce inverted duty effect**: Existing policy charges 7.5% and 10% on imports of parts and full generator/gearbox/tower respectively whereas import of con cast/electrical grade steel attracts duties as high as 15% to 20%
- Proposed import duty waivers on key raw materials could have **potential tax revenue impact of INR 206-241 Cr**
- Improved EODB policies could also lower risk perception and improve attractiveness for financiers, potentially at better cost

Comparison of Chinese and Indian Turbine Cost[1], US dollars/ Watt, ex-GST

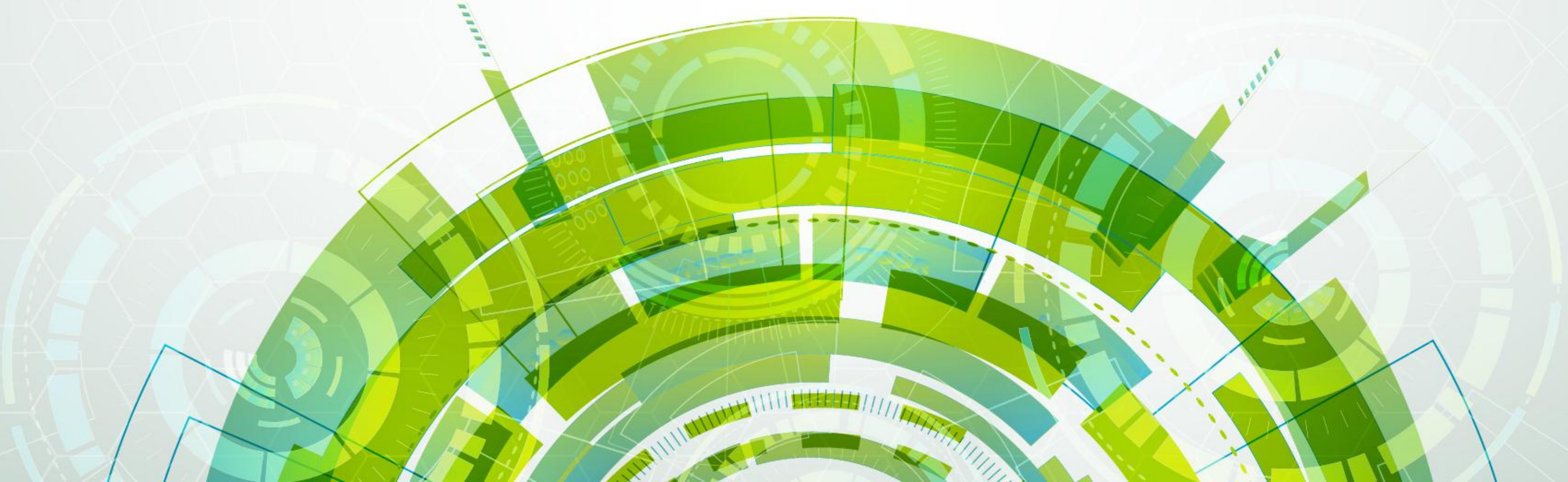


Targeted subsidies on capex and interest subvention

INR 1,700-3,400 Cr till 2030

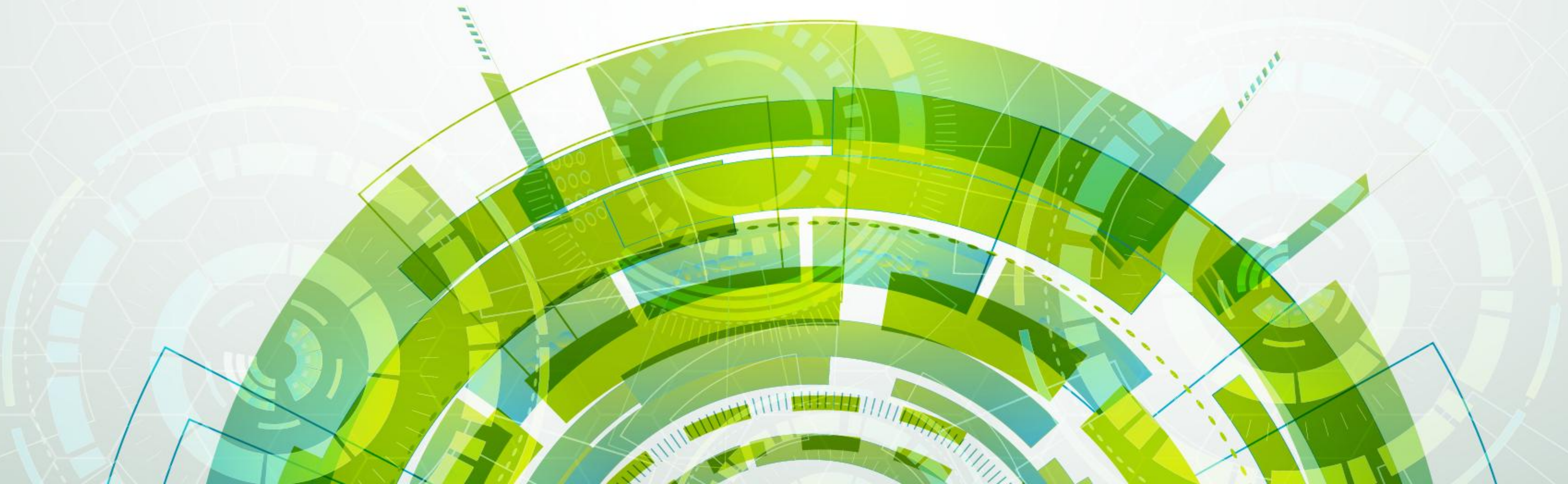
Source: MEC+, RE Supply Chain Report 2024, Industry experts (industry associations, key manufacturing players), Dalberg Analysis

ANNEX



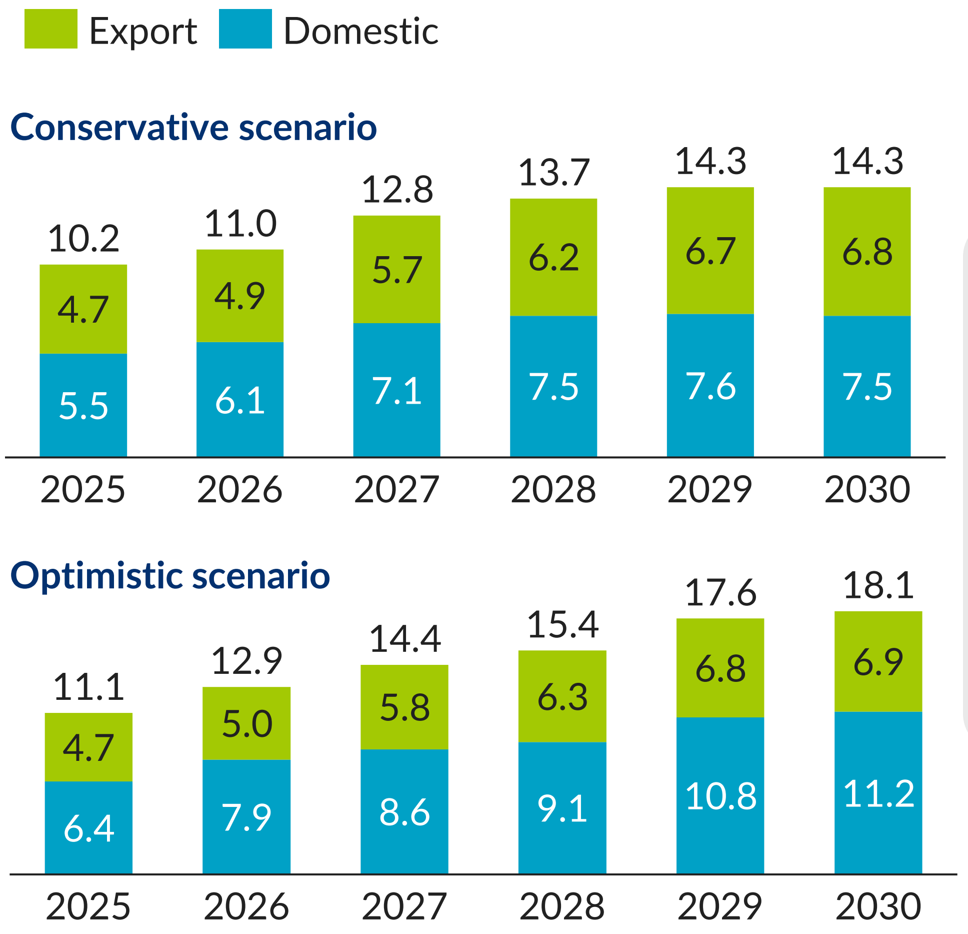
SUB-SECTION ONE

DEMAND & MARKET ARCHITECTURE



Demand growth to be driven by strong domestic targets and rising export potential to global markets

