bharat
CLIMATE FORUM

Blueprint for India's Cleantech Manufacturing Ambition

Accelerating an Aatmanirbhar, Green and Viksit Bharat

Council for International Economic Understanding

Dalberg

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The Bharat Climate Forum (BCF), launched in 2025, is India's national platform to align climate ambition with economic priorities and connect vision with delivery. Co-anchored by the Council for International Economic Understanding (CIEU) and Dalberg Advisors, the Forum convenes government, industry, financiers, academia, and civil society to drive a coherent national strategy for "Make in India" climate solutions.

BCF was established to transform climate ambition into a foundation for national competitiveness, job creation, and global leadership in clean technologies. It serves as a trusted mechanism to foster collaboration, inform policy, and translate dialogue into tangible action.

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The 2025 edition of the Bharat Climate Forum convening laid the groundwork for India's climate–economic agenda by catalysing multi-stakeholder collaboration and launching efforts to strengthen domestic clean technology manufacturing.

The 2026 edition builds on this foundation by shifting focus toward the execution of the cleantech manufacturing agenda via the launch of this blueprint focused on cleantech manufacturing, launch of initiatives to accelerate cleantech manufacturing investments, and the integration of resilience and adaptation into India's clean growth strategy.

CIEU is an independent policy institution that focuses on strengthening India's engagement with global economic, development, and sustainability priorities. Its work centres on international cooperation, economic diplomacy, and policy dialogue, bringing global perspectives into India's national conversations on growth, trade, and climate.

In its role as co-host of the Bharat Climate Forum, CIEU contributes its experience in policy engagement and international convening to support alignment between global climate frameworks and India's domestic priorities. CIEU supports in shaping pathways that translate climate ambition into tangible outcomes for India's clean technology ecosystem.

Dalberg is a strategic advisory firm that works collaboratively across the public, private and philanthropic sectors to drive inclusive and sustainable growth. Our mission is to help build a more inclusive and sustainable world where all people, everywhere, can reach their fullest potential. We partner with and serve communities, governments, and companies throughout the world, providing an innovative mix of advisory, investment, research, analytics, and design services.

As the co-host of the Bharat Climate Forum, Dalberg extends this work into the climate domain by helping structure the platform's agenda, bringing together policymakers, industry, and financiers, and supporting the development of practical, implementable outcomes.

BCF: Governing and Organising Committee

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Shri N.K. Singh

Co-chairperson
Shri Sumant Sinha

Chaired by **Shri N.K. Singh** (Former Member, Rajya Sabha; and Chairman, 15th Finance Commission) and co-chaired by **Shri Sumant Sinha** (Founder, Chairman and CEO of ReNew), the team brings together some of India's most respected leaders across government, industry, and policy to steer the second edition of this landmark convening.

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(National Co-Convenor, Swadeshi Jagran Manch)

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Smt. Meenakshi Lekhi
(Former Minister of State, Ministry of External Affairs & Culture)

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(Non-Executive Chairman, Axis Bank; Former Deputy Governor, Reserve Bank of India)

Member
Shri Rajnish Kumar
(Former Chairman, State Bank of India)

Forewords

N.K. Singh

President, Institute of Economic Growth
Chairman 15th Finance Commission
Chairperson, Bharat Climate Forum Governing Committee

The Bharat Cleantech Manufacturing Platform (BCMP) was launched during the Bharat Climate Forum (BCF) in New Delhi in January 2025. It represents a timely and credible step in India's efforts to align its climate objectives, existential as they may be, while fostering economic growth, harnessing technology which leads to gainful employment and advances the vision of zero carbon by 2070. It is aligned with India's own ambitions and nationally determined contributions.

This Blueprint for Cleantech Manufacturing in India is a synthesis of insights generated through such extensive engagements under the BCMP. It brings together perspectives from across sectors to identify policy interventions that can deliver impact at scale, assessing their implications across technologies and time horizons. The report moves beyond aspiration to examine where targeted action can reduce risk, accelerate capability building, and enable sustained domestic value creation.

India has entered a critical phase in its energy transition with ambition and credibility. Over the past decade, sustained policy direction and institutional credibility have enabled rapid progress in clean energy deployment, infrastructure expansion, and selective growth in domestic manufacturing. Experience across sectors has shown that when priorities are clearly articulated, institutions are empowered, and execution is aligned across levels of government, outcomes can be delivered at scale.

As the transition gathers pace, it is now imperative to move decisively beyond deployment to value creation. Clean energy expansion must translate into tangible gains in domestic manufacturing, employment, and industrial capability across the economy. Achieving this is not optional; it will depend fundamentally on the quality of India's institutional governance. Clear, well-prioritised national policy direction is required, particularly in sectors where India combines large and predictable demand with the potential to build durable competitive advantage. Equally critical is readiness at the state level, where national priorities must be converted into timely and effective on-ground execution. Stronger, more seamless Centre-State coordination is therefore essential to delivering results at scale and securing the full economic dividends of the transition.

I extend my sincere appreciation to the wide range of policymakers, public institutions, industry leaders, financial institutions, multilateral partners, and knowledge organisations who contributed their time, insights, and experience to this work. Their contributions, drawn from across government, regulation, finance, manufacturing, and international cooperation, have helped shape a blueprint that is practical in its recommendations and attentive to the demands of implementation. The dialogue, through this Platform, strengthens the quality of analysis, and grounds it in the realities of scale, coordination, and execution. It is my hope that this Blueprint serves as a useful point of reference for continued collaboration, as India works to build a competitive and resilient cleantech manufacturing ecosystem.

Sumant Sinha

Chairman and CEO, ReNew
Co-Chairperson, Bharat Climate Forum Governing Committee

India's clean energy journey has reached an important inflection point. What began as an effort to expand renewable capacity has evolved into a much broader transformation. One that touches energy security, industrial growth, and India's role in the global economy. The progress achieved over the past decade demonstrates what is possible when policy intent and private enterprise move in step. The next phase will test our ability to build on that momentum with depth, resilience, and long-term value creation.

As India accelerates toward its 2030 goals, the scale of ambition is clear. Clean power, storage, green hydrogen, electric mobility, and modern grids are becoming integral to how the country will meet future demand. But scale alone is not enough. The real opportunity lies in how this transition is executed—whether it strengthens domestic capabilities, anchors supply chains at home, and creates the foundations for sustained industrial leadership.

Over the past year, conversations with policymakers, industry peers, financiers, and technology partners through the Bharat Climate Forum reinforced a clear lesson: manufacturing ecosystems do not emerge automatically from demand growth and require early, coordinated intervention across policy, technology, talent, and finance. This is especially critical in capital and technology intensive sectors such as battery energy storage and green hydrogen, where global supply chains are still being shaped and first-mover advantages remain within reach.

The private sector has a critical role to play in this transition. Industry must lead in scaling investment, particularly in applied R&D, product development, and manufacturing excellence and remain aligned with rapidly evolving global technologies. This will require targeted global partnerships, investment ahead of demand, and stronger innovation across the value chain, alongside a clear commitment to building future-ready skills through training and industry–academia collaboration.

It is against this backdrop that this Blueprint for Cleantech Manufacturing in India has been developed. The report brings together insights from across sectors to examine where India can build competitive advantage and what it will take to move from intent to implementation. Its value lies not only in identifying opportunities but in highlighting the actions required to realise it.

I am honored to be part of this collective conversation, helping shape the next decade and beyond of cleantech manufacturing through collaboration, shared learning, and decisive action.

Ashwini Mahajan

National Co-convenor, Swadeshi Jagran Manch
Member, Board of Governors, CIEU
President, Bharat Climate Forum Governing Committee

I am honoured to present the Blueprint for Cleantech Manufacturing in India, shaped through sustained engagement under the Bharat Climate Forum. This report reflects a year of dialogue and analysis across government, industry, finance, and the research community, and brings together a synthesis of key gaps, opportunities, and policy priorities shaping India's cleantech manufacturing landscape. At a time when the energy transition is accelerating, the report seeks to move the conversation from aspiration to execution.

While progress in clean energy deployment and infrastructure has been notable, the long-term success of the transition will depend on whether it is anchored in domestic manufacturing capability, economic value creation, and institutional strength. For a Viksit Bharat, clean energy must serve not only as a climate imperative, but as a catalyst for industrial growth, employment generation, and technological self-reliance.

The vision of Make in India and Aatmanirbhar Bharat is therefore central to the cleantech opportunity before us. Technologies from power generation and storage to mobility, hydrogen, and grid infrastructure will define competitiveness in the decades ahead. If these value chains remain heavily import dependent, India risks substituting one form of external dependence with another. Strengthening domestic manufacturing across these sectors is thus a strategic necessity, not merely an industrial choice.

This Blueprint responds to that challenge by identifying where India can build competitive advantage and how policy can be designed to unlock impact. It highlights the need to move beyond assembly-led growth toward deeper manufacturing capability, spanning materials, components, capital equipment, testing infrastructure, and skilled manpower. The analysis also underscores the role of MSMEs and domestic suppliers as integral participants in cleantech value chains, with the potential to drive more regionally balanced industrial development.

Equally, the report recognises that manufacturing success depends on capabilities beyond factories alone. Skills development, applied research, process innovation, and productivity improvement will determine whether Indian firms can compete globally. Aligning industrial policy with skilling, innovation, and infrastructure is therefore essential to building a resilient and future-ready manufacturing ecosystem.

By aligning climate ambition with a coherent manufacturing strategy, India has the opportunity to advance its clean energy transition while strengthening domestic industry and reducing external vulnerabilities. Looking ahead, the Bharat Cleantech Manufacturing Platform will aim to further these conversations by facilitating coordination across stakeholders while providing rigorous, in-depth analysis to support informed decision-making in both the public and private sectors.

Meenakshi Lekhi

Former Minister of State for External Affairs and Culture, Government of India
Convenor, Bharat Climate Forum Governing Committee

India's approach to climate action has always been shaped by a deeper civilisational ethos; one that recognises the interdependence between nature, society, and economic progress. As the world confronts the dual challenges of climate change and development, India's response must remain anchored in equity, responsibility, and national interest. The transition to clean energy and clean technologies is therefore not only an environmental necessity, but an opportunity to articulate an Indian model of growth that is inclusive, resilient, and sovereign in its choices.

Over the past decade, India has demonstrated that climate ambition and development priorities need not be in conflict. Through decisive policy action, global partnerships, and a strong domestic reform agenda, the country has emerged as a credible leader in clean energy deployment. Yet, as global supply chains are reconfigured and new technological frontiers emerge, the next phase of leadership will depend on India's ability to shape and not merely adopt the rules, standards, and manufacturing ecosystems that will define the future.

Clean technology manufacturing lies at the heart of this challenge. For India, building domestic capability across critical clean energy value chains is essential to safeguarding energy security, strengthening strategic autonomy, and ensuring that the benefits of the transition accrue equitably across regions and communities. A transition that relies excessively on external dependencies risks undermining long-term resilience. By contrast, one rooted in domestic manufacturing, innovation, and skills can generate employment, foster entrepreneurship, and reinforce India's position as a trusted global partner.

India's clean technology journey also carries significance beyond its borders. By building resilient domestic manufacturing while advancing climate action, India can offer the Global South a model that reconciles development, sovereignty, and sustainability, demonstrating that climate responsibility can be met without importing new dependencies or compromising national agency.

This Blueprint for Cleantech Manufacturing in India offers a timely and rigorous contribution to this effort. Drawing on extensive engagement across government, industry, finance, and research institutions, the report identifies pathways through which India can align its climate commitments with industrial competitiveness and technological capability. Its emphasis on policy coherence, institutional coordination, and long-term capacity building reflects the scale and seriousness of the task ahead.

About the document

The National Manufacturing Mission, announced in 2025, recognised the imperative of strengthening cleantech manufacturing as a pathway to deliver sustained economic growth, secure India's energy transition, and ensure that the country's development trajectory is both competitive and green. While the mission laid out a clear intent, this blueprint aims to support the national mission by providing a comprehensive and integrated assessment of India's cleantech manufacturing ecosystem — where it stands today, what value is captured today, what is the potential, and what reforms and actions are required to build a robust domestic cleantech manufacturing base.

This blueprint, and its technical deep dives made available online, provide a nuanced view of the six key cleantech sector value chains that are material to India's green transition as well as cross cutting structural drivers (e.g., financing and taxation). These six value chains include solar photovoltaics, wind turbines, battery energy storage, electric mobility or e-mobility, green hydrogen, and high voltage transmission. It lays down the specific bottlenecks preventing India from and reforms needed to achieve ~50% indigenisation or domestic value addition over the next five years for each of these value chains. The analysis across each value chain undertakes a comprehensive assessment of the demand outlook and market constraints, research and development and product innovation efforts, supply chain bottlenecks across upstream materials and capital equipment, skilling requirements for cleantech manufacturing, and the financing requirements.

To develop this blueprint, we followed a three-pronged approach:

- First, we undertook extensive desk research and data modelling using publicly available data to assess current manufacturing capabilities, map existing initiatives, and estimate the investments required across the six priority cleantech value chains.
- Second, we held extensive consultations with leading experts across each value chain. This includes representatives from think tanks and research organisations, industry bodies, manufacturers, financiers, and policy experts to address data gaps, validate our findings, and identify pragmatic reforms. These consultations included one on one interactions as well as roundtables and closed door convenings throughout the period of preparation of this blueprint.
- Third, our draft analysis was peer reviewed by a broad set of stakeholders including several experts in the cleantech and cleantech manufacturing ecosystem. This engagement helped strengthen the findings and ensured that the blueprint reflects a comprehensive view of India's cleantech manufacturing ecosystem.

While the approach adopted in this blueprint is comprehensive, a few methodological limitations are important to note:

- The analysis relies significantly on publicly available data, supplemented by expert inputs to address gaps particularly in areas such as estimates of domestic value addition and import dependence. These data remain imperfect due to challenges such as limited component and materiallevel tracking under existing HSN classifications and differing assessments among experts. Wherever feasible, the analysis has sought to triangulate sources and adopt conservative assumptions.
- Cleantech manufacturing is a highly dynamic space being shaped by rapidly evolving policy, investment activity, and geopolitical contexts. Over the course of the research and compiling of this document, several policies and initiatives were announced or updated. All such developments or their full implications may not have been captured. This also includes data and investment announcements regarding manufacturing capacity that has been added.
- Estimates related to import savings and investment requirements build on the underlying data assumptions described above and are intended to provide a directional sense of scale rather than precise figures. Investment estimates vary significantly by manufacturer, technology choice, location, and site-specific factors. The analysis therefore uses average or indicative estimates, focused primarily on bill of materials costs, capital expenditure linked to manufacturing capacity, and investments in research, innovation, and enabling infrastructure. These estimates do not fully capture lifecycle costs.
- The analyses and investment figures for each value chain reflect boundary conditions we have considered for ease of building the narrative. As a result, key costs may be split across multiple value chains. E.g., the analysis on batteries covers stationary and mobile storage applications and as a result these costs do not appear under the e-mobility value chain. Similarly, renewable energy forms a large part of the cost of green hydrogen production. However, the requisite capacity addition has been considered under the solar value chain rather than as capex under green hydrogen value chain.

Taken together, these caveats underscore that the blueprint should be read as a strategic and analytical reference rather than a set of definitive projections. It is intended to inform policy dialogue and reform, and strategy development, and to serve as a coherent blueprint in support of the National Manufacturing Mission for policymakers, investors, and ecosystem actors seeking to reduce external vulnerabilities, attract investment, and build sustained momentum in India's cleantech manufacturing ecosystem.

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Our Partners

Strategic Partner

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Acronym Glossary

AAM	Anode Active Materials
AICTE	All India Council for Technical Education
ALMM	Approved List of Models and Manufacturers
ANRF	Anusandhan National Research Foundation
BCD	Basic Customs Duty
BESS	Battery Energy Storage System
BIRAC	Biotechnology Industry Research Assistance Council
BPP	Bipolar Plate
C&I	Commercial & Industrial
CAGR	Compound Annual Growth Rate
CAM	Cathode Active Material
CVD	Chemical Vapour Deposition
DGT	Directorate General of Training
DST	Department of Science and Technology
DVA	Domestic Value Addition
EU	European Union
EV	Electric Vehicle
GDP	Gross Domestic Product
GST	Goods and Services Tax
GW	Gigawatt
GWh	Gigawatt-hour
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IP	Intellectual Property
ITI	Industrial Training Institutes
kTPA	Kilo Tonnes Per Annum
LD	Liquidated Damages
MHI	Ministry of Heavy Industries
MNRE	Ministry of New and Renewable Energy
MoE	Ministry of Education
MoF	Ministry of Finance
MoM	Ministry of Mines
MoP	Ministry of Power
MSDE	Ministry of Skill Development & Entrepreneurship
MSME	Micro, Small and Medium Enterprises
MW	Megawatt
NCMM	National Critical Mineral Mission
NSDC	National Skill Development Corporation
OEM	Original Equipment Manufacturer
PECVD	Plasma Enhanced Chemical Vapour Deposition
PM-SETU	Pradhan Mantri Skilling and Employability Transformation through Upgraded ITIs
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PTL	Porous Transport Layer
PV	Photovoltaic
PVD	Physical Vapour Deposition
R&D	Research and Development
RDI	Research, Development and Innovation
RE	Renewable Energy
REO	Rare Earth Oxide
SIGHT	Strategic Interventions for Green Hydrogen Transition
SME	Small and Medium Enterprises
TFEC	Total Final Energy Consumption
TRL	Technology Readiness Level
VGF	Viability Gap Funding

Executive Summary

Domestic cleantech manufacturing is no longer optional to securing India's energy security and economic growth

India stands at a pivotal moment where its economic and climate ambitions are converging. The country has set its sights on becoming a Viksit Bharat by 2047 and has committed to achieve net zero emissions by 2070. Both these goals are inalienable from each other but achieving them requires a fundamental transformation – electrifying transport and industry, shifting to clean electricity, and greening hard-to-abate sectors - to avoid locking the country into a high-emissions development pathway. This broad electrification anchored in renewable sources and clean fuels for hard to abate sectors (e.g., green hydrogen) will drive massive demand for clean technologies (or cleantech).

India has set ambitious targets for cleantech deployment to drive this transformation. By 2030, India aims to deploy 500 GW of non-fossil fuel energy capacity, achieve 30% electric vehicle penetration in annual sales, and start shifting key industries to green hydrogen consumption with an annual green hydrogen production target of 5 million metric tonnes (under National Green Hydrogen Mission).

The demand outlook across these sectors is substantial. Annual clean energy investments exceeded USD 70 billion in 2024-25. By 2030, we project that annual solar installations can rise from 26 GW currently to 80+ GW, annual battery demand can exceed 173 GWh, annual electric vehicle sales can jump more than 5x over current levels, and a significant addition of high voltage electricity transmission corridors will also commence.

However, the global context has raised the stakes, making this transformation more complex. Clean technologies and critical minerals have become instruments of techno-nationalism and geopolitical influence. Supply chains for these technologies and minerals are highly concentrated globally and for India. For example, China dominates manufacturing across solar, batteries, and rare earth processing, accounting for over 80% of India's cleantech imports in several categories.

For India, continued reliance on imported cleantech is not just an economic cost but a strategic vulnerability. Geopolitical and trade tensions, export controls, and techno-protectionism could restrict access to key raw materials and technologies, and undermine the country's clean energy transition. Many countries across the globe are rapidly mobilising to diversify their access to clean technologies and securing supplies of critical minerals to ensure their energy security.

Securing India's energy and economic future requires urgent action to advance domestic cleantech manufacturing – the case to do so is compelling. India's cleantech market could reach USD 90-135 billion annually by 2030. Continued dependence on imports of upstream materials, high-value components, and capital equipment across cleantech value chains can create strategic vulnerabilities which could be avoided if India increases its manufacturing capacity for upstream components and raw materials.

Focusing on domestic cleantech manufacturing could deliver economic and developmental gains. Domestic value addition currently ranges from 20-55% across the six sectoral value chains considered in this blueprint. We estimate that cleantech imports stood at USD 18 billion in 2024-25 and could rise to USD 65-97 billion annually by 2030 if current extent of domestic value addition does not change. Raising domestic value addition by 25 percentage points could reduce foreign exchange outflows by USD 48-68 billion through 2030, add USD 20-30 billion to GDP annually. In addition, it could create over 1.8 million jobs and boost MSME development in cleantech manufacturing supply chains.

The Government of India is already advancing this imperative via the National Manufacturing Mission. The National Manufacturing Mission announced in Union Budget 2025 represents a strategic inflection point in India's industrial policy. It builds on initiatives like Make in India and Aatmanirbhar Bharat, to make India into a globally competitive manufacturing hub. It identifies cleantech manufacturing as a priority area with explicit emphasis on building domestic manufacturing ecosystems for solar PV cells, EV batteries and motors, electrolysers, and other components.

Alongside this sectoral focus, the mission emphasizes cross-cutting enablers: improving ease of doing business, building a future-ready workforce, strengthening MSMEs, and ensuring technology availability. The mission also lays down a three-tier governance architecture to provide strategic oversight, ensure cross-ministerial collaboration, and ensure accountability for the mission's objectives.

Momentum for cleantech manufacturing exists but structural bottlenecks limit the extent of domestic value capture

India has made meaningful progress in building cleantech manufacturing capabilities, but upstream manufacturing is negligible. India's existing cleantech manufacturing capacity is largely focused on assembly of components for final product or producing balance of plant components. For example, solar module manufacturing capacity has reached 74 GW, but cell manufacturing lags at 25 GW and polysilicon production is negligible.

These patterns exist across all cleantech value chains. The country has well established production for wind turbine nacelles and towers, but high-value components like gearboxes, converters, and large bearings remain import-dependent especially as higher capacity wind turbine platforms become the norm. Similarly, the domestic capacity for assembling battery packs is growing, but battery cell manufacturing and upstream material processing for cathodes and anodes (including their precursor materials) is nascent. For green hydrogen electrolysers, EV drivetrain and electronics, and HVDC components, India remains dependent on international suppliers for design expertise, technology access, and supply of high value components.

Multiple structural bottlenecks constrain the country's ability to deepen value capture. Demand signals remain uncertain, with stop-start procurement cycles and policy changes limiting long-term investment visibility for manufacturers. Cleantech R&D remains fragmented and grossly underfunded with India's 0.6% gross expenditure on R&D being well below the 2-5% benchmark of leading manufacturing economies.

Critical raw material and input dependencies are also acute. China supplies over 70-80% of India's polysilicon, lithium compounds, and rare earth oxides, while domestic rare earth processing capacity covers less than 5% of projected demand. Capital equipment import dependence ranges from 40-95% across sectors, from CVD reactors for polysilicon to electrode coating lines for batteries.

Financing constraints and duty misalignments further disadvantage domestic manufacturers. Project-level borrowing costs of 11-12% compared to 7-8% for established corporates, and backloaded nature of incentive structures like Production Linked Incentives make upfront capital investments costly. Inverted duty structures in components (e.g., Concast S355 steel vs. wind turbine gear boxes) favour imports and GST misalignments can lock up capital in form of input tax credits. These constraints collectively undermine investment flows into cleantech manufacturing at the scale and speed required to transform the sector in India.

Ten bold actions are needed to expand domestic cleantech manufacturing in India

Based on analysis of the current manufacturing capabilities and structural bottlenecks in advancing manufacturing across the six value chains in this blueprint, we have identified ten priority actions that stakeholders can take to advance cleantech manufacturing ecosystem in the country:

1. **Extend domestic value addition mandates** as part of ALMM and PLI schemes rolled out by MNRE and MHI to cover all six sectoral value chains with phased timelines (gradually increasing to 50% by 2029), taking an end-to-end view of the value chain and not just final assembly.

2. **Focus on building domestic refining of key raw materials and critical minerals** (e.g., rare earth oxides), building strategic stockpiles (25% of annual demand by 2030), accelerating creation of circularity infrastructure for recovery of these minerals through targeted fiscal support, and diversifying supply partnerships by expanding the scope of NCMM being implemented by MoM.

3. **Introduce Viability Gap Funding (VGF) mechanism(s)** under the leadership of MNRE, MHI, and MOP for refining of input materials and critical components (e.g., battery and EV motor manufacturing)

4. **Introduce price guarantees led by MoM to encourage production of key raw materials**, like special grade and electrical grade steel required in cleantech manufacturing, to insulate domestic producers from fluctuations in global prices and cheaper imports from international suppliers.

5. **Drive increase in R&D investment in cleantech manufacturing through two complementary efforts.** First, allocate dedicated funding via the RDI Fund under ANRF, administered by DST, for translational research on prioritised technologies (based on TRL) and creation of R&D infrastructure (e.g., industrial-scale testbeds). Second, introduce tax incentives via MoF for private sector R&D expenditure exceeding 1% of gross revenue, targeted at entities availing PLI support for cleantech manufacturing.

6. **Launch a Cleantech Manufacturing Investment and Technology Accelerator** supported by DPIIT and Invest India to facilitate technology acquisition and investments for domestic manufacturing of capital equipment required for cleantech manufacturing as wells as key components for each of the value chains.

7. **Transform ITIs located near cleantech manufacturing clusters by leveraging PM-SETU funds**, administered by MSDE, to upgrade training infrastructure, establish demonstration facilities, and build trainer capacity. In parallel, drive curriculum modernisation and faculty development across the top 100-200 engineering education institutions to create a pipeline of high-skilled and ultra-skilled talent for the sector.

8. **Introduce partial credit guarantee for cleantech manufacturing**, led by the Ministry of Finance, alongside upfront subsidies and interest subvention mechanisms administered by relevant line ministries (e.g., MHI for battery and EV manufacturing). These measures would lower debt costs and capital requirements for manufacturers establishing cleantech projects. All mechanisms, particularly subsidies, should include sunset clauses limiting government support to five years.

9. **Include technology agnostic cleantech manufacturing under the Harmonized Master List (HML)** of infrastructure sub-sectors, maintained by MoF, to enable availability of lower cost and longer-term credit to cleantech manufacturers from dedicated infrastructure financing entities.

10. **Provide income tax benefits to greenfield cleantech manufacturing initiatives** by extending the timeline of the income tax concession that was made available to new manufacturing activities by MoF and expressly clarifying what types of activities and value chains are included.

Implementing the above and other recommendations included in this blueprint would require catalytic public funding of ~INR 1.85-2.45 lakh crores which can further unlock INR 4.5-7 lakh crores in private investment. This public funding includes funds already allocated but not disbursed across existing government schemes and additional allocation needed to support the development of the domestic cleantech manufacturing ecosystem.

Delivering on this ambition will require strong institutional coordination between different line ministries and the private sector. The National Manufacturing Mission Director's office could play a coordinating role and work closely with MNRE, MOP, and MHI to build sector-specific roadmaps while these ministries coordinate implementation with the private sector. Similarly, other ministries such as MSDE and DST can help push for reforms in other cross cutting areas such as workforce development and R&D and product innovation.

India's clean energy future will be defined not only by what it deploys, but also by what it builds. The coming decade offers a once-in-a-generation opportunity to establish India as a globally competitive cleantech manufacturing hub and secure India's energy and economic future. The market opportunity and policy intent is in place. The policy architecture and governance architecture is also firming up. The imperative is now to move from intent to execution with speed, scale, and strategic focus.

1 India's Cleantech Moment: From Energy Transition to Industrial Strategy

1.1 India at a climate-economy crossroads

India is entering a decisive phase of growth in which climate and economic ambition are increasingly coupled. India has set its ambition to become a USD 10 trillion economy and a developed nation by 2047[1]. Ensuing economic growth in the coming two decades will require rapid expansion in industrial production and service industries, supported by the scaleup of passenger and freight mobility as a critical enabler. Concurrent with this economic growth, the country has committed to achieving net zero emissions by 2070[2].

Electrification of these sectors and greening of the electricity mix is expected to underpin this growth[3]. NITI Aayog's analysis and Office of Principal Scientific Advisor's net-zero roadmap projects that the share of electricity in Total Final Energy Consumption (TFEC) will expand from 18% currently to 50% in 2070 driven by electrification across sectors, installation of renewable energy capacity (solar and wind), and increase in installed nuclear power (up to 250-300 GW)[4]. Achieving net zero will also require ramp up of green molecule usage, such as green hydrogen, ethanol, and bioenergy in key domestic and hard to abate industrial sectors.

Expanding electrification and rapidly greening the electricity mix will be essential to drive India's economic growth without adopting a high-emission growth pathway. As India aims to become the third-largest economy by 2030-2031 and becoming a Viksit Bharat by 2047, policy and investment choices made by the public and private sectors in this decade will lock-in the energy, infrastructure, and technology pathways to reach these goals. The country's power demand is expected to reach 708 GW by 2047, requiring an installed power capacity of ~2,100 GW[5]. To achieve its climate goals, 90% of this electricity generation will need to come from non-fossil fuel sources[6]. Therefore, shifting to a greener electricity mix as India electrifies will be crucial to sustain growth without locking into a high emissions trajectory.

India is already taking policy action to this end. In the near term, i.e., by 2030, India has committed to reducing emissions intensity by 45% over 2005 levels and sourcing at least 50% of its installed electric power capacity from non-fossil fuel-based energy resources[7]. These commitments have been backed by policy action to set a target to deploy 500 GW of non-fossil fuel energy capacity and achieve 30% penetration for electric vehicles in annual vehicle sales by 2030[8]. In areas like green hydrogen, the Government of India has rolled out the National Green Hydrogen Mission (NGHM) with a target of 5 MMT of green hydrogen production annually by 2030[9].

Sustained investment in clean technologies will be central to achieving these 2030 goals and building a foundation for the growth beyond. This includes renewable power, battery energy storage systems, e-mobility, green hydrogen, and national electricity grid upgrades to support renewable power evacuation from generation hubs to consumption centers.

While investments in the sector have been increasing, India's cleantech transition remains import dependent. Annual investments in clean energy increased to USD 100 billion in 2024-2025 compared to USD 68 billion in 2023, reflecting robust growth in solar, wind, and grid investments[10]. Similarly, if the current investment trajectory continues, we estimate that the electric mobility market could reach USD 14-21 billion in 2030[11]. Most of these investments have been on the demand side of the transition, i.e., the deployment of renewable capacity, electric vehicles, and associated infrastructure, underpinned by supportive government policies (Production Linked Incentive (PLI), FAME II, PM E-Drive), robust private sector engagement, and a vibrant startup ecosystem. Nevertheless, domestic value addition (DVA) in cleantech manufacturing remains limited, ranging from 20% in areas such as solar and battery energy storage systems, to up to 55% in HVDC transmission systems. In other words, import dependence within the cleantech sector's value chains varies between 45% and 80%—specifically, solar (80%), wind (65%), battery Sstorage (80%), e-mobility (65%), green hydrogen (65%), and high voltage direct current (HVDC) transmission (45%)[12].

To continue electrification and greening of the electricity mix at scale, the country must reduce this cleantech import dependence. In an era of fractured supply chains, rising techno-protectionism, and volatile trade regimes, relying on imported cleantech is a strategic vulnerability that can derail India' expected emissions and growth trajectory. As countries look to exercise control over clean technologies by tightening export controls and use critical minerals for geopolitical gains, India must seek geopolitically sensitive and pragmatic solutions to safeguard its cleantech transition.

For India, the answer is clear: build at home, at scale, and with speed. The country must domestic cleantech manufacturing capabilities that ensure energy security and economic growth without locking into high-carbon or import-dependent pathways. "Make in India" push will not just be for economic self-reliance, but also securing the foundations of a low-carbon future. This is in line with India's vision to become an Aatmanirbhar and Green Bharat. India's advantageous geopolitical position, competitive labour market, and increasing domestic demand also make it an appealing destination for cost-competitive cleantech manufacturing.

The National Manufacturing Mission links green growth with industrial development and seeks to build domestic capabilities in cleantech manufacturing. The Mission, announced by Honourable Finance Minister during the National Budget 2025, includes cleantech manufacturing as a key focus area. This emphasis is rooted in the recognition that India cannot meet its climate and economic growth ambitions by relying primarily on imported technologies and components. Inclusion of cleantech manufacturing in the mission squarely places it at the intersection of the nation's climate and energy policy, trade policy, and industrial growth policy:

- **Climate and clean energy policy.** As India continues to grow and electrify large sections of its economy, the energy demand is expected to reach 2230 billion units by 2030[13]. This will necessitate at least 950 billion units of renewable power aided by energy storage infrastructure[14]. The pace and cost of this renewable energy infrastructure build-out will be contingent on availability of key technologies and critical components.
- **Trade policy and supply chain shifts.** Global trade, especially in cleantech, is being reshaped by industrial policies across the globe (e.g., the EU's carbon border adjustment mechanism) and geopolitical shifts such that many countries seek to diversify their supply chains. India's cleantech manufacturing could integrate into global value chains to help countries diversify while also reducing its supply chain concentration risks.
- **Industrial policy and the Make in India strategy.** The Government of India's industrial policy anchored in the principles of Make-in-India and Aatmanirbhar Bharat, seeks to deepen domestic cleantech manufacturing and create resilient supply chains to serve domestic and international markets. Given the large and growing domes-demand focus area for industrial policy.

Simultaneously, the goal is to ensure that the energy transition in India is not just a deployment story, but also a driver of productivity, jobs, industrial competitiveness, innovation, and strategic position in line with national ambitions.

1.2 The case for cleantech manufacturing in India

Driving domestic cleantech manufacturing is no longer optional for India's growth. There are three interlinked imperatives:

- An economic imperative to reduce import dependence and capture a large share of value in cleantech sectors where demand is already large or rapidly growing.
- A strategic imperative to reduce exposure to concentrated global supply chains and reduce geopolitical risk, safeguard the pace of the energy transition and avoid stranded downstream energy assets.
- A development imperative to create high-quality jobs and deepen MSME participation.

We detail each of these below.

Figure 1: Three imperatives to invest in cleantech manufacturing in India and potential gains

Potential gains from investing in cleantech manufacturing in India[1,2]

ECONOMIC IMPERATIVE	STRATEGIC IMPERATIVE	DEVELOPMENT IMPERATIVE
USD 48-68 Bn cumulative import bill saving	**USD 1.1-1.7 Bn[3]** research & innovation investment	**~1.8 Mn** direct & indirect cleantech manufacturing jobs

Notes: 1. Figures represent cumulative gains or benefits between 2025-2030; 2. Figures are estimated based on cleantech sectors achieving 50% domestic value addition by 2030; 3. Estimated R&D investment that can be unlocked via public and private actors across cleantech sectors
Sources: Dalberg analysis of six cleantech sectors and their annual/ cumulative gains

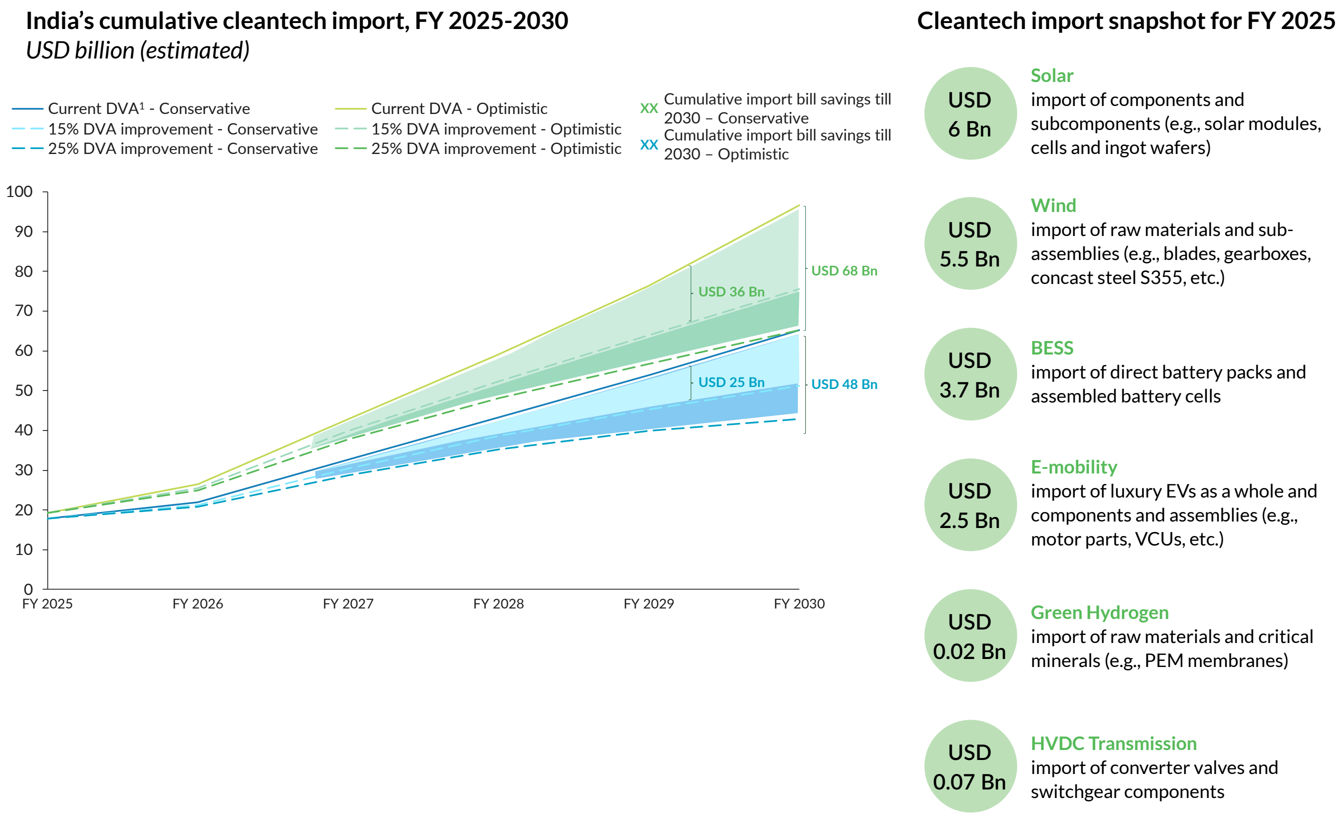
1.3 The economic prize: Market capture, cost competitiveness and decline in foreign exchange outflows

Drive significant import bill savings and prevent foreign exchange outflows

Despite progress, India continues to rely heavily on imports for cleantech deployment. We estimate that in 2024-25, India imported ~USD 18 billion worth of cleantech equipment and components across the six priority sectors. These include solar modules and cells, battery cells and critical materials, battery packs, electrolyser stack components, wind turbine components (such as gearboxes and bearings), and advanced power electronics for EVs, among other components. As deployment accelerates across sectors, this dependence will translate into a rising import bill and persistent pressure on India's current account. We estimate that annual imports of cleantech equipment and components could reach USD 65-97 billion if current extent of domestic value addition does not change[15]. This is equivalent to ~1.8% of India's current nominal Gross Domestic Product (GDP) and is approaching India's current annual oil import bill[16].

Developing domestic manufacturing capacity can reshape this dynamic. Raising domestic value addition by 25 percentage points across sectors can reduce cumulative foreign exchange outflows till 2030 by USD 48 billion, improve the trade balance, and support a more resilient macroeconomic position. It could also shorten lead times for project developers, reduce exposure to global price shocks, and improve project bankability by making supply chains more predictable.

Figure 2: Potential import savings under different domestic value addition improvement scenarios



Notes: 1: DVA refers to domestic value addition, considering only bill of materials costs.
Sources: Dalberg analysis of Comtrade data across six focus sectors

Capture multi-billion-dollar domestic cleantech market

India's cleantech deployment will create one of the world's largest domestic markets across solar, wind, battery storage, green hydrogen, electric vehicles (EVs) and grid equipment. Capturing a greater share of this market through domestic manufacturing is a significant industrial opportunity. We estimate the Indian cleantech market could reach USD 90-135 billion by 2030. Raising domestic value addition by 25 percentage points over current levels across these priority sectors[17] could unlock growth in industrial output and add USD 20-30 billion to the national GDP on an annual basis in FY 2030 alone[18].

Furthermore, domestic manufacturers that scale in the Indian market will also be better positioned to serve export demand as other countries seek to diversify their cleantech supply chains. Global buyers, Original Equipment Manufacturers (OEMs), and project developers are increasingly seeking alternatives to existing supply hubs, and India can offer them a combination of scale and cost competitiveness by building its manufacturing depth in cleantech. This will further boost industrial output and add to the country's GDP. For the country, these earnings can result in higher fiscal revenue (if tax structures are optimised), downstream investments to boost industrial output, and greater competitiveness of domestic firms in the global cleantech market.

Lower deployment cost through economies of scale

Increased domestic manufacturing can help lower the cost of deploying clean technologies in India. The country's captive demand could enable manufacturers in India to unlock economies of scale, reduce logistics and import-related costs, and support the manufacturing of components tailored to Indian conditions. Over time, the localisation of these components can reduce vulnerability to global price spikes and lower the cost of manufacturing them in India. For example, electrolysers form 30-50% of green hydrogen production costs and domestic electrolyser manufacturing can provide significant cost advantages for green hydrogen production[19].

1.4 The strategic focus: Energy security and supply chain resilience in the face of geopolitical changes

Reduce exposure to geopolitical and supply chain shocks

India's cleantech supply chain is highly concentrated in a small number of countries. China dominates global manufacturing across major cleantech value chains including solar photovoltaic (PV) materials and modules, batteries, and several critical minerals. It is also the major exporter to India for several cleantech equipment and components. For example, China accounts for 90% of India's annual import of silicon wafers for manufacturing solar PV modules[20]. It also accounts for more than two-thirds of India's annual import of other cleantech intermediate goods such as silicon ingots, lithium-ion cells for battery packs, and permanent magnets for EV motors[21].

Research from multiple institutions indicates that geopolitical risks have played a key role in disrupting the renewable energy transition across several economies[22]. Concentration in supply chains creates systemic vulnerabilities for dependent countries, in this case India. Trade disputes, export controls and sanctions, logistics disruptions, and domestic policy shifts in these supplier countries can directly affect importing country's ability to source critical technologies and components at predictable prices and timelines. These shocks have already started manifesting for India. For example, in 2023, supply chain disruptions for synthetic graphite created battery procurement delays for EV OEMs in India, and globally[23]. More recently, China has imposed restrictions on the export of critical cleantech technologies[24]. As India's energy system becomes more dependent on these technologies, such shocks represent a strategic risk to India's energy transition. Creating a more resilient value chain is essential to secure supplies for Indian project developers and ensure that India can continue deploying energy infrastructure at the pace it needs.

Safeguard India's climate transition timeline & avoid stranded assets

Supply-chain shocks can lead to prolonged project timelines and under-utilised assets. Delays in critical components can force project developers to postpone commissioning or even cancel projects. In such cases, investments already made (such as land or grid infrastructure) effectively become stranded capital undermining investor confidence. For example, the Global Wind Energy Council highlights that insufficient global manufacturing capacity can create bottlenecks for wind energy projects globally and slow down project completion rates[25].

As India ramps up deployment of cleantech, these risks also scale. Renewable energy projects in India already experience delay-linked cost escalations, including liquidated damages (LD) or penalties up to 5% and ~400 basis points increase in cost of capital due to delays and uncertainty in project commissioning[26]. Further supply chain shocks could increase the project costs and impact upstream and downstream infrastructure. For example, delays in availability of electrolyser or specific balance of plant components can slow down flagship hydrogen projects with knock on effects on associated renewable energy generation capacity (input for green hydrogen production) and downstream off-takers. Similarly, delays in procuring grid components can slow down integration of power assets into the national grid. Strengthening domestic manufacturing and creating resilient supplies of cleantech components are key to safeguarding India's energy transition and avoiding underutilised downstream assets.

Enable leadership in emerging technologies

In line with India's vision of becoming Aatmanirbhar and positioning itself as a key global voice, especially on climate issues for the Global South, strengthening cleantech manufacturing can build its strategic and technological leadership. Countries that build a deep manufacturing base in priority cleantech will also shape product roadmaps, standards, trade dynamics, and investment in the net zero economy. By investing in priority cleantech value chains, India can shape global technology choices and secure better terms in strategic partnerships. With its large captive market and engineering talent, India can emerge as a strong voice globally on cleantech and trade issues such as on tariffs, preventing monopolies on critical mineral supplies, creating global partnerships or platforms to accelerate cleantech deployment, and shaping product standards (e.g., EV charger configurations). Conversely, as a downstream only player, India will have limited influence to shape these agendas.

1.5 The development case: Jobs and MSME growth through a manufacturing focus

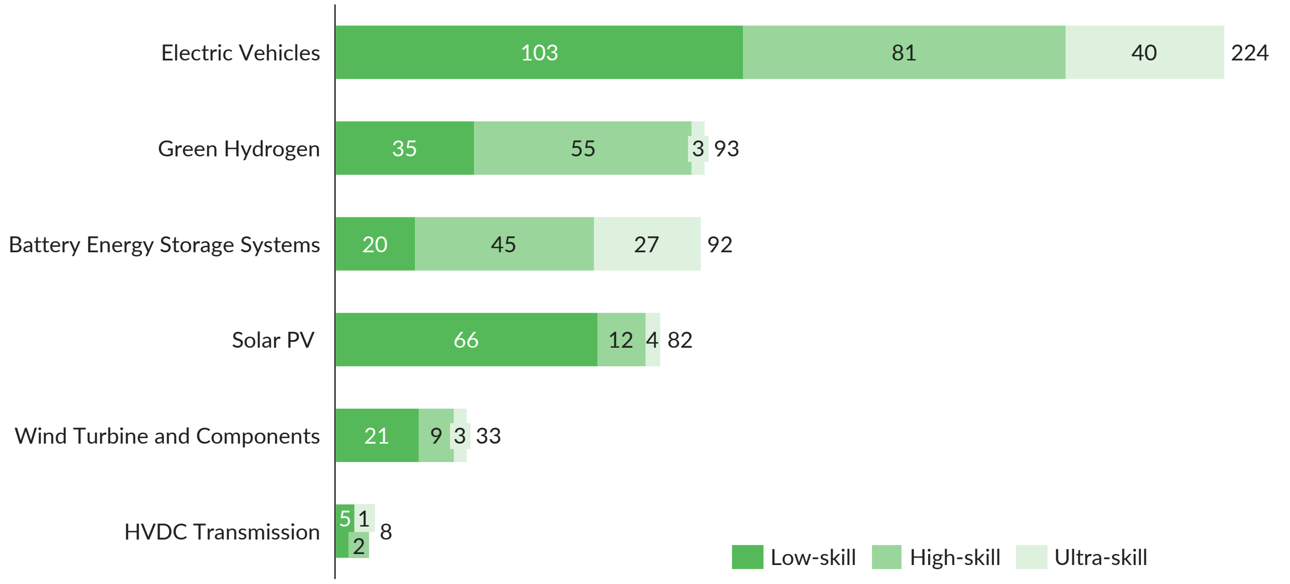
Creating high-quality cleantech jobs across sectors

Investing in cleantech manufacturing can create more than 1.8 million jobs by 2030 across the six priority sectors[27]. India's renewable energy deployment push over the past decade is estimated to have created over 1 million jobs[28]. Investment in cleantech manufacturing across the six sectors can lead to a similar scale of job creation in the next five years. We expect that by 2030 more than 0.5 million high quality direct jobs could be created in cleantech manufacturing if India achieves 50% or more indigenisation across the six sectors[29]. These jobs will cover a wide spectrum of skills from technicians and operators on manufacturing lines, to engineers, researchers, and quality specialists to take on highly skilled roles across the six sectors. Many of these jobs will be created in Tier 2 and Tier 3 cities where industrial clusters or manufacturing facilities are located. These high-quality jobs could further create indirect employment for ~1.3 million individuals in associated sectors and ancillary industries. Sustained investment in skilling and upskilling will be needed to realise this potential but given the size of India's cleantech market, the underlying demand for labour is large and long term.

Figure 3: Estimated cleantech manufacturing direct jobs that can be created by 2030

Direct cleantech manufacturing jobs created by 2030 in India

Thousands of workers



Sources: Dalberg analysis

Strengthening MSMEs as suppliers in tier-2/3 manufacturing ecosystems

Cleantech manufacturing relies on a dense network of small and medium-sized enterprises that supply materials, components and sub-assemblies, as well as services to OEMs. Investing in cleantech manufacturing can unlock significant market opportunities for MSMEs as tier-2 and tier-3 suppliers. For example, MSMEs can contribute to the balance of plant equipment, fabricated structures, precision machined parts, speciality forgings, and logistics services. An industry study estimates that commissioning of all of the PLI-linked solar PV manufacturing capacity announced till date could generate INR 17,500 crore in demand for materials like solar glass and back sheets that could be served by MSMEs[30]. With the scale-up of domestic manufacturing, as OEMs localise more components and deepen their supplier engagement, MSMEs can further raise their productivity and position themselves to serve domestic and global markets.

1.6 The urgency of locking in a cleantech manufacturing edge

India has a once-in-a-generation opportunity to develop a cleantech manufacturing base that matches its scale of deployment and positions the country as a key production hub for a net-zero economy. The coming decade will be critical for three reasons:

- First, India's cleantech demand will scale rapidly, leading to a credible, multi-decade demand base for cleantech manufacturing. However, India must move now to capture this demand, providing upside for investors and manufacturers by providing them with long-term market visibility into demand and policy support to deliver on this long-term manufacturing ambition.
- Second, global supply chains are in flux. Many countries are reassessing their dependencies and seeking new manufacturing partners. Over the next five to ten years, global OEMs and cleantech project developers will restructure their supply chains to ensure more resilience. India has a strategic opportunity to offer scale, stability, and competitive pricing to become a credible partner and attract investments.
- Third, India's policy architecture has already created momentum for cleantech manufacturing. The launch of production-linked-incentive schemes in sectors like solar PV modules and batteries (Advanced Chemistry Cell or ACC), the National Green Hydrogen Mission, FAME and e-FAST for e-mobility, and various state-level measures have catalysed private sector interest and early investments. Structured interventions and policy support can help India move from primarily being an assembly hub to building a deep manufacturing base.

The task ahead is to turn the initial momentum for cleantech manufacturing already created in the country into a structured blueprint that covers the following: where along the value chain India can build depth, what structural bottlenecks exist to build this depth, and how India can incentivise private sector investments in cleantech manufacturing.

2 Where India Stands Today: The State Of Cleantech Manufacturing

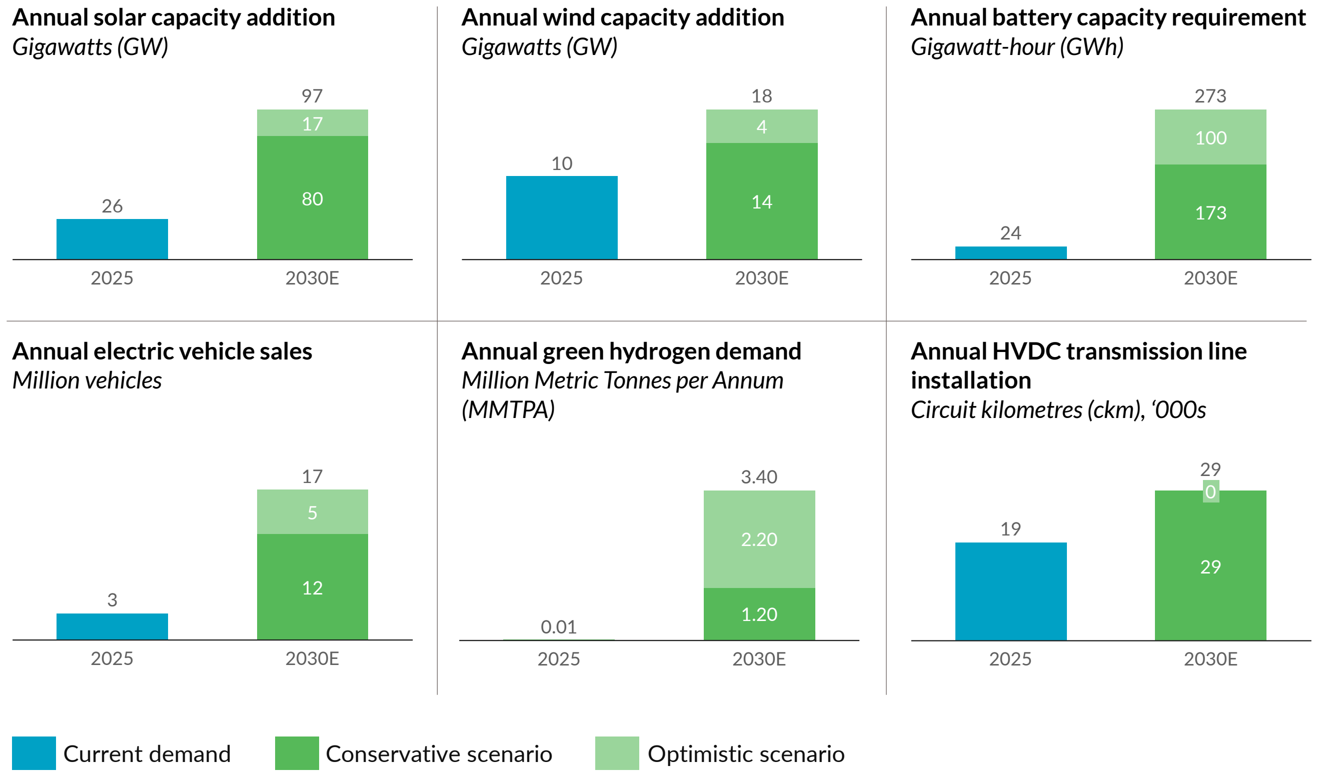
2.1 India's 2030 cleantech demand landscape across priority cleantech sectors

India is on track to become one of the world's largest cleantech markets by 2030. Building on existing national targets and sectoral trends, we estimate that demand for clean energy across solar and wind, battery energy storage, green hydrogen systems, e-mobility and transmission infrastructure will accelerate over the next five years on account of rising electricity demand, industrial growth, and the need for reliable, low carbon energy and mobility. We consider two scenarios:

1. **A conservative scenario** that reflects a baseline rate of growth in cleantech deployment across different sectors and is consistent with the implementation of current policies as well as moderate improvements in ease of doing business for cleantech projects over the next five years.
2. **An optimistic scenario** that projects cleantech demand reflective of stronger policy momentum (e.g., enhanced, longer-term capex subsidies), resolution of implementation bottlenecks to bring manufacturing capacity online, greater market share in export markets, and faster adoption of cleantech in sectors like e-mobility.

Across both scenarios, we project significant capacity additions over the next five years. The demand profile underpins a credible, multi-year market for cleantech. For example, installed solar capacity is expected to exceed ~300 GW by 2030, with annual solar capacity increasing from the current 26 GW to 80 GW by 2030 in the conservative scenario[31]. In the optimistic scenario, if rooftop solar and adoption of solar energy by industry take off due to industrial decarbonisation requirements, the annual rate of solar capacity installation could reach 97 GW by 2030[32]. Similarly, given the falling prices of batteries globally, introduction of Battery Energy Storage System (BESS) mandates, and the rapid adoption of e-mobility in 2W and 3W market, we expect the demand for battery energy storage to be between 173-273 Gigawatt-hour (GWh) by 2030[33]. Figure 4 provides an overview of the expected demand across each of these value chains in both scenarios.

Figure 4: Current and projected annual demand across priority sectors 2025-2030



Notes: Current demand is based on estimates of historical growth rates and where available actual demand; numbers have been rounded off.

Optimistic scenario: Assumes strong and sustained policy support, including continued or enhanced subsidies and supportive regulations; higher market growth rates; rapid technology improvement; high levels of product and business-model innovation; scaled-up adoption; development of supporting infrastructure

Conservative scenario: Assumes limited or no new policy support, with existing schemes mostly just extended rather than expanded; slower technology improvement; slower market growth rates; constrained product and business-model innovation; gradual rather than rapid adoption across user segments; supporting infrastructure expanding more slowly

Sources: Dalberg analysis; MEC+ analysis for wind sector

2.2 Current status of domestic value capture and the value at risk

Currently, cleantech sectors in India capture around 20–55% of the value embedded in deployment, leaving the majority of value locked in imports[34]. If these patterns continue, we estimate the cumulative foregone domestic value could be of the order of INR 4.15-5.8 lakh crore by 2030[35].

Figure 5: Domestic value addition across priority sectors and upside capture potential

Domestic value addition levels across six priority sectors
% of Bill of Materials Cost

	Solar PV Modules	Wind Turbines	Batteries	E-mobility	Green Hydrogen	HVDC Trans-mission
Domestic value capture (current)[1]	~20%	~35%	~20%	~35%	~35%	~55%
Domestic value capture (potential for 2030)[2]	~50%	~60%	~45%	~50%	~60%	~70%

Notes: (1) Cathode Active Material and Anode Active Material; (2) Battery Management System
Source: Dalberg analysis, "Mine to Market: Critical mineral supply chain for domestic value addition in Lithium-ion Battery manufacturing, NITI Ayog, 2023

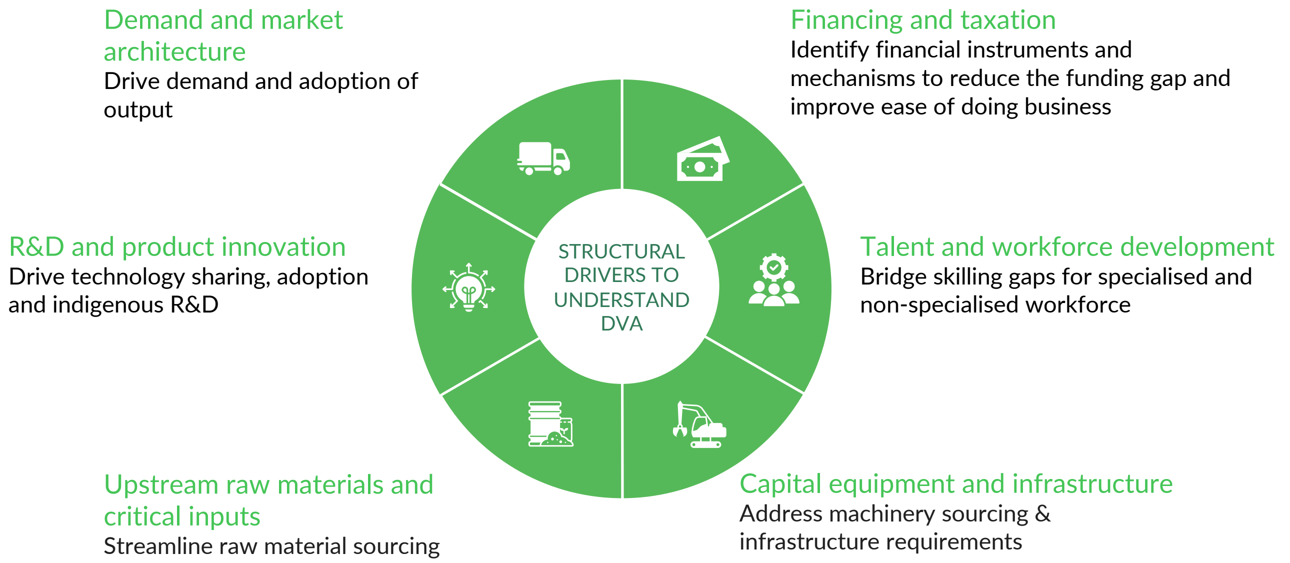
The value capture gap reflects a consistent structural pattern, where India has built meaningful capacity in downstream assembly of cleantech components. India has the manufacturing ecosystem to undertake assembly of components like solar modules, serve balance of plant needs across most of the six value chains, undertake heavy fabrication, and domestically manufacture components that are less capital and technology intensive. However, the manufacturing base remains weak in upstream materials, high-value subsystems, and precision components where the country is dependent on countries such as China, South Korea, Taiwan, Japan, and Germany.

This pattern reflects the underlying structural barriers that limit India's ability to move upstream and capture greater value. Constraints related to demand signalling for cleantech, access to technology, sourcing of capital equipment and raw materials, the depth of the industrial base, and financing conditions collectively restrict upstream component manufacturing. Understanding these constraints is a starting point for designing targeted interventions.

2.4 Six structural drivers that unlock value capture across cleantech manufacturing sectors

Six structural drivers determine what parts of the value chain are or can be attractive to investors to localise manufacturing and interventions needed to address bottlenecks to catalyse manufacturing activity. These six drivers include demand and market architecture, research and development (R&D) and product innovation, upstream raw materials and critical inputs, capital equipment and infrastructure, talent and workforce, and finance and taxation. These are laid out in Figure 6.

Figure 6: Structural drivers that influence investor entry and act as bottlenecks to increasing domestic value addition



Across these six drivers, constraints for investors and value chain localisation manifest in different but often interconnected ways. For example, manufacturers may face fragmented or stop-start demand that limits their long-term offtake visibility or does not justify investment in a manufacturing line that might operate at sub-optimal rates (e.g., for transmission equipment where procurement is often bunched together). Similarly, firms may lack access to the right technologies or capital equipment to undertake higher-value manufacturing activities. Dependence on imported inputs without supply assurance (e.g., critical minerals) can also expose manufacturers to investment risk. Multiple constraints can work together to limit private sector investment in cleantech manufacturing. For example, consistent high cost of capital and long project lead times in India, combined with the constraints mentioned above, have led to muted return expectations for investors and remain a critical bottleneck to unlocking private-sector capital for manufacturing-related investments.

A robust cleantech manufacturing blueprint must systematically address constraints across these six cross-cutting drivers, with targeted interventions tailored to each sector. For example, fiscal incentives or tariff measures alone will not be sufficient if demand remains uncertain, technology access is limited, raw materials are constrained, industrial and skills ecosystems are underdeveloped, or finance is misaligned with sector needs. These six horizontal drivers, therefore, can be used to map the sector-specific bottlenecks but also identify the set of levers required to address these constraints.

Figure 7: Structural drivers, typical constraints, and potential levers to unlock domestic value addition in manufacturing chains

STRUCTURAL DRIVERS	TYPICAL CONSTRAINTS	POTENTIAL LEVERS
Demand & Market Architecture Existence of adequate demand that can be served at competitive prices to warrant investment in creating manufacturing capacity	• Uncertain long-term offtake • Fragmented or stop-go procurement • Limited visibility into policy targets and localisation trajectories • Competition from cheaper imports without domestic value signals	• Localisation mandates • Demand aggregation for scale • Export partnerships
R&D & Product Innovation Access to relevant technologies either via licensing or developed in-house to produce relevant components, adapted to local contexts, that can also provide a competitive advantage	• IP lock-in or high dependence on technology licensing • Weak research-to-manufacturing translation • Limited testbeds and certification facilities • Fragmented industry-academia collaboration	• Joint ventures and licensing facilitation • Mission-driven applied R&D • Pilot line and scale-up support • Testing infrastructure and standards
Upstream Raw Materials & Critical Inputs Secure supplies of input materials to undertake manufacturing activity, at competitive prices	• Concentrated import dependence for inputs • High import duties or tariffs on inputs • Geopolitical or logistics related supply and price shocks • Limited domestic refining/ processing capacity	• Diversification of suppliers and geographies • Long-term offtake agreements • Strategic stockpiles • Domestic refining and processing support • Recycling, reuse and substitution
Capital Equipment & Infrastructure Access to relevant machines and manufacturing equipment, and other infrastructure (e.g., uninterrupted power) to undertake manufacturing	• High upfront capex and long paybacks • Heavy import dependence for machinery or IP lock in on machinery • Gaps in industrial infrastructure • Thin local supplier ecosystems • Regulatory friction	• Support for domestic machinery manufacturing • Bilateral and OEM partnerships for specialised tools • Capex subsidies and interest subvention • Plug-and-play industrial zones • Streamlined clearances
Talent and Workforce Availability of talent with relevant industry ready skills to take on specialised roles in manufacturing operations	• Lack of training or specialised technical skills for manufacturing processes • Weak industry-academia bridges	• Specialised academic programs • Targeted short courses • OEM-led training and on-the-job skilling • Industry-linked certification • Centres of excellence in priority areas
Financing and Taxation Availability of capital at available interest rates that make it viable for private sector to undertake capex investments, alongside favourable taxation and policy structures	• High cost of capital vs. competitors • Lack of adequate capital • Capital lock in due to taxation policies or high taxation burden	• Guarantees and backstops for lending • Concessional and blended finance vehicles • Viability gap funding • Integrated funding packages (capex, R&D, interest) • Revision of taxation and duty structures

2.5 Framework to identify targeted actions for domestic value capture

Not all levers deliver results on the same timescale. Different value chains start from different levels of maturity, and dividends from different levers may materialise over different horizons. While some levers can deliver impact within a few years to start creating a manufacturing base, others are bets that must be initiated early, but with a view to creating long-term value. For example, in relatively mature value chains or where the right technologies exist, short-term levers (within 3 years) can catalyse private sector interest and investment rapidly. These levers include subsidies and fiscal support to encourage the establishment of manufacturing facilities, targeted capex support, and technology licensing facilitation that can enable rapid access to proven designs and production know-how. Other levers may operate over a medium-term horizon (3-5 years). For example, building local supplier ecosystems or developing plug-and-play infrastructure for specialised manufacturing clusters can take longer.

Many of the most transformative levers have longer-term payoffs. These include investments in R&D and translational research, development of domestic capabilities in advanced materials, and creation of circularity infrastructure to ensure feedstock for manufacturing value chains. These are essential bets that must be exercised concurrently with short- and medium-term levers to avoid future lock-in and missed opportunities. Figure 8 lays out a map of these levers.

Figure 8: Opportunity toolbox - potential levers mapped to impact horizon (illustrative and non-exhaustive)

STRUCTURAL DRIVER	POTENTIAL LEVERS		
	SHORT TERM HORIZON (0-3 YEARS)	MEDIUM TERM HORIZON (3-7 YEARS)	LONG TERM HORIZON (7+ YEARS)
Demand & Market Architecture	• Localisation mandates in tenders • Demand aggregation	• Multi-year procurement pipelines • Export credit lines	• Deep integration into global supply chains
R&D & Product Innovation	• Technology licensing • Pilot demonstrations	• Joint development programs • Testbed networks	• Domestic IP creation • Technology platforms
Upstream Raw Materials & Critical Inputs	• Supplier diversification • Offtake agreements	• Domestic refining capacity • Processing hubs	• Circularity and closed-loop systems
Capital Equipment & Infrastructure	• Capex subsidies • Upgrading existing industrial park infrastructure	• Domestic machinery ecosystems • New industrial zones	• Globally competitive integrated facilities
Talent & Workforce	• OEM-led training • Short courses	• Upgraded ITI/ polytechnic programs	• Centres of excellence • Applied research institutes
Financing & Taxation	• Guarantees • Blended finance for pilots	• Integrated funding packages • Risk-sharing instruments	• Deep green capital markets • Patient capital pools

2.6 Cross-cutting enablers for driving action

Three enablers underpin the effectiveness of any levers exercised to advance cleantech manufacturing activity. Without these enablers, even well-designed levers or interventions are likely to have limited impact. These include:

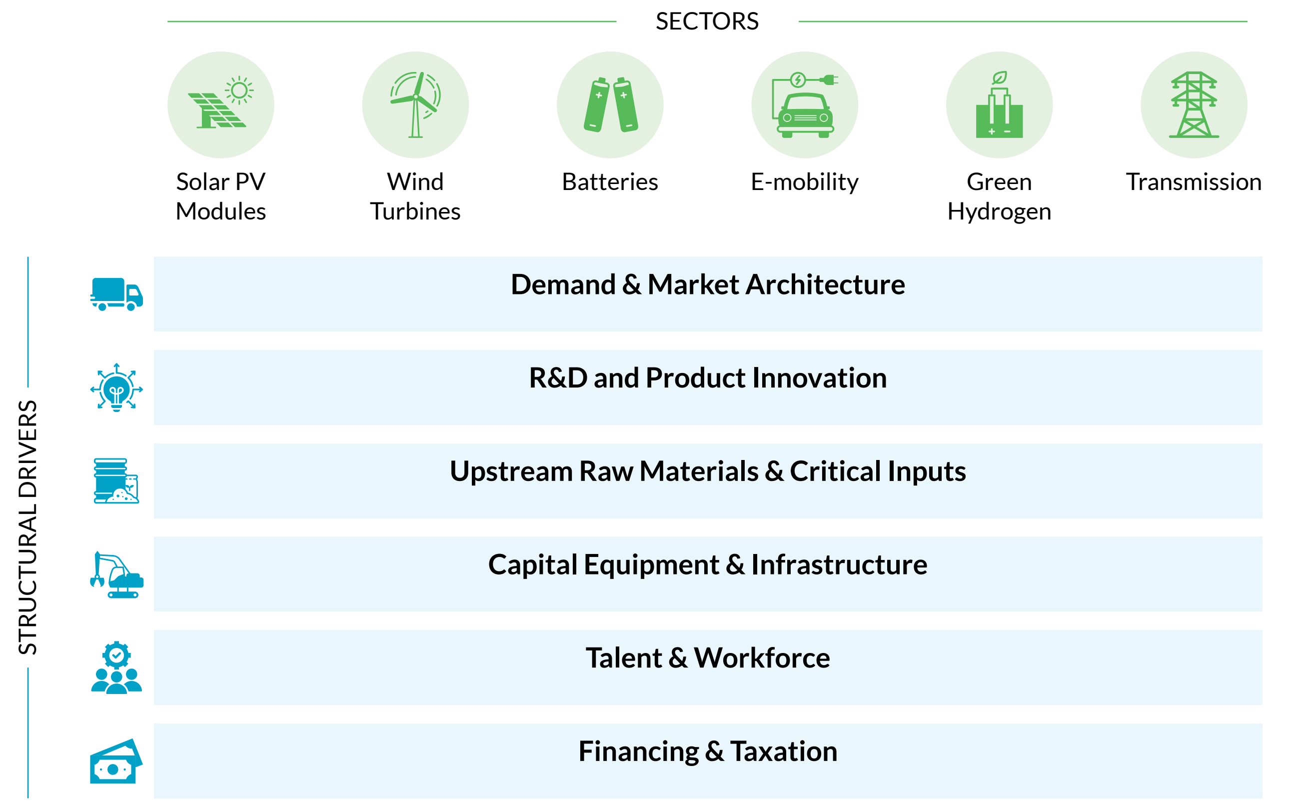
- **International partnerships:** On the technology front, global partnerships can access advanced designs, capital equipment, and co-development opportunities for the right cleantech products. Similarly, they can help secure assured supply of critical minerals and other raw materials. On the demand side, they can underpin market access for export opportunities. Within India, partnerships between government, industry, financiers and research institutions can support ecosystem development.
- **Ease of Doing Business and Regulatory Predictability:** Long lead times for approval, complex licensing regimes, unpredictable policy changes, and slow decision-making can undermine otherwise strong incentives for manufacturers and investors. Conversely, stable and transparent regulation as well as ease of doing business can lower perceived risk, reduce transaction costs and amplify the effectiveness of fiscal and non-fiscal measures aimed at boosting manufacturing activity.
- **State-led Policy and Incentive Measures:** While the national government can set overall direction through missions, targets and central schemes, the states play a crucial role in providing infrastructure and additional incentives to manufacturers. Embedding favourable policies and incentives into state level planning can provide additional impetus for investors and private sector players seeking to invest in the manufacturing segment.

3 India's 2030 Playbook: Sectoral Blueprints to Advance Domestic Cleantech Manufacturing

While the cleantech manufacturing ambition is national, higher domestic value capture requires sector specific strategies and actions. Each of the six priority sectors or value chains – solar modules, wind turbines, batteries, e-mobility, green hydrogen, and transmission – have different starting points with respect to the existing manufacturing base in the country and the bottlenecks that need to be addressed to unlock domestic value capture.

For each value chain, we have systematically analysed the different structural drivers (Refer figure 9) to understand which actions are needed to be taken on a priority basis to draw investments into cleantech manufacturing with a goal to get to higher levels of indigenisation by 2030 and setup the value chain for greater value unlocks beyond 2030. These are presented as sectoral blueprints below.

Figure 9: Framework for achieving indigenisation across cleantech manufacturing sectors



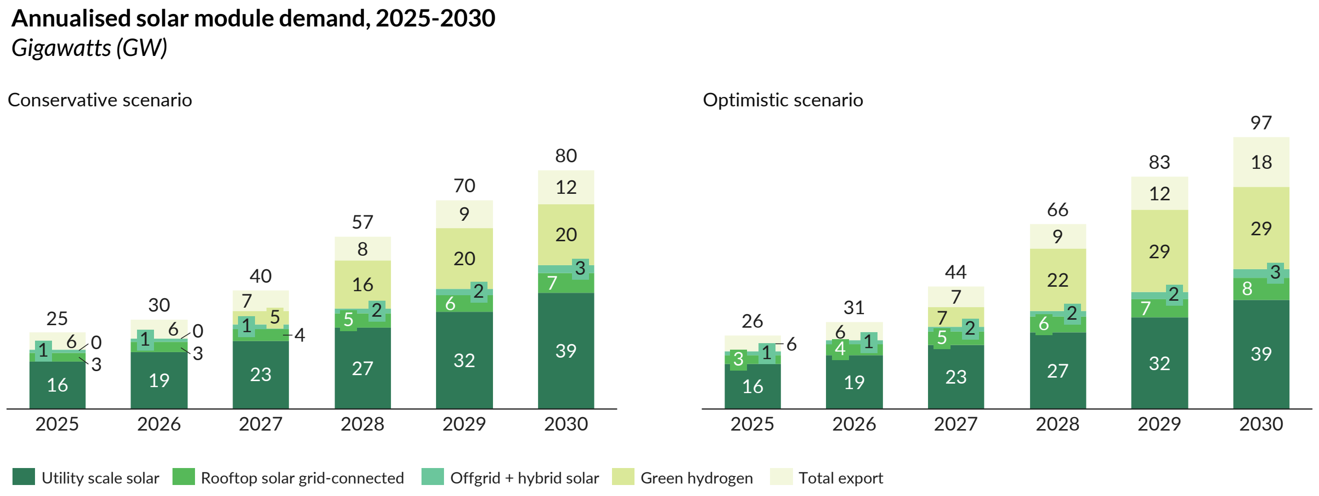
3.1 Solar PV: Shifting from module assembly to integrated value chains

3.1.1 Demand Outlook to 2030

By 2030, India will be one of the largest solar markets globally, creating a long-term, multi-billion-dollar manufacturing opportunity across the photovoltaic value chain. India's solar sector has expanded rapidly, growing at 39% CAGR since 2014[36], driven by policies such as Renewable Purchase Obligations (RPOs), Green Open Access, PM-KUSUM and PM-Suryaghar. Expansion of utility scale installations and increase in rooftop solar deployment among commercial and industrial consumers, the introduction of Renewable Consumption Obligations (RCOs), installation of efficient energy storage systems, and energy requirement for sectors like green hydrogen, will further increase the demand for solar power. Based on these factors, by 2030, we expect India to exceed 300 GW of installed solar power capacity in the conservative scenario and 350 GW in the optimistic scenario[37].

The scale of demand translates into a sizable and recurring annual domestic market for modules and upstream components such as cells, wafers, ingots and polysilicon. The increase in installed solar power capacity will have a knock-on effect on the annual demand for solar modules in the country. The demand for solar modules could increase from 25 GW in 2025 to 80 GW in 2030 under the conservative scenario, and potentially 97 GW in the optimistic scenario. This demand for solar modules represents a potential market of INR 85,000–98,000 crore in 2030[38].

Figure 10: Projected annual demand for solar modules across end use segments



Note: Figures for 2025-30 are projected based on scenario conditions; numbers are rounded up
Source: Dalberg analysis

3.1.2 Value chain structure, cost stack & domestic value capture

Most of the economic value in the solar PV value chain lies upstream of module assembly, but India currently captures only a fraction of this value. The crystalline silicon PV value chain comprises five broad stages starting from polysilicon production, ingot and wafer manufacturing, cell manufacturing, module assembly, and balance materials such as solar glass, frames, junction boxes, and other inputs. While the cost stack varies by technology (e.g., Tunnel Oxide Passivated Contact (TOPCon) vs. Monocrystalline Passivated Emitter and Rear Cell (mono PERC) vs Heterojunction (HJT)), for a typical crystalline silicon module, approximately 70–80% of total material value sits upstream of module assembly.

India captures value meaningfully only in module assembly though there is growing presence in cell production and select ancillary components. Most upstream value is imported through polysilicon, wafers, and high-efficiency cell technologies. As a result, India's domestic solar manufacturing industry captures ~20% of the value of a finished PV module. By contrast, fully integrated players that span polysilicon through modules can capture ~60–70% of the module value[39].

Figure 11: Domestic value capture across different stages of solar module value chain

Solar PV value chain and current domestic value capture

Key Components in the PV Value Chain	Polysilicon	Ingots/ Wafers	Cells (assembly)	Ancillary Components[1]	Modules (assembly)
Cost Contribution (%)	15%	15%	10%	55%	5%
Current DVA[2] (approximated)	~0%	~0%	~22%	~29%	~45%
Current Manufacturing Presence	• Not existent	• Limited wafer capacity	• Limited capacity for PERC and TOPCon cells	• Limited capacity for junction boxes, connectors and backsheets	• Module assembly across TOPCon and PERC technology
Critical Value Chain Dependencies[3]	• Metallurgical grade silicon • High purity quartz	• Ingot and Wafer Manufacturing	• Silver Paste • Expansion of cell manufacturing	• Solar Glass • Aluminium Frames	

Notes: (1) Includes Glass, Aluminium frames, Silver paste, etc.; (2) DVA has been calculated based on each component's cost contribution and component level import reliance; (3) While there are capacity installation announcements for such components, installed manufacturing capacity is limited.
Source: Dalberg analysis, "RE Supply Chain Report", MEC+, 2024

3.1.3 Manufacturing footprint: current, announced, and gap to 2030

India has rapidly expanded module and cell manufacturing capacity and is beginning to build upstream polysilicon and wafer manufacturing lines. Compared to a few years ago, when module assembly was negligible, India has added substantial capacity for module and cell manufacturing to create a manufacturing base for the solar industry. Current domestic manufacturing capacity is 74 GW for modules, 25 GW for cell, and 2 GW for ingot and wafer production[40]. Even with the currently announced pipeline on top of this existing capacity, upstream gaps remain material relative to expected 2030 demand.

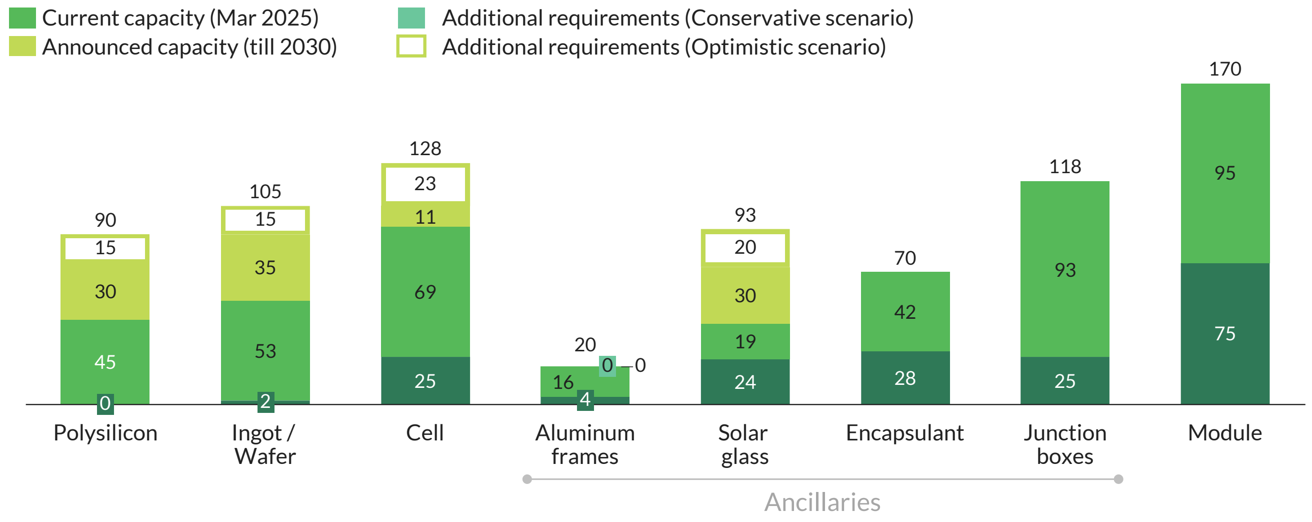
The capacity ramp-up has been driven by favourable policies such as PLI allocations, imposition of basic custom duties on imported modules and cells, and provision of an Approved List of Models and Manufacturers (ALMM) regime that has created a credible demand environment for domestic manufacturers[41]. These measures have improved the share of domestic modules in new installations. The announced and under construction capacity for manufacturing solar components is even larger. Announced PLI and non-PLI capacity accounts for additional 95 GW of modules, 69 GW for cells, 53 GW for ingots and wafers, and 45 GW for polysilicon that could come online by 2030[42]. If realised, this would provide India with a credible base for integrated solar manufacturing that can serve domestic module demand and export markets for nations looking to diversify beyond a single dominant supplier.