Wind Domestic and Export demand 2026-2030, GW



	2025	2026	2027	2028	2029	2030
Conservative scenario – Export	4.7	4.9	5.7	6.2	6.7	6.8
Conservative scenario – Domestic	5.5	6.1	7.1	7.5	7.6	7.5
Conservative scenario – Total	10.2	11.0	12.8	13.7	14.3	14.3
Optimistic scenario – Export	4.7	5.0	5.8	6.3	6.8	6.9
Optimistic scenario – Domestic	6.4	7.9	8.6	9.1	10.8	11.2
Optimistic scenario – Total	11.1	12.9	14.4	15.4	17.6	18.1

Basis the analysis of existing and expected domestic demand trends, we anticipate cumulative wind installations will fall short of the 2030 targets

Scenario description

Conservative scenario assumes:

- **Strong existing pipeline:** Driven by the recent upswing in tender volumes in the past few years
- **State RAP alignment:** Expected to be capped at 26.3 GW as per resource adequacy plans announced by top states till 2030
- **C&I wind installations:** Expected to increase from current levels, though at a slower pace compared to the ambitious scenario.
- **Export:** Same share of global demand as observed in 2024

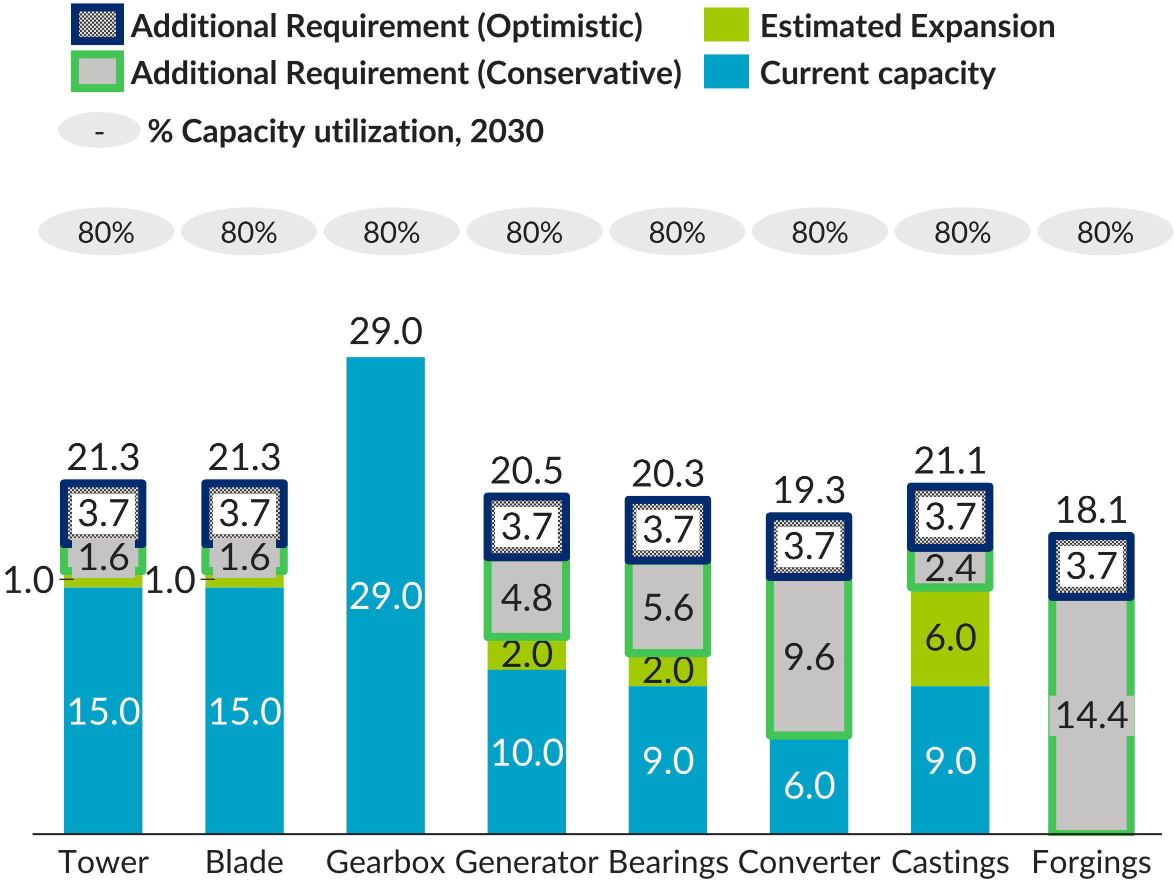
Optimistic scenario assumes:

- **State RAP alignment:** Wind requirement of all state as per resource adequacy plans will be met
- **Grid availability:** Assumed at the current pace of 15–16 GW augmentation year-on-year with no constraint on installation
- **C&I wind installations:** Further acceleration is expected as corporates adopt cost-competitive hybrid power to achieve net-zero emissions and RE100 targets by 2030.
- **Export:** Same share of global demand as observed in 2024 for US & Europe with a higher share for ME and Africa region

Source: GWEC 2025 report, mec+ analysis

Meeting demand indigenously would be enabled by improved existing utilization levels along with capacity expansions across components to cater to higher size WTGs (3MW+)

Manufacturing capacity required to achieve demand targets, 2030, GW



Key Insights:

- India has considerable manufacturing capacity across major WTG components, however some of these components like gearbox, generator, converter currently operate at capacity utilization of less than 40%
- With increase in demand, the capacity utilization of these components is expected to increase before additional capacity additions are done by the players
- In terms of size, over the last 3 years the industry has witnessed a shift towards high capacity 3MW+ turbines, with the same trend expected for future demand, capacity additions of components would be to cater to such higher capacity WTGs
- To build scale and reduce import dependence, it is critical to strike a balance between cost competitiveness and the effective utilization of domestic capacity

Source: NITI Aayog, mec+ analysis

Policy interventions such as local content requirement, duty structures alignment along with policies to attract global suppliers of components could drive WTG components demand

	Recommendations	Rationale
	Manufacturing	
Value chain demand driver	- Develop and implement across **components local content requirement roadmap** in a **phased** manner - **Align duty structures to create domestic pricing competitiveness** of sub-system level components - **Policy to attract global suppliers** of components who are not currently present in India to set-up manufacturing facilities in India (for e.g. policy introduced by MoHE for investments by global manufacturers for passenger EV cars)	- Encourages gradual localisation, allowing time for ecosystem development - Brings in advanced manufacturing technologies and global quality standards - Encourages price competitiveness, fostering a stronger domestic manufacturing base

Category	Intervention type	Inputs and assumptions	Key recommendations	Total Impact, INR Cr	
				Conservative Scenario	Optimistic Scenario
Duty structure alignment	**Duty waivers for concast steel** **Reduce inverted duty effect on gearbox and generators**	- Contributes 15% on import of raw materials such as concast steel and electrical steel - Existing 5% and 10% on imports of parts and full generator /gearbox	- Address inverted duty structure by reducing duty on concast and electrical steel at a level lower than duty on parts (such as core etc.) and full generator/gearbox - Increase duties of assembled gearbox, generator, casting and forging products by 2.5%	~350	~400

Note: Leveraging INR 15,050 Cr (USD 1.75 Bn) EXIM Line of Credit1 at the interest subvention of INR 350– 400 Cr to boost wind exports to key African countries, APAC excludes India and China