Despite this announced capacity addition, significant gaps remain. Even if the entire announced capacity materialises, India would still need to rely on imports for its polysilicon needs. There is also execution risk with many announced projects including delays in project clearances, challenges in securing technology partnerships, and the need to achieve cost competitiveness against established global suppliers.

Figure 12: Gap in manufacturing capacity for solar PV components to achieve 50% indigenisation

Manufacturing capacity addition required for 50% indigenisation, 2030

Gigawatts (GW)



Notes: 1. Figures for 2025-30 are projected based on scenario conditions; 2. Numbers are rounded up; 3. Chart excludes ancillaries such as silicone sealants, interconnects and back sheets due to data gaps and limited contributed to overall value addition

Source: Company announcements;"RE+: Adani Solar targets 10GW of solar cells and modules in next 18 months, rethinks polysilicon plant timeline," PV Tech, 2024; Solar PLI data; MNRE, Accessed 2025; Industry experts (industry associations, key manufacturing players); Dalberg analysis

3.1.4 Structural bottlenecks to scaling solar manufacturing

India's solar manufacturing build-out has been fast with surge in module capacity but limited addition in other parts of the value chain. Weak demand signals by cell technology type, limited upstream integration and R&D investments, gaps in capital equipment acquisition, lack of a well-equipped workforce, and high cost of capital constrain upstream manufacturing expansion and domestic value addition.

- **Demand and market architecture:** India's expected solar capacity addition is yet to turn into predictable and consistent demand for solar module manufacturers domestically. Policy tools have raised import barriers but continued competition from imports has prevented deeper localisation:
  - Manufacturers lack clear, multi-year visibility on demand by type of solar PV technology. While module manufacturing capacity has expanded rapidly, 47 GW of older mono PERC module assembly lines are at risk as buyers shift to other PV technologies such as TOPCon and HJT. This has led to concerns among investors and manufacturers around stranded capacity if technology transitions are not managed well or if policy shifts favour different technologies (e.g., Perovskite).
  - While policy tools such as ALMM and imposition of Basic Customs Duty (BCD) have supported localisation, design changes and implementation uncertainty have hindered demand. Moreover, imposition of BCD has been ineffective in altering competitive dynamics as the import prices of cells and modules have remained significantly low despite duties (imported module ranges between $0.16–0.17 per watt after BCD compared to domestic prices at about $0.27 per watt)[43]. As a result, the investment case for manufacturing cells, ingots, wafers and polysilicon remains hard to justify in face of cheaper imports.
  - Ancillary industries focused on balance materials such as for manufacture of solar glass and aluminium frames are scaling unevenly. Manufacturers downstream of these components are unsure of supplies for these materials even as panel imports fall.

- **R&D, technology and product innovation:** India has not built a solar innovation ecosystem that systematically identifies technologies to support for translational research and moves them from labs to commercialisation[44]:
  - Firms remain dependent on global product development and imported intellectual property (IP) for high efficiency cells. Core process know-how, critical equipment and IP for advanced cells and modules remain largely imported, even where domestic firms have adopted newer technologies.
  - There is no coherent national policy to prioritise solar technologies using global technology readiness or impact criteria, leading to fragmented R&D efforts.
  - Public labs and IITs host advanced infrastructure, but access is complex and applied research is largely de-linked to commercial needs and specific value chain gaps.
  - Late-stage R&D, prototyping and scale up are chronically under financed, and as a result promising innovations often stall at pilot stage.

- **Upstream raw materials and critical inputs:** Upstream inputs are a major strategic vulnerability for undertaking at scale domestic manufacturing of solar PV components. Currently, polysilicon is imported entirely in wafer or cell form, while other critical inputs, such as quartz, graphite, and high-purity aluminium, are either wholly or primarily sourced from abroad. Without upstream integration, India will continue to import most of the value added in the PV stack and cannot realistically reach 50 percent indigenisation by 2030. Several challenges perpetuate this status quo:
  - India lacks domestic reserves for minerals that serve as a feedstock for polysilicon manufacturing. While India's requirement for polysilicon is projected to reach 967 kilo tonnes between 2025-2030[45], China currently accounts for 86% of the international supply[46]. It remains challenging to secure diversified sources of these or associated minerals such as graphite even as domestic refining is expensive to build and requires access to refining technologies.
  - Circularity infrastructure for PV materials is nascent[47], leading to limited recovery of high-quality silicon and other materials at end of life, and no meaningful buffer against upstream shocks.

- **Capital equipment and infrastructure:** India has scale in downstream facilities but not yet the depth and capital equipment capabilities to undertake upstream manufacturing:
  - India has limited capability to produce advanced capital equipment such as Chemical Vapour Deposition (CVD) reactors, Plasma-Enhanced Chemical Vapour Deposition (PECVD) systems, diffusion furnaces, metallisation lines and precision wafering tools to undertake polysilicon, ingot and wafer manufacturing.
  - Machines imported from China are more efficient and cost-effective, making it hard for Indian manufacturers to compete. Long design-to-commercialisation timelines mean domestically developed equipment could already lag the global technology frontier by the time it reaches the market.
  - Scale of domestic demand is advantageous but requires additional protection to localise or acquire capital equipment. India is targeting 160 to 170 GW of solar manufacturing capacity addition by 2030. While this is sizable, China added 180 GW of new solar capacity in 2024 alone, limiting the economies of scale available for localising capital equipment[48].

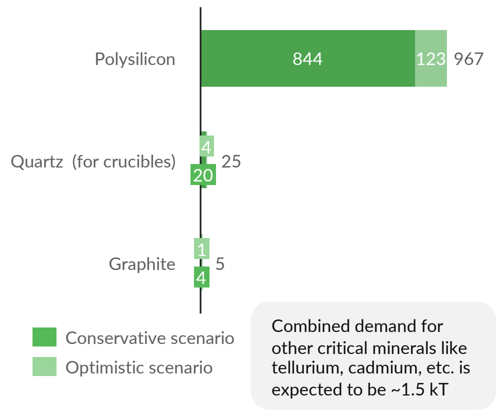
- **Talent and workforce development:** India needs specialised talent to undertake cleanroom and advanced solar cell manufacturing processes. We estimate India will need 90,000 workers across manufacturing of ingot, wafer, cell and module by 2030 if it is to achieve 50% indigenisation levels[49]. The current workforce development setup is not yet tuned to this need:
  - Manufacturers continue to rely on foreign trainers for machinery setup and process training for processes such as polysilicon, ingots, and wafer manufacturing. While essential, this limits the ability within the domestic workforce to absorb skills for more complex upstream operations and there is no coordinated action to facilitate transfer of these skills to trainers within India.
  - Current training programs focus on conventional manufacturing and lack cleantech-specific modules such as for cleanroom operations. This is compounded by the lack of specialised courses and engagement between manufacturers and skilling institutions to develop and execute shared skill roadmaps, curriculum, and trainings.

- **Financing and taxation:** We estimate INR 80,000 – 1.54 lakh crores of investment is needed by 2030 to reach 50% indigenisation levels for solar modules including additional subsidies and investments in manufacturing ecosystem creation[50]. High cost of capital, competition from lower priced imports, and investments in duty structures currently constrain private investments and necessitate this public funding:
  - Domestically produced solar cells are 43% more expensive than cells imported from China. Even with the scale-up of domestic manufacturing, we estimate that Indian cells may remain up to 15% more expensive compared to Chinese imports[51,52]. Additional measures may be required to bring production of cells in India to price parity with imports or offer manufacturers long term demand assurance despite the price difference.
  - Manufacturers interested in establishing upfront manufacturing capacity face high cost of capital (~11-12%) for project level finance. The high cost of capital and lack of instruments that can offer longer debt tenors often make project financing unviable for manufacturers or force them to raise capital at expensive rates. While schemes such as Production Linked Incentives (PLIs) have been successful in creating seed projects, they are backloaded (i.e., tied to actual sales post commissioning of projects) leading to limited impact on manufacturers financial calculus when considering capital investments.
  - Inverted duty structure for solar components results in locking up capital for MSMEs and manufacturers in India. Many inputs required for manufacturing of modules are taxed under the 12% regime compared to the taxes on modules at 5%. As a result, manufacturers often face significant capital locked in as input tax credits owing to slow refund cycles[53].

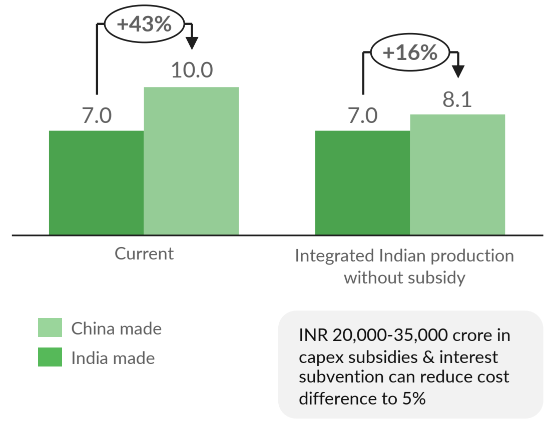
Figure 13: Solar manufacturing requirement for materials, talent, equipment, and investment

Breakdown of mineral, workforce, capital equipment and investment requirement for solar PV

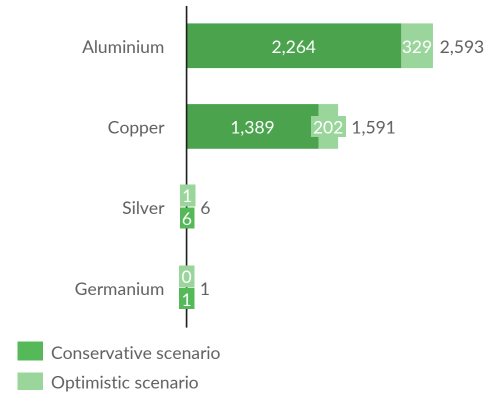
Cumulative critical mineral demand, 2025-2030[1,2]
Kilo tonnes (kT)



Landed cell cost comparison
US cents per watt, excluding GST



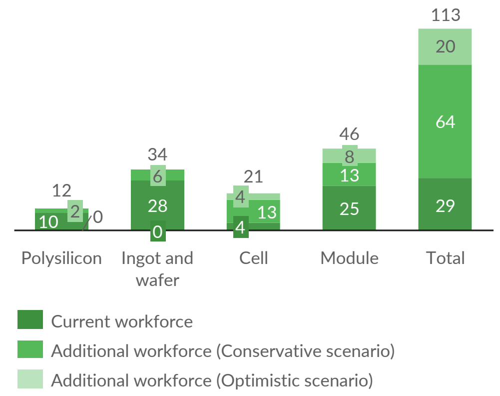
Cumulative metal demand, 2025-2030
Kilo tonnes (kT)



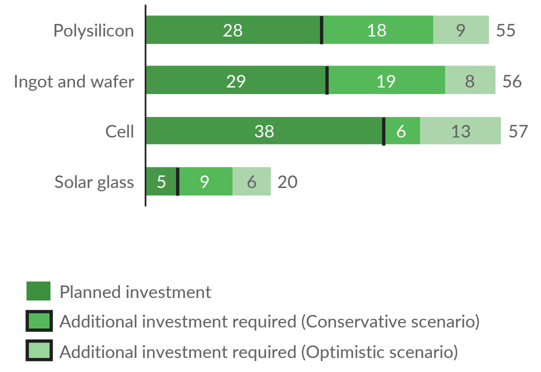
Capital equipment import dependence[3]
%

Component	Key machines/ capital equipment	Capacity required (GW)	Capital equipment import (%)
Polysilicon	CVD reactors	75-90	NA
Ingots/ wafers	Solar Cz pullers, diamond wire saws	90100	100%
Cells	PECVD system	80-100	80-100%
Modules	Tabbing and stringing lines, laminator	95	95-100%
Glass	Glass furnace, etching machines	50-70	60-80%
Aluminium frames	Furnace, anodizing equipment	15	100%

Workforce requirement for solar value chain
'000s of workers



Cumulative capital investment requirement in domestic manufacturing[4,5]
INR '000 crores

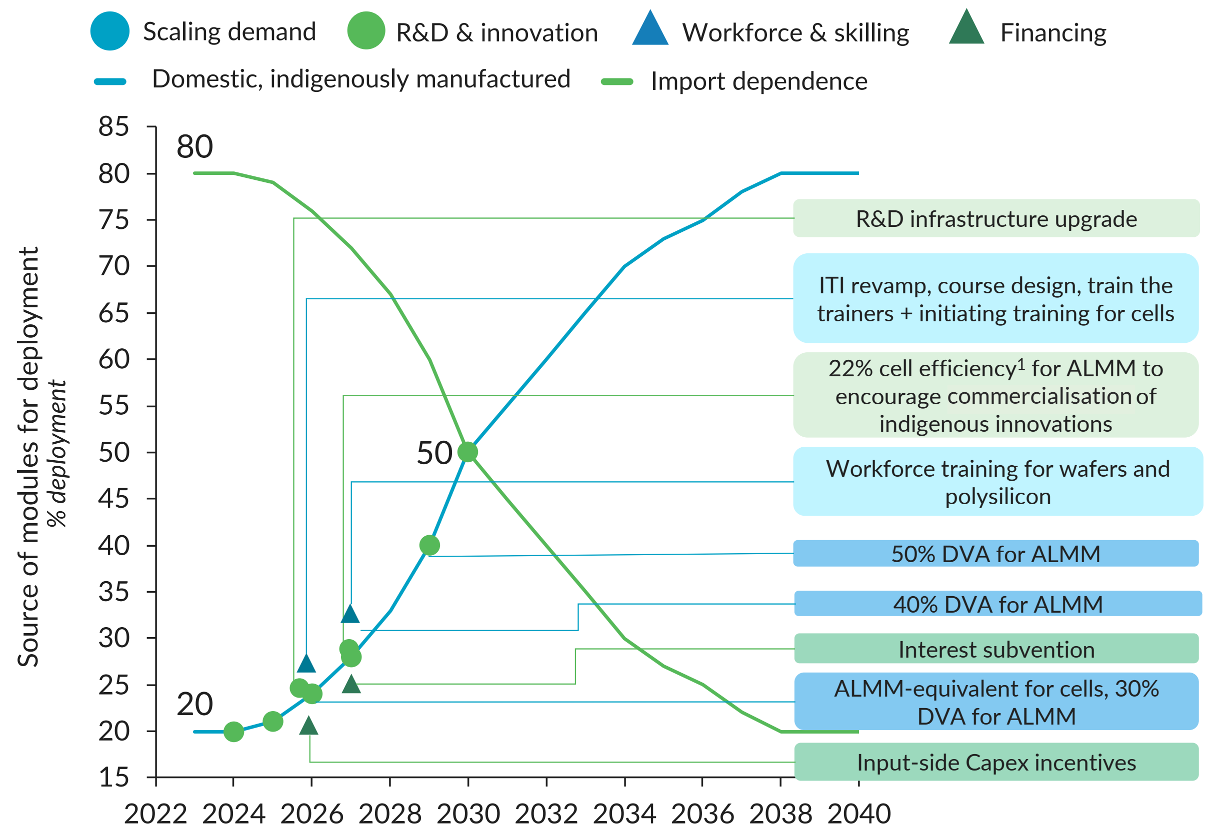


Notes: 1. Estimated cumulative import demand based on current costs of imports; 2. Polysilicon obtained from quartz which was recently classified as a Major Mineral by the Ministry of Mines; 3. All numbers based on projections for 2025-2030;; polysilicon capital equipment import dependence is 0% as there is no polysilicon refining in the country today; 4. Chart excludes ancillaries such as Silicon sealant, Interconnects, Backsheets due to limited information available and lower contribution to value addition. Module capacity as per ALMM April 2025; 5. Assumed planned capacities have already been funded
Optimistic scenario: 1. Existing policies continue and about half of commercial and industrial consumers shift to domestic solar modules 2. Around 70% of green hydrogen is produced using solar–wind hybrid projects that also meet DVA requirements for solar modules 3. Export growth is supported by EXIM credit for Africa and moderate US demand growing at about 8% annually
Conservative scenario: 1. About 70% of commercial and industrial consumers move to domestic solar modules; 2. All green hydrogen is generated from solar–wind hybrid projects with DVA-compliant solar modules; 3. Export growth is driven by EXIM credit for Africa and faster US demand expansion at about 10% annually.
Sources: "Ministry of Mines classifies Barytes, Felspar, Mica and Quartz as Major Minerals," Press Infromation Bureau, 2025; "China extends cleantech dominance over US," Bloomberg, 2024; "USGS – Mineral Commodity Summaries," US Department of the Interior, 2025; "Export Import Database," Ministry of Commerce and Industry, Accessed 2025; "RE Supply Chain Report," MEC+, 2024; "Feasibility Analysis for c-Si PV Manufacturing in India," CSTEP, 2018; "Domestic solar cells capacity to be over 47 GW by June 2026: CRISIL," Economics Times, 2024; "Solar PV Global Supply Chains," IEA, 2022 ; Govt. of India, Union Budget 2024-25, Accessed 2025; Industry experts (industry associations, key manufacturing players), Dalberg analysis

3.1.5 Pathway to indigenising the value chain

Figure 14: Prioritised recommendations timeline to increase DVA in the solar sector

Solar Indigenisation Pathway to Increase DVA and Reduce Import Dependence



Note: 1. Cell efficiency for utility scale solar for c-Si modules compared to 20% today (target efficiency for other applications such as rooftop and off-grid could be adjusted in-line)
Source: Company announcements; "Production Linked Incentive (PLI) Scheme: National Programme on High Efficiency Solar PV Modules," MNRE, Accessed 2025; Industry experts (industry associations, key manufacturing players); Dalberg analysis

India can move from a module-heavy, import-dependent solar PV value chain to integrated value chain that captures 50% of the value domestically by 2030. This requires expanding module manufacturing capacity and undertaking targeted actions to build 75-90 GW of domestic polysilicon refining capacity over five years. The table below summarises the priority levers by various structural drivers that India should prioritise:

Figure 15: Prioritised recommendations to indigenise solar manufacturing

STRUCTURAL DRIVERS	PRIORITY LEVER
Demand and market architecture	**Short term (0-5 years)** • Integrate phased DVA requirements into existing ALMM policies (30% by 2027, 40% by 2028, and 50% by 2029) with clear published timelines. This will also cover DVA requirements for solar modules expected to be deployed in other cleantech sectors such as manufacturing of green hydrogen thereby ensuring that rapid scale up of these cleantech technologies also pull up demand for domestically manufactured solar components. • Consider calibrated increases in Basic Customs Duty (BCD) on ancillary components such as solar glass, EVA, and encapsulants and where necessary, Anti-Dumping Duties (ADD) to protect against below-cost imports while maintaining downstream competitiveness. • Leverage EXIM Line of Credit[54] to boost solar module exports to key African markets[55], while also establishing links with EU and Middle East countries with high solar demand, strong trade ties with India, supportive renewable energy (RE) policies. • Align export promotion efforts to India's plans to build integrated capabilities (polysilicon to module manufacturing) and make it a cornerstone of country level dialogues and trade delegation visits to identify synergies in solar value chain, undertake joint investments (e.g., with European Union (EU) and enable market access to strengthen solar PV trade.
R&D and product innovation	**Short term (0-5 years)** • Prioritise high-impact solar technologies by accelerating R&D and commercialisation for breakthrough technologies such as POE encapsulants (reducing degradation from 8% to 3.5%) and perovskite–silicon tandem cells (24.5% efficiency)[56]. • Establish 10–12 development labs and 4–5 integrated testing labs between 2025–27, at a total cost of INR 800-900 crore, to support prototype validation and process optimisation while upgrading leading facilities such as IIT Bombay, IIT Delhi, and IIEST, and setting up a national testing centre at the National Institute of Solar Energy (NISE). • Increase ALMM cell efficiency to 22%[57] from 2027 to boost commercialisation of indigenous solar innovations. **Medium term (5-7 years)** • Create structured industry–academia consortia focused on commercialising indigenous coatings and cells and introduce co-financing models with 1:1 public–private matching leveraging INR 700-1,100 crore in public funding[58]. • Create open access protocols for manufacturers and MSMEs to use public labs for prototyping, testing, and quality certifications. • Expand grant-based funding for early-stage R&D (INR 600–1,200 crore) and open pathways for private equity and venture capital in later-stage prototyping. **Long term (7+ years)** • Fund frontier research in pure perovskite tandem, busbar-less and dye-sensitised cells, linked to industrial scale-up pathways rather than stand-alone academic grants.

STRUCTURAL DRIVERS	PRIORITY LEVER
Upstream raw materials and critical inputs	Short term (0-5 years) • Secure diversified long-term contracts through government-to-government partnerships for metallurgical-grade silicon and cost-effective access to raw inputs such as bituminous coking coal critical for polysilicon refining. Medium term (5-7 years) • Extend PLI coverage to upstream materials and incentivise co-location of refining capacity creation in semi-conductor clusters to serve multiple industries (also refer financing recommendations). Long term (7+ years) • Build a circularity ecosystem for PV materials by linking recycling investments to scrap availability as well as access to module delamination and material purification technologies to recover high-quality silicon and other critical materials from end-of-life modules
Capital equipment and infrastructure	Short term (0-5 years) • Support MSMEs to indigenise building select equipment for solar manufacturing (equipment having synergies with existing industries such as Diamond wire cutters with stone crushing industry; Submersible Electric Arc Furnace (EAF) with Steel EAF etc.) • Leverage bi-lateral G2G partnerships with countries like Germany, Japan, and South Korea to enable accelerated import for highly specialised solar capital equipment to manufacture polysilicon, ingots, wafers, cells, modules and glass (i.e. CVD reactors, PECVD systems, and metallization lines)
Workforce and talent development	Short term (0-5 years) • Implement "train-the-trainer" programs to train 200–300 academicians and instructors from the top 100 engineering colleges, supported by 25 international experts through government-to-government (G2G) partnerships with the EU, Korea, Japan, and China. • Expand practical training through upgraded Industrial Training Institutes (ITIs), demo-scale lines and structured apprenticeships to support training for polysilicon and wafers. • Link 15 solar manufacturers with 60–90 ITIs through public-private partnerships (PPPs) using ITI-upgradation funds and roll out a national digital cleantech training platform for scalable online learning, certifications, and job-matching. Medium term (5-7 years) • Institutionalise sector specific skill councils and continuous learning pathways so that workforce can keep with new emerging technologies.

STRUCTURAL DRIVERS	PRIORITY LEVER
Financing and taxation	Short term (0-5 years) • Provide upfront capex subsidy and interest subvention of INR 7,500-12,500 crore to support creation of additional 30-45 GW of polysilicon refining, beyond what has already been announced[59]. Incorporate sunset clauses and progressively taper the subsidy over a five-year horizon. • Introduce measures such as 25% capex subsidy for capital equipment acquisition and interest subvention to lower borrowing costs by 25% for MSMEs in ancillary industries like solar glass, establishment of solar cell manufacturing lines, and other parts of the value chain. • Introduce duty waivers on inputs like quartz crucibles and graphite hotzones. • Reduce Goods and Services Tax (GST) on modules and address inverted duty structure between module components and modules to unlock capital in the form of GST refunds due to manufacturers.

3.2 Wind Turbines: Moving beyond towers into high-value components

3.2.1 Demand outlook to 2030

India's wind turbine market is poised to grow significantly by 2030, creating a substantial opportunity for deepening domestic manufacturing across the turbine value chain. India has an installed capacity of 51 GW of wind energy making it the fourth largest market globally[60]. Policy commitments such as dedicated wind procurement trajectory for turbines and components (ALMM-Wind), annual issuance of 10 GW of wind tenders in recent years and increase in wind Renewable Purchase Obligation (RPO) from 0.67% to 3.48% by 2030 are expected to underpin demand for wind turbines over the next five years[61].

By 2030, we estimate the annual wind turbine demand could reach 14-18 GW combining both domestic and export demand. This is a step-change from recent installation rates and reflects a combination of structural demand drivers. On the domestic side, demand will be driven by renewed onshore wind procurement, hybrid and round-the-clock (RTC) tenders that combine wind and solar, and a growing repowering opportunity as older, lower-capacity turbines reach the end of their economic life. Over the medium term, early moves into offshore wind will further add to this demand. On the external side, as global OEMs and buyers seek to diversify supply chains beyond a few existing hubs, India can emerge as a competitive base for turbine and component exports.

This demand profile underpins a credible market for a wide range of turbine components such as blades, towers, nacelles, gearboxes, generators, converters, castings, forgings and bearings. It provides India the scale needed to justify investments not only in downstream assembly but also in higher-value drivetrain and power electronics components, provided India can address cost competitiveness and ecosystem constraints.

3.2.2 Value chain structure, cost stack & domestic value capture

Most of the economic value in a wind turbine is concentrated in a small set of high-value components where India's value capture is modest. A typical onshore wind turbine can be decomposed into three major assemblies (rotor, nacelle, and tower). Across these assemblies, eight components including blades, towers, gearboxes, generators, converters, castings, forgings and bearings, account for ~80% of a turbine's material cost. Within this, gearboxes, large bearings, converters and advanced blades are particularly value-dense and technology-intensive.

India's current domestic value addition in wind turbine and component manufacturing is estimated to be 35% of a turbine's value. Domestic manufacturers have built meaningful capability in towers, nacelles and many cast and forged components, and some local production of blades and generators exists. However, value dense and technology intensive components such as gearboxes, large precision bearings and converters are still imported or produced under foreign designs with limited local value addition. As a result, an estimated 65% of total turbine value is effectively imported through high-value components and subassemblies.

Figure 16: Wind turbine value chain and current domestic value capture

Wind value chain and current domestic value capture

Key Components in the Value Chain	Rotor[1]	Tower	Nacelle[2]	Others[3]
Cost Contribution (%)	32%	22%	28%	18%
Current DVA[4] (approximated)	~50%	~25%	~45%	
Current Manufacturing Presence	• Rotor blades • Raw casting and further machining	• Sub-component assembly and final tower assembly • Anchor cages and paints	• Limited generator core (including stator and rotor) capacity • Final generator assembly • Subcomponent level machining across gearboxes, bearings, converters	• Transformers, • Switchgear
Critical Value Chain Dependencies	• Glass fibre • Epoxy resins • Balsawood • Pig-iron • Steel scrap	• S355 concast steel and tower-grade plates • Tower flanges • Cables and fall-arrest systems • New flange / ring-rolling and heavy-fabrication capacity for larger tower sizes	• Generator rotor and stator • Electrical grade-steel for stator and rotor cores • Gearbox gears, shafts, bearings	• Advanced grid-compliant converters, and control systems produced at scale • Accredited labs to test and certify local components

Notes: (1) Includes blades, and hub and mainframe castings; (2) Includes gearbox, generator, main, blade and yaw bearings, converter and main shaft forgings; (3) Primarily includes other components such as yaw systems, transformer, mechanical brakes, castings, cables and sensors. These components have not been included in the indigenisation analysis; (4) DVA has been calculated based on each component's cost contribution and component level import reliance.
Source: Dalberg analysis, "RE Supply Chain Report", MEC+, 2024

3.2.3 Manufacturing footprint: Current base, announcements, and gaps to 2030

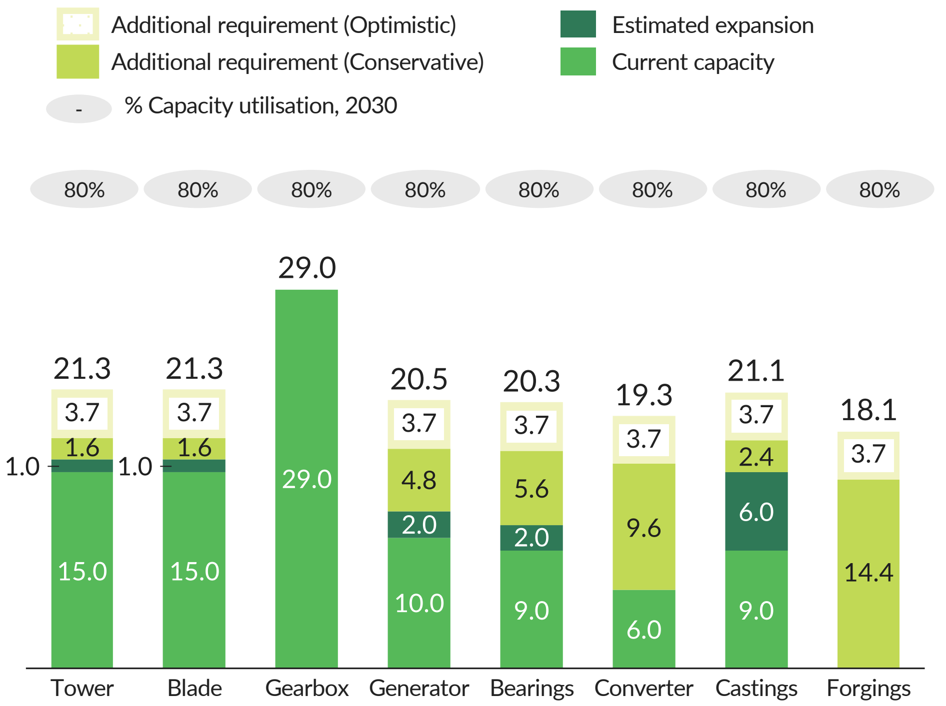
India already has one of the more advanced wind manufacturing ecosystems outside Europe and China, but the depth and sophistication vary sharply by component. Current nacelle assembly capacity is estimated at around 20 GW per year, supported by both domestic and international OEMs. Tower manufacturing is robust, with multiple firms able to supply onshore towers on a meaningful scale. Casting and forging capacity for hubs, frames and key structural components is also well established, building on India's broader strengths in heavy engineering.

However, many critical subsystems run at low utilisation and remain technologically shallow relative to future demand. Gearbox, generator and converter lines are currently operating at less than 40% utilisation, reflecting a combination of past demand stagnation and cost pressure relative to imports. At the same time, the market is shifting toward larger 3 MW plus turbines, requiring upgrades in design, tooling and process capability.

Domestic manufacturing capacity in advanced blades, gearboxes, large bearings and converters remains limited. Blade manufacturing exists but is not yet at the scale or technological frontier required for the latest high-capacity turbines and potential offshore projects. Gearbox and bearing manufacturing often rely on imported designs, critical subcomponents and materials. Converters and other power electronics are still predominantly sourced from global suppliers, with modest local value addition.

Figure 17: Current wind manufacturing capacity vs. additional required to meet 2030 demand by component

Manufacturing Capacity Required to Achieve Demand Targets, 2030
Gigawatt (GW)



Notes:
Optimistic scenario: Assumes all state RAP (Resource Adequacy Plan) wind requirements are met, grid availability continues with 15–16 GW annual augmentation, C&I (Commercial & Industrial) wind accelerates as corporates adopt hybrid power for net-zero and RE100 (Renewable Electricity 100%) targets, and exports follow 2024 global demand with a higher share from the Middle East and Africa.
Conservative scenario: Assumes a strong existing pipeline, capping RAP (Resource Adequacy Plan) demand at 26.3 GW, moderate growth in C&I (Commercial & Industrial) wind installations, and the same export share of global demand as in 2024
Source: "Domestic Manufacturing Capacity and Potential Cyber Security Challenges in the Wind sector and way forward", Niti Aayog, 2024, Dalberg and MEC+ analysis

Meeting the projected annual demand of 14–18 GW by 2030 while raising indigenisation to 60% is possible but will require optimum use of existing capacity and targeted expansion in manufacturing value-dense components. We estimate that India would need between 20-29 GW of manufacturing capacity across key components to achieve 60% indigenisation. While India is already well-placed to meet a large share of demand for towers, nacelles, and structural components, additional capacity will be required to manufacture blades, gearboxes, generators, bearings, converters, and other components.

3.2.4 Bottlenecks to scaling domestic manufacturing

India's wind manufacturing ecosystem faces several interlinked bottlenecks that must be addressed to unlock higher domestic value addition. These include:

- **Demand and market architecture:** Despite the requirement of higher manufacturing capacity across most components, inconsistency in demand and competition from cheaper imports have prevented manufacturers from pursuing manufacturing capacity expansion:
  - Annual wind turbine installations have grown at the rate of 8% CAGR from 2014-2025. However, muted demand in this period and delayed PPA signing by tendering agencies or wind farm operators have resulted in underutilisation of existing capacity. Manufacturers perceive the lack of PPA signing as a project risk which, combined with a move to higher wind turbine capacities that may render existing manufacturing lines unsuitable, prevent them from expanding operations.
  - Existing manufacturing lines for wind turbine generator components such as for gearboxes and converters operate at less than 40% utilisation[62] despite growing demand for these components. OEMs rely on imported components due to cost advantages (also refer financing and taxation) and to avoid technology risk. As a result, manufacturers are wary of new investments until existing capacity can be utilised.
  - Levelised cost of wind energy has increased from INR 2.8-3.3 per kWh in 2020 to INR 3.3-3.8 per kWh in 2024 owing to higher steel prices[63]. Higher transmission tariffs for wind energy are further expected to increase electricity prices resulting in perceived demand uncertainty for manufacturers.

- **R&D and product innovation:** India's wind R&D ecosystem remains fragmented and without a clear commercialisation roadmap to adapt the ecosystem to emerging technological shifts:
  - Limited investments in identifying high impact technologies (e.g., advanced blade materials) and undertaking targeted research have resulted in a lack of product innovation momentum within the country. No unified stakeholder or OEM alignment exists on priority technologies to commercialise and scale in India.
  - Existing labs have outdated equipment and lack facilities to support industry grade prototyping and testing. OEMs have stayed away from creating dedicated research labs in the country.
  - Wind turbine component standards and testing protocols are calibrated to European wind conditions rather than Indian wind regimes creating performance gaps for local platforms and lack of domestic testing structure that can optimise design for Indian wind conditions.

- **Upstream raw materials and critical inputs:** High levels of import dependence and unfavourable duty structures on key raw materials have created supply risks for domestic manufacturers:
  - Raw material, including steel, accounts for an estimated 60-70% of a turbine's cost base. Continuous cast S355 steel (Concast S355 steel) alone accounts for 21% of the turbine cost base[64]. Despite a mature steel industry with domestic capabilities, OEMs import this steel due to limited domestic availability and cost advantages. Domestically produced Concast steel is 3-5% more expensive than imported steel while limited demand has prevented steelmakers from expanding production.
  - Other raw materials like glass fibre and balsa wood used in the construction of blades are also imported due to limited domestic availability and a lack of alternatives.

- **Capital equipment and infrastructure:** System-level component manufacturing is constrained by the dependence on imported capital equipment and gaps in casting and forging capabilities for domestic MSMEs serving the sector[65]:
  - MSMEs serving the wind sector do not have the capital equipment and know how to undertake larger castings and forgings (e.g., for hubs and frames) that are required by the higher capacity wind turbine platforms being deployed today. Lower than anticipated manufacturing demand in the past years has prevented manufacturers from investing in larger facilities.
  - MSMEs lack the sophistication and cost competitiveness to match Chinese suppliers. India made castings and forgings are expected to be 3-5% more expensive than Chinese alternatives. Indian manufacturers are also unable to offer long term fixed price contracts due to the variation in price of imported raw materials leading OEMs to prefer imports.
  - India relies extensively on imported capital machinery for casting and forging, particularly ring-rolling machines, forging presses, and precision Computer Numerical Control (CNC) lines. Investing in these systems requires substantial upfront capital investment from MSMEs as these are not core competencies for OEMs. Much of the required capital equipment is also subject to export restrictions from China.

- **Workforce and talent development:** Developing wind turbine and component manufacturing requires engineering talent as well as manufacturing line operators skilled at operating heavy fabrication machinery for larger wind turbine capacities. We estimate that manufacturing capacity expansion can add between 45,000-70,000 workers by 2030. Of these, 80% are expected to be low-skilled roles while the rest will be highly skilled and ultra skilled engineering talent. The ecosystem currently faces challenges in contributing to this workforce:
  - Engineering institutions, training institutes and ITIs have limited wind-specific curricula. Weak industry linkages and a lack of mechanisms to deliver on-the-job training for turbine and turbine component manufacturing has further constrained workforce development.
  - No specialised courses for wind turbine design and manufacturing exist to prepare graduate engineers for absorption by the Indian industry. At the same time, limited investment in R&D infrastructure by Indian OEMs has resulted in less than expected demand for such talent in the country.

- **Financing and taxation:** We estimate INR 28,500-43,000 crores in investment is needed by 2030 to achieve 60% or more indigenisation levels for wind turbine and component manufacturing[66]. Higher domestic manufacturing costs that can result in competition from imported turbine components, combined with higher import duties on specific raw materials has prevented private sector investment in wind turbine manufacturing:
  - Current landed costs for Indian turbine components are 17% higher than Chinese components. We estimate that this gap could widen to 25% as turbine manufacturing capacity expands to reach 60% domestic value addition. As a result, the levelised cost of electricity could go up by 3-4%.
  - Higher import duty on Concast and electrical grade steel (15-20%) compared to 7.5-10% duty on imported generators and gearboxes (or their parts) leads OEMs to directly procure imported components. For manufacturers, after accounting for GST, the inverted duty structures also result in capital lockup in form of input tax credits that are slow to be refunded[67]. Current capex incentives for manufacturing for these components in India and increasing production capacity of Concast S355 steel are insufficient to meaningfully reduce the cost difference in the short term compared to these imports.

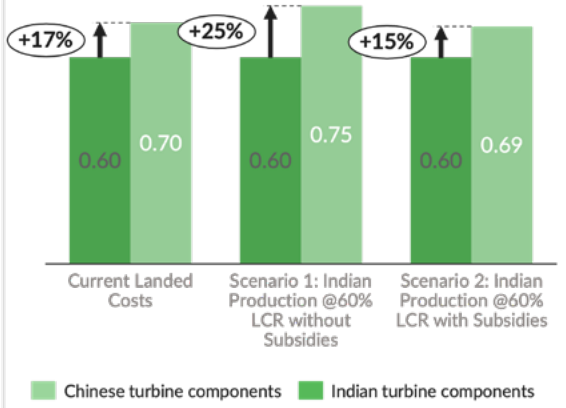
Figure 18: Wind manufacturing requirement for materials, talent, equipment, and investment

Breakdown of mineral, workforce, capital equipment and investment requirement for wind

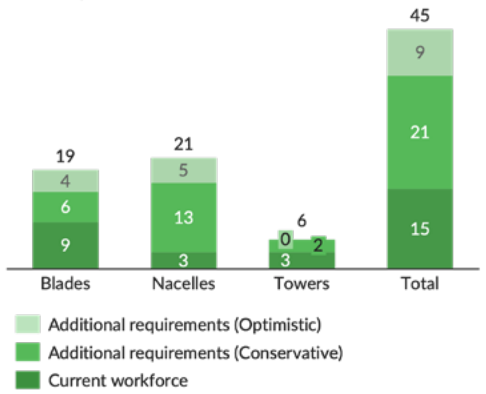
Key raw materials dependence for wind component manufacturing

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%

Landed turbine cost comparison
US dollars per Watt, excluding GST



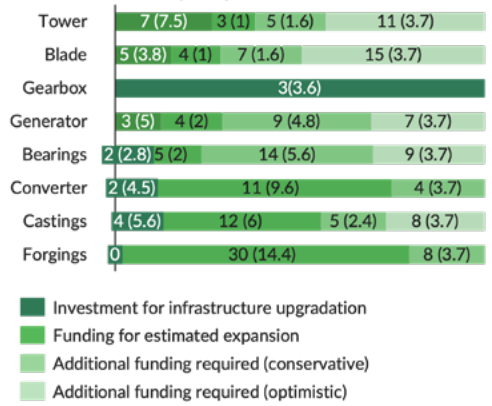
Workforce requirement for wind value chain[1]
'000s of workers



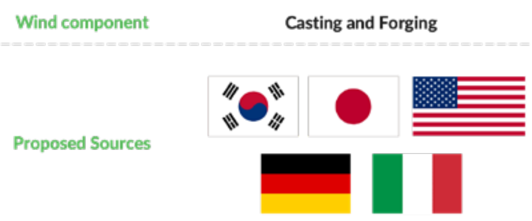
Capital equipment import dependence
%

Component	Sub-component	Sourcing	Capability	Local content impact[2]
Tower	Flanges	Imported	Forging	~2-3%
Gearbox	Gear/Shaft	Imported	Forging	~3-4%
Gearbox	Housing	Imported	Casting	~1%
Generator	Shafts	Imported	Forging	~0.5%
Generator	Housings	Imported	Casting	~0.5%
Castings	Hub/mainframe	Imported	Casting	~2-3%
Main shaft forging	Shafts	Imported	Forging	~1-2%
Bearings	Rings	Imported	Forging	~2-3%

Cumulative capital investment requirement by 2030[3]
INR '000 crores (Capacity in GW)



Potential sources to procure specialised equipment

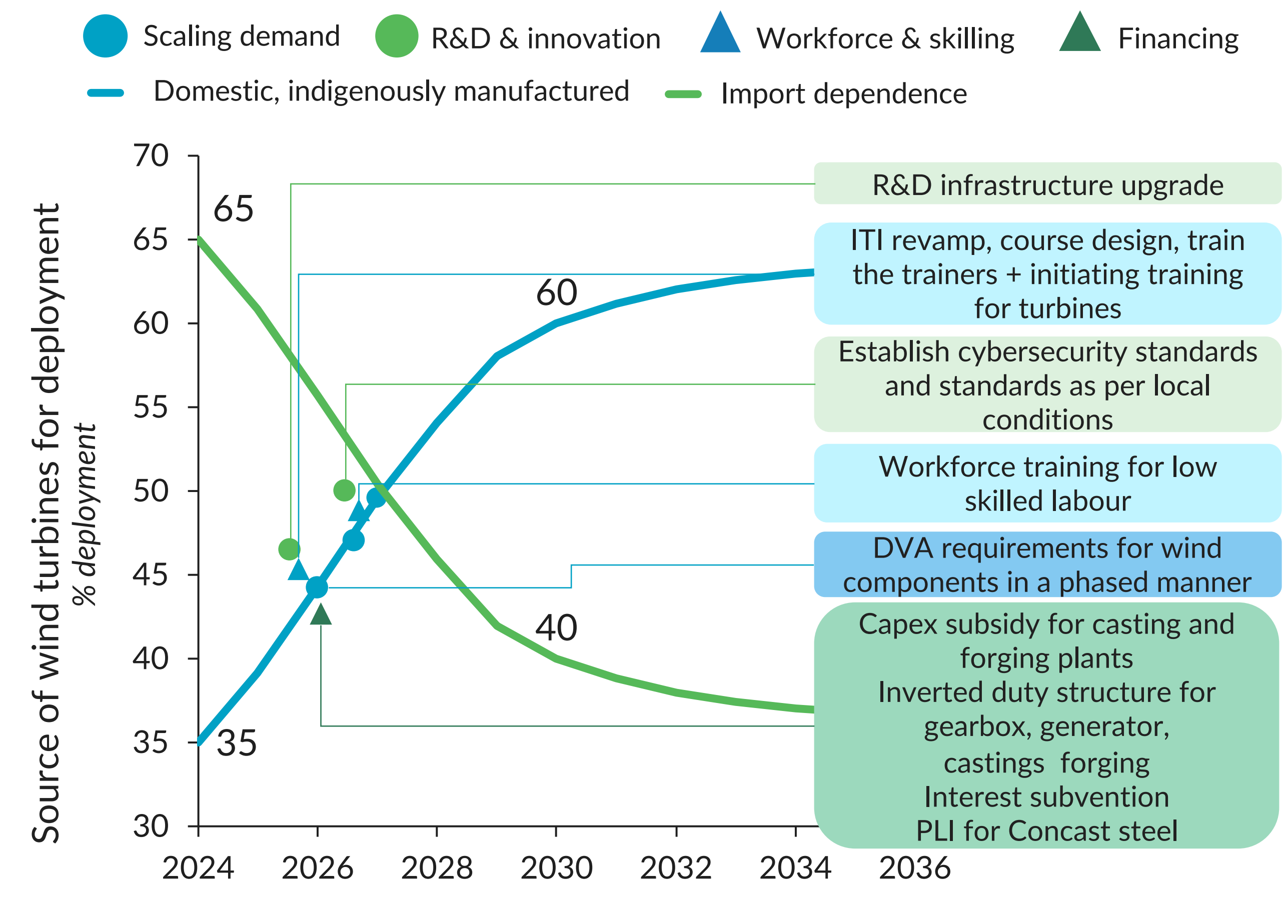


Notes: 1. 80% are low skilled roles, ~24,000 jobs; 2. LCR impact at the turbine level; 3. Assumed that planned capacities have already been funded
Optimistic scenario: 1. State level wind requirements expected to meet Resource Adequacy Plans; 2. Grid availability is assumed to augment at 15-16 GW year-on-year with no constraint on installation; 3. Further acceleration expected amidst Commercial and industrial consumers as corporates adopt cost-competitive hybrid power to achieve net-zero emissions and RE100 targets by 2030; 4. Exports expected to retain same share of global demand as observed in 2024 for US & Europe with a higher share for ME and Africa region
Conservative scenario: 1. Existing policies continue and the recent upswing in tender volumes in the past few years drives the demand pipeline; 2. State Renewable Purchase Obligation (RPO) expected to be capped at 26.3 GW as per resource adequacy plans announced by top states till 2030; 3. Commercial and industrial consumer uptake expected to increase from current levels; 3. Exports expected to retain same share of global demand as in 2024
Sources: MNRE; Ministry of Power; "Materials used in US Wind Energy Technologies", NREL, 2023; "Raw materials demand for Wind and Solar PV Technologies in the tranistion towards a decarbonised energy system", European Commission, 2020; "Domestic Manufacturing Capacity and Potential Cyber Security Challenges in the Wind sector and way forward", Niti Aayog, 2024; "Assessment of Materials and Rare Earth Metals Demand for Sustainable Wind Energy Growth in India", Nawshad Haque, 2022; "Experimental study on the interaction between Backfill and surrounding Rock in the Overhand Cut and Fill method", Wei Lang, 2022; "Trade-offs of wind power production: A study on the environmental implications of raw materials mining in the life cycle of wind turbines", Journal of Cleaner Production-Volume 460, 2024; RE Supply Chain Report, MEC+, 2024; "Global Wind Report", Global Wind Energy Council, 2025; "India's expanding clean energy workforce", CEEW, 2022; "Global Wind Workforce Outlook", GWEC, 2024; "Renewable Energy Benefits - Leveraging Local Capacity for Onshore Wind", IRENA, 2017; "Workers wanted:The EU wind energy sector skills gap", European Wind Energy Technology Platform, 2013; Dalberg and MEC+ analysis

3.2.5 Pathway to indigenising the value chain

Figure 19: Prioritised recommendations timeline to increase DVA in the wind sector

Wind Indigenisation Pathway to Increase DVA and Reduce Import Dependence



Source: : "Domestic Manufacturing Capacity and Potential Cyber Security Challenges in the Wind sector and way forward", Niti Aayog, 2024, Dalberg and MEC+ analysis

India has the potential to raise indigenisation for wind turbine components to 60% by 2030 via targeted interventions to create the required manufacturing capacity across wind turbine components and drive price parity with respect to imports. The suggested interventions are summarised in the table below:

Figure 20: Prioritised recommendations to indigenise wind manufacturing

STRUCTURAL DRIVERS	RECOMMENDED LEVERS
Demand and market architecture	Short term (0-5 years) • Pair ALMM (Approved List of Models & Manufacturers) – Wind with domestic content requirement mandates for awarding of government or government backed projects. Introduce phased DVA requirements with gradual but well defined ramp up. • Announce a multi-year procurement trajectory for onshore wind (e.g., 10 GW per year auctions) with clear timelines, standardised bid structures, and power purchase agreement (PPA) guarantees in consultation with states. • Scale hybrid, round the clock and storage-linked tenders that leverage complementarities between solar and wind, or pair wind energy with battery energy storage system to create predictable demand for larger wind turbines.
R&D and product innovation	Short term (0-5 years) • Create a wind technology roadmap that prioritises 10-20 high impact technologies such as advanced blade materials, modular gearboxes, etc. • Fund 5-6 development and 4-5 regional testing labs with open access for industry and academia. • Develop standards and testing simulations suited to Indian wind conditions and ensure quality standards are in place for raw materials and components such as Concast steel, blade materials, and nacelle subcomponents across the industry. • Integrate cybersecurity standards and digital control system testing into turbine and component certification. Medium and long term (5+ years) • Support R&D grants for frontier technologies including next generation towers, modular structures, advanced composites, AI enabled wind farm control, etc. • Develop one Indian research hub as a global testbed for turbine design and digital optimisation tools.
Upstream raw materials and critical Inputs	Short term (0-5 years) • Correct inverted duty structure by reducing duties on concast and electrical steel while increasing duties on assembled gearboxes, generators, and castings to improve price competitiveness of Indian-made components • Undertake dialogue with steel manufacturers to encourage production of S355 Concast and other high capacity steels, potentially by aggregating demand across sectors and with support from a PLI scheme to the tune of ~ INR 5,000 crore[68] to expand production. Consider offering price guarantees to insulate steel producers from reduction in international prices or competition from cheaper imports. • Leverage G2G partnerships with key steel and raw material producers (Japan, South Korea), to secure raw material access to meet demand and drive co-investments in domestic glass fiber manufacturing. Medium and long term (5+ years) • Advance early-stage R&D into recycling and reuse of tower sections, shafts, bearings, and cast components to reduce long-term import intensity and build domestic circularity
Capital equipment and infrastructure	Short term (0-5 years) • Provide INR 2,600-3,100 crore in fiscal support via a 25% capex subsidy and similar extent of interest subvention (i.e., up to 25% of the prevailing interest rate) for MSMEs to expand casting and forging capabilities across different wind turbine components. • Support MSMEs to localise non-specialised capital equipment (arc furnaces, moulding systems) where there are cross-sector synergies (steel, railways, heavy engineering) from other industries. Medium term (5-7 years) • Leverage G2G partnerships to secure advanced capital equipment, i.e. specialised machinery such as ring-rolling mills, forging presses, and precision CNC lines from EU, Japan, and Korea.
Talent and workforce development	Short term (0-5 years) • Revamp ITI and engineering curricula and roll out train-the-trainer programs for turbine-manufacturing specific coursework. • Deploy 3–6-month programs covering basic skills (across safety and turbine assembly), offering certifications through ITIs and National Skill Development Corporation (NSDC) programs to train ~24,000 low-skilled workers needed by 2030.[69] • Establish structured apprenticeships to build operator-level depth in advanced materials, large-format component handling, and emerging 3 MW+ turbine technologies. Medium term (5+ years) • Establish centres of excellence in technical universities with 50% public private funding to train highly skilled engineers and develop certification programs for wind turbine manufacturing professionals.
Financing and taxation	Short term (0-5 years) • Provide INR 1,700-3,400 crores in input subsidies and interest subvention support to OEMs to limit the impact of additional investments on price of domestically produced components. • Offer import duty waivers to the tune of INR 2,600 crore on key raw materials such as Concast and electrical grade steel to kickstart domestic manufacturing while increasing duty (by 2.5%) on assembled gearboxes, generators, castings and forgings.

3.3 Batteries and BESS: Building an advanced cell and materials ecosystem

3.3.1 Demand outlook to 2030

By 2030, India's annual demand for batteries across stationary (grid energy storage) and mobility applications (EVs) could reach 173–273 GWh[70]. This increase over current levels (25 GWh) will be primarily driven by falling global battery prices, electrification of two- and three-wheelers, and implementation of grid-scale and behind-the-meter storage mandates. In the conservative scenario, achievement of EV30@30 goals and battery energy storage mandate announced for utility scale solar by the Ministry of Power[71,72] can lead to a 7x increase in annual demand for batteries over current levels by 2030. In the optimistic scenario, technological breakthroughs, the falling cost of ownership of passenger EV4W in urban areas, and the expanded energy storage mandate for all renewable energy installations, could result in additional 100 GWh of annual battery demand by 2030. This reflects 2.2-5.5 % of the projected global demand for batteries in 2030[73].

This scale of demand, spanning e-mobility and grid applications, creates a large and recurring domestic market for cells, packs and upstream materials. It anchors sufficient volume to justify investments in cell manufacturing, active material processing and recycling, provided India can close cost gaps and address structural bottlenecks in manufacturing batteries domestically.

3.3.2 Value chain structure, cost stack, and domestic value capture

Most of the value in batteries is created upstream in active materials and midstream in cell manufacturing. While costs vary based on battery chemistry and end-use application, processing of active materials and cell manufacturing account for ~60% of the final pack costs. This includes cathode and precursor material processing (Cathode Active Material (CAM)/ Precursor for Cathode Active Material (PCAM)) that account for ~17% of pack cost, anode materials for 5% of pack cost, electrode manufacturing for another 24% of the battery pack cost and cell manufacturing and assembly for 14% of pack cost. Separately, battery pack assembly accounts for roughly 40% of the cost[74].

India currently captures a small share of this value concentrated in pack assembly for EVs and small-scale stationary energy storage systems. Most domestic capacity focuses on assembling imported cells into packs for EVs and stationary systems and integrating these with battery management or power systems depending on the end application. Nearly all active materials processing for cathodes and anodes and their raw materials, as well as cell manufacturing, are currently undertaken by foreign suppliers. As a result, current domestic value addition is estimated at roughly 20% of total pack value[75].

Figure 21: Battery and storage value chain and current domestic value capture

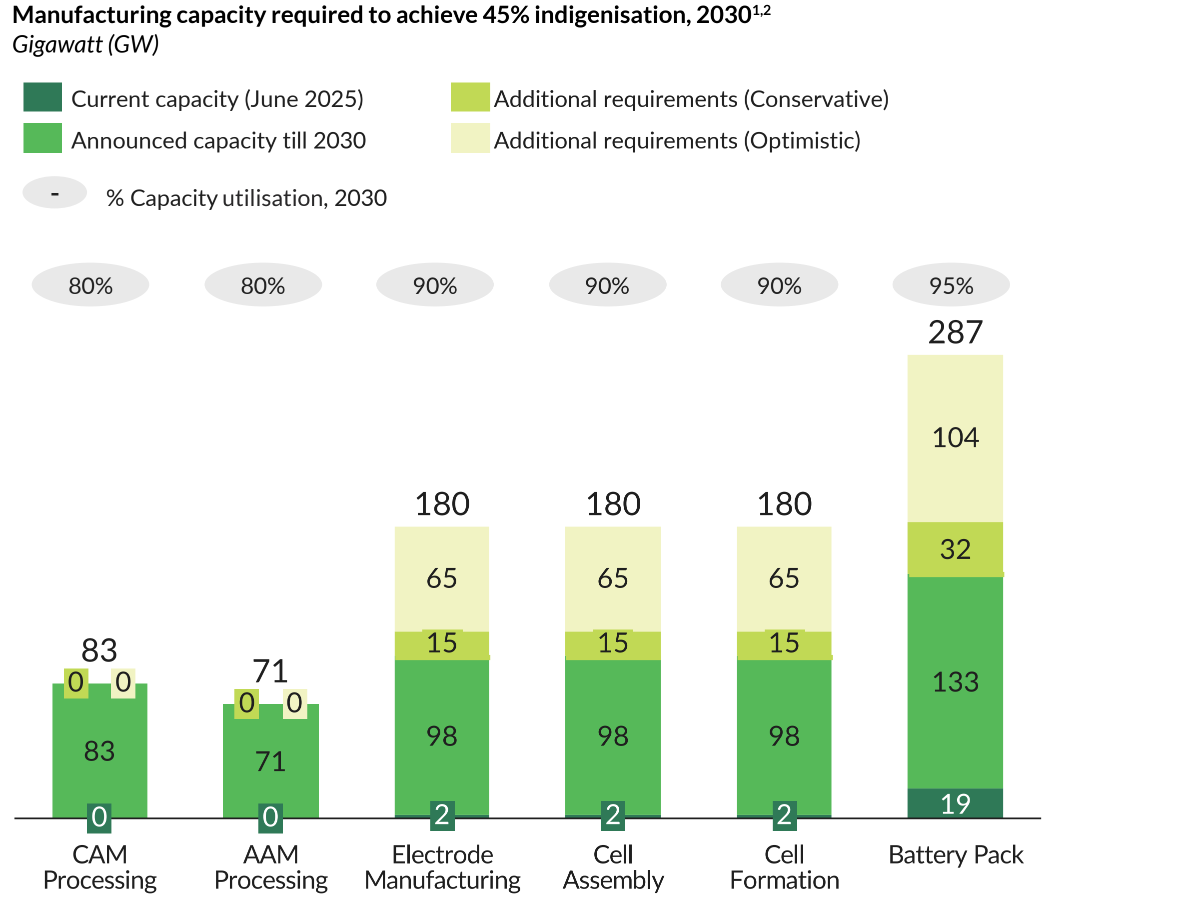
Key Components in the Value Chain	Mineral and Metals[1]	Electrodes	Cells (assembly and formation)	Battery Pack (assembly)
Cost Contribution (%)	22%	24%	14%	40%
Current DVA[2] (approximated)	~0%	~0%	~8%	~45%
Current Manufacturing Presence	• Not existent	India currently has minimal manufacturing capacity across upstream cell component and cell manufacturing stages.		Across arhitecture: • Pouch • Prismatic • Cylindrical
Critical Value Chain Dependencies	• Lithium carbonate • Nickel sulphate • Cobalt sulphate • Battery-grade graphite	• Battery-grade • active materials - • CAM/AAM[3]	• Reliable supply of electrodes • Coated separators	• Localised BMS[2]

Notes: (1) Including cathode and anode precursors for LFP batteries; (2) DVA has been calculated based on each component's cost contribution and component level import reliance; (3) Cathode Active Material and Anode Active Material; (4) Battery Management System
Source: Dalberg analysis, "Mine to Market: Critical mineral supply chain for domestic value addition in Lithium-ion Battery manufacturing, NITI Ayog, 2023

3.3.3 Manufacturing footprint: Current base, announcements, and gap to 2030

Compared to an estimated annual demand of 25 GWh in 2025, current domestic manufacturing capacity is 19 GWh of battery pack assembly. At the cell and upstream material level, India has an installed capacity of 2 GWh of cell manufacturing compared to the 180 GWh needed by 2030. Several gigafactory scale projects have been announced under the PLI scheme for Advanced Chemistry Cell (ACC-PLI)[76]. However, the announced capacity falls short of projected requirements even if it were to fully come online by 2030. Further, the gigafactories face execution risks due to declining lithium iron phosphate (LFP) prices that can make investments unviable as well as the capital and technology intensive nature of the value chain.

Figure 22: Current battery manufacturing capacity vs. additional required to meet 2030 demand by component



Notes: 1. CAM and AAM refer to Cathode Active Material and Anode Active Material; 2. Assuming 2–3-year delay in announced timelines due to global market conditions and that cell capacity announcements refer to 'cell to pack' manufacturing
Optimistic scenario: 1. Mobility: EV adoption exceeds targets, with overall EV new vehicle sales at 38% and very high penetration in 2- and 3-wheelers by 2030; 2. Stationary storage: 2-hour BESS is co-located with 100% of utility-scale solar and wind by 2030, while other storage uses remain as in the conservative case
Conservative scenario: 1. Mobility: EVs reach 30% of new vehicle sales by 2030 with existing policy support; 2. Stationary storage: 2-hour BESS co-locates with 40% of new solar and wind capacity, focused on grid stability and peak management, with C&I storage largely excluded.
Source: Company announcements; "PM E-Drive Portal," Ministry of Heavy Industries, Accessed 2025; "National Electricity Plan Vol I," CEA, 2023 ; Industry experts; Dalberg analysis

3.3.4 Bottleneck to scaling domestic manufacturing

India's battery ecosystem is growing but nascent. Structural bottlenecks across demand and in particular upstream raw materials, as well as capex and capital equipment, must be addressed in parallel to achieve greater indigenisation. Key bottlenecks include:

- **Demand and market architecture:** India's battery demand is large and growing, but policy signals and price trends have created an uneven investment environment for domestic manufacturers especially for cell manufacturing:
  - Policy mechanisms such as FAME and PM e-Drive incentivise local manufacturing of batteries. However, the current policy thrust for local content requirement is only on the assembly of battery pack and does not extend to cell and electrode components. While this was reflective of the battery manufacturing capabilities in India, the lack of focus on upstream stages results in fewer direct pull mechanisms for cell manufacturing and CAM/ Anode Active Materials (AAM) processing.
  - Battery pack prices declined by 33% between 2020 and 2025 and are expected to fall further[77]. The competition from lower price imports has led to delays in the commissioning of cell manufacturing projects announced under ACC PLI. Combined with the lack of visibility on future chemistry mix and the pace of offtake, manufacturers are unable to make investment decisions regarding specific cell chemistries to invest in.

- **R&D and product innovation:** Battery R&D efforts are led primarily by academic and public research institutions such as IITs, IISc, NISE, ARCI, and CSIR labs, complemented by growing private sector participation from OEMs and energy startups. However, the R&D ecosystem for battery tech remains fragmented:
  - R&D efforts lack a unified roadmap and applied research orientation aimed at supporting translation of laboratory breakthroughs into manufacturing designs and processes, especially for LFP, sodium-ion and advanced chemistries suited to Indian use cases and duty cycles.
  - Existing labs lack prototyping facilities and modern equipment for cell formation, safety testing, ageing and recycling process validation. Consequently, capabilities for industrial scale prototyping and validation are limited.
  - Much of the IP for cell chemistries sits outside India with only early-stage research into discovering and adapting cell chemistries like LFP, sodium-ion, and other advanced chemistries for Indian use cases, duty cycle, and environment. Recent grants under Anusandhan National Research Foundation (ANRF) and other research schemes have started to support research into battery management systems, battery heat management, and newer battery chemistries, but focus on translation remains limited.

- **Upstream raw materials and critical inputs:** Domestic refining capacity for battery minerals (e.g., lithium, nickel, cobalt, graphite) is limited and planned projects face challenges in achieving competitive power tariffs, access to long-tenor capital and environmentally compliant operations:
  - India has limited reserves of key materials such as lithium, nickel, cobalt and graphite required for cell manufacturing. The country depends on a small set of countries (especially China) to acquire these minerals. Even if domestic refining and battery circularity capacity is created, up to 90% of feedstock will need to be sourced internationally[78].
  - The domestic refining capacity for these minerals is negligible and expected to remain uncompetitive at current cost structures. For example, electricity accounts for 45% of the cost for refining materials like graphite[79]. High power tariffs combined with expensive capital equipment for refining operations, and long payback periods make investments in domestic refining unattractive.
  - India lacks a closed-loop circularity model for battery collection, refurbishment and recycling for second life batteries and material recovery. While current feedstocks are expected to be thin as the majority of batteries in use are recent deployments, we estimate that 96 GWh of second-life batteries and 970 kilo tonnes per annum (kTPA) of recycled material could be recovered and refurbished annually by 2040[80]. However, this requires stronger regulations and standards under e-waste collection rules and upfront investment in establishing collection centres and processing plants.

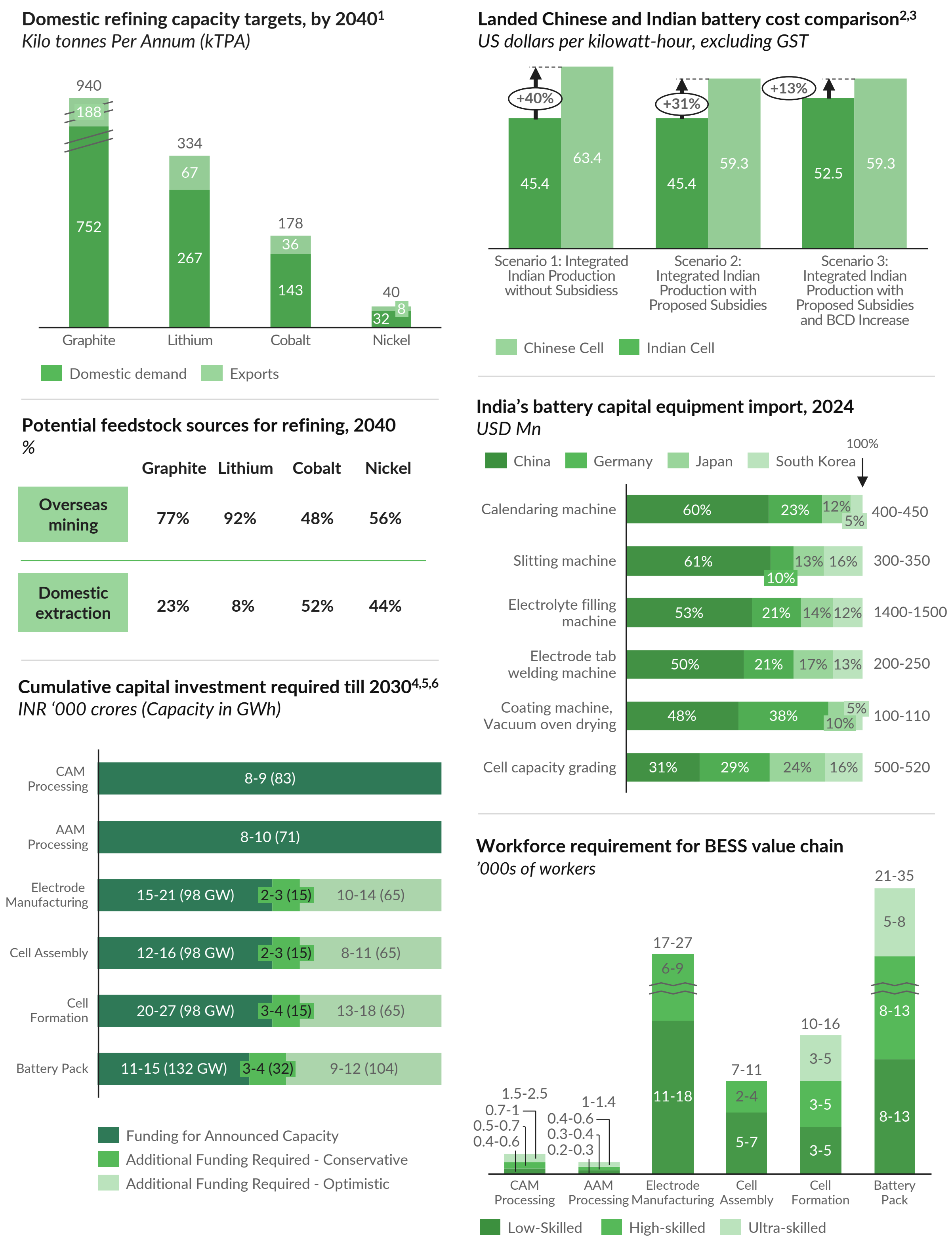
- **Capital equipment and infrastructure:** India's battery manufacturing ecosystem is heavily import reliant for key machinery and equipment. This import reliance and resulting sourcing complications could risk successful expansion of domestic battery manufacturing capacity:
  - Domestic capability to manufacture capital equipment for battery manufacturing is restricted to low-precision components. Indian manufacturers are dependent on international suppliers for critical battery equipment like electrode coating lines, formation equipment, dry rooms, and high precision mixers. 50–60% of capital equipment for battery manufacturing is currently sourced from China, and another 10-20% from Japan and South Korea[81]. Restrictions on export of IP protected machinery and delays in sourcing related capital equipment have delayed project timelines for manufacturers and led to capital lock-in for investors.
  - High upfront capex requirements and high cost of capital (see note on financing), combined with technology risk and global oversupply concerns, has led to underinvestment in fully integrated facilities for cell and battery manufacturing.

- **Talent and workforce development:** India's battery manufacturing ecosystem requires a parallel scale-up in skilled workers, which is currently constrained by weak training infrastructure. We estimate 58,000 to 90,000 additional workers will be needed for the battery value chain manufacturing by 2030[82]. However, the talent pipeline remains shallow, particularly for ultra-skilled roles and technicians with experience on manufacturing lines or applied R&D to operate and manage modern highly automated cell and battery manufacturing lines:
  - India's battery manufacturing plants will need a workforce that can operate and maintain integrated facilities across refining, electrode processing, cell assembly, pack assembly and recycling. Current training programs and institutions such as ITIs are not configured to deliver job-ready workers for advanced battery plants, with relevant skills in quality control, automated machine maintenance, and safety.
  - Advanced machinery setup and cell manufacturing still depend heavily on foreign technical experts. Engineering institutions lack targeted courses and linkages with manufacturers to produce highly skilled talent that can undertake process engineering and quality control to support efficient cell and battery manufacturing.

- **Financing and taxation:** An estimated INR 2.6 - 3.7 lakh crore will be required between 2025 and 2030 to achieve 45% indigenisation in the battery manufacturing chain[83]. This includes investments in creating the manufacturing and upstream mineral processing capabilities, but also workforce development and R&D infrastructure to support battery manufacturing across stationary energy storage, and mobility applications. However, concerns around poor cost competitiveness and the lack of appropriate de-risking mechanisms may restrict investment:
  - Landed cost of domestically manufactured cells, without any subsidy support, is expected to be 40% higher compared to imported cells. While the ACC PLI scheme has led to the announcement of several battery manufacturing projects, input costs such as the high price of electricity and capex investments are major drivers of this cost differential. Without additional fiscal support to reduce these input costs, domestic manufacturers are unlikely to be able to achieve price parity with imports in the immediate term.
  - We estimate that investments of more than INR 1.4 lakh crores are needed across upstream refining and circularity infrastructure. However, lack of low-cost debt for capex heavy projects with long payback timelines has prevented and lack of coverage for upstream and circularity infrastructure in existing subsidy schemes (e.g., ACC PLI) has led to limited investments in creating this capacity within the country.

Figure 23: BESS manufacturing requirement for materials, talent, equipment, and investment

Breakdown of mineral, workforce, capital equipment and investment requirement for batteries



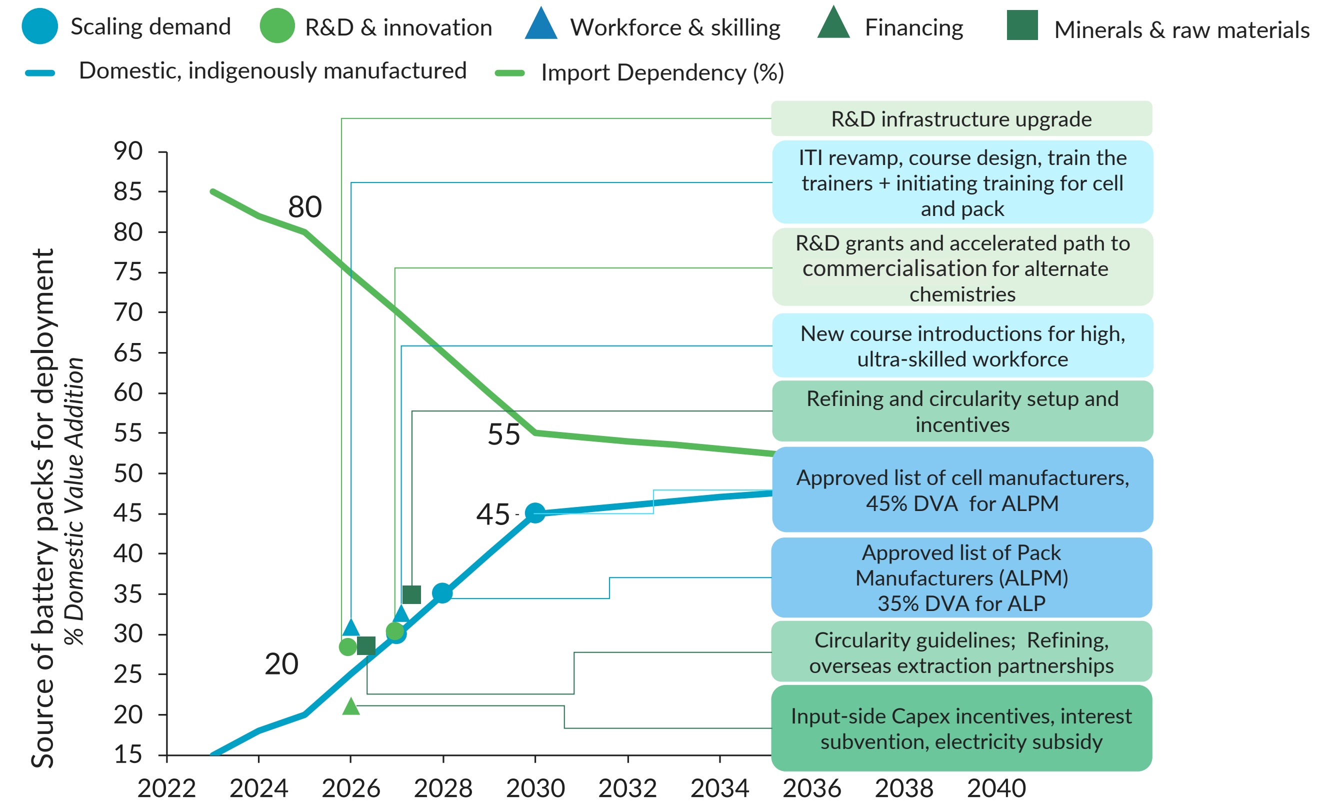
	Graphite	Lithium	Cobalt	Nickel
Overseas mining	77%	92%	48%	56%
Domestic extraction	23%	8%	52%	44%

Notes: 1. Battery mineral demand analysis undertakes a long term view beyond 2030 as greater mineral refining capacity is required till 2040. Phased incentives over a 10-15 year horizon can help drive development of requisite capacity; 2. Landed costs for Cells for stationary applications potentially 5-7% lower, average cell price assumed; 3. Chinese cell landed cost assumed to remain consistent via interventions like BCD; 4. CAM and AAM refer to Cathode Active Material and Anode Active Material respectively; 5. Assumed that announced capacities have already been funded and that cell capacity announcements refer to 'cell to pack' manufacturing; 6. Assumed 2-3-year delay in commissioning of announced capacities across value chain due to global market conditions
Optimistic scenario: 1. Mobility: EV adoption exceeds targets, with overall EV new vehicle sales at 38% and very high penetration in 2- and 3-wheelers by 2030; 2. Stationary storage: 2-hour BESS is co-located with 100% of utility-scale solar and wind by 2030, while other storage uses remain as in the conservative case
Conservative scenario: 1. Mobility: EVs reach 30% of new vehicle sales by 2030 with existing policy support; 2. Stationary storage: 2-hour BESS co-locates with 40% of new solar and wind capacity, focused on grid stability and peak management, with C&I storage largely excluded.
Sources: Dalberg analysis; Shanghai Metal Market, Accessed 2025; Industry experts (industry associations, key manufacturing players); "Initial findings positive for lithium blocks in Argentina," The Hindu, 2025; "Indian state firm's seek stake in SQM's Lithium projects in Australia," Reuters, 2025

3.3.5 Pathway to indigenising the value chain

Figure 24: Prioritised recommendations timeline to increase DVA in the BESS sector

Battery Indigenisation Pathway to Increase Domestic Manufacturing



Note: Assumed 2–3-year delay in announced timelines due to global market conditions and that Cell capacity announcements refer to 'cell to pack' manufacturing

Source: Company announcements; "PM E-Drive Portal," Ministry of Heavy Industries, Accessed 2025; "National Electricity Plan Vol I," CEA, 2023 ; Industry experts; Dalberg analysis

Achieving 45% indigenisation across the battery value chain by 2030 will require coordinated progress across creation of upstream material refining, circularity infrastructure, and cell manufacturing capacity. These need to be complemented with measures to assure demand for domestically manufactured electrodes and cells, alongside investments in product innovation and workforce development capable to meet the country's battery manufacturing needs by 2030 and beyond. Specific recommendations are highlighted below.

Figure 25: Prioritised recommendations to indigenise battery manufacturing[84]

STRUCTURAL DRIVERS	PRIORITY LEVERS
Demand and market architecture	Short term (0-5 years) • Introduce phased domestic value-addition requirements linked to an Approved List of Pack and Cell Manufacturers, targeting 35% pack-level DVA by 2028 and 45% cell-level DVA by 2030. • Expand BESS co-location to cover all utility-scale renewable projects (100% solar & wind) by 2030, increasing storage duration requirements from 2 to 4 hours to ensure stable and long-term demand for domestic battery manufacturers. Medium term (5-7 years) • Expand use of BESS beyond utility scale renewable energy projects to include commercial & industrial (C&I) applications and distribution-level storage, backed by clear tariff and remuneration mechanisms. • Leverage EXIM lines of credit and bilateral partnerships to open export markets for Indian packs and, over time, cells in emerging economies particularly Africa.
R&D and product innovation	Short term (0-5 years) • Establish a mission-driven battery R&D framework to identify 10–20 priority battery technologies suited to Indian conditions and use cases, and aggressive cost-benefit targets. • Build translational research and prototyping capabilities that can support scale-up from lab cells to production-scale lines, including safety, ageing and recycling processes. Create 12–16 battery development and testing labs focused on electrodes, cells, and battery recycling with a public investment of INR 600-1,200 crore[85]. Operate these labs as open-access facilities with standardised testing to validate cell chemistry, pack designs, and recycling processes. • Develop structured public–private consortia around priority chemistries and applications, with shared IP and technology transfer frameworks. Medium term (5-7 years) • Support early-stage R&D and prototyping through targeted public funding (~ INR 300–600 crore[86]) tied to technology readiness level (TRL) based commercialisation milestones. Long term (7+ years) • Support frontier research in next generation chemistries (for example solid-state, advanced sodium-ion) and circularity technologies, via targeted grants to small set of academic research groups.

STRUCTURAL DRIVERS	PRIORITY LEVERS
Upstream raw materials and critical inputs	Short term (0-5 years) • Provide INR 16,300 crores[87] in upfront capex support and interest subvention to encourage manufacturers to set up refining capacities for select minerals, especially battery-grade graphite. • Provide ~ INR 12,000 crores in targeted capex support and concessional finance for refurbishment and recycling facilities to enable recycled materials and refurbished batteries to become part of the value chain by 2030. • Build strategic stockpiles of processed minerals supported by long-term overseas extraction and refining bilateral and G2G partnerships to secure inputs needed for rising DVA requirements. Medium term (5-7 years) • Roll out electricity subsidies, raw material imports duty waivers and open access of electricity for mineral refining plants developed in the intervening years to keep opex costs manageable. • Scale circularity investments to accelerate collection, refurbishment, and recycling of end-of-life batteries through existing and upcoming Material Recovery Facilities (MRFs). Support the creation of 160–180 battery waste collection centres through upfront capex subsidies and working capital support of INR 1,200-1,500 crore. Long term (7+ years) • Notify rules for battery circularity and waste collection to create a closed loop circularity ecosystem for battery and associated material recovery in the country.
Capital equipment and infrastructure	Short term (0-5 years) • Localise and build domestic manufacturing for non-specialised machinery such as calcination furnaces, grinding mills, coating machines, drying ovens, and laser welding machines by leveraging cross-sector capabilities • Secure high-precision specialised machinery, such as electrolyte filling, electrode coating, calendaring, and tab welding machines, through global technology partnerships from diverse sources (Germany, Japan, South Korea, USA). Medium term (5-7 years) • Develop dedicated battery manufacturing parks with reliable power, logistics and shared testing and recycling infrastructure.
Talent and workforce development	Short term (0-5 years) • Repurpose part of the ITI upgradation budget to create public–private skilling partnerships across 40–50 ITIs, and invest INR 3,000–5,500 crore in training infrastructure, with blended finance and CSR support – to build capacity across all skill levels. • Launch new courses in consultation with industry and train-the-trainer programs focused on electrode processing, cell assembly, and battery testing • Attract global experts and visiting faculty to deliver specialised short-term modules in advanced battery technologies, supporting technology transfer and domestic capability building Medium term (5-7 years) • Establish R&D-linked demonstration facilities at engineering institutes and research parks to provide hands-on training for high- and ultra-skilled talent.