Source: ET, Renewable watch, EV policy

SUB-SECTION TWO

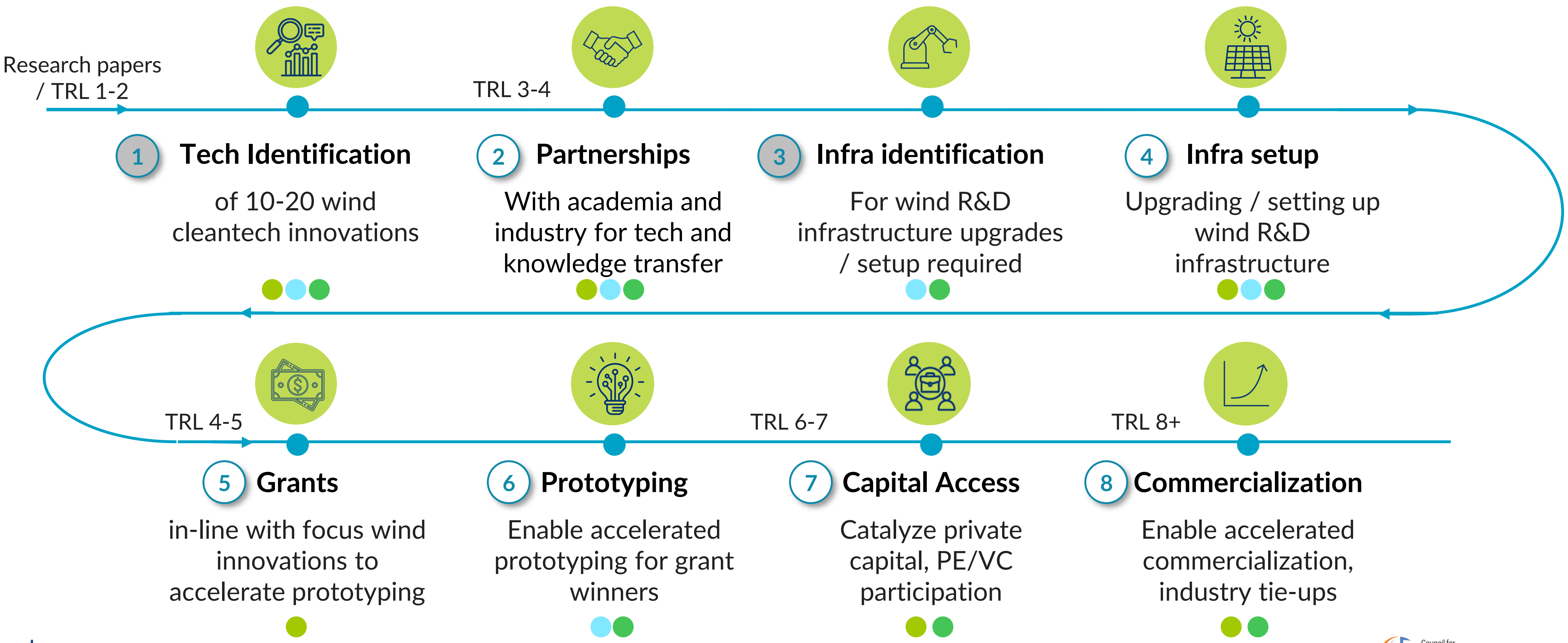
WIND R&D & PRODUCT INNOVATION

India can accelerate indigenous wind energy innovation, from initial concepts to prototypes and commercialization, by fostering strong collaboration among industry, academia, and government

MNRE and ANRF could establish a Core Working Group (with representation from industry, academia, government) to spearhead this effort and engage relevant stakeholders across various steps

Steps for wind cleantech R&D acceleration

🟡 MNRE/MST and other line ministries 🔵 Academia 🟢 Industry (x) Detailed ahead



Research papers / TRL 1-2

1 Tech Identification
of 10-20 wind cleantech innovations
🟡🔵🟢

TRL 3-4

2 Partnerships
With academia and industry for tech and knowledge transfer
🟡🔵🟢

3 Infra identification
For wind R&D infrastructure upgrades / setup required
🔵🟢

4 Infra setup
Upgrading / setting up wind R&D infrastructure
🟡🔵🟢

TRL 4-5

5 Grants
in-line with focus wind innovations to accelerate prototyping
🟡

6 Prototyping
Enable accelerated prototyping for grant winners
🔵🟢

TRL 6-7

7 Capital Access
Catalyze private capital, PE/VC participation
🟡🟢

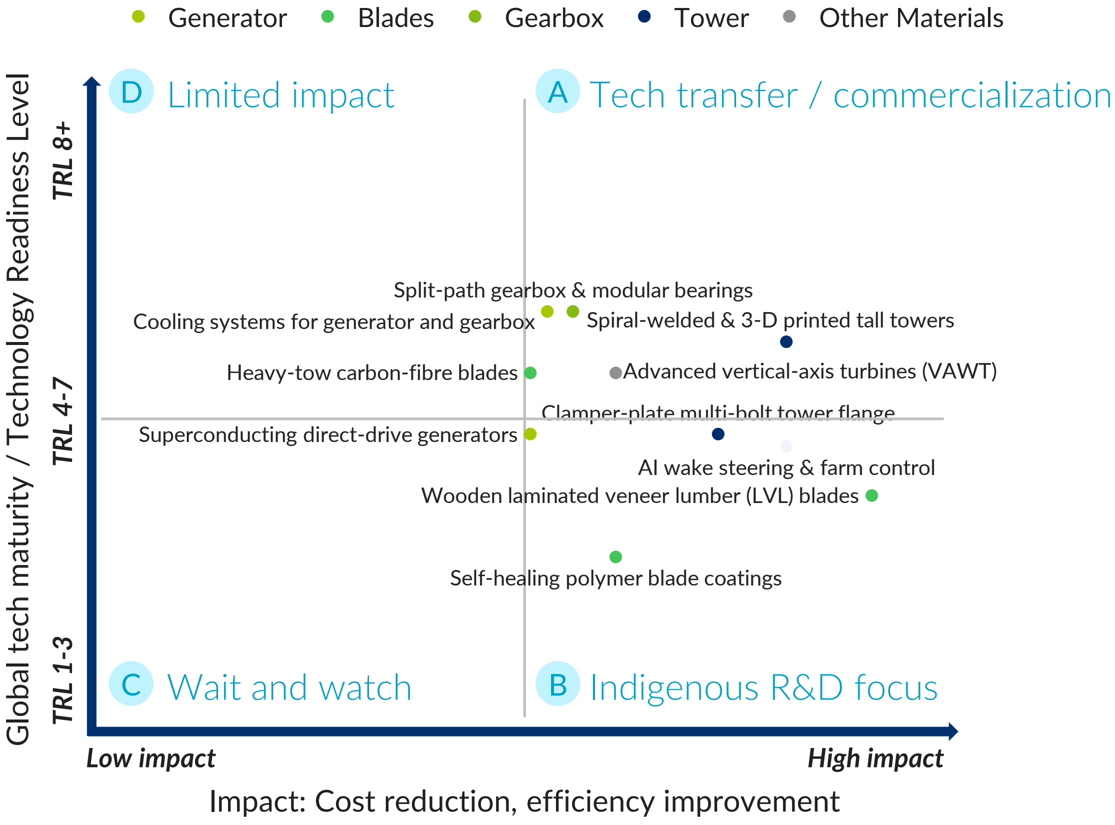
TRL 8+

8 Commercialization
Enable accelerated commercialization, industry tie-ups
🟡🟢

Identification and discoverability | It is critical to identify key wind initiatives with inputs from relevant stakeholders for targeted R&D efforts and pathways to commercialisation

Wind initiatives can be prioritised based on their impact potential and TRL levels globally to identify focus technologies for tech-transfer or indigenous R&D and innovation

Focus R&D and innovation technologies[1]: Wind



Key Insights

Identification of wind focus R&D technologies:

- **Landscape assessments** to build pipeline of potential wind related initiatives
- **Undertake impact-based prioritization** to focus on wind technologies with the highest relevance and potential for India based on impact of LCOE and efficiency
- **Use Technology Readiness Level (TRL) frameworks** to map appropriate pathways for wind initiatives indigenisation or transfer

Next steps:

- **Integrate** these prioritized wind technologies **into wind R&D infrastructure planning**, ensuring alignment with TRL- stage requirements
- Most required R&D initiatives for India are quite mature in developed economies, so poised for **commercialization**

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(1) Technologies considered in this initiatives are based on stakeholder inputs and wind supply chain assessment for onshore wind conducted by mec+

Source: MEC Analysis; Stakeholder consultations across wind supply chain, IEA; Mercom India; Energetica India Magazine; Company websites and news reports

R&D infrastructure | There is need to assess R&D infrastructure requirements (upgrades/ new setups) to drive commercialization for wind initiatives (1/2)

Establishing select, open-access R&D development and testing labs across HEIs, public and private sector research labs can help maximize resource efficiency and encourage public-private collaboration

	KEY LEVERS	RATIONALE
①	**Create new, open-access infrastructure**	• **Improve access to R&D infrastructure** overcoming current issues like lab use restrictions and complex processes of academic R&D labs • Promote **public-private collaborations and resource sharing** across stakeholders from academia and industry
②	**Focus on developing standards and testing simulations as per local conditions**	• Crucial for ensuring wind technologies perform reliably in **India's diverse environment**, accounting for varying wind patterns, and extreme weather • OEMs rely on power curves developed in European conditions leading to difference in actual generation outputs
③	**Upgrade existing R&D infrastructure**	• **Enable financial efficiency** by optimizing India's existing labs progressing on wind innovations • **Build on trained human resource** and existing wind know-how
④	**Ensure operational efficiency and alignment with industry**	• Robust **operational management** can help **maximize capital utilization** and sustained use of infrastructure (currently not optimum in R&D labs) • Ensure **cybersecurity requirements for turbine level** are aligned across the industry