STRUCTURAL DRIVERS	PRIORITY LEVERS
Financing and taxation	Short term (0-5 years) • Offer targeted upfront capex incentives, interest subvention, and electricity subsidies to help domestic cell and pack manufacturers bridge cost gaps while commissioning new lines. • Restore the 26% BCD on imported battery cells (from the current reduced rate of 5% for e-mobility and BESS applications) once domestic cell manufacturing picks up and in conjunction with the proposed DVA timelines (see earlier recommendation). • Introduce priority sector lending for batteries and component manufacturing to improve working capital access and finance large capital-intensive facilities. • Provide INR 4,500–6,500 crore of Viability Gap Funding (VGF) between 2027–2030[88] to offset global price differentials and reduce total cost of ownership for domestic 4W EVs, supporting compliance with higher DVA thresholds

3.4 E-Mobility: Turning India's automotive base into an EV manufacturing hub

3.4.1 Demand outlook to 2030

By 2030, India will be among the largest EV markets globally, driven by high penetration of electric 2 and 3 wheelers and growing adoption of electric passenger cars. Policy ambitions point to rapid electrification of transportation in urban and commercial segments. We estimate that annual EV sales could reach 12 to 17 million vehicles by 2030 across all segments[89]. Most of this demand will be driven by 2-wheeler and 3-wheeler segments where the total cost of ownership and duty cycles already favour electrification, as well as light commercial vehicles and passenger cars that are expected to scale more gradually but will add significant demand in the next five years.

The growth in electric mobility is expected to translate into large and diversified requirements for EV components like battery packs, traction motors, controllers, power electronics, vehicle platforms, and software. Consequently, it will also underpin a substantial demand for upstream battery materials (refer previous section) and charging ecosystem components. Together, these factors are expected to create a deep and recurring domestic market for EV and EV ancillaries to underpin domestic manufacturing of EVs within the country.

3.4.2 Value chain structure, cost stack, and domestic value capture

An electric vehicle's values lies mainly in the battery drive train and power electronics, while India's current manufacturing is concentrated in the manufacturing of the vehicle platform and overall vehicle assembly. A typical EV cost structure allocates roughly 35% of the total vehicle cost to the battery pack, 15% to the electric motor and drive train, another 20% to power electronics and semiconductors. Of the remaining, 15% cost sits in the vehicle platform including chassis, body, interiors, suspensions etc. and another 10% is associated with vehicle software and telematics[90]. Drawing on its conventional base of automotive manufacturing, the Indian industry is competitive in manufacturing the vehicle body and its assembly. However, the most value dense subsystems like battery packs, permanent magnets for different types of motors, and power electronics are largely imported. Consequently, India's current domestic value addition across EVs is estimated to be around 35%, although it varies by vehicle segment and between OEMs.

Figure 26 : Electric mobility value chain and current domestic value capture

Electric mobility chain and current domestic value capture[1]

Key Components in the Value Chain	Battery Pack	BMS[2]	Motors	Power Elec-tronics	Chassis and Body	Others
Cost Contribution (%)	35%	5%	15%	20%	15%	10%
Current DVA[3] (approximated)	~10%	~30%	~30%	~40%	~80%	~40%
Current Manufacturing Presence	Across architecture: • Pouch • Prismatic • Cylindrical	• Nascent BMS software development	• Limited stator, rotor production • Emerging rare-earth free motor manufacturing	• Some sensors used in circuit breakers, etc. • AC and DC charging inlet assembly Invertor and motor controller assembly	• Suspension • Tyres and wheels • Brakes • Sheet metal • Rubber components	• Wiring harnesses • Brake fluid • Coolant
Critical Value Chain Dependencies	• Traction cells • Electrode precursor materials	• Automotive-grade semiconductor chips	• Rare-earth magnets • Specialised electrical steel	• semiconductors	• HVAC[4] • Crash, durability and corrosion-testing capacity	• Semi-conductors and software for Vehicle Control Units, • Other sensors and connectors

Notes: (1) The upstream battery value chain is excluded from this analysis, as it is covered under the BESS section. (2) Battery Management System; (3) DVA has been calculated based on each component's cost contribution and component level import reliance; (4) Heating, Ventilation and Air conditioning
Sources: "Driving self reliance – localizing EV components in India", Praxis Global Alliance, 2025; "Magazine Issue no. 50", EV Reporter, 2025; Expert consultations

3.4.3 Manufacturing footprint: Current base and announced gap to 2030

India is structurally strong in platform manufacturing and final vehicle assembly, with decades of experience in Internal Combustion Engine (ICE) vehicles; localisation of key EV subsystems is growing but yet to enter high value subsystems. Leading OEMs already assemble electric two- and three-wheelers, buses and some passenger vehicles domestically. This includes traditional automotive manufacturers as well as newer OEMs exclusively focused on EVs. Local supplier ecosystems developed by these OEMs are well positioned to support chassis development, body manufacturing, and many conventional components. Domestic firms also perform battery pack assembly and vehicle integration of motors and controllers for all types of EVs. However, most high-value subsystems such as cells, permanent-magnet motors, inverters, DC-DC converters, on-board chargers, power modules and advanced control electronics are sourced internationally. For example, manufacturing capability in traction motors and power electronics is developing but still limited in scale and technology depth. Many plants rely on imported rotor and stator assemblies, magnet stacks, high-power devices and critical tooling.

Raising domestic value addition towards 50% by 2030 will require a step change in manufacturing trajectory of high value components. This includes localisation of motors and controllers, power electronics, battery management systems, enclosures and thermal systems, alongside selective localisation of upstream materials and capital equipment.

3.4.4 Bottlenecks to scaling domestic manufacturing

India's e-mobility ecosystem is scaling, but structural bottlenecks across demand, R&D, upstream raw materials, capital equipment, skills and financing must be addressed simultaneously to drive up domestic value addition alongside meeting the 30@30 goal for EVs:

- **Demand and market architecture**: India's EV demand is scaling, but the shift to deeper localisation risks increasing EV prices and slowing adoption unless demand-side support and charging infrastructure scale in tandem:
  - Policy support from schemes such as FAME I and II and PM e-Drive currently have helped make EVs more affordable through targeted subsidies at the point of purchase. However, even with the current level of subsidies, achieving 50% or more localisation could increase EV prices by 15-25%[91] due to higher local production costs of components such as batteries. This increase in prices could adversely impact demand and slow down EV adoption.
  - Persistent gaps in charging infrastructure (100K charging point deficit as of Aug 2025)[92] reduce consumer confidence and constrain the pace of fleet electrification, including commercial and shared mobility applications.
  - High upfront costs and constrained availability of finance for commercial segments (up to 7%[93] higher interest rates comparable v/s ICE buses/trucks) weaken fleet economics and have slowed demand ramp-up in these segments.

- **R&D and product innovation:** EV manufacturing-focused R&D and product innovation remains concentrated on incremental improvements and vehicle platforms with limited indigenous capability in high-value subsystems such as rare-earth magnet-free motors, advanced power electronics, and vehicle telematics. While there is a growing body of EV OEMs investing in this research, further R&D and product innovations remain constrained due to several factors:
  - Current R&D efforts are focused on chassis and body development as well as drive-train innovation for 2- and 3-wheelers. While some OEMs have ongoing research efforts to manufacture rare earth free motors and battery management systems, investment in research in such frontier EV technologies remains limited.
  - R&D ecosystem is fragmented and underutilised with academic and private facilities operating in silos and competing mandates. Lack of collaboration to build upon each other's research and translate lab findings to manufacturing designs has prevented on-field piloting and commercialisation push for product innovations in the country. Grants under schemes such as ANRF that have been rolled out, for example, in battery and EV research, but these focus on academic development without dedicated industry linkages or roadmap for adoption of these designs into product lines.
  - Technology transfer and adaptation of vehicle segments such as zero-emission trucks is also lagging. While acquiring these technologies internationally can accelerate their introduction, further innovation is needed to adapt these platforms for Indian road and vehicle loading conditions. End-users such as transporters remain wary of accepting products that have not been adapted and tested for Indian road conditions.

- **Upstream raw materials and critical inputs:** Scaling localisation of key EV components, particularly traction motors and battery minerals is constrained by the supply of critical minerals. While we discussed upstream raw material constraints in the blueprint for batteries, for traction motors used in EVs, Indian manufacturers remain dependent on international suppliers for rare earth oxides and permanent magnets. Several constraints exist in securing these supplies reliably:
  - We estimate demand for rare earth oxides to exceed 8,000 metric tons by 2030 and potentially 34,000 metric tons by 2040. However, the supply of these Rare Earth Oxides (REO) is concentrated in China. It accounts for two-thirds of rare earth extraction and more than 90% of global REO production. Current domestic production base is limited to 2,600 tonnes per annum. As a result, as the Indian EV ecosystem grows, Indian manufacturers could be exposed to strategic supply chain and pricing risks preventing investments in establishing downstream manufacturing lines.
  - India has the third-largest deposits of light rare ores (estimated to be 480 million metric tonnes) but exploration of these reserves and expansion of refining capacity remains slow. Even with expansion of refining capacity and securing supplies of heavy rare earth ores or oxides, Indian REO production is expected to be up to 35% costlier limiting the incentives for scaleup by domestic manufacturers, despite a clear strategic case to build these capacities in house[94].

- **Capital equipment and infrastructure:** India lacks the capital equipment manufacturing base to produce specialised machinery required for scale-up of EV component manufacturing. The resulting supply bottlenecks and lack of domestic manufacturing support has constrained the speed of manufacturing line expansion:
  - India imports 60-80% of machines required for EV component manufacturing[95]. This includes machines for (Surface Mount Technology) SMT lines, rotor magnet insertion, coating and electrode formation etc. that create long lead times, cost, and geo-political exposure risk. Recent Chinese policy measure to restrict export of such equipment will further constrain the establishment of domestic manufacturing lines that anchor on these machines.
  - Supportive policies like the National Semiconductor Mission and PLI for electronics manufacturing have led to increased investments in electronics manufacturing in the country. Despite some overlaps with consumer electronics machinery (e.g., PCB assembly, solder-paste printers, rotor balancers), domestic capabilities for specialised EV capital equipment such as hairpin coil winders, thermal-management assembly systems and die-bonding tools remain narrow due to technology gaps and limited incentives for local design and the manufacturing of capital equipment.

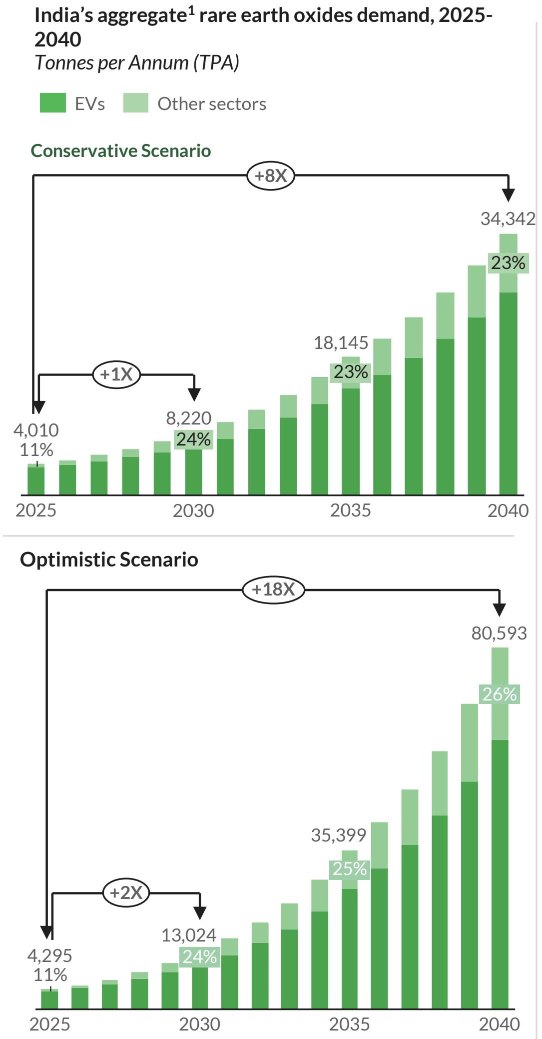
- **Talent and workforce development:** We estimate 600,000 direct and indirect workers will be required in domestic EV manufacturing by 2030[96]. While the automotive skills training ecosystem in the country is more developed compared to other sectors, especially with the industry playing a critical role in training, equipping the workforce for EV manufacturing lines as well as creating the right high skilled and ultra skilled talent base (one-third of the estimated jobs required) will require strengthening the training pipelines:

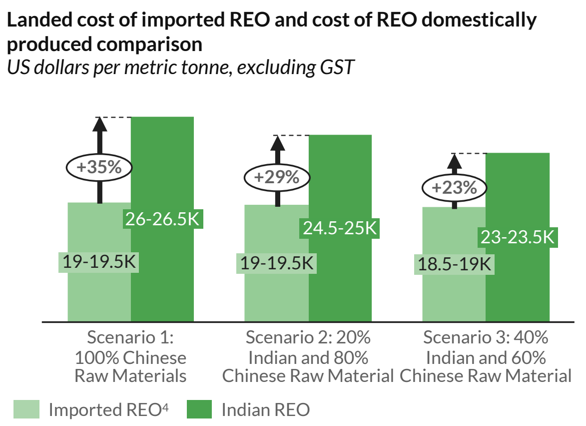
- Skilling efforts for manufacturing line workers are fragmented across ITIs, manufacture led initiatives, and private training institutions. Limited industry-oriented curricula, certification programs, and high retraining costs impact the development and availability of a trained workforce for the EV industry.
- Tie-ups between academic institutions, including engineering universities and ITIs, and industry for on-the-job training and demonstration facilities are limited. Consequently, workers graduating from these programs lack exposure to modern EV-specific manufacturing lines.

- **Financing and taxation:** We estimate that approximately INR 2.2 -3 lakh crore in investments is needed (excluding battery manufacturing) over five years to scale domestic manufacturing and achieve 50-60% indigenisation for EV manufacturing. However, investments flows remain constrained for MSMEs that form the tier 2 and tier 3 supplier ecosystem, and for product innovation overall:
  - We estimate that the landed cost of Indian EVs could rise by 15-25% in the short to medium term on account of investments in creating domestic manufacturing capacity and increase the domestic value addition. To achieve parity or narrow the cost gap, input costs for manufacturers will need to be lowered (e.g., lower cost of debt or capex cost reduction) but currently available support is in form of backloaded, sales-based incentives (auto-PLI).
  - Further, e-bus manufacturers often operate on leasing models with large transport operators, including public transport authorities. Revenue risk originating from operators being unable to meet contractual payment requirements and lack of sufficient downside protection in such scenarios has led to concerns around expanding manufacturing capacity for these vehicle segments.
  - Localisation of EV supplier base remains constrained due to limited avenues for financing. Current capex support subsidies, including under PM e-DRIVE are demand side subsidies available to OEMs. However, tier 2 and tier 3 suppliers lack targeted schemes to support the expansion of products and also face constraints in accessing affordable capital to make the required capex investments.

Figure 27: Electric mobility manufacturing requirement for materials, talent, equipment, and investment

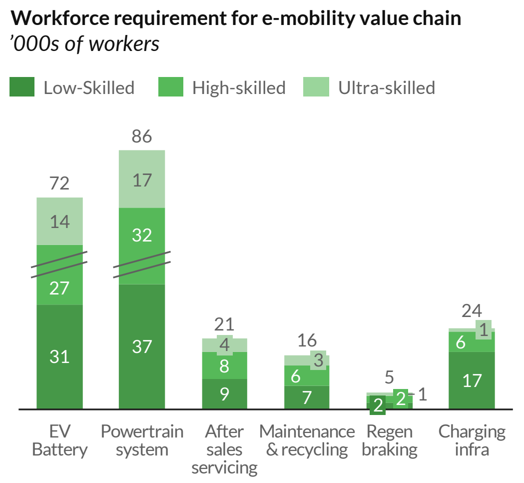
Breakdown of mineral, workforce, capital equipment and investment requirement for e-mobility





Capital equipment import dependence
%

Component	Import Reliance[5]	Key Machines that are import dependent
Power Electronics	70-80%	Machines used in PCB assembly - Surface Mount Technology (SMT), etc.
Motors	~60%	Rotor Magnet Insertion and Embedding machines, Rotor Balancing machines, etc.
Battery Management System (BMS)	70-80%	BMS testing equipment and machines used in PCB assembly
Battery Pack	70-80%	Machines across CAM processing and Electrode formation – Coating machine, etc.



Capex financing needs across the EV ecosystem

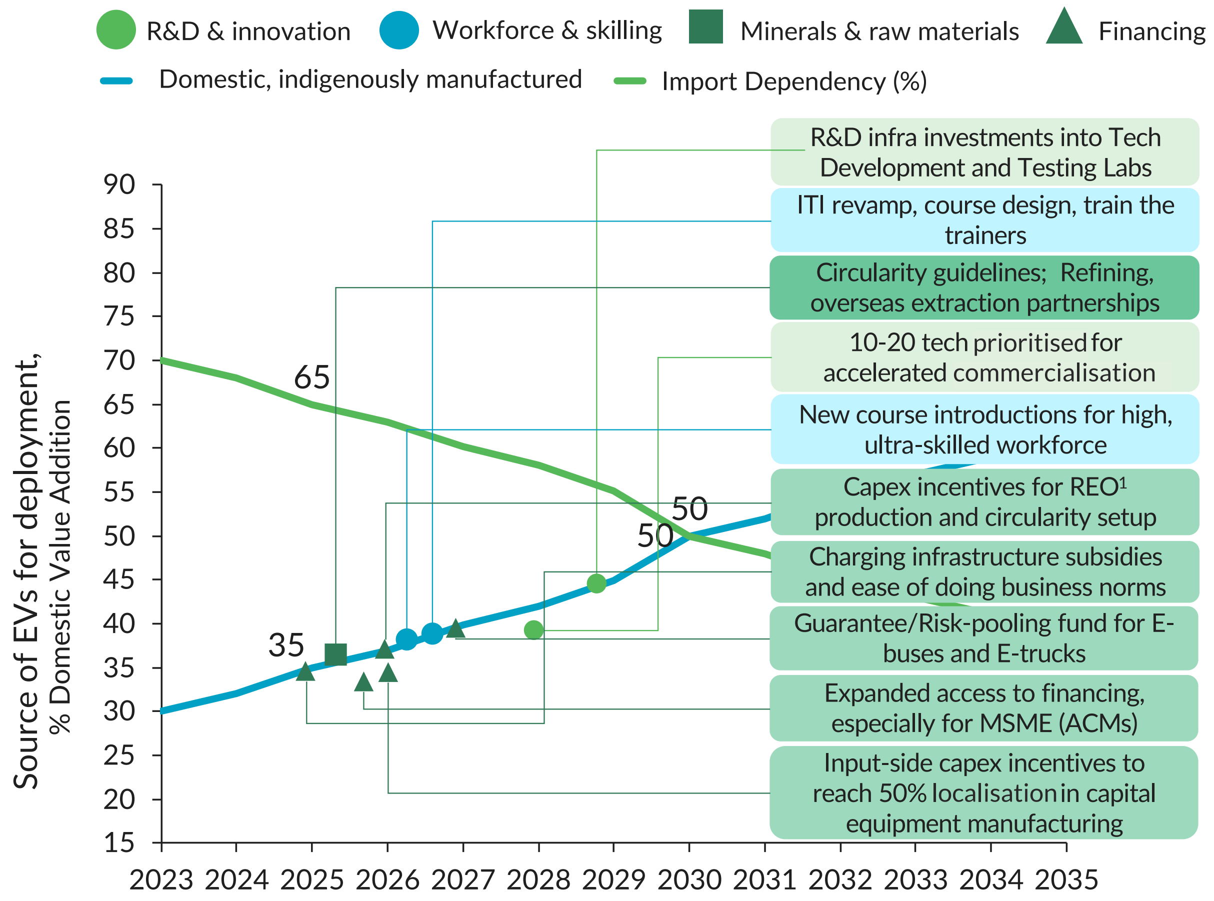
Capex component	Total Estimated Investment *(INR crore)*
Component manufacturing	~44K
OEM-led Vehicle assembly	26-64K
Charging infrastructure manufacturing	40-52K
Interest costs[6]	33-50K
Capital equipment manufacturing	9-16K
Other ecosystem investments	3-13K
TOTAL	165-230K

Notes: 1. Refers to total REO demand including demand represented by finished REO products (rare earth magnets) and REO itself. It is assumed that 15% of total annual EV demand will continue to be met by imports – REO demand for the same has been excluded from this assessment; 2. Continued import dependence for Rare Earth Oxides could result in import bills worth USD 100-160 Mn by 2030, (assuming 90% import reliance); 3. Across scenarios, 95% of EVs are assumed to have Rare Earth Oxide magnets and REO weight is considered to be 30% of permanent magnet weight; 4. The cost of Imported REO has been adjusted basis the composition of Rare Earth Oxide achieved by mixing Indian and imported Rare earth concentrates in different proportions; 5. Import reliance is based on number of machines that are imported amongst all relevant machines to manufacture a component 6. Interest costs calculated based on 11% interest rate, considering 70% Debt component and a 7 year loan tenure for capex financing. 20% of these costs are expected to be met via the government led concessional deck
Rare Earth Oxide Demand estimation:
Optimistic Scenario: 1. EV penetration expected to rise more aggressively in the optimistic scenario, thus increasing absolute REO demand from EVs; 2. REO demand from other sectors expected to rise proportionately to EVs in the optimistic scenario due to policy tailwinds (e.g., VGF scheme for offshore Wind, National Manufacturing Mission to boost consumer electronics production, rising funding for defence sector); 3. Thus EVs' share in total REO demand in optimistic scenario differs minimally from conservative
Conservative Scenario: 1. In 2025, EVs assumed to account for 11% of total REO demand; 2. By 2030, rising EV penetration expected to more than double EVs' share to 24%; 3. Beyond 2030, EV share anticipated to grow at a deaccelerated pace due to expected growth in demand from other sectors (e.g., Offshore Wind)
Sources: Dalberg analysis; Expert consultations; Industrial market places (IndiaMart and Alibaba); "Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors," MEITY, Accessed 2025; "Union Budget 2025-26 proposes to remove 7 custom tariff rates for industrial goods," Press Information Bureau, 2025 ; "Material and energy requirement for Rare Earth production," JOM, 2013

3.4.5 Pathways to indigenising the value chain

Figure 28: Prioritised recommendations timeline to increase DVA in the e-mobility sector

EV Indigenisation Pathway to Increase Domestic Manufacturing



Source: Dalberg analysis; Industry expert inputs

Achieving 50% domestic value addition in e-mobility by 2030 (up from ~35% today) while meeting the 30@30 electrification goal will require coordinated progress across demand creation (especially charging and fleet programs), indigenous R&D and testing for high-value subsystems (batteries, BMS, motors and power electronics), securing critical inputs such as REOs and magnets through a mix of domestic capacity and circularity, scaling component and equipment manufacturing, and building a job-ready workforce alongside improved access to affordable finance—particularly for MSMEs. Specific priority levers are summarised in the table below.

Figure 29: Prioritised recommendations to indigenise e-mobility manufacturing

STRUCTURAL DRIVERS	PRIORITISED LEVER
Demand and market architecture	Short term (0-5 years) • Create a tapering Viability Gap Funding (VGF) pool of INR 4,500–6,500 crore[97] to offset 15–25% cost increases from localising batteries, motors and electronics. • Accelerate rollout of public and depot charging infrastructure by providing subsidies of INR 4,000 crore[98] to Charge Point Operators (CPO) including charging infrastructure setup and concessional land leases. Complement the measure with lower GST on charging and a unified single-window national portal for approvals. • De-risk e-bus manufacturers by setting up a INR 3,000 crore guarantee under PM e-Bus Sewa for procurement of additional ~32,000 e-buses to cover Gross Cost Contracts (GCC).[99] Similarly, setup INR 2,000 crore guarantee fund under PM E-DRIVE for e-truck manufacturers.[100] Medium term (5-7 years) • Embed progressive domestic value addition requirements aligned with cost and reliability benchmarks for public procurement and fleet mandates. Link rollout of future capex subsidies for passenger EVs in future schemes to domestic value addition targets.
R&D and product Innovation	Short term (0-5 years) • Upgrade 6–8 existing centres (IITs, ICAT, DHI CoEs) into state-of-the-art, open-access EV R&D and testing facilities under PPPs, covering prototyping, compliance testing and real-world validation with government investment of INR 1,300 -2,300 crore. • Launch INR 1,000-1,200 crore[101] co-financed grant program (public–private matching) for commercialising high-impact EV technologies with clear cost and efficiency gains (e.g., in-rotor inductively excited synchronous motors, push belt CVTs, and phase-change materials etc.) • Establish a national R&D coordination council of leading OEMs and academic centres and create IP-protected mechanisms for shared access to industrial R&D infrastructure so startups and smaller OEMs can use advanced facilities. Medium term (5-7 years) • Create TRL linked commercialisation pathways to support scale-up from lab validation to pilot manufacturing lines using shared facilities and milestone-based grants. • Institutionalize a mission-driven EV technology roadmap, periodically refreshing priority areas as vehicle architectures evolve (e.g., software-defined vehicles, advanced power modules).

STRUCTURAL DRIVERS	PRIORITISED LEVER
Upstream raw materials and critical input	Short term (0-5 years) • Provide targeted capex support (INR 100–300 crore) to scale domestic rare earth oxide (REO) refining, enabling 50–65% self-sufficiency in refining by 2030. • Expand bilateral partnerships with Brazil, Australia, Myanmar, and Vietnam to ensure steady access to Heavy REE concentrates. • Build strategic REO stockpiles equivalent to ~25% of 2030 demand through bilateral partnerships and long-term offtake agreements. Medium term (5-7 years) • Scale magnet circularity infrastructure, enabling recovery of 2000 tonnes of rare earth permanent magnets by 2040 via expanded vehicle scrappage and recycling networks. Build on existing recycling schemes (e.g., critical mineral recycling incentive scheme) to create 160-180 new waste collection centres and 350-360 vehicle scrappage facilities. • Notify and enforce closed-loop circularity norms for magnets (and batteries), routing recovered materials back into domestic EV supply chains.
Capital equipment and infrastructure	Short term (0-5 years) • Localise manufacturing of priority EV capital equipment such as SMT lines and rotor magnet insertion machines by leveraging cross sector capabilities in electronics, defence and aerospace, with capex incentives of INR 2,000-3,600 crore. • Forge bilateral technology partnerships with Germany, Taiwan, and South Korea to access advanced equipment such as Coil Winding, SMT Pick and Place Machines, SMT, Automated Optical Inspection Machine. • Accelerate localisation of EV charging equipment by scaling domestic PCB assembly for EVSEs and testing infrastructure. • Shift toward input-side capex incentives for MSMEs to encourage localisation of EV-specific capital equipment. Medium term (5-7 years) • Develop dedicated EV component, vehicle and charging infrastructure manufacturing clusters with shared testing, certification and supplier-development infrastructure, particularly to support MSME participation.
Talent and workforce development	Short term (0-5 years) • Invest INR 6,500–11,500 crore[102] in industry-aligned training programs and demo facilities, using innovative financing models such as skill bonds and pooled public–private funds. • Introduce standardised, modular EV courses across ITIs and engineering colleges from short-term certificates to master's programs, co-developed with leading OEMs and Tier-1 suppliers and aligned with industry standards • Launch a national "Train the Trainer" program to develop 200–300 master trainers across the top 100 engineering colleges and ITIs, supported by government-to-government partnerships with global EV leaders (EU, Korea, Japan). Medium term (5-7 years) • Establish R&D-linked demonstration and apprenticeship facilities at engineering institutes and research parks to build high- and ultra-skilled talent. • Create platforms to attract global EV experts to train Indian academicians and engineers through exchange programs and visiting professorships.

STRUCTURAL DRIVERS	PRIORITISED LEVER
Financing and taxation	Short term (0-5 years) • Offer targeted capex incentives of INR 4,600-8,700 crore[103] for expanding domestic production capacity across EV components, vehicle assembly and charging infrastructure aligned to domestic value addition milestones, with gradual tapering off subsidy over five-year horizon. • Provide concessional finance support worth INR 5,800-8,000 crore[104] to reduce cost of finance for manufacturers in the EV ecosystem. • Improve access to affordable debt for MSMEs in EV sector through priority sector classification and credit guarantee instruments that reduce cost of capital.

3.5 Green Hydrogen: Deepening electrolyser stack and component manufacturing

3.5.1 Demand outlook to 2030

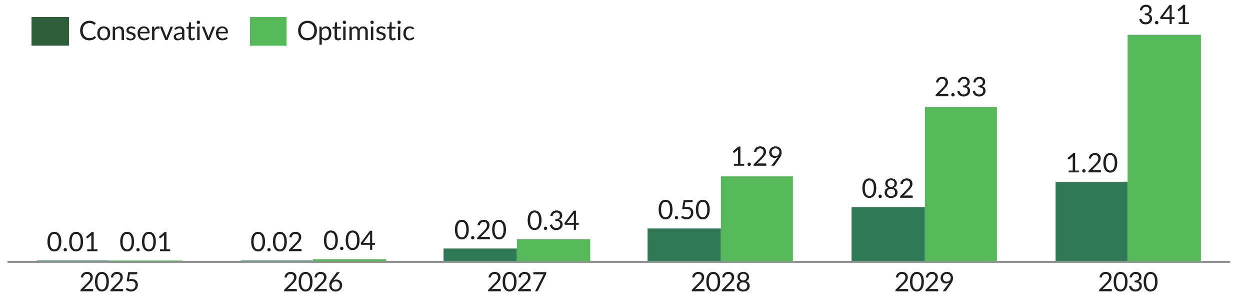
By 2030, we estimate India's green hydrogen demand could reach between 1.2-3.4 million tonnes per annum (MTPA), combining domestic consumption and export-oriented production. Domestic demand is projected to reach 0.6-1.6 MTPA, driven primarily by early adoption in refining, green ammonia substitution in fertilizer manufacturing, blending in city gas distribution, and pilots in hard-to-abate sectors like steel and chemicals. Export-linked demand including for green ammonia exports, bunkering and other international uptake arrangements could add another 0.6-1.8 MTPA contingent on domestic manufacturers' ability to secure long term contracts in global markets, and sustain prices discovered through recent SECI tenders.

Translating this into electrolyser capacity, we estimate that India will require electrolyser installations of ~10-28 GW by 2030. This capacity deployment will be shaped by the pace at which early projects for green hydrogen take off and achieve financial closure, the success of the PLI schemes for manufacturing within green hydrogen, and the evolution of offtake mechanisms under the National Green Hydrogen Mission.

Figure 30: Green hydrogen and electrolyser manufacturing demand

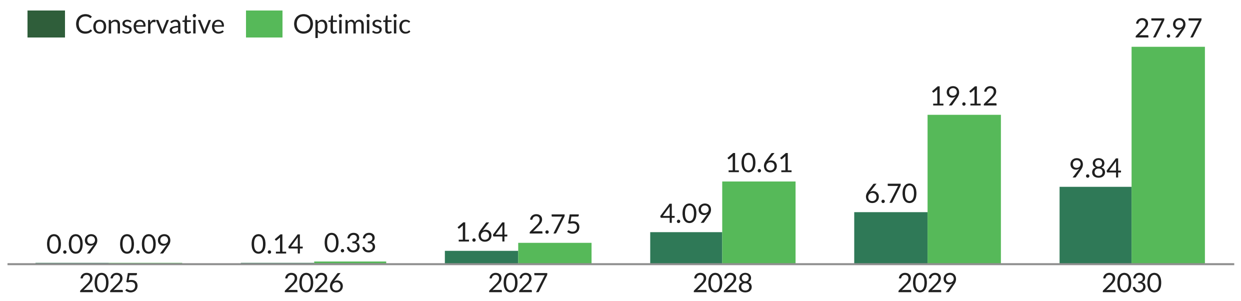
Green hydrogen total projected demand including domestic & exports, 2025-30

Million Metric Tonnes per Annum (MMTPA)



Required electrolyser capacity to meet projected demand, 2025-30

Gigawatt (GW)



Notes: 1. Export potential was calculated based on import requirements for regions that will rely on imports (EU, Japan, Singapore, South Korea and the UK) based on their respective hydrogen strategies and outlook; 2. Refinery sector was assumed to reach 309 Mtpa of capacity by 2030 from 256 in 2024; 3. Additional 6,800 TPA authorised to JSW Energy under the SIGHT scheme has been factored in 2025 demand over and above the built 3,800 TPA

Conservative scenario: 1. Fertilizer demand correspond to tendered green ammonia capacity; 2. Refinery corresponds to a gradual green H2 blending from 5% in 2027 to 15% by 2030 for refiners with >50KTPA H2 consumption; 3. Assumes that India will capture 10% of the export market by 2030

Optimistic scenario: 1. Fertilizer demand assumes 100% import substitution of ammonia by 2030; 2. Refinery corresponds to a gradual blending from 5% in 2027 to 30% by 2030 for refiners with >50KTPA H2 consumption; 3. Assumes that India will capture 30% of the export market by 2030

Source: CEEW and Dalberg analysis

3.5.2 Value chain structure, cost stack, and domestic value capture

India currently captures value in balance of plant (BoP) manufacturing and system integration, leaving much on the table when it comes to the electrolyser stack and its critical components. Across alkaline and PEM electrolysers, balance of plant forms 68-76% of total electrolyser costs. Domestic firms have experience in undertaking metal fabrication for these balance-of-plant components (e.g., frames, vessels, piping, etc.) and integrating off-the-shelf components (e.g., control or SCADA systems) with the core electrolyser stack. Despite these strengths, components like power electronics and sensors remain import dependent. Beyond BoP, key stack components like membranes and diaphragms, electrodes, catalysts, bipolar plates, and the porous transport layers, account for 24-32% of total electrolyser cost and are both material and IP-intensive. Even though they represent a smaller share of total electrolyser cost, these components are the locus of upstream innovation and technology differentiation. Domestic value addition is negligible across most stack components. As a result, India's current domestic value addition is around 35% range for electrolyser systems depending on the final configuration and the extent of BOP localisation[105].

Figure 31: Green Hydrogen value chain and current domestic value capture

Battery and Storage value chain and current domestic value capture[1]

Key Components in the Value Chain		Membrane	Electrodes	Porous Transport Layer (PTL)	Bipolar Plates	Balance of Plant[2]
Cost Contribution (%)	Alkaline	5%	11%	4%	4%	76%
	PEM[3]	6%	16%	7%	3%	68%
Current DVA[4] (approximated)		~0%	~0%	~0%	~15%	~45%
Current Manufacturing Presence		• Non-existent	• Non-existent	• Nascent porous transport layer manufacturing	• Stainless-steel plate blanking, and stamping • Gold coating of stainless-steel roll	• Strong pumps, vessels, power systems
Critical Value Chain Dependencies		• Zirconium dioxide • Nafion membranes • Roll-to-roll casting, sintering machines	• Electrode materials (Platinum, Iridium) • Electrode coating / sintering tools	• Titanium powder • Resin polyacrylonitrile (PAN) • Nickel foam	• High-grade stainless steel / Titanium sheet	• H_2-grade compressors, dryers, storage • Power electronics and sensors in Electrolysers

Notes: (1) While renewable energy contributes over half of green hydrogen costs and is covered under the solar sector, this section focuses on the electrolyser stack. (2) Includes components such as compressors, power electronics, power control systems (sensors), etc. ; (3) Proton Exchange Membrane; (4) DVA has been calculated based on each component's cost contribution and component level import reliance;

Sources: Dalberg analysis; Expert consultations

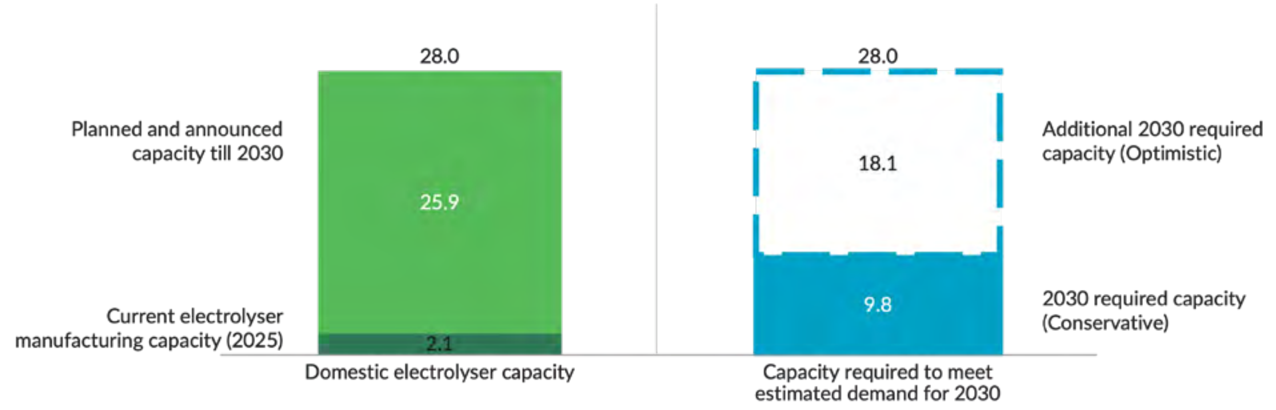
3.5.3 Manufacturing footprint: Current base, announcements, and gap to 2030

India's existing electrolszer manufacturing footprint is set to expand and will be able to serve the projected green hydrogen demand. Existing electrolyser manufacturing capacity in the country stands at ~2.1 GW/year[106]. The existing manufacturing base is well positioned to serve the ~9.8 GW of installed electrolyser capacity needed in 2030 to meet the projected demand for green hydrogen production in the conservative scenario. Additionally, ~26 GW/year of electrolyser manufacturing capacity has been announced of which ~3 GW /year is expected to come up under the PLI scheme.

However, over 90% of the announced manufacturing capacity is yet to begin construction and focus is skewed towards assembly rather than stack localisation[107]. Construction is yet to begin for most of the announced projects. The announced capacity coming online could result in overcapacity compared to the likely demand for green hydrogen in 2030. Given the weak demand signal, the entire announced capacity is unlikely to come online. Further, the announced manufacturing plants are expected to continue to rely on imported membranes, catalyst coatings, and other key stack elements via technology partnerships from international suppliers. While this pipeline could establish India as a large electrolyser assembly hub, without targeted incentive to deepen stack manufacturing, the sector risks locking into an assembly led pathway with continued dependence on imported embedded value.

Figure 32: Cumulative domestic electrolyser capacity vs. required to meet 2030 demand

Electrolyser manufacturing capacity vs. required to meet 2030 demand
Gigawatt (GW)



Note: Based on interviews with industry representatives, electrolyser components are still predominantly (~60–80%) imported and assembled domestically. Therefore, while labelled domestic, still would predominantly depend on imported stack components that are only assembled in India
Source: CEEW and Dalberg analysis

3.5.4 Bottlenecks to scaling domestic manufacturing

Despite strong policy intent under the National Green Hydrogen Mission, India's green hydrogen manufacturing ecosystem remains constrained by a set of interlinked bottlenecks that collectively raise costs, delay scale-up, and weaken incentives for deep localisation[108]. Slow and uncertain demand growth limits the ability of manufacturers to commit to capital-intensive investments in electrolyser stacks and components. Fragmented R&D and dependence on imported materials and equipment constrain domestic learning and technology absorption. Together, these challenges risk locking India into an assembly-led manufacturing pathway:

- **Demand and market architecture:** Slow and uncertain demand growth, and high cost of green hydrogen has undermined manufacturing intent:
  - Higher prices of green hydrogen compared to grey hydrogen has limited offtake. Green hydrogen (typical price of USD 3.5-5 per kg) is 1.5-2x more expensive compared to grey hydrogen (typical price of USD 2.3-2.5 per kg). Higher DISCOM charges levied on renewable electricity supply contribute to 50-70% of this cost differential[109]. The higher price has resulted in limited voluntary offtake, including delays in signing of long-term contracts needed to underwrite investments in electrolyser manufacturing capacity. While the price discovery for green hydrogen during Solar Energy Corporation of India (SECI) led green ammonia tendering in 2025 indicates a sharp reduction in green hydrogen prices may be possible, whether the discovered prices can be sustained remains unclear.
  - The absence of strong, phased blending mandates and green hydrogen price stabilization mechanisms have further led to uncertainty around offtake making it difficult for manufacturers to justify investments in building stack components, despite announced intentions to create this capacity.
  - Current green hydrogen and electrolyser manufacturing PLI schemes are delinked from each other. While electrolyser manufacturing PLIs emphasise domestic value addition, overall green hydrogen production incentives do not specify any requirement to procure domestically manufactured electrolysers. As a result, most production happens via imported electrolysers that are only assembled in India, missing out on a strong signal for producers to uptake electrolysers manufactured locally.