Source: Academia and industry experts

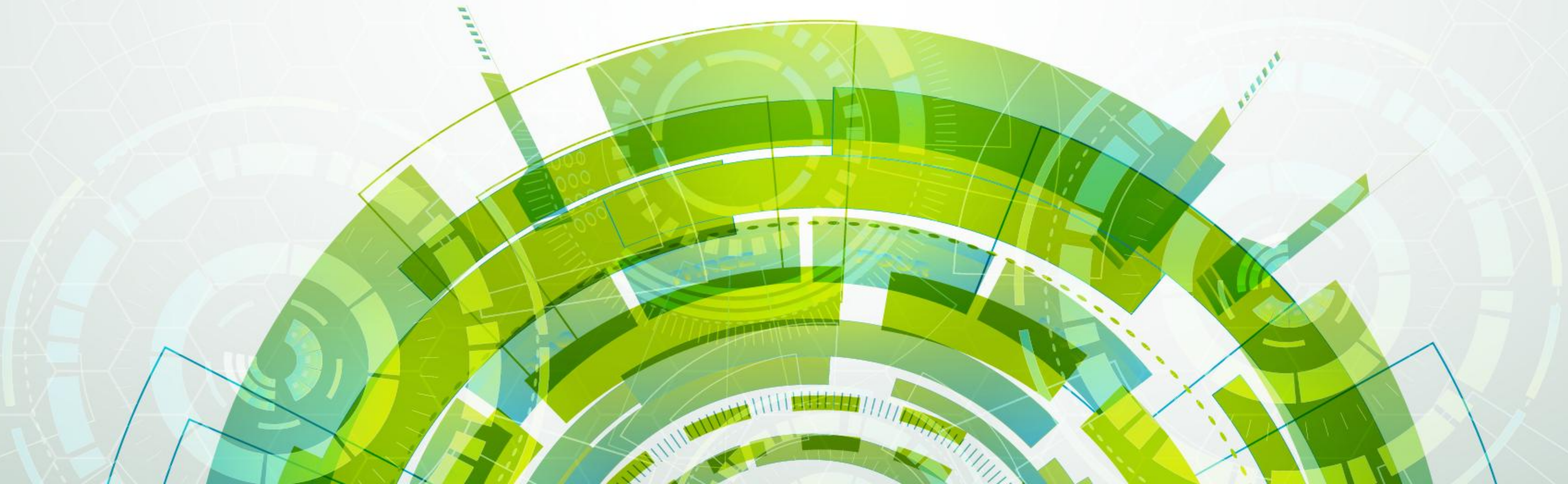
R&D infrastructure | India could invest INR 450-500 Cr across 10-12 R&D labs to upgrade current wind R&D labs, establish new facilities, and ensure needed human resource for efficient lab operations (2/2)

	DEVELOPMENT LABS	TESTING LABS
Number of labs	**5-6 development labs** *~2-3 each for existing and new labs*	**4-5 testing labs** *About 4 regional testing labs under 1 central facility*
Cost per lab	**INR 400-450 Cr** *INR 50 Cr/ lab for upgrades; INR 100 Cr/ lab for new setup*	**INR 4-10 Cr** *INR 1-2 Cr for upgrades/ new setup*
Prospective existing labs for upgrade	• *To be evaluated*	**Central testing facility** नीवे NIWE *NIWE lab*
Machinery needs	• Device fabrication equipment • Coating machines • CNC gear machines • Heat treatment and metallurgical analysis	• Material testing equipment • Efficacy testing machines (including Full-scale blade test rigs, vibration rigs, gearbox benches, fatigue/lifecycle rigs and others)
Manpower and support needs	**Advanced training** for new equipment/ materials; leveraging researchers' pre-existing tech know-how	• **PPP-driven lab management team** for max. capacity utilization, avoid delays, and develop industry connect • **Market needs assessment** of upcoming tech trends to inform relevant research

Source: Academia and industry experts

SUB-SECTION THREE

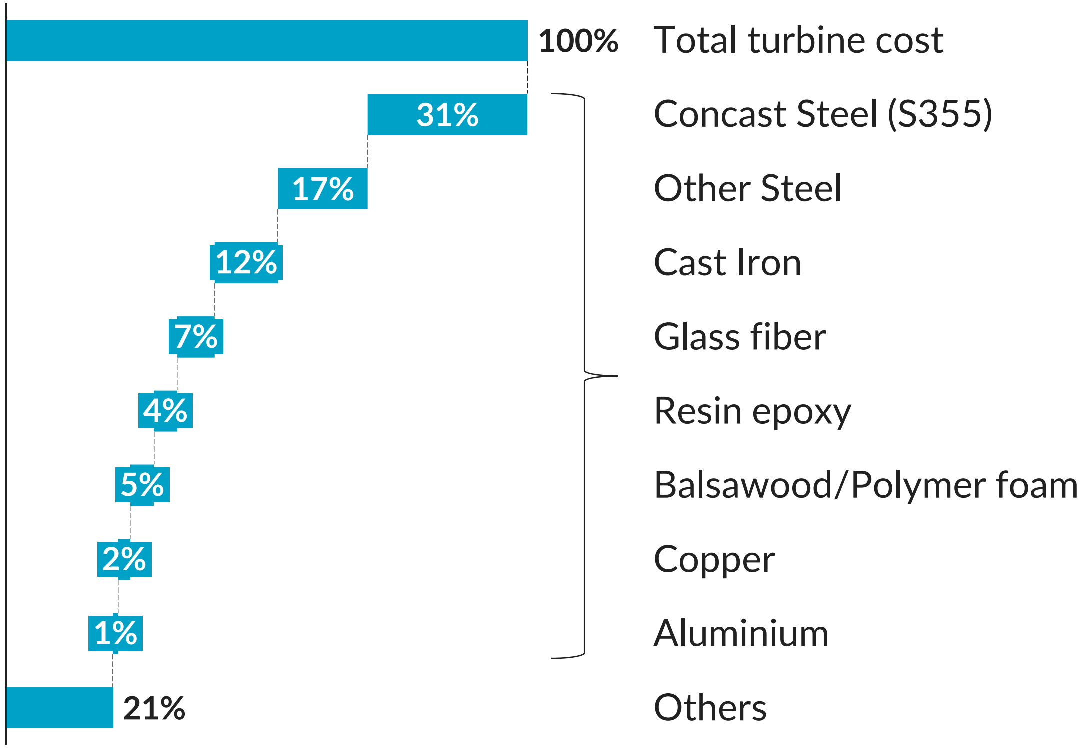
UPSTREAM RAW MATERIALS & CRITICAL INPUTS



India imports a large quantity and value of raw materials used in the manufacturing of a WTG, despite having domestic capability to produce some of these, like steel

A wind turbine has following raw materials along with the given value contribution

Raw materials account for ~60–70% of the total cost of a wind turbine in India



Key raw materials like continuous casted steel S355, glass fiber and balsawood are imported in India

Component name	Quantity required till 2030 ('000 t)	Current procurement	Domestic availability	% of total reserves
Continuous casted steel (S355)	5,456	Import	Yes	0.02%
Glass Fiber	727	Import	Yes	NA
Balsawood	273	Import	No	NA
Aluminium	909	Domestic	Yes	0.02%
Copper	136	Domestic	Yes	0.01%

- **India imports large quantities of raw materials like concast steel S355**, despite having domestic reserves, due to their high local cost as limited domestic demand and capabilities with few companies
- India also imports glass fiber due to fluctuating domestic prices and balsawood for blades due to their **unavailability in the domestic market**

Source: MNRE; Ministry of Power; NREF; EU Commission research; Niti Aayog; IJRET; Material Assessment; Mdpi; Research Paper; MEC+ analysis

India should reduce raw material import dependence by improving S355 steel manufacturing capability through ~INR 2500 Cr production linked incentives (PLI) to bridge capex GAP

Of the three potential pathways to reduce import dependence for S355 steel, two-thirds of the domestic demand could be met by increased domestic manufacturing capacities by 2030

Pathways for reducing India's raw material import dependance in the wind value chain

Sources of minerals and metals

	2030 Potential	Investment / Enabler
Improving S355 steel manufacturing capability	Total concast S355 steel required by 2030: 8 lakh tonne/year[1]	Incremental investment for improving existing and developing additional manufacturing facilities: ~INR 10,000 to 15,000 Cr[3] Total PLI required: ~INR 5,000 Cr[2]
Scaling circularity	R&D in early stages, currently low potential for reuse in wind in India	*To be estimated*
Diversifying import partners	Additional imports required to meet balsawood, glassfiber demand and unmet capacity	Leverage bi-lateral, multilateral G2G partnerships with other Steel producers, Glassfiber producers - **Japan**, **South Korea**

Key insights

- India possesses the capability to produce S355 concast steel plates, but low demand and limited scale make domestic supply expensive compared to imported alternatives
- R&D in early-stage on **recycling and reusing turbine components like tower, shafts, bearings etc.** to enable closed-loop circular use and reduce imports
- The domestic demand would still require some imports for glassfiber, balsawood and some S355 steel till the time its localised

Note: (1) Concast steel is ~30% of total turbine weight i.e. 100 tonne/MW (2) PLI is considered as ~25% of CAPEX requirement in order to get breakeven in ~8 years (3) Cost for setting up 1 plant of 1 lakh tonne annual capacity in India taken as ~1,250 Cr; total 8 lakh tonne/year capacity required

Source: MNRE; Ministry of Power; NREF; EU Commission research; Niti Aayog; IJRET; Material Assessment; Mdpi; KTH institute, Sweden; MEC+ analysis

The government should support S355 steel manufacturing for domestic use & exports through PLI, secure key raw materials via domestic sourcing & strategic imports & invest in steel production infrastructure

Roadmap for self-reliance on concast steel S355

PLI scheme for domestic S355 steel manufacturing (2025-2028)