- **R&D and product innovation:** India's green hydrogen R&D ecosystem lacks the scale, collaboration, and infrastructure required to accelerate electrolyser and component development[110]:
  - Existing infrastructure is distributed across multiple institutions (e.g., IITs, IISc, research centres, and national labs). These centres often operate in silos and are de-linked from industry. Fragmented R&D efforts across these organisations reduce the opportunity to build on collective learning, drive strong feedback loops between researchers and industry, and undertake commercialisation-oriented design, testing, and manufacturing process improvements for electrolysers.
  - Many domestic research initiatives are focused on electrolyser components but the lack of megawatt (MW) scale testing and validation infrastructure has restricted this research to TRL 3-5 levels, delaying their commercialisation and increasing reliance on imported technologies for domestic manufacturers.
  - Research investments for finding alternatives to imported membranes, catalysts, and coating are limited. As a result, domestic IP creation is slow and any innovation in core stack materials that are tailored to Indian operating conditions is yet to reach commercialisation.

- **Upstream raw materials and critical inputs:** India's electrolyser manufacturing supply chain relies heavily on imported minerals and proprietary materials making it vulnerable to international suppliers:
  - India has near-total import dependence for materials such as nickel, zirconium dioxide, titanium, platinum, and iridium that are required to manufacture membranes and porous transport layers. None of these minerals are mined or refined domestically. As a result, electrolyser manufacturers are exposed to global price volatility limiting their ability to provide electrolyser systems at competitive prices.
  - Proprietary membrane technologies (e.g., Nafion and Zirfon) are produced by a small set of global firms creating supply security issues and leading to higher licensing costs that reduce profitability for domestic manufacturers, especially if production scale is limited in view of muted or unclear demand.
  - Nascent green hydrogen and electrolyser industry means India currently lacks domestic refining and circularity pathways for minerals highlighted above. As a result, recovery value from end-of-life systems is unclear for manufacturers to be able to hedge against long-term raw material supply concerns.

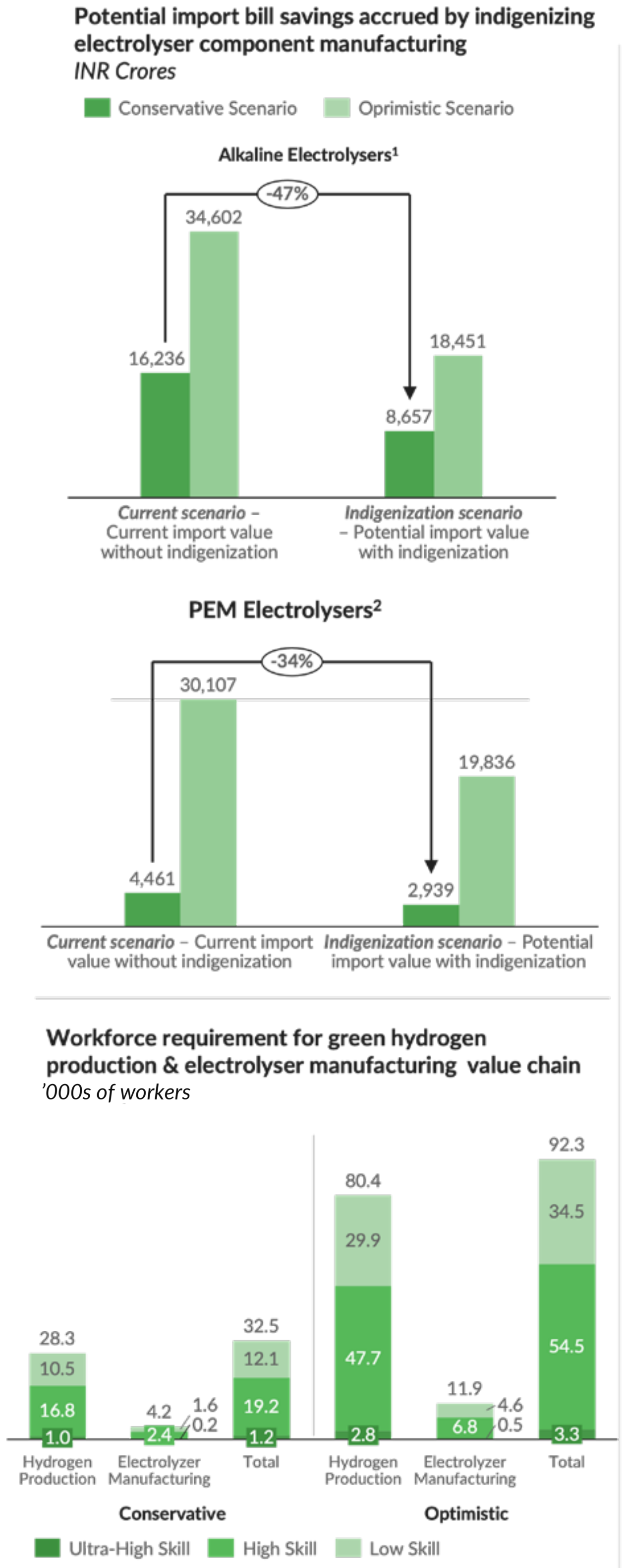
- **Capital equipment and infrastructure:** Limited domestic capabilities to manufacture and maintain specialised equipment required for electrolszer manufacturing has constrained the country's ability to build a competitive manufacturing ecosystem for green hydrogen:
  - Limited availability of high precision equipment for membrane casting, bipolar plate stamping, and advanced coating equipment has restricted domestic production of high-value stack components. Reliance on imported capital equipment has lengthened project timelines and increased upfront capex for setup of electrolyser manufacturing units, particularly for first movers attempting to localise stacks, limiting further investments in electrolyser manufacturing ecosystem.
  - Partial retrofitting of adjacent-industry machinery can support domestic manufacturing but investments in these adapting these machinery are yet to materialise.

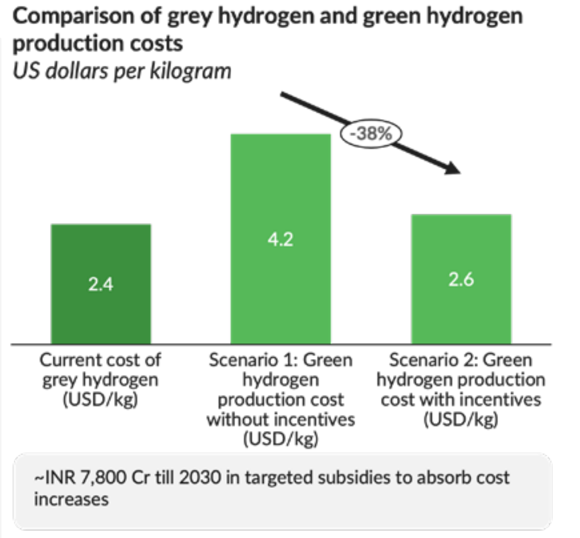
- **Talent and workforce development:** The current training infrastructure is inadequate to meet the estimated requirement for 92,000 direct workers across the green hydrogen and electrolyser manufacturing value chains by 2030[111]:
  - Outdated manufacturing-oriented curricula and lack of demonstration infrastructure for green hydrogen and electrolyser production in ITIs will limit the availability of job-ready technicians for stack manufacturing, testing, and O&M operations as these units come online.
  - India's green hydrogen workforce development will also be constrained by shortage of faculty with exposure to the green hydrogen value chain as most trainers lack hands-on expertise in hydrogen production systems, fuel cells, and safety standards.
  - Industry-linked learning models for ITI and engineering graduates are currently missing. While some structured apprenticeship and internships programs exist, they are yet to be scaled up to meet the expected workforce demand over next five years.

- **Financing and taxation:** We estimate that an investment of INR 20,400 - 46,300 crore is needed over five years to achieve higher indigenisation in the green hydrogen value chain, including electrolyser manufacturing. However, lack of price parity with green hydrogen and limited risk-sharing mechanisms have deterred investment flows into manufacturing scaleup:
  - Investors are wary of large capex investments in electrolyser manufacturing and green hydrogen production due to uncertain long term offtake potential of green hydrogen, and competition from grey hydrogen.
  - Localising the stack is expected to increase the price of domestic electrolysers relative to electrolysers assembled from imported components in the initial years. The lack of financing instruments that can cover investors' risk and ensure low-cost capital for establishing production lines has further constrained and in some cases led to shelving of planned investments in electrolyser manufacturing.

Figure 33: Green Hydrogen manufacturing requirement for materials, talent, equipment, and investment

Breakdown of mineral, workforce, capital equipment and investment requirement for Green Hydrogen





Green hydrogen raw materials dependence

Electrolyser type	Mineral	Current procurement	Import dependency
Alkaline	Nickel	Import	Indonesia, Russia, Canada
	Molybdenum	Import	China, Thailand, Chile
PEM	Platinum	Import	South Africa, UAE, UK
	Iridium	Import	South Africa, USA, UAE
	Titanium	Import	China, Netherlands, South Korea

Capital investment required for setting up electrolyser gigafactories by 2030

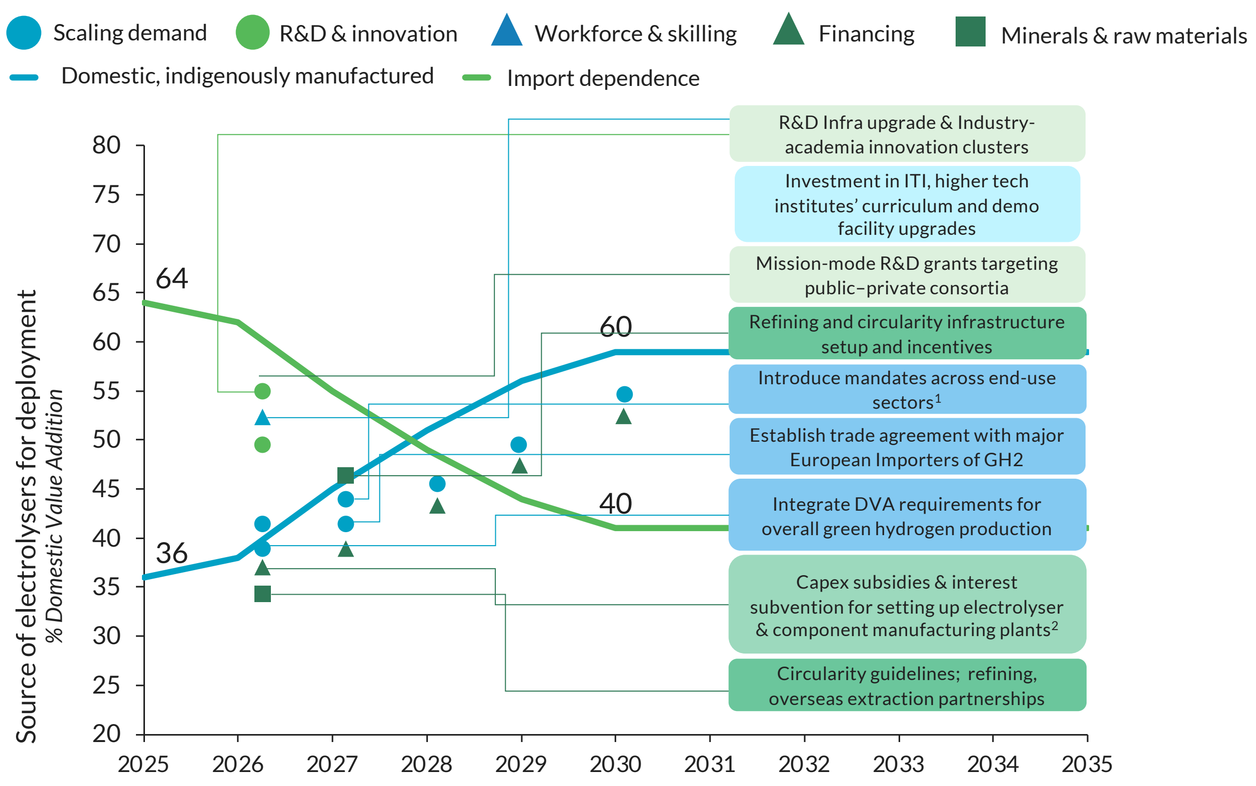
	Electrolyser gigafactories		
	Forecasted additional domestic electrolyser capacity (GW)¹	Required capital investment for setting up electrolyser gigafactories (INR Cr per GW)²	**Total capital investment required (INR Cr)**
Conservative Scenario	6.4	1,760	**11,200**
Optimistic Scenario	21.8	1,320	**28,740**

Note:
Optimistic scenario: 1. Assumes 100% import substitution of ammonia starting 2027; 2. Corresponds to a gradual blending from 5% in 2027 to 30% by 2030 for refiners with >50KTPA H2 consumption; 3. Assumes that India will capture 30% of the export market by 2030
Conservative scenario: 1. Fertilizers correspond to tendered green ammonia capacity; 2. Corresponds to a gradual green H2 blending from 5% in 2027 to 15% by 2030 for refiners with >50KTPA H2 consumption; 3. Assumes that India will capture 10% of the export market by 2030
Sources: 1. Alkaline electrolyser analysis based on: CEEW's Study, 2 PEM electrolyser analysis based on: NREL's Study ; "How can India indigenize and boost domestic hydrogen electrolyser manufacturing," CEEW, 2024; "Manufacturing Cost Analysis for Proton Exchange Membrane Water Electrolyzers," NREL, 2025 ; Indian Minerals Yearbook, Accessed 2025; Industry experts; "Skill Gap Assessment Across Green Hydrogen Sector In India," SSCGJ, 2024; "New ITI upgradation plan aims to enhance employability and seat utilisation," Hindustan Times, 2025; "IITs spends Rs 5.2 Lakh per year per student," Skill Outlook, 2018 "From Promise to Purchase: Unlocking India's Green Hydrogen Demand," CII report, 2025; CEEW & Dalberg analysis

3.5.5 Pathway to indigenising the value chain

Figure 34: Prioritised recommendations timeline to increase DVA in the green hydrogen sector

Green Hydrogen Indigenisation Pathway to Increase DVA and Reduce Import Dependence



Notes: 1. Blending mandates will be phased from 2026-30; 2. Fiscal incentives will be phased from 2026-30; 3. Numbers are based on preliminary analysis and are subject to changes based on industry expert inputs; 4. This assumes that domestic electrolyser manufacturing projects will be constructed and commissioned in time to be part of green hydrogen plants by 2030. If this construction gets delayed, then green hydrogen plants would have to rely on imported electrolysers, thus pushing the achievement of 55% DVA beyond the 2030 timeframe

Source:"How can India indigenise and boost domestic hydrogen electrolyser manufacturing," CEEW, 2024; Dalberg analysis; NGHM website, MNRE, Accessed 2025; "RfS Document for Selection of EM for Setting up Manufacturing Capacities for Electrolysers in India under SIGHT Scheme (Tranche-II)," SECI, 2024

Achieving 60% domestic value addition by 2030 for green hydrogen production will require coordinated progress across all of the above drivers, especially demand creation. Creating and sustaining long term demand for green hydrogen can provide the largest unlock for indigenisation for the value chain. Doing so will require targeted fiscal and non-fiscal measures. Simultaneously, these will need to be complemented with measures to secure supply of critical minerals and capital equipment, creation of R&D infrastructure, and establishing appropriate workforce preparation pathways for the expected demand for skills. Specific recommendations to deliver on these priorities are laid out in the table below.

Figure 35: Prioritised recommendations to indigenise green hydrogen manufacturing

STRUCTURAL DRIVERS	PRIORITISED LEVER
Demand and market architecture	**Short term (0-5 years)** • Introduce phased mandates for refineries, starting at 5% green H_2 in 2027 and rising to 15% in the conservative case and 30% by 2030 if there is industry appetite. These mandates could be targeted only at large refineries (>50 KTPA production capacity) and set at the portfolio level for refiners[112]. • Mandate City Gas Distribution (CGD) blending of 2% (and 5% of suppliers and technological feasibility permits) by 2030, focusing on Piped Natural Gas (PNG) and Compressed Natural Gas (CNG) in high-density CGD states to enable multi-buyer clustering and reduce delivered-cost penalties[113]. • Expand SECI-backed green ammonia tenders beyond initial tranches. The 2025 tender prices were supported by ~INR 1,500 crore in Strategic Interventions for Green Hydrogen Transition (SIGHT) subsidies, introduce future tenders with similar subsidies (additional ~INR 5,000 crore for 100% ammonia import substitution)[114] to accelerate offtake and maintain price competitiveness. • Transition from single tenders to multi-year offtake frameworks for refineries and fertiliser sectors that create predictable electrolyser orderbooks and support standardisation of contracts and performance terms. • Embed weighted DVA scoring within green hydrogen production incentive schemes to favour projects that use indigenously manufactured electrolyser stacks and components, ensuring demand growth also pulls through domestic manufacturing. **Medium term (0-5 years)** • Establish trade agreements and dedicated export corridors with major importers (Europe and others) to lock in long-term export of green hydrogen, while exploring eventual export of indigenously produced stacks/components once supply chains mature **Long term (7+ years)** • Create a long-term green hydrogen roadmap for offtake in hard to abate sectors like steel and end use applications with high potential for substitution if technology readiness is established (e.g., shipping).
R&D and product innovation	**Short term (0-5 years)** • Set up 1–2 national development labs and 4–5 testing labs with to provide MW scale and industry grade testing and validation capacity for electrolyser and sub-components[115]. • Deploy mission-mode TRL 4–5 grants for membranes, porous transport layers (PTLs), bipolar plates (BPPs) and coating processes prioritising public-private/academia-industry partnership and clear manufacturing linked milestones. • Operationalise open-access testbeds with standardised protocols to validate indigenous stacks and enable domestic suppliers to meet DVA targets. **Medium term (5-7 years)** • Create commercialisation pathways that move validated components readily into pilot lines, tying continued support to yield improvement, durability, and cost targets. **Long term (7+ years)** • Maintain a rolling, mission-driven R&D portfolio that upgrades testing infrastructure as technologies evolve (e.g., next-gen membranes/coatings), preventing lock-in to imported IP as scale grows and to establish technological edge.

STRUCTURAL DRIVERS	PRIORITISED LEVER
Upstream raw materials and critical inputs	Short term (0-5 years) • Prioritise supply assurance through diversified sourcing recognising that raw material import dependence will persist to 2030 and beyond for key minerals and proprietary materials where India lacks reserves and refining capacities. Medium term (5-7 years) • Build refining and circularity infrastructure (where feasible) and align incentives so end-of-life recovery begins feeding domestic supply chain. Initiate circularity pathway (standards, traceability, responsibility for recovery), even if volumes remain modest pre-2030 Long term (7+ years) • Scale circularity pathways and explore securing scrap feedstock internationally for domestic recycling and recovery infrastructure. • Secure overseas extraction/refining partnerships to reduce long-run exposure to supply concentration and volatility.
Capital equipment and infrastructure	• Short term (0-5 years) • Retrofit adjacent-industry PVD/CVD, machining and forming equipment for electrolyser components to accelerate near term stack component localisation. • Import specialised machinery where domestic capability is absent including slot-die R2R membrane lines, die-cutting systems and BPP stamping presses. Secure international partnerships with Germany, Japan, and Netherlands to secure this advanced machinery. Medium term (5-7 years) • Build domestic manufacturing capability for critical equipment (e.g., polymer/zirconia membrane casting and commercial-scale BPP stamping) and expand capacity in coating/electrodeposition where partial synergies exist.
Talent and workforce development	Short term (0-5 years) • Launch green hydrogen specific engineering courses and ITI curricula with "train-the-trainer" programs and upgraded demo facilities for SRU, membrane and coating processes at select ITIs. • Create industry-linked apprenticeships for manufacturing, R&D and O&M roles to provide students and graduates with on-the-job skilling opportunities. • Build applied learning infrastructure for stack assembly, BoP production and safety training.
Financing and taxation	Short term (0-5 years) • Deploy a targeted subsidy package of ~INR 5,800 crore to stabilise green hydrogen offtake across ammonia, steel and CGD sectors and enabling demand ramp up[116]. • Provide ~ INR 2000 crore Viability Funding Gap to reduce the cost differential between domestic and imported electrolysers, and thereby incentivising local manufacturers to compete[117]. • Provide interest subvention of ~ INR 200 crore to manufacturers for procurement of membrane/coating/sintering/stamping machinery to reduce cost of manufacturing of critical stack components[118].

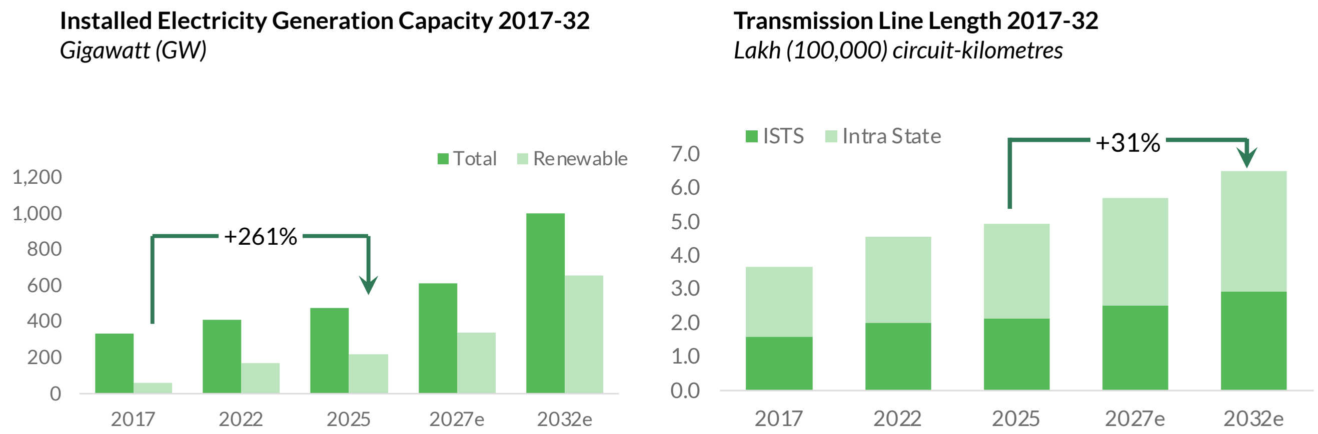
3.6 HVDC Transmission: Localising advanced grid equipment and materials

3.6.1 Demand outlook to 2030

India's power system expansion is expected to add over 6.4 lakh circuit kilometres (ckm) of transmission lines, including high voltage corridors, by 2031-32. The National Electricity Plan (NEP) projects strong growth in renewable electricity generation capacity by 2032 requiring efficient power evacuation to load centres. Accordingly, the plan envisages addition of over 75,000 circuit kilometres (ckm) of high voltage transmission lines between 2027-2032.

High Voltage Direct Current (HVDC) is expected to play a central role in this next phase of India's electricity grid build out. Given the renewable expansion, new transmission corridors will be required to connect renewable energy hubs in states like Rajasthan with load centres in other states. Given the long distances involved in evacuating this power, creation of HVDC transmission systems will be vital. While these systems have a 30-40% higher upfront capital cost compared to HVAC transmission lines, owing to reduced losses and avoiding the need for multiple parallel AC lines, they deliver 5-10% lower levelised cost of electricity for transmission distances above 800 km. Accordingly, NEP envisages major HVDC build-out including ~33 GW of HVDC bi-pole links and (for FY28–FY32 specifically) around 15,000 circuit km of HVDC lines. This translates to ~8% of the planned total line additions between 2022-2032. Development of these HVDC corridors will create a sizable market for HVDC equipment including converter stations with converter transformers, valves, DC switchgear, conductors, and towers[119].

Figure 36: Transmission grid capacity and infrastructure



Notes: High Voltage Transmission: ≥220 kV
Source: CEA National Electricity Report "National Electricity Plan Vol I - Generation", CEA, 2023 & "National Electricity Plan Vol II - Transmission", CEA, 2024; PIB press releases; "Transmission sector overview", Ministry of Power, Accessed October 2025

3.6.2 Value chain structure, cost stack, and domestic value capture

Approximately 70% of the HVDC transmission project's value, excluding civil works, is concentrated in substations and converter components, rather than line-infrastructure[120]. Converter hall components such as converter transformers, converter valves, and DC switchgear require specialty materials and precision engineering, and form the majority of an HVDC transmission project cost. Line infrastructure, including towers and conductors, while large in their physical scale, account for only 30% of the value of a typical HVDC project. This is different compared to High Voltage Alternating Current (HVAC) systems where line infrastructure accounts for 70% of the overall cost.

India has limited manufacturing capabilities to manufacture these components in house. The HVDC value chain comprises three broad blocks including sub-station and switchyard, converter stations, and transmission lines and towers. India has a strong industrial base for manufacturing of transmission lines and towers. However, unlike HVAC equipment manufacturing where deep localisation exists, domestic capability in producing high value HVDC component such as converter valves, advanced DC switchgear and breakers, and the associated power electronics systems (e.g., power filtering and control) is limited. As a result, domestic value addition for HVDC transmission systems in India is approximately 55% compared to 80-90% for HVAC systems[121].

Figure 37: HVDC Transmission value chain and current domestic value capture

Battery and Storage value chain and current domestic value capture

Components in the Value Chain	Converter Transformer	Converter Valves	DC Switchyard	Lines
Cost Contribution (approximate %)	30%	25-30%	10-15%	30%
Current DVA[1] (approximate %)	~70%	~30%	~5%	~80%
Current Manufacturing Presence	• Core, windings, bushings and most of the other ancillary components	• Valve Hall assembly and installations	• DC capacitors and reactors at lower voltages (<400KV)	• Towers, conductors, cables and insulators/joining kits
Critical Value Chain Dependencies	• CRGO[2] steel	• Valve module packaging and sub assembly using semi-conductor devices, heat sinks, cooling systems and other HV[3] passive components	• DC capacitors and reactors at higher voltages (>400KV)	• Electrical-grade copper

Notes: (1) DVA has been considered at an individual component level, amounting to ~30% DVA across the value chain; (2) Cold Rolled Grain Oriented Steel; (3) High Voltage
Sources: Dalberg analysis; Expert consultations

3.6.3 Manufacturing footprint: Current base, announced capacity, and gap to 2030

India has a strong manufacturing base for conventional transmission equipment and a growing footprint in select HVDC components, but high-end and value-dense converter and HVDC equipment remain import-dependent. On the HVAC front, India already manufactures a wide range of equipment including transmission conductors, insulators, transformers, reactors, controllers and a broad portfolio of switchgear and substation components. Domestic firms have the volume and quality to meet most of the HVAC requirements in India. However, the broader HVDC manufacturing picture is mixed. While India is self-sufficient in manufacturing towers and conductors, OEMs in India also have some manufacturing capability for HVDC transformers, associated AC switchgear and related auxiliary systems. However, domestic capability in manufacturing advanced components, such as converter valves, DC breakers, specific control and protection systems, is non-existent. Much of this equipment is supplied by a small set of global OEMs who do not currently undertake manufacturing operations in India for these components. While several manufacturers have announced intention to set up manufacturing facilities that can undertake local assembly or manufacturing of some of these components, the required manufacturing investments or sites remain in the pipeline stage.

3.6.4 Bottlenecks to scaling domestic manufacturing

The National Electricity Plan envisages an investment of INR 1.5 lakh crore to set up the required HVDC transmission infrastructure in India by 2032. While this represents sizeable demand, India's HVDC manufacturing ecosystem is faced with several interrelated bottlenecks that prevent it from reaching a stage where the high-value components can be manufactured domestically and competitively:

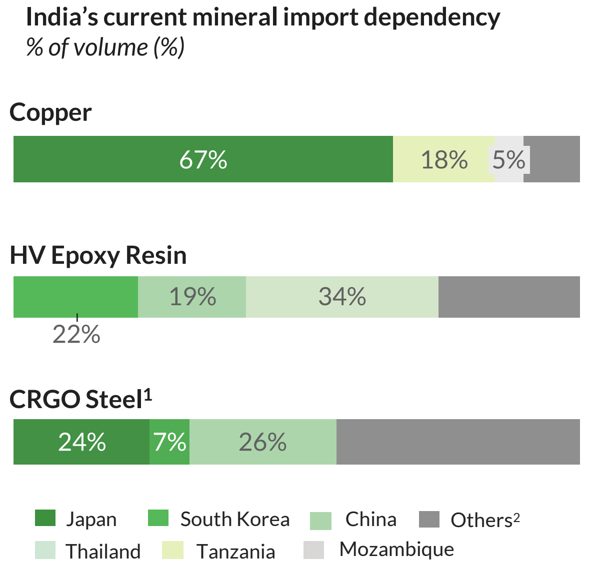
- **Demand and market architecture:** Although there is a well-recognised long-term need for HVDC transmission corridors in India, project-level demand and component demand visibility over a long term remain disaggregated for manufacturers:
  - CEA's National Electricity Plan (NEP) sets out the system-level roadmap for transmission infrastructure to 2032, including addition of 75,000 ckm of high voltage transmission lines by 2032. However, this plan has not translated into a clear, component-level demand outlook. Lack of project level design specifications across HVDC projects mean that component requirements can differ widely, preventing OEMs from building an aggregated and predictable view of demand volume across components like converter valves, DC breakers, reactors, and switchgear. Without credible multi-project, component level visibility, domestic manufacturers and international OEMs who might be interested to set-up production lines in India, face high risk of underutilised capacity.
  - HVDC projects are large, awarded as infrequent tenders bunched together and are often subject to process frictions like component eligibility screening and right-of-way reroutes that disrupt order implementation timing. The uneven and uncertain order book makes it challenging for manufacturers to justify investments in new product lines.
- **R&D and product innovation:** HVDC technologies are complex requiring adaptation for India's unique geographical and environmental conditions and an advanced testing base for key components. However, research and product innovation for these equipment remains limited and scattered across multiple institutions without a single mission-oriented approach:
  - Core HVDC technologies such as modular multilevel converters, DC breakers, advanced installation systems, and ultra-high voltage DC filters require sophisticated laboratories and test beds. However, laboratories and organizations lack the required infrastructure for system-level simulation, prototyping, and testing to develop and qualify these HVDC components in line with global standards. Their efforts are also fragmented between each other and lack linkages with OEMs to undertake mission-mode R&D.
  - Most advanced HVDC components such as converter-valve dies and optical triggering systems are concentrated in a few global firms with strong IP protections. Indian man-

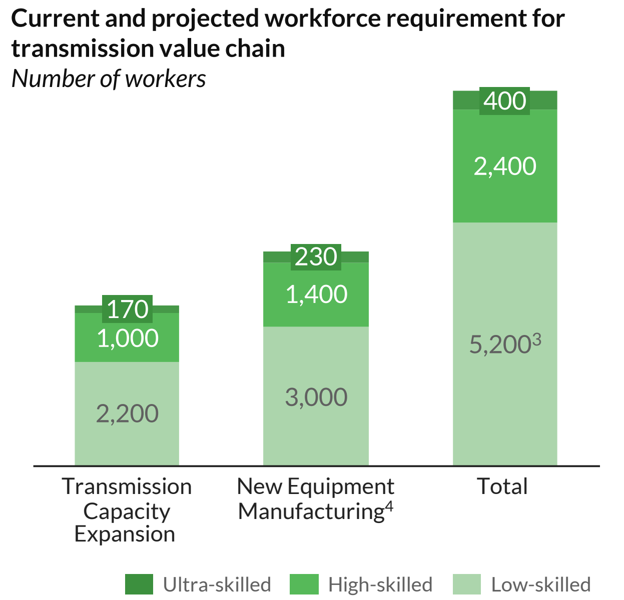
ufacturers mostly operate as assembly points using imported sub-assemblies with limited transfer of design or process know-how.

- **Upstream raw materials and critical inputs:** Besides reliance on imports for high-value sub-assemblies, India remains dependent on imports of key upstream materials for manufacturing of other components such as conductors and insulators:
  - More than 90% of India's Cold Rolled Grain Oriented Steel (CRGOS) required for manufacturing of transformers and other equipment is imported despite a mature steel industry[122]. The absence of long-term, aggregated demand assurance to steel manufacturers have prevented manufacturers from making capex investments to establish dedicated steel mills for this speciality grade steel.
  - More than 50% of India's copper requirements for producing high grade conductors are met via imports. Limited circularity for metals and critical materials used in HV equipment, and recycling of complex components has further constrained the domestic supply.
  - Similarly, high voltage insulation materials and epoxy resins required for components like arresters and bushings, are largely sourced from countries such as Thailand, China, and South Korea with limited domestic know-how for manufacturing these materials.
- **Capital equipment and infrastructure:** IP protection and the limited view of capital equipment required for sophisticated plants and precision machinery used in HVDC component manufacturing, present entry barriers for manufacturers:
  - Establishing manufacturing for HVDC valves, DC switchgear and converter components requires specialised production lines operating with high precision machinery in clean environments. Global demand for such manufacturing equipment for HVDC is limited and IP for specialised machines rests with a handful of firms. Localisation of manufacturing for these capital equipment remains unjustified due to technological complexity and limited anticipated volume for such machinery in India, even if manufacturing was to be localised.
- **Talent and workforce development:** The country lacks the skilling and training infrastructure to impart specialised skills required to meet India's workforce needs in HVDC manufacturing – an estimated ~8000 workers over the next five years[123]:
  - Tier I/II engineering curricula offer limited training in HVDC, VSC and modern grid systems, while most ITIs lack advanced labs for hands-on high-voltage learning.
  - Absence of skilling roadmaps that are aligned to transmission sector needs and weak linkages between ITI and Small and Medium Enterprises (SMEs) responsible for ~90% of component production, mean that the latter have little participation in skilling of ITI students despite their talent requirement. Unlike large OEMs, they also lack the capacity to run specialised training programs in-house.
- **Financing and taxation:** We estimate that an investment of more than INR 27,200-33,200 crore is needed to create the HVDC transmission infrastructure and domestic component manufacturing capacity in the country. However, the high cost of capital and revenue risk originating from a narrow customer base result in higher perceived risk by private sector to invest in domestic manufacturing operations in India:
  - HVDC component manufacturers face high upfront capex costs for establishing production lines and acquiring specialised machinery. Given the long payback timelines for transmission projects and the lack of tailored financial instruments to offer financing over such long periods, capital availability for manufacturing expansion is limited.
  - Potential revenue for manufacturers is concentrated in a limited number of turnkey contractors and buyers (primarily central and state transmission utilities) which increases risk to revenue due to delayed project execution and payment timelines. Combined with potential price competition from global OEMs and technological obsolescence risks, investments in HVDC projects are considered high risk.

Figure 38: HVDC manufacturing requirement for materials, talent, equipment, and investment

Breakdown of mineral, workforce, capital equipment and investment requirement for transmission





Capital equipment import dependence
%

Component	Import reliance[5]	Key machines – Already manufactured in India	Key machines – Import dependent
Transformers (Power & Converter)	70-80%	CNC press brake, CNC HV/LV wire-winding machine, vacuum drying oven, CNC plasma cutting table, column & boom welding manipulator, pressboard cutting	Foil winding machine, mobile VPD service plant, step-lap core cutting line, offline/automatic core-stacking robot & software, automatic insulation taping machine
GIS	70-80%	Heat-treat ovens, floor-type horizontal boring & milling, large-envelope VTL, clean/dry room, Ag/Ni plating line	Low-pressure die-casting cell, 5-axis gantry machining centre, filtration & storage skids, APG press, vacuum epoxy casting system, gas evacuation & recovery cart
Converter Valves	40-50%	Lightning impulse generator, HV AC/DC sources, clean assembly hall, vacuum brazing furnace, DI/UPW system	Fiber harnessing benches, SMT line, IEC 60700-1 valve test bay, burn-in racks, precision hydraulic clamping rigs, PD measurement system

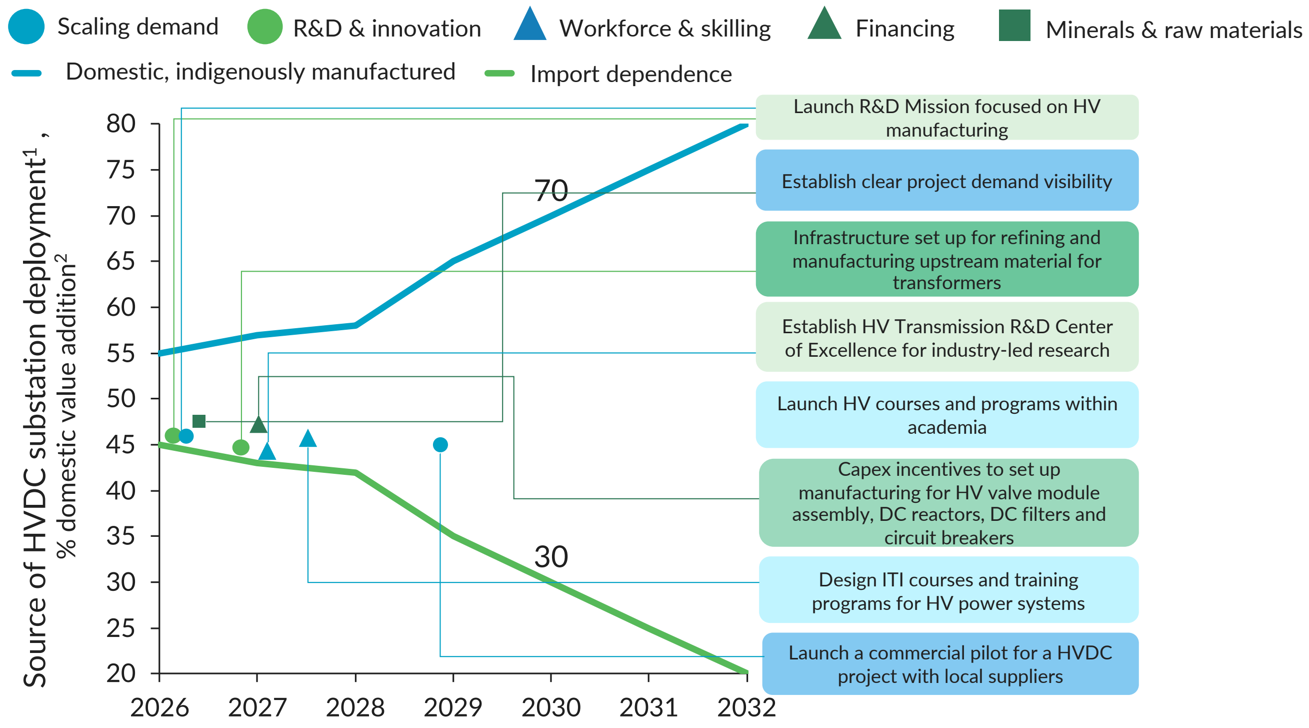
Already manufactured in India · Import dependent

Notes: 1. Ministry of Commerce track CRGO under HSN code 72251100 which includes both cold rolled and hot rolled grain oriented electrical steel; b) India is still importing CRGO from China because of the existing contracts; 2. Others' category may include countries already shown in the legend; 3. 65% are low skilled roles, ~5000 jobs; 4. Includes 100% indigenisation of AC and DC switch gear for HVDC systems; 5. Calculated by cost and volume required to fulfil component demand for 2032 5.Demand under the transmission sector is primarily government driven, and has been estimated by CEA to reach 6.5 lakh ckm by 2032.
Source: "Tradestat EXIM Data Bank", Ministry of Commerce and Industry , accessed October 2025, "Copper Quality Control Order: A step towards Atma Nirbharta", Ministry of Mines, 2024; "Copper in India", International Copper Association India, 2024; "World Energy Employment Report", IEA, 2024; "Transforming Industrial Training Institutes", Niti Ayog, 2023; "National Electricity Plan, Volume II – Transmission", MoP CEA, 2024; Company announcements; Dalberg analysis

3.6.5 Pathways to indigenising the value chain

Figure 39: Prioritised recommendations timeline to increase DVA in the transmission sector

Transmission Indigenisation Pathway to Increase DVA and Reduce Import Dependence



Notes: 1. Only substation costs are considered for the analysis of DVA and includes 30% installation and civil costs that are already indigenised; 2. DVA calculated based on cost contribution to the value chain and not the margins; Numbers are based on preliminary analysis and are subject to changes based on industry expert inputs
Source: "National Electricity Plan, Volume II – Transmission", MoP CEA, 2024, Company Announcements, "BHEL Product Profile", BHEL, Accessed in October 2025, Industry experts, Dalberg Analysis

India can turn its HVDC build out into an opportunity to build manufacturing capabilities for technology intensive components. To attract manufacturers and achieve 70% indigenisation, India must build a clear 10–15-year roadmap for inter-state and intra-state projects to signal credible demand, invest in developing high-end testing facilities and provide fiscal and non-fiscal support to manufacturers to localise critical HVDC equipment. The table below provides prioritised recommendations for India to build a globally competitive HVDC manufacturing base:

Figure 40: Prioritised recommendations to indigenise transmission manufacturing

STRUCTURAL DRIVERS	PRIORITISED ACTIONS
Demand and market architecture	Short term (0-5 years) • Translate NEP and planned corridors into a clear HVDC project pipeline with indicative commissioning timelines and component-level demand estimates. • Structure upcoming HVDC tenders to include localisation roadmaps and clear component evaluation guidelines for higher domestic value addition, especially in valves, DC switchgear, capacitors and reactors. • Leverage flagship corridors as anchor projects for domestic HVDC component deployment, with structured risk-sharing and performance-based acceptance criteria Medium term (0-5 years) • Move from project-by-project localisation clauses to a phased framework of minimum DVA thresholds for critical HVDC components across all central and state procurement. • Position India as a regional supplier of HVDC components and systems to South Asia, the Middle East and Africa, aligning standards and interoperability to target export markets.
R&D and product innovation	Short term (0-5 years) • Create equipment testing and certification network at laboratories across institutions such as CPRI and BHEL with capabilities in simulation studies, prototyping, and high voltage testing via provision of INR 500 crore. • Establish an HVDC R&D mission with cross institution collaboration and joint workstreams focused on priority technologies such as advances insulation, Modular Multilevel Converter (MMC) topologies, DC filters, and DC breakers. Medium term (5-7 years) • Create structured programs such as faculty in industry, industrial fellowship, and industry sponsored research programs to accelerate knowledge transfer to accelerate HVDC design and manufacturing knowledge from OEMs to dedicated academic institutions and research groups. • Develop shared testbeds and pilot installations within live or planned HVDC projects to validate domestically developed components under real operating conditions.