- Ministry of Steel and MNRE should introduce a targeted **PLI scheme** to support Indian steelmakers in scaling up high-grade S355 steel production and **compete with low-cost imports**
- This initiative aims to **drive investments by steelmakers in S355 concast steel production** which is currently low due to low-cost competitiveness of domestic supply

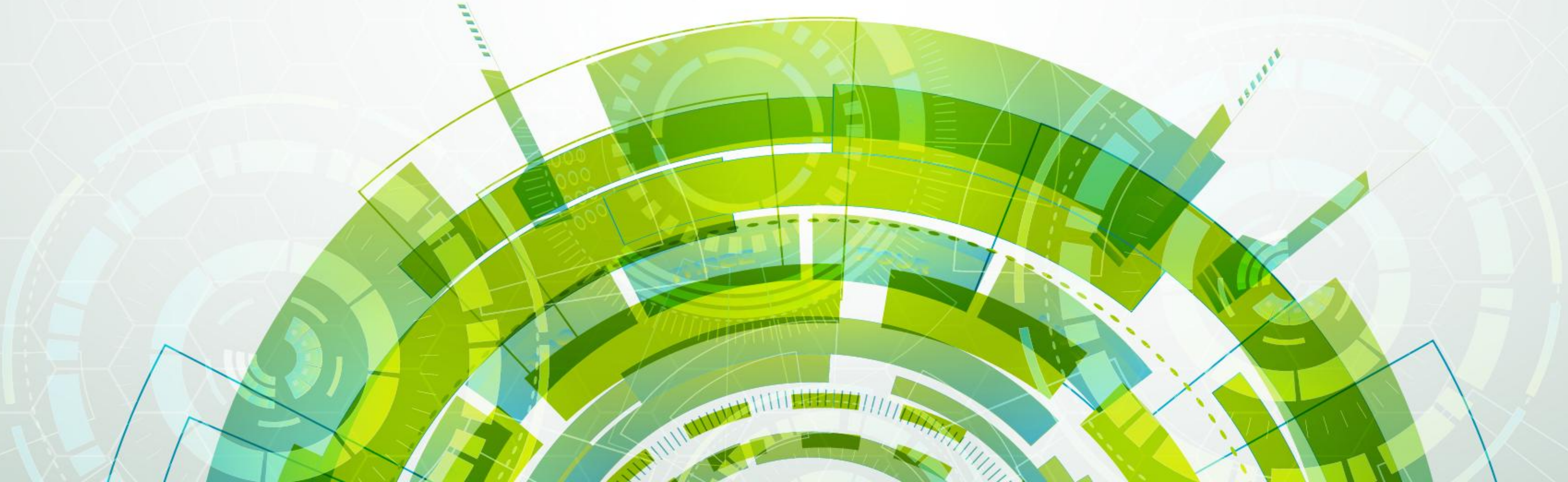
Infrastructure investment for specialized steel production (2028-beyond 2030)

- India currently has limited facilities for S355 production
- **To improve localisation and aim to become steel hub**, India should invest in clean steel technology, rolling capacity and quality testing

Source: MNRE; Ministry of Steel; Niti Aayog; IJRET; MEC+ analysis

SUB-SECTION FOUR

CAPITAL EQUIPMENT & INFRASTRUCTURE



India’s wind sector faces localisation challenges due to reliance on imported components, driven by inadequate domestic manufacturing infrastructure for casting and forging impacting ~15% potential local content

To boost indigenisation of India's wind supply chain, it is essential to enhance domestic sourcing of system-level wind turbine components, which are currently imported due to limited casting and forging capabilities

Current landscape of wind turbine manufacturing value chain in India

- WTG manufacturing occurs at 3 key stages: raw materials, system-level components, and assembly. **Increasing localisation across all stages is essential to boost domestic value addition**
- System-level infrastructure interventions can help develop India’s capability to manufacture **system level components (such as gears, shafts and housing) that are integrated into assembly-level units (gearbox)**
- System level interventions are impactful in increasing local content in major components such as towers and gearboxes
- **Blades and power electronics are less suited for system-level localisation**—blades manufacturing involves manual labor hence process refinement is difficult, while power electronics include IP-protected parts like power stack modules that cannot be manufactured in India

WTG system level components current sourcing and challenges

Component	Sub-component	Sourcing	Capability	Details	Local content impact
Tower	Flanges	Imported	Forging	Flange forging capabilities limited to 3m diameter while WTG tower needs 4.5m flanges	~2-3%
Gearbox	Gear/Shaft	Imported	Forging	Forging capabilities exist, but cost and quality remain concerns	~3-4%
Gearbox	Housing	Imported	Casting	Lack of dedicated facilities impact cost, quality & availability	~1%
Generator	Shafts	Imported	Forging	Forging capabilities for bearing and shaft are limited in India	~0.5%
Generator	Housings	Imported	Casting	Casting capabilities for housing & enclosures are limited in India	~0.5%
Castings	Hub/mainframe	Imported	Casting	Capability is focused on 2 MW+ turbines and is limited for 3MW+	~2-3%
Main shaft forging	Shafts	Imported	Forging	Forging shafts of capacity more than 2.5 MW are not possible due to dimension and specification requirements	~1-2%
Bearings	Rings	Imported	Forging	Limited ring forging and heat treatment capability drives costs	~2-3%

(1) LCR impact at the turbine level

Source: GWEC Report on global wind energy supply chain; MEC+ analysis

Scaling casting & forging capabilities in India needs to overcome challenges such as limited economies of scale, inverted duty structure, cheaper imports and capabilities vs. global players to scale

Key challenges in developing domestic system level manufacturing:

Limited domestic capability	Wind castings are highly customized for specific turbine models, but manufacturing large castings is not a core competency for WTG OEMs, leading them to rely on third-party suppliers.
Cheaper imported castings	Indian OEMs prefer Chinese castings for their lower cost and stable long-term pricing, Indian castings are 3–5% costlier, with domestic suppliers unable to offer fixed-price contracts due to smaller scale, as a result, OEMs adopt a mixed sourcing model balancing cost and risk.
Inverted duty structure	Inverted duty structure supports import of finished casting product (7.5% duty) instead of raw materials such as concast steel (15% duty)
Economies of scale	Demand uncertainty is discouraging both new and existing component suppliers from investing in localisation or expanding manufacturing capacity.

Improving casting and forging capabilities in India through dedicated infrastructure interventions would help increase indigenisation in system level components, however indigenous CAPEX manufacturing for them could be deprioritised

CASE STUDY: Lessons from China

- ***Context:*** The country manufacturers nearly all WTG components domestically
- **China's focus on indigenisation from the start**
- **Focus on increasing demand**
  - Encouraged joint ventures and laid out financial support
  - Programs to double installed base, encouraging local content – not mandating it
- **Promote local manufacturing**
  - Exempting import duties and VAT on parts
  - Mandating 50% then 70% local intent
  - Tax and R&D incentives awarded to manufacturers
- **Improved standard and became market leader**
  - Enhanced quality control and certifications

Sources: RE Supply Chain Report, 2024; IEA: Renewable Energy Market Update; Ministry of Petroleum and Natural Gas, Circular for Minimum Local Content (MLC) for purchase preference; MEC+ analysis

India can reduce its capital equipment import dependence by up to ~80% in casting and ~10% in forging by manufacturing select equipment domestically

Domestic capacity for capital equipment manufacturing could be built for equipment with cross-sector synergies and economies of scale potential, low tech expertise needs, and low efficiency and cost gaps vs. imported machines

Potential pathways for enhancing India's capital equipment manufacturing:

🟢 High 🟡 Medium 🔴 Low

Pathway criteria	**1** **Domestic manufacturing** ***for select, non-specialized wind equipment***		**2** **Import** ***highly specialized, advanced wind capital equipment***	
Scale Up Capabilities	🟢	**Existing synergies** with adjacent industries (similar machine/ components/ processes like wind)	🔴	No existing synergies
Fix Cost Barriers	🟢	Need **marginal improvements**/ tweaks to existing machines	🔴	China leads in technical expertise; India to face very long lead time to build comparable domestic know-how
Secure Demand	🟡	Potential to attain global competitiveness in tech and cost efficiencies	🔴	Highly tech and cost-efficient Chinese capital equipment; domestic production unlikely to catch up
% Capex contribution		**~80% - casting, ~10% forging** Potential domestic manufacturing for machinery across casting and forging Examples: induction/arc furnace, moulding systems		**~20% - casting, ~90% forging** Continued import dependence for machinery across casting and forging Examples: ring rolling mill, forging presses, CNC machine lines

Source: RE Supply Chain Report, 2024; GWEC Report on global wind energy supply chain; MEC+ analysis

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Potential pathways for enhancing India's capital equipment manufacturing:

🟢 High 🟡 Medium 🔴 Low

1 Domestic manufacturing ***for select, non-specialized wind equipment***

2 Import ***highly specialized, advanced wind capital equipment***

Key Benefits

1:

- Potential to repurpose and build on **existing capacity**
- Reap benefits of **economies of scale and long term market opportunity**
- Initiate building resilience against foreign supply shocks

2:

- **Leverage existing foreign capabilities** to procure at effective costs and diversify supplier base
- **Quick access** to capital equipment supports rapid production ramp up

Pathway unlocks

Identify equipment synergies for wind equipment with other sectors

- **Synergies with other industries**, e.g., Arc furnace in steel & metallurgy, railways, heavy engineering etc; Moulding equipment in construction equipment, agriculture machinery etc
- **Synergies in same industry for other applications**, e.g., Casting & forging machinery can be used across multiple components of wind turbine (tower, gearbox, generator, bearing)

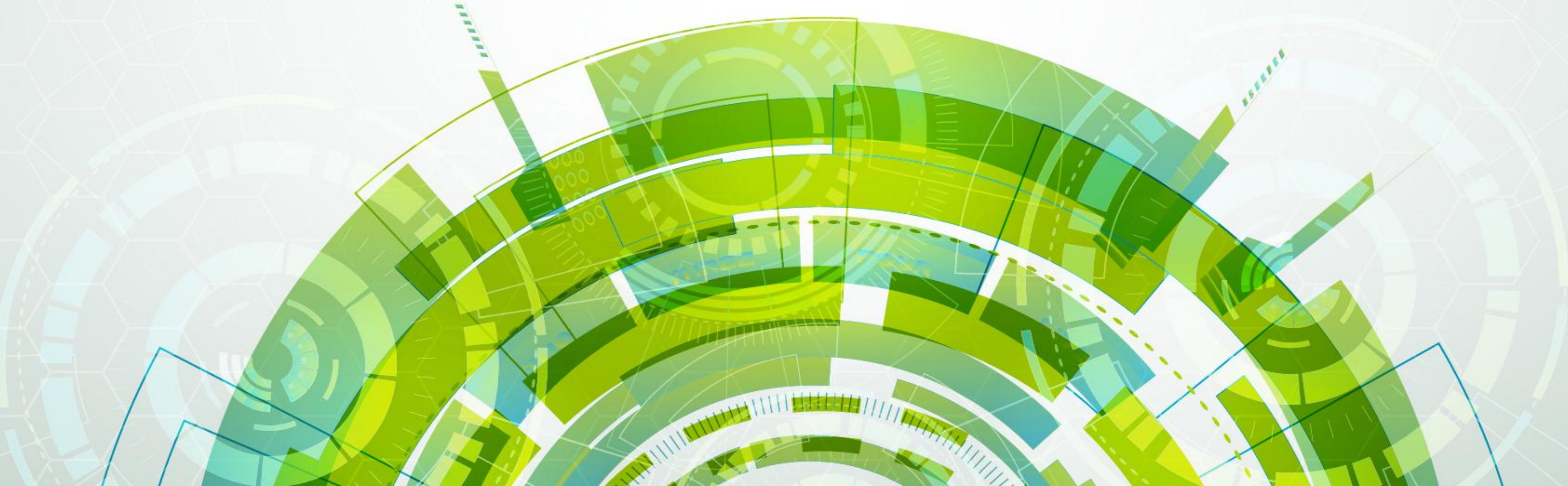
Potential to explore partners beyond China for capital equipment sourcing

wind component	Castings	Forging
Existing capacity	Germany, Japan, USA, Italy, South Korea	Germany, Japan, USA, Italy, South Korea

Source: RE Supply Chain Report, 2024; GWEC Report on global wind energy supply chain; MEC+ analysis

SUB-SECTION FIVE

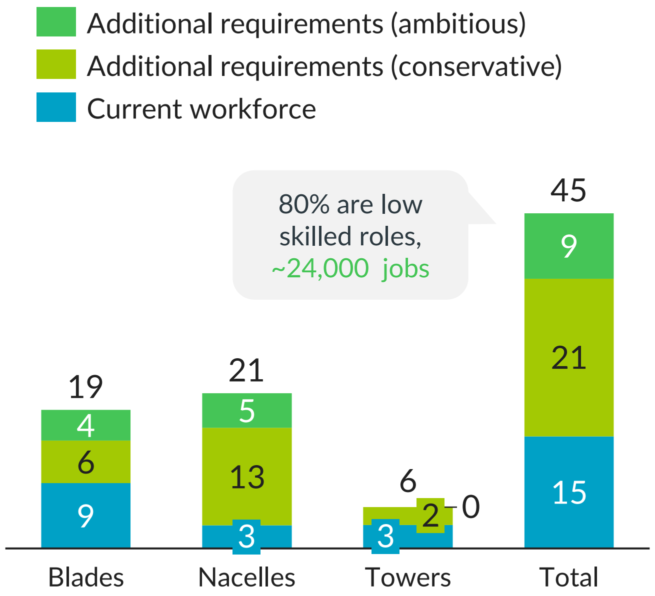
TALENT & WORKFORCE



India would require an additional 24,000 low skilled workers across wind manufacturing by 2030, who could be trained with ~4-5% of ITI upgradation budget

Workforce efforts should target nacelle components—gearboxes, generators, control systems and other nacelle components—where local content lags blades (85% local content) and towers (100% local content)

Current and projected (2030) workforce requirement for wind manufacturing value chain, in '000



80% are low skilled roles, ~24,000 jobs

Skill level and sources of talent for wind manufacturing

Focus

Ultra-skilled

R&D and digital Innovation experts
Research labs, PhD/Postgrad, programs, Tier-1 engineering and technical institutes

High-skilled

Engineers & component specialists
Tier-1 and Tier-2 engineering colleges, lateral hires from automotive/aerospace sector

Low-skilled

Production line workers
ITIs, vocational training programs

Industry insight

Nacelles components- power electronics

- **Shortage of ultra-skilled workers** for R&D to developing IP-protected converters and controllers. India lacks manufacturing capability for these critical components

Shortage of skilled workers

- Manufacturers report a **severe worker shortage (skilled engineers, technicians)**, forcing them to overspend on talent and reducing overall operational efficiency

Lack of training in institutes

- India's training institutes **lack the capacity and quality** to prepare skilled workers for the wind energy sector. Subpar programs and limited subsidies deepen the shortage of workforce

Total training cost[1]
INR 480-880 Cr

+

Total demo facility investment[2]
INR 2,100-2,220 Cr

Total budget (estimated share of ITI upgradation budget)[3]
INR 2,580-3,100 Cr (~4-5%)

Note- (1). Training cost for additional low-skill workers required; (2) Assumption: 2–3 ITIs tagged to each manufacturing plant (total 16 plants today; assuming 20% new plants will come up by 2030 to total of 18 plants); (3) Wind turbine industry could benefit from ITI skilling programs but could also cross-hire from competitive industry, thus, excluded from current investment estimation

Source: CEEW; Global Wind Workforce outlook; NRDC; IRENA; EU Workforce skill gap; GE 2006; MEC+ Analysis

To successfully build this workforce, action would be required across four key levers; education and training system, industry participation, policy and incentives and research and certification

LEVERS	CURRENT STATUS	RECOMMENDATIONS
Education & Training System	• Limited programs focused on renewable energy manufacturing • Lack of applied research in turbine tech • Limited industry exposure in engineering and vocational programs	• Develop wind-specific curriculum with industry partnerships; Integrate wind tech modules in engineering, diploma and ITI programs • **Incentivize joint R&D projects in partnerships with industry**; establish wind energy centers of excellence in technical universities • Launch a "Train the trainer" program for professors and academicians at Tier 1 Engineering colleges and ITI centres with wind manufacturing specific programs
Industry Participation	• Inconsistent engagement of OEMs in skilling efforts • Few structured apprenticeship or upskilling models.	• **Co-develop training curricula** with OEMs and suppliers • Create government-incentivized apprenticeships and in-factory training programs
Policy & Incentives	• Skill policies exist but lack focus on green manufacturing • Weak enforcement of local employment/training mandates	• Align industrial and skill policies to support local wind manufacturing • **Link subsidies and clearances to local workforce development targets**
Research & Certification	• Minimal R&D for advanced turbine tech locally • Lack of standardized certification pathways for wind-related roles.	• **Fund R&D through national centers of excellence in wind tech** • Establish national certification frameworks aligned with global wind industry standards.