STRUCTURAL DRIVERS	PRIORITISED ACTIONS
Upstream raw materials and critical inputs	Short term (0-5 years) • Secure expansion of domestic manufacturers of high-voltage epoxy resin (i.e., Bisphenol A and Epichlorohydrin) and specialised composites through demand assurance and capital subsidies. • Support accelerated commissioning of recently announced CRGOS manufacturing capacity and creation of additional capacity by offering price-based guarantees that can insulate manufacturers from reduction in international prices. • Provide capex subsidies for creation of copper recycling capacity to meet 40-50% of the transmission demand locally and formalize and upgrade the currently unorganised collection and recycling sector. Medium term (5-7 years) • Encourage investments in domestic production of select HVDC-grade materials where economically viable by establishing manufacturing clusters and facilitating approvals for creation of these facilities. Long term (7+ years) • Integrate HVDC components into broader critical materials and circulatory strategies including recycling and recovery of metals such as copper and other specialised components from decommissioned transmission and other electrical equipment
Capital equipment and infrastructure	Short term (0-5 years) • Provide targeted subsidies and demand assurance to domestic manufacturers to adapt equipment and scale production of machines such as CNC brake machines, wire winding machines, boring and milling machine tools for Gas-Insulated Switchgear (GIS) manufacturing, and other machines with a domestic base.
Talent and workforce development	Short term (0-5 years) • Set up a dedicated Centre of Excellence for HVDC systems with an investment up to INR 100 crore that can support curriculum development, provide simulator exposure and platforms to engineers, run specialised courses, and coordinate apprenticeships with OEMs and utilities. • Launch skilling programs to train around skilled workers across high-voltage engineering, converter design, testing, installation and O&M. Medium term (5-7 years) • Embed specialised HVDC design and manufacturing coursework as specialisations in undergraduate and graduate engineering programs with structured apprenticeships with HVDC OEM manufacturers. • Launch upskilling courses for engineers and technicians across private sector but also transmission utilities like PGCIL to upskill on evolving HVDC technologies.
Financing and taxation	Short term (0-5 years) • Create a dedicated HVDC fund under existing infrastructure or green-energy schemes, targeting INR 3,000–4,000 crore to support high-priority but commercially marginal corridors (e.g., remote RE zones, cross-border links). Medium term (5-7 years) • Leverage blended finance structures and infrastructure bonds to crowd in private capital for HVDC manufacturing.

4 National Policy Agenda for Cleantech Manufacturing

The sectoral blueprints shared in the previous chapter highlight common structural bottlenecks that constrain India's ability to scale cleantech manufacturing. The National Manufacturing Mission, announced in the Union Budget 2025-26, explicitly identifies cleantech as a priority area and commits to building domestic ecosystems for solar PV cells, EV batteries, motors and controllers, electrolysers, wind turbines, and grid-scale batteries[124].

This chapter translates cross-cutting constraints into a coherent policy agenda that builds on and strengthens existing initiatives. Together, these recommendations address six structural drivers: demand and market architecture; R&D and product innovation; upstream raw materials and critical inputs; capital equipment and infrastructure; talent and workforce development; and financing and taxation.

4.1 Architecting demand and market to incentivise domestic value addition

Clear and predictable demand signals are among the most critical enablers for domestic cleantech manufacturing. These signals are essential for manufacturers and investors to spot opportunities and understand the business value proposition to make investment decisions. On the other hand, demand uncertainty can limit investments in cleantech manufacturing. The policy agenda for driving demand for domestically manufactured cleantech components rests on two pillars (figure 41):

Figure 41: Pathways to accelerate cleantech demand and unlock domestic value addition

A — Drive cleantech adoption in domestic end-use sectors and export markets

Introduce mandates and incentives in domestic end-use sectors to drive cleantech adoption and capture additional demand via export markets

B — Drive demand for local components through domestic content mandates

Integrate phased DVA requirements into existing and new government schemes to build demand for domestically manufactured components

Creating demand through end use mandates, private sector incentives, and export market development: As the sectoral analyses in the previous chapter demonstrate, cleantech demand visibility is largely short-term across sectors. Shifting policy, short tenor tendering, and fluctuations in tendering have led to demand related uncertainty. In solar, tender issuance fluctuated significantly between 2020 and 2023, with below-par volumes contributing to installation shortfalls. In electric mobility, the transition from FAME-II to PM E-DRIVE created interim uncertainty, while EV subsidy revisions in states like Gujarat (where purchase incentives were reduced in 2023) have affected manufacturer planning horizons[125]. Green hydrogen remains at the pilot scale, with NGHM's Strategic Interventions for Green Hydrogen Transition (SIGHT) program disbursing limited volumes against ambitious 2030 targets.

These stop-start patterns result in a lack of bankable demand pipelines for manufacturers to anchor on, deter investments in manufacturing capacity, and lead to higher perceived risk that existing plants or those already under construction might operate below capacity. Building a credible demand pipeline requires action on four areas:

- **Introduce end-use mandates in sectors with large utility-scale projects and significant public sector involvement.** Incorporating strategic demand interventions such as mandatory blending mandates for green hydrogen in refineries and fertilizer plants, as well as sectors like city gas networks can anchor predictable demand for green hydrogen. Similarly expanding mandates for battery energy storage systems (beyond utility scale solar) can create long term demand assurance in key sectors.

- **Provide targeted incentives to help private sector actors to absorb transition-related price increases.** For example, in electric mobility, PM E-Drive already provides demand-side support through purchase incentives and charging infrastructure linked subsidies.[126] Additional measures such as fleet financing mechanisms are needed to ensure that the total cost of ownership for commercial vehicles is favourable. Similarly, fiscal mechanisms (e.g., viability gap funding) are needed to complement existing sales-linked subsidies that can ensure manufacturers are able to maintain price parity with imports while building their competitiveness over time.

- **Tap export opportunities as global buyers seek supply chain diversification.** India's solar module exports surged from USD 87 million in FY 2021-22 to over USD 2 billion in FY 2023-24 as buyers globally sought alternatives to their traditional suppliers[127]. Even as the current geopolitical environment is in flux, deepening bilateral and multilateral ties with potential markets like EU, Africa, and ASEAN nations can expand demand for cleantech components like solar modules, wind turbines and green hydrogen manufactured in India.

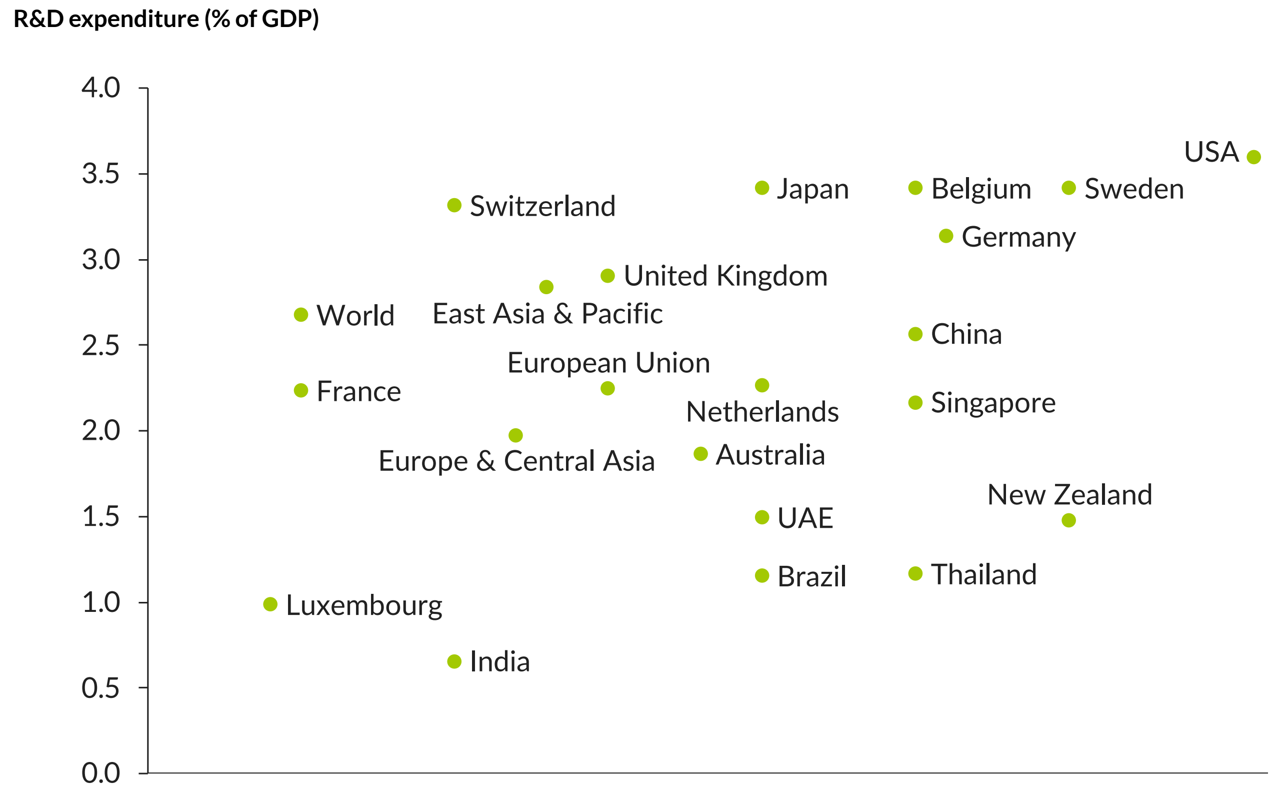
Driving demand for local components via domestic content mandates. Demand creation must be consistently linked to domestic value addition requirements to channel off-take into upstream value chain manufacturing. Existing policy instruments already demonstrate progress on this front, but gaps persist. The approved list of models and manufacturers for the solar industry has driven domestic module manufacturing capacity to 74 GW as of March 2025[128]. However, the cell manufacturing capacity still lags at 25 GW and imports reached a record 29.5 GW in the first three quarters of 2024 alone[129]. The revised ALMM mandating domestically manufactured cells from June 2026 represents the next phase of localisation[130].

However, such mandates need to be seamlessly integrated across sectors including wind, green hydrogen, and battery energy storage systems. Creating these linkages requires:**Phased DVA requirements appropriately timed to domestic capacity build-out.** Solar and wind sectors should see immediate strengthening of ALMM via higher and quantified requirement for DVA integration mandated by MNRE. Similarly, for batteries the approved list of pack-in-cell manufacturers should be operationalised and progressively increased by MHI once domestic cell production starts to scale. Similarly for e-mobility, green hydrogen and HVDC transmission, phased DVA mandates should be introduced in the short to medium term reflecting end-to-end supply chain considerations and not just the final product (example including domestic electrolyser as a component of DVA in green hydrogen manufacturing).

4.2 Building a cleantech R&D and innovation backbone

India's cleantech innovation ecosystem requires clear technology prioritisation and coordinated investment to move beyond assembly-led manufacturing. India's Gross Expenditure on R&D (GERD) stands at approximately 0.6% of GDP[131], well below the global benchmark of 2–5%[132]. This historical underinvestment, combined with fragmented efforts across institutions, limits India's ability to develop indigenous capabilities in core cleantech. R&D efforts in cleantech remain siloed with no national prioritisation framework, risking duplication and missed long-term value creation opportunity. Unlocking R&D efforts requires an integrated framework to drive translational research that assesses emerging technologies on maturity and potential impact and can guide investments in domestic R&D efforts. This framework could help identify a prioritised set of technologies by classifying them into four groups:

Figure 42: India's GERD compared to other countries



Note: Data years differ by country (2020–2023, latest available)
Source: "Research and development expenditure (% of GDP)," World Bank Group, Accessed 2025

- **Technology transfer and commercialisation-ready technologies:** Market-ready technologies suitable for technology transfer (e.g., via licensing) and rapid localisation.
- **Indigenous R&D focus technologies:** Early-stage technologies where India can build competitive advantage through accelerated R&D and prototyping.
- **Technologies for strategic monitoring:** Early-stage and potentially frontier innovations where long term commercialisation potential is unclear and that need long-term tracking before committing resources.
- **Technologies with limited likely impact:** Technologies with limited near-term impact on cost and efficiency or those not suitable for Indian conditions.

This prioritisation could be reviewed annually to align the country's R&D roadmap with the evolving global and domestic cleantech landscape.

To aid the identification of technologies and then drive subsequent research efforts, policy action along four areas is needed:

A. Upgrade research infrastructure and enable access to specialised equipment. India's cleantech research infrastructure is fragmented, with few open-access facilities beyond Atal Innovation Centres, select IITs and underutilised government Centres of Excellence. Access to high-cost, sector-specific equipment such as green hydrogen test beds, clean rooms, and grid simulators for high voltage research, is also uneven. A national network of sector-specific, state-of-the-art R&D labs building on existing Department of Science and Technology (DST) backed research centres and SATHI facilities in IITs could provide open access testbeds and development labs for technology research, development, and certification.

B. Ensure capital access via ANRF and RDI is mapped to the risk appetite for lower TRL bands. Early-stage innovations often face a valley of death where perceived risk can deter funding for R&D. Even where government schemes to disburse grants for research and product innovation exist, researchers often face complicated application requirements to prove viability, long decision-making timelines, delayed fund disbursement, and complicated utilisation led reporting that can slow down the pace of research efforts. Unlocking funding rapidly and through the right mechanisms to early-stage innovations can ensure that bold R&D efforts are not hampered. The Anusandhan National Research Foundation (ANRF) and schemes like Research, Development, and Innovation (RDI) can lead efforts to channel mission-driven funding by drawing upon lessons from successful programs like BIRAC in the life sciences and IDEX to back innovations, especially in TRL 4 to 6 stages. The following exhibit summarises potential instruments that could catalyse investments in cleantech R&D across TRL bands[133]:

Figure 43: Potential instruments to finance R&D at different TRL levels

TRL Band	Recommended Interventions	Details
TRL 1–3 Idea to lab proof	Dedicated innovation fund	A pooled pre-seed innovation fund blending public R&D grants with corporate CSR/VC catalytic capital
	Challenge-based innovation prizes	Modeled on global ARPA-E/EIC calls, prize-based competitions for MSME innovations for various cleantech sectors. Similar to China's **"Little Giants"** program which certifies high-tech SMEs for preferential loans, subsidies, and research partnerships – demonstrating how early-stage public support plus recognition can unlock MSME innovation
	Co-funded industry–academia challenge programs	Use joint government–industry funding models (e.g., IMPRINT) to launch challenge calls that deepen collaboration between MSMEs, academia, and global partners, accelerating early-stage cleantech innovation
TRL 4–6 Prototype to pilot in a relevant environment	Blended-finance bridge funds	Structures that pair concessional debt or first-loss guarantees with private VC.
	Extended EvolutionS-type programs	Larger ticket sizes (INR 2–5 crore vs. INR 50 lakh) through state incubators, tied to performance milestones
	OEM-backed pilot funds	Co-financing pools where OEMs and Tier-1s share pilot risk with MSMEs, ensuring order visibility
	Enhance utilisation of equity fund from SIDBI	Simplify access and broaden eligibility for MSMEs while building readiness programs for equity investments to ensure fuller fund utilisation
TRL 7–9 Pilot plant to commercial scale	MSME-tier PLI	Lower eligibility thresholds (e.g., INR 50 crore revenue instead of INR 500 crore) and milestone-based disbursal
	Interest subvention funds	Dedicated concessional loan window reducing MSME borrowing costs from ~12–17% down to 7–8%
	Transition funds with co-investment	Government-backed cornerstone investors catalysing family offices/DFIs into MSME tech-upgrade funds

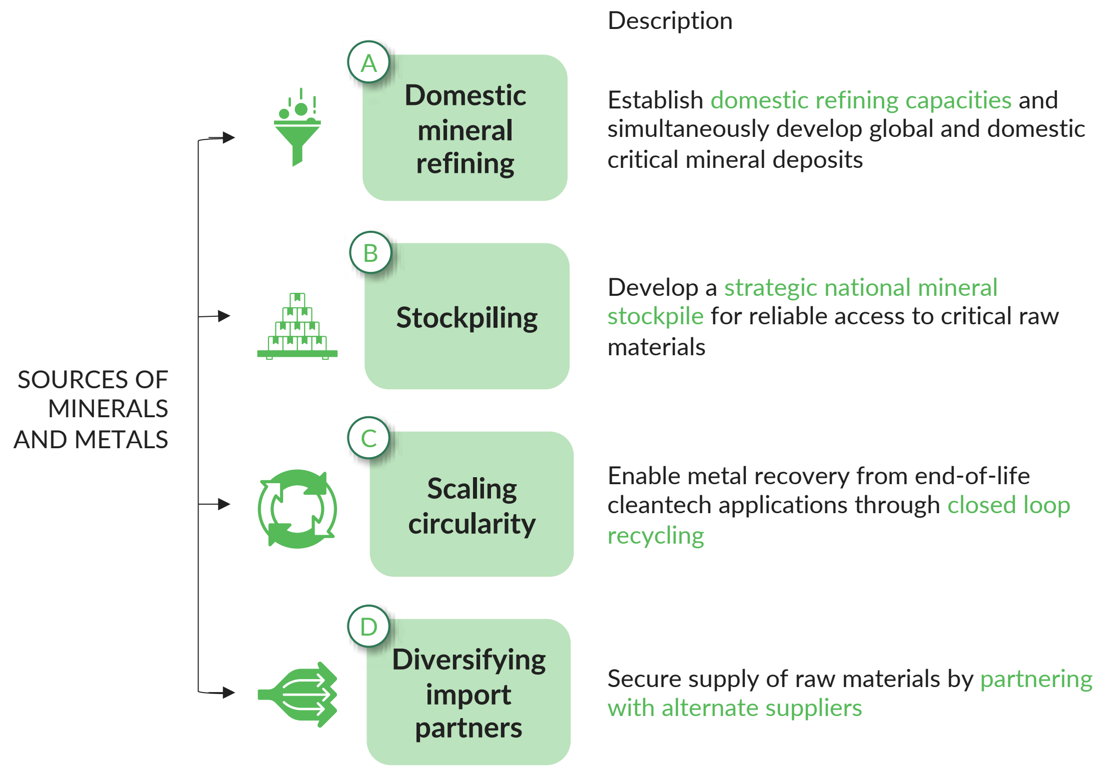
Sources: Dalberg analysis; Expert consultations

C. Strengthen industry-academia-government collaboration. ANRF can spearhead the cleantech R&D mission for the country advised by key ministries such as MNRE and also industry representatives. A dedicated body, with representatives from different ministries, leading academic institutions, and industry could undertake joint activities to set national research priorities in line with industry needs, oversee the implementation of various research schemes, and lay down clear commercialisation pathways. Further integration such as the joint vetting of research proposals and co-investments (e.g., matching grants or follow on equity) could also aid commercialisation.

D. Incentivize private sector to increase investment in R&D and innovation. Ministry of Finance can offer tax deductions on R&D investments for corporates availing benefits under the PLI scheme as incentive to drive greater allocation of their funding towards the six cleantech value chains. This could be structured as 150-200% deduction on entire R&D expenditure on technologies for these value chains provided that the R&D expenditure exceeds at least 1% of the company's gross revenue.

4.3 Securing critical raw materials and capital equipment

Figure 44: Pathways for reducing India's critical mineral import reliance across cleantech value chains



Source: Dalberg analysis

Securing raw materials, including critical minerals to support cleantech manufacturing, requires co-ordinated action across four pathways - domestic mineral refining, strategic stockpiling, scaling circularity, and import diversification. India's cleantech manufacturing expansion is constrained by heavy import dependence of raw materials, especially critical minerals, on imports. For example, China supplies more than 80% of India's lithium, 76% of the country's silicon, and over 85% of bismuth[134]. Similar levels of import dependence on China persist across other minerals such as rare earth elements (imported mainly as rare earth oxides or REOs). On the other hand, the domestic refining capacity for these minerals is limited, even when domestic deposits exist, due to limited exploration activity to identify and turn reserves into mines, and limited technology access for refining. Material circularity that could strengthen domestic material supply is also nascent due to poor waste-collection and processing systems. The National Critical Minerals Mission (NCMM) launched in January 2025 under the Ministry of Mines (MoM) with an outlay of ~INR 34,000 crores, provides the institutional framework to take coordinated action across the critical mineral value chains[135]. Specific actions within and complementary to the mission include:

- **Expand domestic refining capacities and develop global and domestic critical mineral deposits.** India can expand its refining capacity for polysilicon, battery-grade graphite, and light rare earth oxides through targeted capex incentives under NCMM, existing duty exemptions, and electricity-cost support while accelerating mineral exploration through composite licence auctions. Domestically, the Geological Survey of India has undertaken 368 exploration projects for critical minerals over the past three years, with 195 projects underway in FY2024-25[136]. India has also been successful in tapping overseas mineral deposits with KABIL's 2024 agreement with Argentina to drive exploration and development of five lithium brine blocks covering ~15,700 hectares as well as partnerships with Australia's Critical Minerals Office[137]. To meet the country's requirements, there is a need to accelerate domestic exploration projects as well as blocks acquired internationally. This needs to be complemented with additional international partnerships to acquire, explore, and develop other critical minerals like nickel and cobalt, as well as acquire refining technology.

- **Develop a strategic national mineral stockpile for reliable access to critical raw materials.** Focus on stockpiling an equivalent of 25% of annual demand by 2030 for stable forms of critical minerals like lithium carbonate, cobalt sulphate, battery-grade graphite and rare earth oxides. This stockpile can help buffer domestic manufacturers against price volatility and external shocks. Leveraging its experience in setting up the Indian Strategic Petroleum Reserves Ltd. (ISPRL) for petroleum, India could explore a similar PSU-led stockpile for critical minerals.

- **Scale closed-loop recycling for material recovery from end-of-life cleantech applications.** India must invest in waste-collection infrastructure across e-waste, EVs, and batteries to recover copper, battery and other critical minerals. The E-Waste Management Rules 2022 and Battery Waste Management Rules 2022 establish Extended Producer Responsibility (EPR) frameworks with escalating collection and recycling targets rising to 80% e-waste collection by FY2028-29 and 90% battery recovery by FY2026-27[138]. However, implementation is lagging with 90–95% of e-waste still being handled by the informal sector, and ~1% of lithium-ion batteries being recycled into usable materials[139]. While the NCMM also rolled out a INR 1,500 crore incentive scheme for recycling of batteries, rare earth magnets, copper and platinum group minerals, additional support is needed to ensure compliance with recycling mandates, developing large scale collection and recycling infrastructure, and capex support for establishing material recovery infrastructure.

- **Secure supply of raw materials by partnering with alternate suppliers.** Long-term supply agreements with countries such as Australia, Brazil, Japan, South Korea, and resource-rich African nations can reduce reliance on concentrated value chains and ensure stable access to upstream materials ranging from rare earth concentrates to metallurgical-grade silicon, as well as other inputs like balsawood and glass fibre for wind components.

4.4 Ensuring capital equipment access

Figure 45: Two-pronged approach to developing a domestic capital equipment supply landscape

1 Domestic manufacturing for select, non-specialised equipment

Prioritise manufacturing for equipment displaying synergies with existing industries and focus on efficiency and cost improvements

2 Import highly specialised, advanced capital equipment

Diversify imports for specialised equipment with limited domestic tech capacity and low cost efficiency

India must address high import dependence for capital equipment. Current import dependence for capital equipment ranges from 40-95% across the six sectors (figure 46). Limited capabilities in precision engineering and underinvestment in creating the capital equipment base have undermined India's ability to meet capital equipment needs in-house.

Figure 46: Current capital equipment import reliance across cleantech sectors

SECTORS	IMPORT DEPENDENCE % SHARE	CAPITAL EQUIPMENT (NOT EXHAUSTIVE)
Solar	65 – 100%	CVD reactors, Solar Cz pullers, diamond wire saws, PECVD systems, metallization, tabbing and stringing machines, furnaces
Wind	96 – 99.5%	Casting and forging machines to manufacture flanges/gear/shaft components and sub-components
Battery	~100%	Electrolyte filling, calendaring, slitting, coating, electrode tab welding, cell capacity grading machines and vacuum drying ovens
E-mobility	70 – 80%	SMT machines, pick and place, sinter bonder, rotor magnet insertion, hairpin coil winding tech, and BMS testing equipment
Green Hydroen	40 – 100%	Slot die roll-to-roll, die cutting, metal coating and sintering, large-scale bipolar plates stamping machines
Transmission	40 - 80%	Computer Numerical Control (CNC) HV/LV wire-winding machines, foil winding, low-pressure die-casting, and SMT machines

Notes: Import reliance is calculated basis a high-level approximation, based on Dalberg estimate of number of machinery types required for each sector and potential machinery available in India

India should follow a two-pronged approach to acquire capital equipment for its cleantech manufacturing ambition. This includes:

- **Localise equipment with existing synergies from other industries or feasible to acquire via technology transfer.** Prioritise domestic development and manufacturing of equipment with moderate technical complexity where synergies with machines in existing industries offer a path to developing localised equipment without long lead times and at price parity with international suppliers. This includes adapting machinery such as diamond wire cutters, electric arc furnaces, PVD/CVD coating systems and precision machining units that are required during manufacturing of solar modules, wind turbine components, and electrolysers.

At the same time, leveraging intra-sector synergies where families of casting, forming, machining and assembly equipment serve multiple components across solar, wind or transmission can improve utilisation levels and expand markets for domestic machine builders, strengthening the business case for local capital equipment manufacturing. Other capital equipment where there is large demand and interest from international players to expand production to India could be localised by facilitating technology partnerships with OEMs in Taiwan, South Korea and Germany.

- **Diversify imports for highly specialised, advanced capital equipment via G2G partnerships.** For advanced machinery, where technological complexity and scale constraints (i.e., lower demand for machinery) hinder the business viability of producing this equipment locally, diversifying the import base will be essential. India can partner with economies having strong machine-tool ecosystems, such as Germany, Japan, South Korea, Taiwan, Switzerland and the Netherlands to secure long-term access to advanced forging, machining, automation, coating and battery-equipment systems. G2G partnerships can help secure technology-transfer pathways while import friendly policies such as duty exemptions, supporting transhipment through Southeast Asia, and streamlined clearance processes can help reduce delays and cost overruns during capacity ramp up.

The technology transfer for localisation of capital equipment or import of advanced capital equipment could be facilitated by setting up a dedicated Cleantech Manufacturing Investment and Technology Accelerator that provides matchmaking services between domestic and international players, and extends other facilitation support (under guidance from Invest India).

4.5 Developing workforce capabilities

Building workforce capabilities for cleantech manufacturing requires differentiated interventions across skill tiers. India's talent pipeline for cleantech manufacturing faces constraints at multiple levels including an outdated skilling ecosystem, limited exposure to advanced cleantech processes, weak industry-academia linkages, and dependence on foreign experts for technology setup and machinery operation. These differentiated actions must reflect in the policy approach towards equipping the workforce:

- **Invest in creating the next generation of cleantech researchers via faculty training, global exposure, and industry-oriented research support:** India must build a domestic cadre of 200-300 faculty and globally exposed trainers per value chain through train-the-trainer programs spanning the Ministry of Skill Development & Entrepreneurship (MSDE), Ministry of Education (MoE) and Directorate General of Training (DGT) and supported by structured international partnerships with leading institutions in the EU, Korea, Japan and China. Parallel measures such as Quality Improvement Programs can upskill Tier-2/3 faculty in overlapping domains like EV motors, drivetrains and power electronics.

Further, faculty members and graduate students should be supported with industry-linked fellowships, joint PhDs with global universities, and Centres of Excellence in Tier-1 institutes co-developed with industry to align academic research with manufacturing needs. Dedicated electives in graduate science and engineering programs for advanced batteries, HVDC, electrolysers and power electronics, should be introduced.

- **Introduce curriculum upgrades and certifications in cleantech manufacturing to prepare a cadre of highly skilled engineers:** Undertake a systematic curriculum upgrade coordinated by the Ministry of Education (MoE) and the All India Council for Technical Education (AICTE) to embed cleantech manufacturing-oriented modules for power electronics, cleanroom operations, smart grids, HV transmission, EV powertrains and electrolyser fundamentals. The curricula could include co-delivery of coursework with OEMs and introduction of plant-based apprenticeships or internships with such organisations.

These measures must be complemented by upgrading laboratory infrastructure through the deployment of electrolyser rigs, battery cell-testing stations, switchgear benches and HVDC/smart-grid demonstrators across engineering colleges to provide hands-on training. The introduction of short-term certifications and one-year specialisations in sectors like batteries, high voltage transmission systems, electrolyser manufacturing, and EV powertrain manufacturing can equip graduates with job-ready skills.

- **Upgrade select set of ITIs by leveraging funds under PM SETU scheme and developing standardised qualification packs and training programs:** Leverage a part of the INR 60,000 crore funding available under the PM SETU scheme for ITI infrastructure and faculty upgradation to create training facilities, demonstration equipment, and a cadre of faculty members across select ITIs located in close proximity to current or proposed cleantech manufacturing clusters. Additionally leverage private sector partnerships to help build this infrastructure and provide on the job training to students to ensure they have the specialised manufacturing skills required for cleantech manufacturing operations.

Additionally, state skill missions and sector skill councils can prepare standardised qualification packs, competency frameworks, and 3-6 month short term skill upgradation programs on the lines of existing programs like Suryamitra and Vayumitra. These can focus on basic and advanced manufacturing processes, line operations, and ensuring occupational health and safety. Introduction of these skill upgradation pathways can draw workers from adjacent industries like automotives for EVs, electronics manufacturing for HVDC and battery management systems, and glass fabrication into cleantech roles for ingot/wafer processing, battery pack assembly, drivetrain machining, CAM/AAM processing and turbine-component fabrication.

4.6 Bridging the financing gap for domestic cleantech manufacturing

Financing requirements for fostering the growth of domestic cleantech manufacturing and recommendations to shape public funding for the sector are covered in more detail in the next chapter. But other policy actions that go beyond directing subsidies will also be crucial to unlock investments in cleantech manufacturing in the country. These include:

- **Address inverted duty structures and tax anomalies where they exist:** : Manufacturers across solar, wind, batteries and EVs face inverted duty structures and inconsistent tax regimes at various stages that often make raw materials or intermediate goods manufactured in India costlier than finished imported components. Policy direction on this front has been supportive. The Budget 2025-26 reduced basic customs duty on modules from 40% to 20% and on cells from 25% to 20%[140]. The GST council also approved comprehensive rate rationalisation for renewable energy in September 2025 by reducing GST on solar cells, modules, and other renewable energy components from 12% to 5%[141]. The council also introduced process reforms to partially address the inverted duty structure challenge by allowing businesses to claim 90% provisional refunds against accumulated input tax credit which can support manufacturer liquidity[142].

However, residual challenges remain. For example, solar module components are taxed at a higher rate of 18% compared to solar modules at 5%. Import duty on concast steel and electrical grade steel is 15-20% compared to 7.5-10% duty on finished components such as generators and gearboxes. Systematic duty rationalisation that lowers input duties while maintaining protection for finished foods can help improve manufacturer economics.

- **Include cleantech manufacturing in the Harmonized Master List of Infrastructure sub-sectors-** The Department of Economic Affairs, Ministry of Finance, can amend the Harmonized Master List (HML) of infrastructure sub-sectors to include a technology agnostic cleantech manufacturing category. This can help unlock long-tenor, lower-cost infrastructure-aligned finance for these capital-intensive assets and thereby accelerate India's domestic supply-chain scale-up. Crucially, cleantech manufacturing is aligned with the HML's infrastructure-equivalence test and the Cabinet Committee on Infrastructure (2012) criteria as it entails large sunk, long-lived and immobile assets, creation of shared ecosystem infrastructure (testing/certification/R&D), and can deliver non-tradable national benefits and positive externalities such as energy security, grid stability, emissions reduction, and job creation, that exceed private returns.
- **Extend the dedicated, long horizon income tax incentive for greenfield cleantech manufacturing:** The Ministry of Finance can support greenfield cleantech manufacturing by expressly extending the concessional corporate tax regime under Section 115BAB that was previously available for new manufacturing activities. Further, given the sector's high upfront capital intensity, long gestation periods, and delayed cash-flow stabilisation, the current time-bound and sector-agnostic design of Section 115BAB could create uncertainty and limit the effectiveness for cleantech investments. Explicit, technology-agnostic coverage for notified cleantech manufacturing activities applied on a pan-India basis, would provide long-term tax certainty, improve post-tax project viability, and crowd in patient capital for domestic supply-chain scale-up.

4.7 Enabling ease of doing business and creation of cleantech manufacturing clusters in states

State level ease of doing business critically determines whether cleantech manufacturing investments materialise and scale. Many states are already taking proactive steps, particularly in sectors such as solar and electric vehicles, by offering targeted provisions rather than relying solely on sector-agnostic industrial incentives. For example, Telangana has combined a streamlined single window clearance system with dedicated clean energy and EV policy frameworks improving approval predictability for manufacturers[143]. Gujarat has focused on creating execution-ready industrial ecosystems by developing large, well-serviced industrial estates and offering manufacturing-linked incentives such as capital support and tax reimbursements supported by strong state level facilitation[144]. Where such state level measures align with central policy by reducing execution risk, lowering operating costs and improving predictability, the combined effect can be transformative for manufacturers.

States can exercise several complementary levers to facilitate ease of doing business and attract cleantech manufacturers. They can:

- **Enhance administrative effectiveness:** Create well-functioning single-window systems that provide timely approvals for manufacturing site setups and operations and ensure that various state agencies are responsive and predictable in applying their compliance processes. This can be supported by the creation of dedicated cleantech manufacturing desks or nodal officers and proactive investor engagement.
- **Create the right set of incentives in industrial clusters:** Setup industrial parks or clusters that have logistics connectivity and certification labs to support cleantech manufacturing operations. Dedicated capex subsidies for cleantech manufacturing can further improve the value proposition for cleantech manufacturers.
- **Reduce operating costs for manufacturers:** Lower electricity-related charges, duties, and surcharges that materially impact input costs for cleantech manufacturing. Targeted utility provisions, such as concessional electricity access, and dedicated industrial feeders can further ensure reliability for manufacturers and improve operating economics.

Figure 47: Comparison of ease of doing business across 9 states

		ANDHRA PRADESH	GUJARAT	KARNATAKA	MAHARASHTRA	ODISHA	RAJASTHAN	TAMIL NADU	TELANGANA	UTTAR PRADESH
POLICY SUPPORT	Manufacturing-focused cleantech policy	Leading	Leading	Leading	Emerging	Leading	Leading	Emerging	Leading	Emerging
	Industrial clusters, parks or land for cleantech	Emerging	Leading	Leading	Emerging	Developing	Leading	Emerging	Leading	Emerging
INFRASTRUCTURE SUPPORT	Access to utilities (i.e. open access/ grid connection & industrial water supply	Leading	Leading	Leading	Leading	Leading	Emerging	Leading	Leading	Leading
	Access to ports, logistics infrastructure & corridors	Leading	Leading	Leading	Leading	Emerging	Leading	Leading	Emerging	Emerging
FISCAL INCENTIVES	Capital incentives & subsidies	Emerging	Leading	Developing	Emerging	Leading	Developing	Leading	Emerging	Emerging
	Power tariff & surcharge waivers	Developing	Leading	Developing	Leading	Emerging	Leading	Leading	Emerging	Developing
	Other concessions and waivers	Developing	Emerging	Emerging	Emerging	Developing	Leading	Leading	Leading	Developing
INVESTMENT FACILITATION & SUPPORT	Single window clearance system for cleantech	Emerging	Leading	Emerging	Leading	Emerging	Leading	Leading	Emerging	Emerging
	Dedicated investment facilitation agency	Leading	Leading	Emerging	Emerging	Emerging	Leading	Emerging	Leading	Leading

Leading / Emerging / Developing

Note: States assessed based on the relative strength of their provisions in each category, compared with the other states
Source: Dalberg and BlueLotus analysis

The opportunity now lies in states building on existing initiatives by adopting more integrated, execution-focused approaches to cleantech manufacturing. Strengthening facilitation capacity, easing administrative processes, and proactively using cost and infrastructure levers to support priority cleantech value chains can help translate national policy ambition into sustained manufacturing scale. As more states align these execution enablers with central policy frameworks, the scope for accelerating cleantech manufacturing across regions expands significantly.

5 Financing the Cleantech Manufacturing Ambition

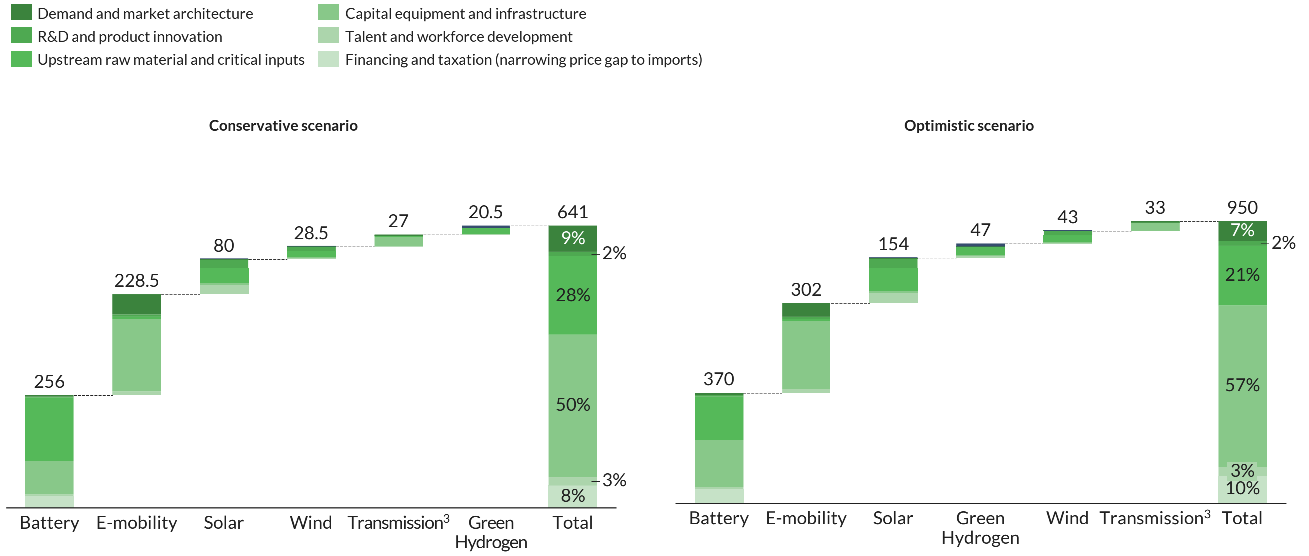
5.1 Investment required across the six priority sectors

Transforming India's cleantech manufacturing base to achieve 50% domestic value addition will require ~INR 6.4 lakh crore in additional investment over the next five years. This refers to new investments, public and private, that will need to be mobilised across these six sectors to create the additional capacity required to reach the target of 50% domestic value addition. In our optimistic scenario, the required investment could increase to INR 9.5 lakh crore.