Source: CEEW; Global Wind Workforce outlook; NRDC; IRENA; EU Workforce skill gap; GE 2006; MEC+ Analysis

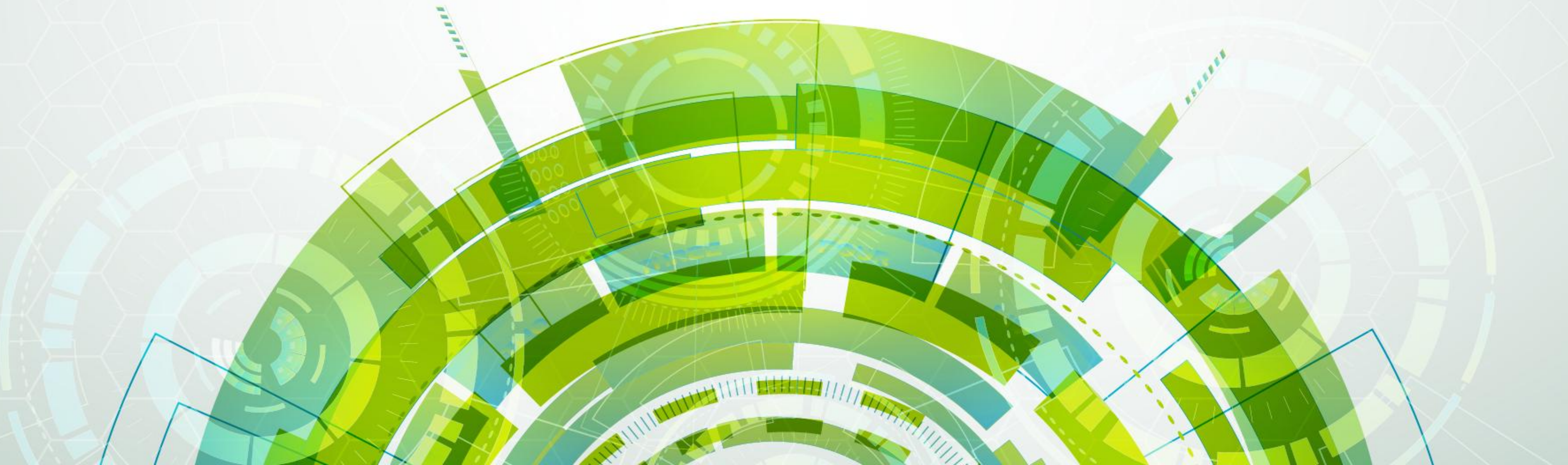
Skilling efforts for wind manufacturing across skill levels could focus on strengthening industry linkages and global partnerships, along with offering specialized courses in engineering colleges and ITI’s

Skill level	Recommendations	Responsible Ministry/Agency
Ultra-skilled	• **Fund PhD/Postdoc research in advanced materials, blade design, and control systems** to make wind turbines more efficient	Ministry of New and Renewable Energy (MNRE)
	• **Promote global research collaboration**, for more comprehensive research. This could be done by relax visa restrictions on foreign technicians	Council of Scientific and Industrial Research (CSIR)
	• **Establish Centers of Excellence in wind tech**, especially focused on making wind turbines more cost-efficient and accessible	Ministry of Education (MoE)
High-skilled	• **Develop wind energy modules in BTech/diploma courses** or add a course for specialization in Renewable Energy	Ministry of Skill Development & Entrepreneurship (MSDE)
	• **Promote industry internships** and project-based learning	All India Council for Technical Education (AICTE)
	• **Upskill in quality control**, lean manufacturing, and supply chain	Sector Skill Councils (e.g., Capital Goods, Green Jobs SSC)
Low-skilled	• **Run short-term skilling programs (3–6 months) in manufacturing basics**, safety, and turbine assembly	MSDE, National Skill Development Corporation (NSDC)
	• **Enable on-the-job training with local OEMs**, to speed up manufacturing/ commissioning process	Directorate General of Training (DGT)
	• **Offer certifications through ITIs and NSDC programs**	State Skill Missions

Source: CEEW; Global Wind Workforce outlook; NRDC; IRENA; EU Workforce skill gap; GE 2006; MEC+ Analysis

SUB-SECTION SIX

FINANCING & TAXATION



INR 0.29 to 0.43 Lakh Cr would be required during 2025-30 to achieve 60% cost-competitive indigenisation across the wind value chain, build a cohesive R&D ecosystem and train the required workforce

Government funding of INR 10,000-12,400 Cr would be required across demand acceleration, R&D, workforce skilling and subsidies on capex and interest by 2030 to achieve these goals

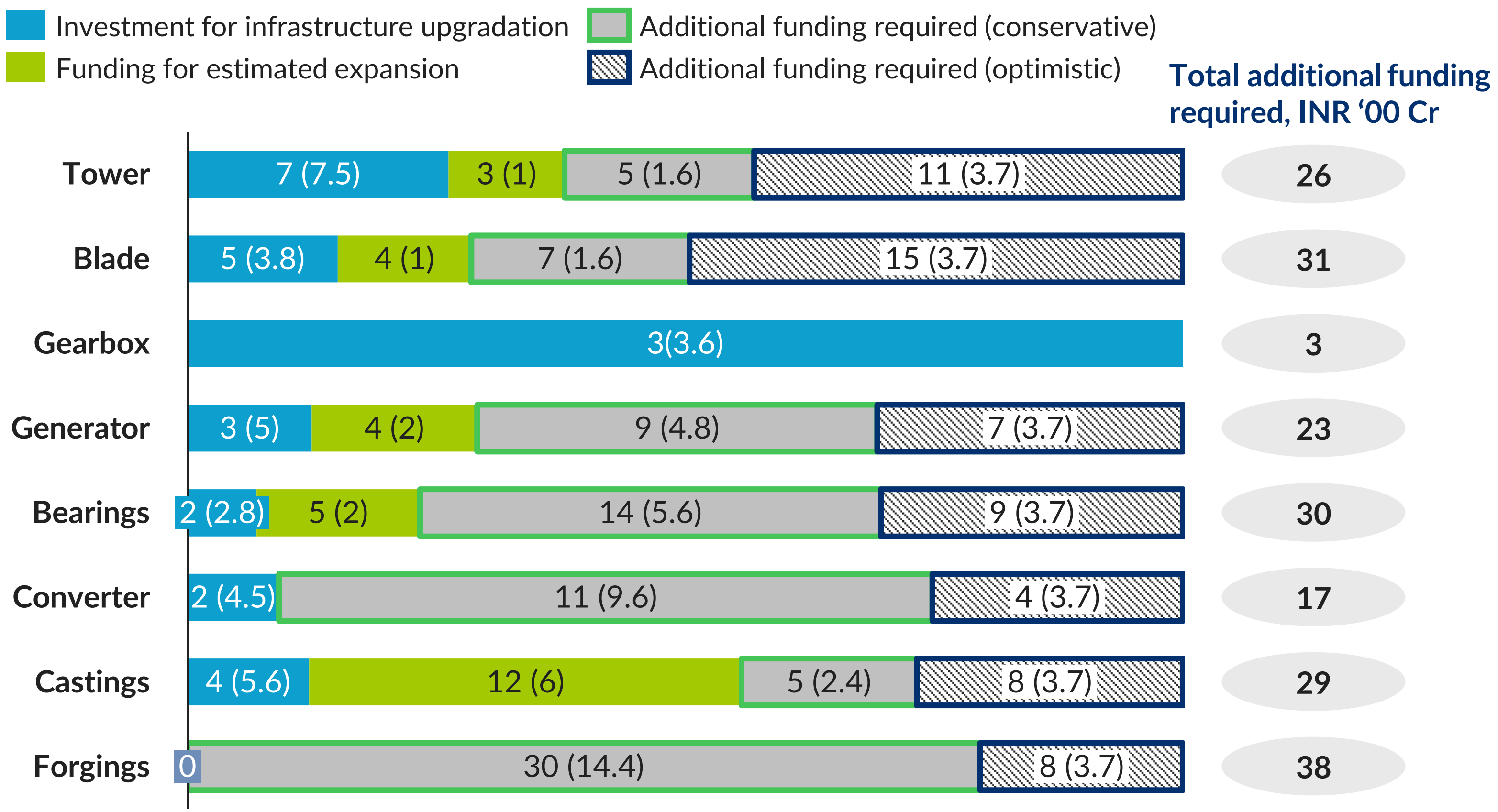
Theme	Total Funding Required (INR Cr)	Government Funding Required (INR Cr)	Key Activities	Potential outcomes
Demand & Market Architecture	350-400	350-400	EXIM Line of Credit[1] interest subvention for wind turbine export in (Africa)	Boost wind turbine export and reduce risks of dependency on the US and EU as the main export market
R&D & Product Innovation	450-500	450-500	R&D infrastructure: INR 450-500 Cr	Prototyping to commercialization of high-potential 10-20 wind innovation initiatives with industry-academia-government collaboration
Upstream Raw Materials & Critical Inputs	10,000-15,000	5,000	PLI to reduce the cost difference in raw materials, and investment in improving S355 steel manufacturing capability	Increase in local content of towers and gearbox contributing to ~18% of overall turbine DCR
Capital Equipment & Infrastructure Ⓐ	13,500-20,700	Detailed in cost competitiveness below	Invest in capex expansion across the value chain; Support MSMEs to build select casting and forging domestically	Reduce import dependence for casting and forging capabilities where feasible; Ensure accelerated capacity expansion to meet 60% DCR
Talent & Workforce	2,580-3,100	2,580-3,100	Training additional 20,000 low-skilled workers across wind value chain and set up demo training facility at ITIs	Ensuring a stable supply of workers, reducing attrition and lowering training costs for manufacturers
Cost Competitive-ness Ⓑ	1,700-3,400	1,700-3,400	Input subsidies on capex and interest subvention till 2030 and address inverted duty structure leading to potential tax revenue impact of INR 1,727-3,361 Cr	Increased cost competitiveness of domestic wind turbine– potentially bringing within 15% of Chinese landed costs
TOTAL	28,600-43,100	10,100-12,400		

(1) India announced USD 2 Bn support as LOC for renewable energy development to Africa ;

A Capital Equipment & Infrastructure| Despite announced capacity additions, additional capital investment of up to INR 26 Hundred Cr would be required to achieve 80% indigenisation across wind (optimistic scenario)

Availability of subsidized financing and clear demand signals across the value chain are required to catalyze additional capital investment required to meet 80% 2030 indigenisation target

Cumulative capital investment required by 2030, INR '00 Cr (Capacity in GW)



Key initiatives required

- **Incentives** to increase domestic supply of system level components such as large castings (hub), generators and for sub-system level manufacturing set up in the country
- **Aligned duty structures** to create domestic pricing competitiveness of sub-system level components, such as small castings, machined gears, forged rings, stator and rotor sub-assemblies, tower internals including flanges above 3m etc.

Incremental capex investment required, 2026-30

Conservative Scenario:

INR 13,500 – 14,500 Cr

Optimistic Scenario:

INR 19,700 – 20,700 Cr

Note: Assumed that planned capacities have already been funded; RoDTEP: Remission of Duties and Taxes on Exported Products; PLI: Production Linked Incentive
Source: mec+ analysis

B **Cost Competitiveness** | INR 1,700-3,400 Cr of targeted capex subsidies and low-cost financing, could improve cost competitiveness for Indian wind turbines at 60% LCR levels

Indigenisation of upstream components, subsidized capex and interest subvention could reduce domestic wind turbine costs by 10% vs. current costs, ensuring no impact on LCOE and cost competitiveness with current landed costs

Current landscape indicate strong need for cost competitiveness

- Current landed costs for Indian wind turbine components are up to 17% higher than Chinese turbine components, with this cost gap potentially widening to 25% if Indian production at 60% LCR (Local Content Ratio) operates without subsidies

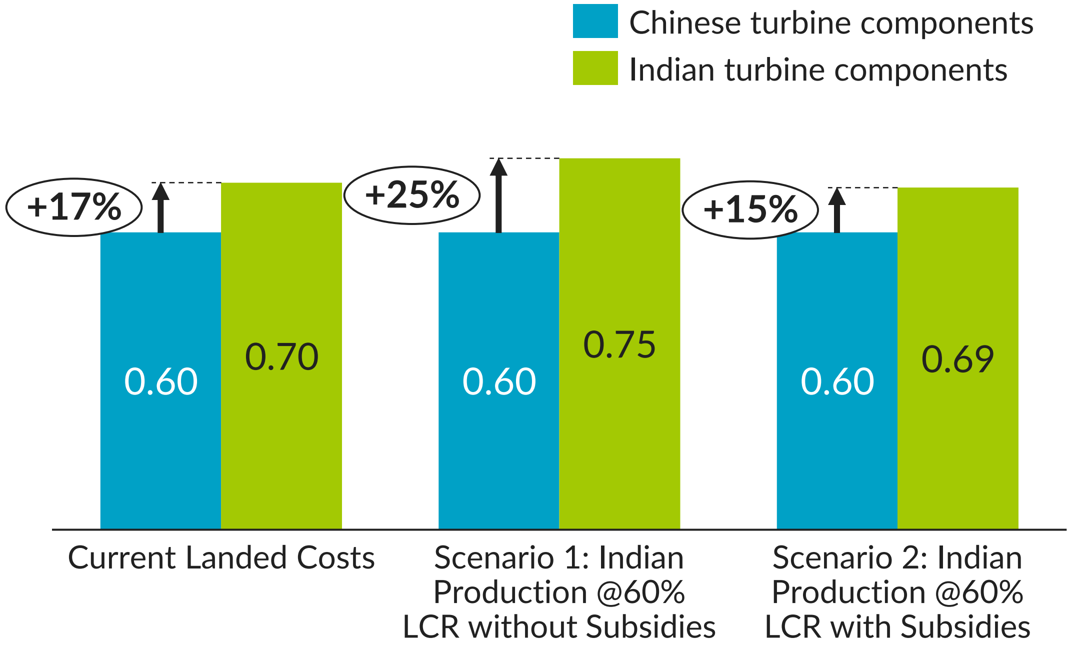
60% indigenisation could increase LCOE by 3-4% (6-8p/kWh), proposed subsidies could keep LCOE flat at current level:

- **Upfront capex subsidy** of **25%** up to **INR 1,225-2,700 Cr**
- **Interest subvention** of **23%** up to **INR 296-420 Cr**

Proposed interventions:

- **Reduce inverted duty effect:** Existing policy charges 7.5% and 10% on imports of parts and full generator /gearbox/tower respectively whereas import of con cast/ electrical grade steel attracts duties as high as 15% to 20%
- Proposed import duty waivers on key raw materials could have **potential tax revenue impact of INR 206-241 Cr**
- Improved EODB policies could also lower risk perception and improve attractiveness for financiers, potentially at better cost

Comparison of Chinese and Indian Turbine Cost[1], US dollars/ Watt, ex-GST



Targeted subsidies on capex and interest subvention

INR 1,700-3,400 Cr till 2030

Source: MEC+, RE Supply Chain Report 2024, Industry experts (industry associations, key manufacturing players), Dalberg Analysis

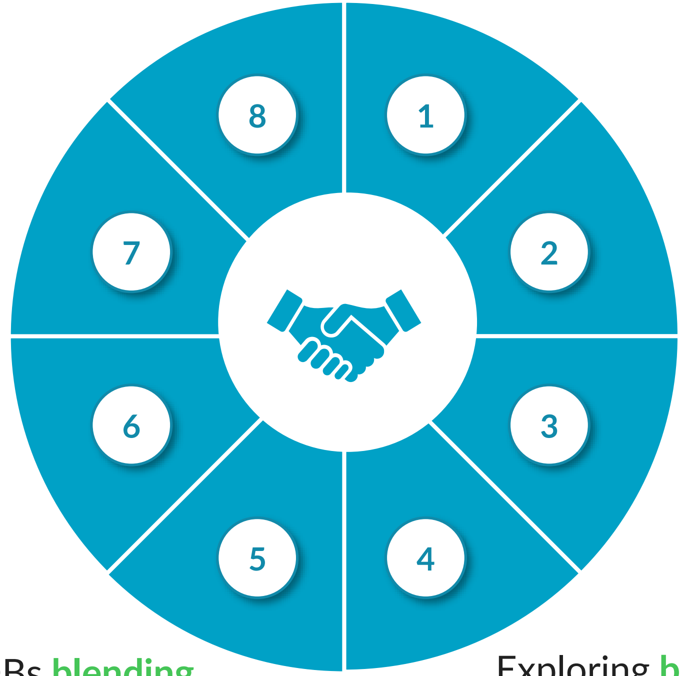
B

Capex and financing costs, and key raw materials are key cost drivers targeted for subsidies

Category	Intervention type	Inputs and assumptions	Key recommendations	Total Impact, INR Cr	
				Conservative Scenario	Optimistic Scenario
Input Subsidy	**CAPEX Subsidy**	• INR 13,500-21,000 additional capex required • Out of which, INR 4,900 - 11,000 Cr is required for casting, forging and bearing	• **25% capex subsidy** proposed • Covering incremental capacity required for casting, forging and bearings	~1,225	~2,700
	Interest Rate Subsidy	• Interest rates assumed at 11% p.a.	• **23% interest subvention** proposed • Effective rate of 8.5% p.a. • Proposed for upgrades, announced and additional capacity required	~296	~420

2 Financing costs could also be lowered via concessional capital from DFIs, MDBs, bilateral funding, and lowering domestic borrowing costs through credit guarantees, concessional lines of credit, among others

Government must create an enabling environment to facilitate tapping of domestic and international capital sources at concessional rates – targeted policies for wind and other cleantech manufacturers required



Leveraging DFIs and Multilateral concessional capital potentially backed by EU, bilateral guarantees E.g. EU Global Gateway strategy, India-ETFA TEPA

Utilizing GIFT-IFSC's regulatory flexibility and lower transaction costs for green/transition bond listings and attracting foreign equity

Easing access to equity capital by **relaxing exchange listing requirements** on profitability for wind manufacturers to reflect their longer path to profitability

Exploring **bilateral concessional funding with Middle Eastern nations** for setting up overseas manufacturing and deepening trade partnerships

Developing **structured bonds** with DFIs and MDBs **blending INR and foreign currency** denominated tranches to fund projects requiring significant imports of capital machinery

Establishment of proposed **National Green Finance Institution** with dedicated corpus and relevant enablers to provide low-cost financing for wind deployment and manufacturing

Extending Priority Sector Lending and **concessional line of credit** to banks for wind manufacturing (similar to China's CERF program)

Structured guarantee instruments and **grants to reduce guarantee fees** to promote green bond issuances among first time issuers

Source: Industry experts (industry associations, key manufacturing players), Dalberg Analysis

bharat
CLIMATE FORUM

Thank you!

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