Most of this funding will be required in the form of capex investments followed by additional demand side incentives to play a market making-function. Of the required amount, we estimate ~78% of the funding will be required as investments in establishing upstream manufacturing (e.g., raw material refining) and capital equipment manufacturing across the six sectors. An additional 8-10% of the funding will be needed in form of targeted capital support and viability gap funding to create a runway for the domestic manufacturing industry to narrow the price differential in comparison to imports[145]. The remainder is accounted for by investments in workforce development, research and development, and advanced manufacturing ecosystems to deliver long-term value creation in cleantech manufacturing.

Figure 48: Total investment required across cleantech sectors and key levers to achieve 50% indigenisation by 2030

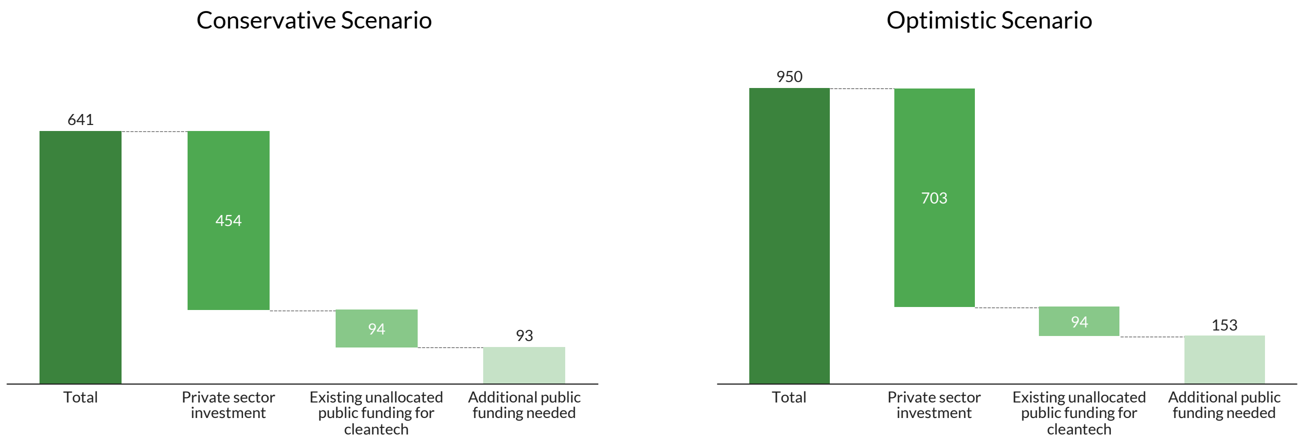
Total investment required to achieve 50% domestic value addition by 2030[1,2]
'000 crores



Notes: (1) Investment estimations assume all announced capacity under PLI schemes or other public announcements are already funded, and thus only cover investment required to develop additional cleantech manufacturing capacity needed to achieve 50% indigenisation by 2030, beyond announcements; (2) Figures have been rounded off to the nearest INR 500 crore for ease of representation; (3) While Capital equipment and infrastructure represents nearly all of the investment required under the Transmission sector, investments worth INR 5,000-6,700 crore are also needed across Demand and market architecture, R&D, Upstream raw materials and Talent and workforce development levers, in conservative and optimistic scenarios respectively,
Source: Industry experts; Dalberg analysis

Figure 49: Total private sector investment and public funding needed to advance domestic cleantech manufacturing

Breakdown of projected funding requirement for cleantech manufacturing by source[1,2]
INR '000 crores



Notes: (1) Investment estimations assume all announced capacity under PLI schemes or other public announcements are already funded, and thus only cover investment required to develop additional cleantech manufacturing capacity needed to achieve indigenisation levels laid out earlier in the report; (2) Figures have been rounded off to the nearest INR 500 crore for ease of representation
Source: Industry experts; Dalberg analysis

5.2 Constraints in mobilising private capital

Private capital can account for 70% or more of the required investment, but bankability and access to affordable credit concerns for cleantech manufacturing will need to be addressed to bring down the cost of capital. Private capital inflows into cleantech manufacturing in India have been increasing. Capital markets are well-equipped to support the scale of India's cleantech manufacturing ambition. Combined AUM across these markets and institutional asset pools stands at INR 178 lakh crores[146, 147]. Similarly, outstanding bank credit across scheduled commercial banks is ~INR 185 lakh crores[148]. Scheduled commercial banks and infrastructure finance institutions also possess the debt capacity to provide the requisite financing to manufacturers seeking to set up manufacturing facilities. However, the constraint to private investment is not capital availability but perceived risk and lack of bankability (access to credit). Cleantech manufacturing projects in India are often faced with higher cost of debt leading to higher cost of capital (>11%). As a result, project level economics and financial structuring are often constrained (e.g., requiring greater capital infusion by promoters or higher equity to debt ratio or higher rates of interest due to actual and perceived risk). Five constraints affect the bankability of cleantech manufacturing projects in India:

- **Higher market and technology risk:** Manufacturing of components such as polysilicon, ingots and wafers, semiconductors for power electronics, and battery cells is technology intensive and manufacturers face technology obsolescence risk and demand uncertainty. The concentration of input supply chains with international suppliers leads to a higher risk perception around cost competitiveness, and hence profitability of the project. Consequently, lenders typically seek 9-12% interest rate for cleantech manufacturing projects. For example, (Indian Renewable Energy Development Agency) offers 11-12% interest rates for EV and battery manufacturing projects[149]. This is meaningfully higher than the typical 7-8% cost of capital that corporate bonds with AAA- rating are able to secure[150]. Given that the Indian cleantech manufacturing sector is on the cusp of a large and strategic build-out, this risk premium serves as a binding constraint. Bridging this risk premium or lowering it by de-risking debtors and investors is critical to unlocking private capital towards cleantech projects.

- **Market structure risk:** The higher cost of capital is also driven by perceived risk from competition from China, and relative the lack of experience of Indian firms entering cleantech manufacturing for the first time. While the former has massive economies of scale and control over raw material supply, perceived lack of capabilities and competitiveness of Indian manufacturers also contributed to the higher risk premiums forcing cleantech manufacturing promoters and entrepreneurs to contend with a higher cost of capital. For comparison, the weighted average cost of capital for cleantech projects in China is approximately half of that of India. Owing to higher perceived risks in India, the cost of debt is also much lower[151] in China.

- **Tenor mismatch:** Upstream manufacturing projects are capital-intensive and typically require 15–20-year time horizons for payback. However, lenders in India offer 7–8-year tenors for such projects given lower risk appetite and asset-liability management constraints. Similarly, India's corporate bond market, despite growing to INR 51 lakh crore in outstanding value as of December 2024[152], remains characterised by limited tenors rarely exceeding 7-8 years for manufacturing ventures[153]. Consequently, manufacturers are often unable to secure the right type of finance aligned with typical project cash flow cycles requiring them to either secure higher equity infusion or undertake refinancing which can compromise project viability.

- **Working capital stress in supplier ecosystems:** MSMEs engaged in cleantech manufacturing, such as the assembly of battery management systems, thermal management systems, mounting structures, and other balance-of-plant components typically have long payment cycles. As a result, significant pools of their revenue are tied up as receivables, requiring working capital finance that erodes operating margins. These liquidity constraints not only compromise their ability to bid for and serve orders but also result in limited capacity expansion, preventing the development of a value-dense and sophisticated supplier ecosystem.

Peer economies have leveraged public funds effectively to bridge similar bankability gaps and catalyse their cleantech manufacturing sector. For example, China's industrial policy provided ~ USD 231 billion between 2009 and 2023 to the EV and battery supply chains. This included support via sales tax exemptions, buyer support, infrastructure investments, and R&D incentives[154]. This systematic support was a key factor in driving capital cost reductions and massive scale-up of manufacturing capacity. Similarly, in Germany, the government and its development bank KfW established a dedicated EUR 30 billion fund to lower financing hurdles for manufacturers focused on renewable energies and future technologies via a combination of low-cost public capital, debt, and risk mitigation instruments[155]. Finally, in South Korea, the government has committed ~USD 29 billion over five years through low-cost debt, credit guarantees and purchase agreements to support the battery manufacturing sector[156].

India must similarly deploy public funding as a market-making instrument and a means to de-risk private capital to drive investments to cleantech manufacturing.

5.3 Public funding as a catalyst for unlocking private investment

INR 1.85-2.45 lakh crore in public funding over next five years can have a transformative effect for cleantech manufacturing in India. Deploying these funds can provide ~2.5-4x leverage to unlock between INR 4.5 – 7 lakh crores in private investment for cleantech manufacturing. Of this quantum, ~ INR 93,000 crore could be leveraged from unutilised funds across existing government schemes focused on cleantech manufacturing such as ACC PLI, PLI for module manufacturing, and auto PLI, while the remaining INR 93,000 - 153,000 crore could be an additional provision.

The required public funds amount to less than 5% of the Government of India's annual expenditure and the investment case is compelling. In fact, the additional public funds required form a negligible increment (2%) over the government's annual expenditure in FY 2024-25[157]. India's government debt to GDP ratio is ~81%[158], which is lower than comparable economies and the marginal increase may not be distortionary for macroeconomic stability. As such the additional funds required could be unlocked via domestic or international borrowing, which could be via Multilateral Development Banks, or through the government's taxation revenue without burdening the exchequer. The gains can more than offset the required public investment. As noted above, deploying this funding could unlock ~ INR 7 lakh crore in private sector investment drive import savings of USD 48-68 billion until 2030, and create more than 1.8 million jobs[159]. Our estimates suggest that the tax revenues from expanded manufacturing activity could exceed the total public investment required during these five years.

Not just the quantum but the stage and timing of deployment for these public funds will be crucial. While the Government of India has already launched several schemes to advance cleantech manufacturing (e.g., National Green Hydrogen Mission, PLI for ACC batteries, permanent magnet manufacturing), the deployment of funds can be improved in four ways to incentivise cleantech manufacturing across the six sectors:

- **Align incentives to capital cycles of the project:** Many of the current subsidy schemes are back-ended. For example, the PLI scheme disburses incentives over five years based on production milestones. As a result, a manufacturer investing INR 5,000 crore in setting up a manufacturing line for advanced batteries, does not receive PLI incentives until five years after the project's award (considering a 2-3-year setup period). The expensive bridge finance in the interim period can undo any potential benefits that the back-ended PLI could deliver and lower the overall profitability.

- **Channel funds through the right instruments:** Most cleantech manufacturing schemes are deployed as direct subsidies to manufacturers. While these subsidies can support manufacturers, for capital intensive projects, supporting manufacturers with instruments that lower their cost of capital (to AAA- or lower rates) might be better suited to improve project economics and unlock investments. These include instruments that offer lower interest rates (e.g., concessional finance, interest subvention) or absorb project risk (e.g., guarantees).

- **Direct support to the right stage of the value chain:** Several schemes such as the auto and ACC PLIs focus on supporting OEMs in later stages of the value chain such as battery pack assembly, assembly of an EV, or green hydrogen production. They may or may not have domestic value addition requirements. For example, green hydrogen incentive schemes are delinked from the use of locally manufactured electrolysers. Unlocking flows for upstream manufacturing through targeted public funding support can offer significant value addition for the country.

- **Deploy innovation capital fast:** RDI funds channelled via ANRF and funds available for R&D in other schemes such as National Green Hydrogen Mission and Atal Innovation Mission offer a substantive opportunity to back translational research and drive-up investments in innovation. Evidence from the successful implementation of schemes such as BIRAC seed fund and iDEX Spark program indicate that identifying bold projects with commercialisation potential couple with faster disbursal of funds can deliver outsized innovation outcomes.

5.4 Instruments to channel public funds

Six primary instruments can form the mainstay of directing public funds to cleantech manufacturing. The primary instruments are directed towards unlocking capital for manufacturers. These include:

- **Partial credit guarantee facility:** Create a facility for providing partial credit guarantees to cleantech manufacturing projects that improve credit profile of the borrower and reduce lenders' risk perception, thereby lowering the upfront cost of finance. Guarantees can bring down the cost of financing by 2.5-3%. Further, they can provide up to a 7x leverage for mobilising private sector capital for credit provisioning. Such a guarantee could be provided through National Credit Guarantee Trustee Company (NCGTC) or housed within GIFT City if international funds are to be mobilised or channelled through a public sector bank. Collaborations with development finance institutions such as World Bank, Asian Development Bank, and other bilateral partners could provide the necessary capital to create and capitalize this guarantee institution.

- **Dedicated viability gap funding and price guarantees:** Create dedicated funding instruments to help manufacturers attain competitiveness and lower demand side risk. This could include viability gap funding to help domestic producers set up manufacturing lines for raw materials and components such that the manufactured goods narrow the price gap with respect to cheaper international imports. For other raw materials where domestic manufacturing faces competition from lower priced imports or dumping of goods (e.g., special grades of steel), consider establishing price guarantees that can compensate manufacturers if prices fall below a threshold.

- **Concessional financing mechanisms:** Extend concessional refinance to cleantech manufacturers through apex development finance institutions such as SIDBI (Small Industries Development Bank of India), NABFID or NABARD, and also NIIF (National Investment and Infrastructure Fund) by creating a dedicated fund for these institutions to on-lend to manufacturers. Lower cost of capital for these funds and longer tenors could help drive much-needed lending activity and also drive capital structures that draw in other lenders for co-financing.

- **Direct interest subvention:** Provide direct interest rate subvention to reduce the cost of capital for manufacturers. Such subvention could be tied to achieving capex investment and project execution milestones rather than sales milestones (as is the case with PLIs), while simultaneously ensuring risk coverage for lending institutions. Such support will effectively reduce the cost of capital borne by manufacturers and improve project economics.

- **Front-loaded capex subsidies:** Repurpose unallocated funds from back-ended schemes into upfront capex subsidies to manufacturers establishing production lines. These can be structured as milestone-based payments tied to project installation and commissioning-related milestones such as first concrete, machinery installation, etc. rather than sales milestones. This upfront infusion of capital will materially change project economics and viability for manufacturers by reducing the financing gap and improving returns on investment.

- **Public procurement mechanisms to lower demand-side risk:** Establish scaled public procurement platforms to protect manufacturers from demand uncertainty by converting public expenditure into assured offtake. These could include volume guarantees for assured procurement of clean technologies by government entities, revenue recovery mechanisms (e.g., revenue risk in lease contracts of e-buses by public transport authorities), and long-term offtake contracts.

Apart from the above, complementary measures such as co-funding for ITI upgrades via public private partnerships or early-stage grants for R&D projects could ensure that the funds earmarked for ecosystem development are also deployed effectively (refer chapter 4 for more details).

While this public funding will be essential, these instruments will need to be designed such that they perform a market-making function and do not become permanent features that prevent the private sector from developing global competitiveness in the long run. To do so, the following features will be crucial:

- **Statutory sunset clauses** with a five-year period where the funding support tapers down to zero by the final year of the scheme. This is in line with best practices and design of similar interventions undertaken in countries such as South Korea and Germany.
- **Performance-linked disbursement with clawbacks** where support should be tied to measurable outcomes especially on domestic value addition targets and capacity commissioning. Clawback provisions could further create strong execution incentives.
- **Fiscal safeguards** that back the instruments with adequate provisioning (e.g., budget provision for the contingent liability from the guarantee) and limit the benefit available to any single entity (i.e., capping the extent of funds for a scheme or incentive that can be provided to a single company or group of companies).

Through right sizing these instruments and ensuring that design matches the needs of the sector, the financing required to power the goal of 50% domestic value addition for cleantech manufacturing seems well within reach. The key will be to move on these decisively, in an industry aligned way, and in conjunction with recommendations that make up the manufacturing blueprint for each priority sector.

6 Institutional Architecture and Delivery

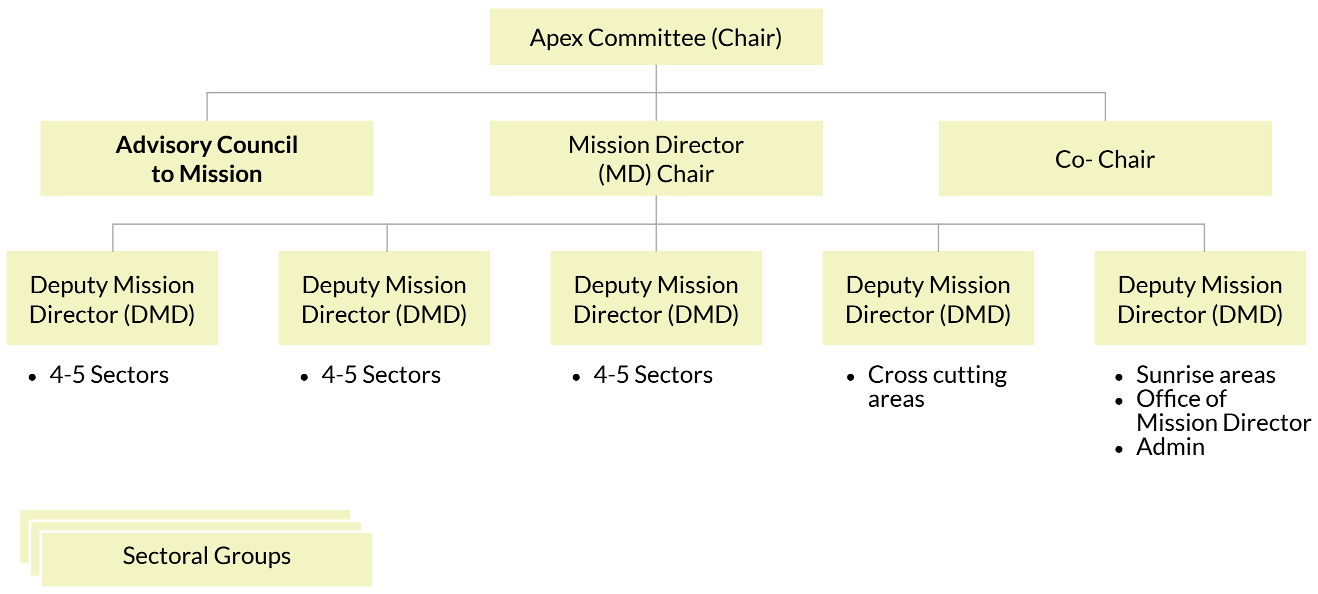
6.1 Institutional architecture for steering and coordination

Cleantech manufacturing in India requires an institutional approach that can build and sustain momentum for execution and ensure coordination across multiple ministries and departments. As seen earlier, establishing manufacturing across the six value chains requires high capital intensity, long technology gestation cycles, creating and sustaining domestic demand, and strong interlinkages with research and innovation. It also requires strategic coordination across domestic and international spheres to secure critical minerals and raw material supplies, and access to international markets for manufacturers. The complexity of execution, combined with the scale of India's ambitions, necessitates a governance model with a clear centre of gravity to ensure unified decision making and seamless coordination across ministries, as well as strong political ownership to build and sustain execution momentum.

The National Manufacturing Mission (NMM) already provides a governance framework that can be leveraged to undertake this coordination and provide strategic steer for cleantech manufacturing. The NMM announcement in 2025 laid down the contours for a whole-of-government platform for manufacturing transformation that brings together core levers spanning industrial policy and sectoral missions. Cleantech manufacturing, which was included as a core focus area for the mission, can leverage this platform to drive execution while integrating with other strategic manufacturing priorities (e.g., ease of doing business reforms and creating a future ready workforce). Post the mission's announcement, an Inter-Ministerial Committee (IMC) was convened to define various aspects of the mission, including its institutional structure, strategic approach, interaction between the centre and states, roles and responsibilities of various actors, as well as the anticipated outcomes and impact. Based on extensive deliberations and stakeholder consultations, the IMC proposed a three-tier governance framework for the mission that was designed to provide strategic oversight, enable effective implementation, and foster cross-sectoral collaboration.

The three-tier governance architecture lays down clear lines of ownership and accountability for different sectoral and cross-cutting priorities. At the top tier, the apex committee, chaired by a senior minister, is responsible for setting the overall vision and providing strategic direction to the mission across sectors. The committee comprising ministers and secretaries from key ministries, the Cabinet Secretary, CEO of NITI Aayog and other eminent private sector individuals will also approve time bound targets for the mission and undertake quarterly review of mission progress and target achievement. The execution core comprises the Mission Director and the Secretariat who will function as the central coordinating engine and translate mission priorities into actionable execution roadmaps for different sectors. For the final tier, dedicated sectoral groups that report to the Mission Director will be responsible for undertaking detailed diagnostics, executing sector specific strategies to achieve mission targets, and ensuring alignment across clusters and stakeholders. Separately, an advisory council has been proposed to advise the Mission Director and sectoral groups on sector specific plans and interventions, and support overall execution. Beyond the sectoral focus, the proposed governance structure includes a focus on strengthening cross-cutting enablers such as ease and cost of doing business, skills and workforce development, tax and tariffs reform, R&D and innovation, worker housing, etc.

Figure 50: Proposed institutional structure of the National Manufacturing Mission (NMM)

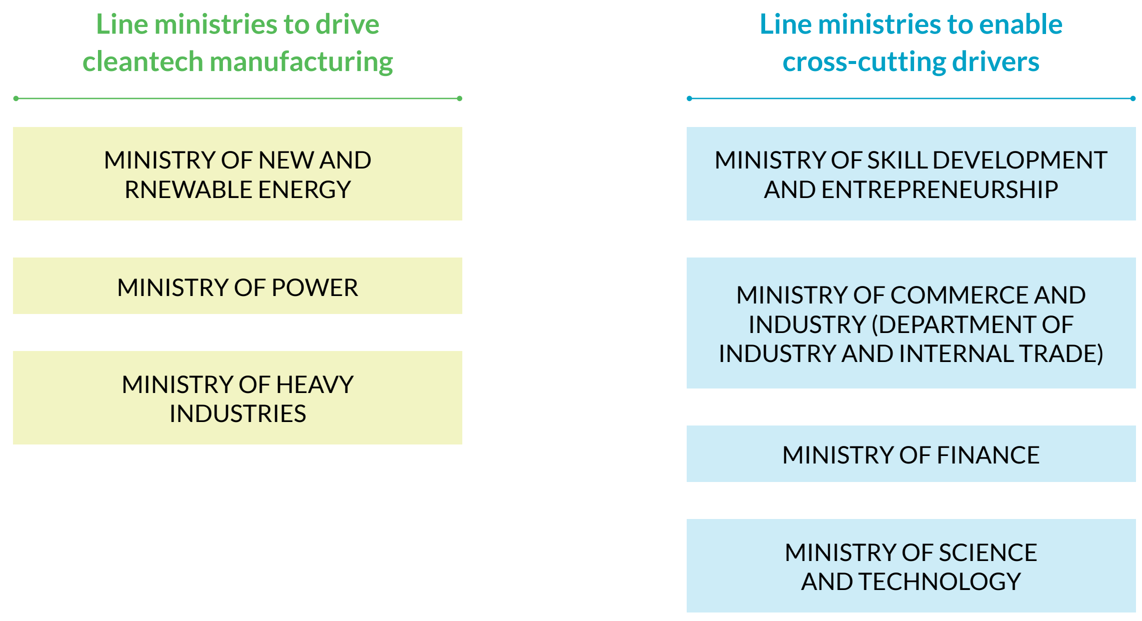


Source: "Draft Report of the Inter-Ministerial Committee on the National Mission on Manufacturing," Government of India, 2025

Within this NMM governance architecture, three core ministries, namely the Ministry of New and Renewable Energy (MNRE), Ministry of Power (MoP) and Ministry of Heavy Industries (MHI) will be key to delivering on cleantech manufacturing priorities. These ministries will play a central role in shaping the vision and driving execution across the six priority cleantech sectors (solar, wind, BESS, e-mobility, green hydrogen, and high voltage transmission). While working closely with the NMM's institutional architecture, these ministries should shape and own timebound sectoral roadmaps, and drive the creation of appropriate demand mechanisms, manufacturer and financier incentives, and regulatory frameworks for the sectors. Their engagement with the Mission Director, the secretariat and sectoral groups could focus on sharing sector-specific diagnostics, investment requirements and implementation learnings, as well as using the NMM institutional structure as a platform to flag inter-ministerial dependencies and resolve cross-cutting constraints where needed.

Other line ministries such as the Ministry of Skill Development and Entrepreneurship (MSDE), the Department for Promotion of Industry and Internal Trade (DPIIT) under the Ministry of Commerce & Industry, and the Ministry of Finance (MoF) will need to play an enabling role. Their role will be crucial to strengthening the underlying ecosystem required to sustain manufacturing capacity expansion. MSDE's support will be needed to align workforce planning and skilling systems with evolving cleantech manufacturing needs and ensure integration with various skilling initiatives that exist within the country. DPIIT could support industrial policy coherence, realignment of tariffs and duties, support ease-of-doing-business reforms, and facilitate investments in manufacturing R&D. Finally, the MoF could enable access to the right subsidies, affordable access to credit, and help structure risk mitigation mechanisms to unlock private sector investments into cleantech manufacturing. Through structured engagement with the Mission Director, the secretariat and sectoral groups, these ministries could help ensure that skills, industrial policy and finance are sequenced and targeted in a way that reinforces cleantech manufacturing outcomes, while continuing to operate within their respective mandates.

Figure 51: Key ministries responsible for boosting cleantech manufacturing in India



The above approach would allow cleantech manufacturing under the NMM to be both sector-led and system-enabled. While the line ministries will be responsible for sector-specific capacity creation and strengthening the enabling environment, the NMM will provide an effective platform for coordination, convergence and strategic steer.

In this context, the Bharat Cleantech Manufacturing Platform (BCMP) aims to serve as a catalytic platform that complements the NMM institutional structure by supporting active coordination between public institutions, industry players, and finance enablers. The BCMP aims to strengthen the shared evidence base on cleantech manufacturing pathways, help identify system-level gaps across priority technologies, and translate strategic objectives into action-oriented problem statements for policymakers and industry stakeholders. The BCMP could also facilitate collaboration among domestic and international stakeholders, support partnership formation, and help collaboration across domestic and international stakeholders, support partnership formation, and help surface investible opportunities aligned with India's cleantech manufacturing ambitions. By operating as an enabling and integrative platform, the BCMP could help accelerate momentum, crowd in private investment, and reinforce India's trajectory towards becoming a globally competitive hub for cleantech manufacturing.

Figure 52: BCMP's potential role in accelerating India's cleantech manufacturing ambition

BCMP will focus on 6 key sectors for accelerating indigenous cleantech manufacturing

- Solar PV Modules
- Wind Turbines
- Batteries
- E-mobility
- Green Hydrogen
- Transmission

The platform's key objectives will focus on bringing together multiple stakeholders to accelerate cleantech indigenisation

Foster coordination for promoting cleantech manufacturing	Build recommendations to promote manufacturing **capital equipment for cleantech**
Build recommendations to address India's **high raw material import dependence**	Support design of **ease of doing business** reforms and state-level interventions
Design enablers to fuel **India's R&D and innovation** investments for cleantech sectors	Design implementation enablers at **special cleantech manufacturing zones** to accelerate cost competitive cleantech manufacturing
Build frameworks to address shortage of **skilled workforce** for cleantech manufacturing	Build a **cohesive 'India Plus Many' strategy** to forge strategic partnerships and investment agreements with partner countries
Design **demand drivers** to scale adoption of domestic cleantech outputs	Curate enablers to facilitate **large-scale investments** for cleantech manufacturing

Source: Bharat Climate Forum

7 Conclusion

India's trajectory toward becoming a developed economy by 2047 and achieving net zero by 2070 will be shaped by decisions made in this decade. The scale of cleantech deployment required to meet near-term goals (500 GW of renewable capacity, 30% EV penetration, 5 MMT of green hydrogen, and thousands of kilometres of high-voltage transmission corridors by 2030) represents both an unprecedented market opportunity and a strategic imperative. The 2030 targets, while ambitious, represent only the first phase of India's energy transition.

This blueprint lays out the case for why this deployment must be matched by a parallel transformation in domestic manufacturing: to capture economic value, secure supply chains against geopolitical disruption, and create high-quality jobs across the country. A robust domestic manufacturing base established by 2030 will also enable India to pursue more aggressive cleantech deployment targets in subsequent decades, reduce the cost of its own transition through economies of scale, and position Indian firms to serve the growing global demand for cleantech.

The analysis underscores that India possesses the foundational ingredients for driving cleantech manufacturing - a large and growing domestic market that can provide credible demand visibility, an established industrial base with engineering talent, policy momentum through the National Manufacturing Mission and sector-specific schemes, and a geopolitical moment where global buyers are actively seeking to diversify supply chains. The focus now must be on disciplined execution to build the technological and manufacturing capabilities required for this cleantech transformation.

Key recommendations to do so include:

- Extend end-to-end domestic value addition mandates under ALMM and PLI schemes (MNRE, MHI) across all six value chains, phasing to 50% by 2029.
- Expand NCMM (MoM) to prioritise domestic refining of critical minerals, build strategic stockpiles (25% of annual demand by 2030), scale circularity infrastructure, and diversify supply partnerships.
- Introduce VGF mechanisms (MNRE, MHI, MoP) for production of key raw materials and critical components (e.g., batteries, motors) across all six value chains.
- Deploy price guarantees (MoM) for key raw materials like special-grade and electrical-grade steel to insulate domestic producers from import price volatility.
- Drive R&D investment via two tracks: (i) dedicated funding through RDI Fund under ANRF (DST) for translational research and shared infrastructure; (ii) tax incentives (MoF) for private R&D exceeding 1% of gross revenue by PLI beneficiaries.
- Launch a Cleantech Manufacturing Investment and Technology Accelerator (DPIIT, Invest India) to facilitate technology acquisition and capital equipment localisation across value chains.
- Transform ITIs near cleantech clusters via PM-SETU (MSDE) and drive curriculum and faculty development across top 100–200 engineering institutions to build a high-skilled talent pipeline.
- Introduce partial credit guarantees (MoF) and capital support mechanisms (upfront subsidies, interest subvention) with five-year sunset clauses to de-risk lending for cleantech manufacturing.
- Include technology-agnostic cleantech manufacturing in the Harmonized Master List (MoF) to unlock lower-cost, longer-tenor infrastructure financing.
- Extend MoF's income tax concessions for new manufacturing to greenfield cleantech projects with express clarification on covered value chains and extended timelines.

The window for undertaking these actions is finite. Global cleantech supply chains are being reconfigured now, and investment decisions made over the next three to five years will lock in cleantech manufacturing pathways for next two decades. India can either emerge from this period as a globally competitive production hub that supplies both domestic and international markets or remain primarily a deployment market that imports the technologies powering its own growth. The National Manufacturing Mission provides the institutional architecture to drive the former outcome. The imperative for policymakers, industry leaders, and investors is to move from intent to execution with urgency and build the industrial foundations for a Viksit and green Bharat.

Annexure A

State-wise Summary of Ease of Doing Business

ANDHRA PRADESH			
Policy & Investment Support Mechanism		**Relative Assessment**	**Key Evidence**
Policy Support	Manufacturing-focused cleantech policy	Leading	• Multiple sector-specific policies collectively cover EVs, batteries, solar, wind, green hydrogen, power electronics, and component manufacturing • Policies include AP Sustainable Electric Mobility Policy, Integrated Clean Energy Policy 2024, Industrial Development Policy 4.0, and the AP Green Hydrogen Policy 2023
	Industrial clusters or parks for cleantech	Emerging	• No dedicated cleantech clusters; solar parks exist in Kadapa, Kurnool and Ananthapuram • One large green industrial cluster is under development in Kakinada
Infrastructural Support	Access to utilities (i.e. open access/grid connection & industrial water supply	Leading	• Reliable 24×7 power, strong transmission network • Large industrial parks have dedicated bulk water schemes from canal projects with 10-20+ MLD capacity at park level
	Access to ports, logistics infrastructure & corridors	Leading	• Key industrial clusters (Vizag, Mulapeta, Krishnapatnam, Kakinada, and Kadapa) are port-linked or located within 15 km of national highways, with access to 3 international and 3 domestic airports typically within 50–100 km • Major corridors and port roads are already used for transport of wind blades, nacelles, and large transformers
Fiscal Incentives	Capital incentives & subsidies	Emerging	• EV policy of AP provides a 20% capital subsidy (capital investment) specific to EV manufacturing only • For solar, wind & RE, ICE 2024 provides up to 25% of fixed capital investment subsidy
	Power tariff & surcharge waivers	Developing	• No explicit electricity duty, electricity tax, or surcharge waiver
	Other concessions and waivers	Developing	• 100% exemption from motor vehicle tax and registration charges for EVs which are more demand side incentives rather than concessions to support the manufacturing industry directly • Priority allotment of government land provided under ICE 2024 for solar, wind & RE but does not have direct fiscal impacts
Investment facilitation & support	Single window clearance system for cleantech	Emerging	• AP operates a single-window system covering all industries, not sector-specific to cleantech
	Dedicated investment facilitation agency	Leading	• Active state nodal agencies provide investor handholding and conduct structured outreach • NREDCAP (New & Renewable Energy Development Corporation) is the state nodal agency for implementation of renewable programmes.

GUJARAT			
Policy & Investment Support Mechanism		**Relative Assessment**	**Key Evidence**
Policy Support	Manufacturing-focused cleantech policy	Leading	• Cleantech governed through a layered policy framework comprising the Industrial Policy 2020, Aatmanirbhar Gujarat Schemes 2022, and sector-specific overlays (RE Policy 2023, EV Policy 2021) • Cleantech manufacturing is designated a thrust sector, explicitly covering green energy ecosystem and EV mobility, with ancillary and indirect industries also recognized
	Industrial clusters, parks or land for cleantech	Leading	• Gujarat has five dedicated cleantech clusters, including Dholera SIR (semiconductors, solar, Li-ion batteries), Mandal–Becharaji SIR (auto and EV manufacturing), green hydrogen hubs in Kutch and Banaskantha (electrolysers and hydrogen), PCPIR Dahej (battery chemicals and solar materials), and the Khavda Renewable Energy Park (solar–wind generation anchoring manufacturing demand)
Infrastructural Support	Access to utilities (i.e. open access/grid connection & industrial water supply	Leading	Industrial power available 24x7, supplied with high reliability & express feeders. • Industrial water supply available supplied via Narmada Canal network
	Access to ports, logistics infrastructure & corridors	Leading	• Gujarat's maritime and logistics network is anchored by 49 all-weather ports (Kandla plus 48 non-major), with Mundra as the heavy-lift hub, offering strong cluster connectivity (Sanand ~270 km from Mundra; Dholera SIR ~60 km from Bhavnagar) • Export-oriented movement is enabled by Adani Logistics Park (Mundra), the Sanand MMLP, reinforced heavy-haul roads, and Sanand's location on the Western Dedicated Freight Corridor
Fiscal Incentives	Capital incentives & subsidies	Leading	• Capital subsidy provided up to 25% for MSMEs • Interest subsidy available at flat 7% for 10 years under Aatmanirbhar Scheme
	Power tariff & surcharge waivers	Leading	• 100% Electricity duty exemption provided for 5 years for new manufacturing units
	Other concessions and waivers	Emerging	• Net SGST reimbursement available up to 100% of Fixed Capital Investment and EPF reimbursement for 10 years
Investment facilitation & support	Single window clearance system for cleantech	Leading	• Gujarat Energy Development Agency (GEDA) operates an "online RE portal" specifically for the registration, accreditation, and clearance of renewable energy and off-grid projects.
	Dedicated investment facilitation agency	Leading	• Gujarat brings in-house RFP and procurement expertise through GUVNL (commercial strategy), GEDA (technical nodal agency), and GPCL (solar park infrastructure and land). • Investor outreach and bidding support are institutionalized via Vibrant Gujarat and national RE events, complemented by GEDA's online portal for registrations and applications, together driving over INR 5 lakh crore in renewable and green hydrogen commitments.

KARNATAKA			
Policy & Investment Support Mechanism		**Relative Assessment**	**Key Evidence**
Policy Support	Manufacturing-focused cleantech policy	Leading	• Covers cleantech manufacturing policy under renewable energy policy 2022 - 2027 and clean mobility like EV and batteries is covered under the Karnataka clean mobility policy 2025 - 2030
	Industrial clusters, parks or land for cleantech	Leading	• Developing clean mobility clusters at Gauribidanur, Dharwad, and Harohalli to co-locate OEMs and component manufacturers, alongside a green hydrogen cluster at Mangalore serving the Belagavi region. • The state offers scale-ready infrastructure through 141 industrial estates and 490 single-unit complexes across 11 clusters, all under a uniform policy with plug-and-play utilities.
Infrastructur-al Support	Access to utilities (i.e. open access/grid connection & industrial water supply	Leading	• Supports 24/7 industrial operations through reliable utility systems with N+N redundancy for critical industries. • The state has abundant water resources across seven major river basins, with ~0.5 BCM allocated for industrial use
	Access to ports, logistics infrastructure & corridors	Leading	• All clusters are integrated with industrial corridors / ports with national and state highways. Karnataka has one major port New Mangalore port and twelve minor ports in the 300 KMs coastline. • All clusters have access to rail heads and heavy lifts
Fiscal Incentives	Capital incentives & subsidies	Developing	• A one-time INR 7- 10 cr subsidy is provided to anchor industries • There is no broad % capex subsidy like other states in the range of 15-20% & no land subsidies
	Power tariff & surcharge waivers	Developing	• There is no electricity duty/tax/surcharge waiver
	Other concessions and waivers	Emerging	• Investment promotion subsidy provided up to 2.25% of annual turnover for 6-10 years and up to 40-60% value of fixed assets • 100% reimbursement on land conversion fee and stamp duty • Concessional registration charges at 0.1%
Investment facilitation & support	Single window clearance system for cleantech	Emerging	• Has a district level single window clearance committee in the Karnataka Udyog Mitra (KUM) portal which covers various sectors including the cleantech sector
	Dedicated investment facilitation agency	Emerging	• Karnataka renewable energy development limited (KREDL) issue cluster specific RFPs to attract renewable energy OEMs and components makers • Invest Karnataka has undertaken domestic and international roadshows, though investor promotion remains non-institutionalized

MAHARASHTRA			
Policy & Investment Support Mechanism		**Relative Assessment**	**Key Evidence**
Policy Support	Manufacturing-focused cleantech policy	Emerging	• Has energy policies for renewable energy and the Mahatma phule renewable energy infrastructure technology ltd (MAHAPREIT) which focuses on cleantech and emerging tech like green hydrogen, EVs, and energy efficiency • Introduced Magnetic Maharashtra 3.0 for renewable energy and linked to its green hydrogen policy 2023.
	Industrial clusters, parks or land for cleantech	Emerging	• Identified 3 main industrial clusters for green hydrogen production - Mumbai - Navi Mumbai- Thane- Taloja, Thal- Dolvi-Raigad and Chandrapur-Nagpur corridor. • The cleantech policy under the green hydrogen policy 2023 is planning a cluster specific approach • MIDC developed industrial parks / clusters designed as plug and play.
Infrastructur-al Support	Access to utilities (i.e. open access/grid connection & industrial water supply	Leading	• 24/7 uninterrupted power supply is being ensured in most industrial clusters • 36 districts with industrial estates of 292 ,27 IT parks and 9 SEZ covered with adequate substations and grid corridors to balance any outages • Adequate water supply for industrial clusters available through ground water sources
	Access to ports, logistics infrastructure & corridors	Leading	• Clusters well integrated with 2 major ports and 48 smaller ports and the state has a coastline of 720 km • 292 industrial parks, 27 IT parks and 9 SEZ are covered through 6200 km of rail network & 18 national highways (99.2% of villages covered) and covered to neighbouring 6 states • The national /state highways are connected to all industrial clusters and access roads allow / cater to transport of oversized/ heavy equipment such as wind blades, transformer and nacelles
Fiscal Incentives	Capital incentives & subsidies	Emerging	• Capital subsidy up to 30% provided for eligible green hydrogen / green ammonia anchor units (15–30% depending on category) • The first 20 green hydrogen refuelling stations are eligible for 30% capital subsidy. • Land and related taxes are fully exempt for designated GH/GA projects • A subsidy of INR 50 per kg of green hydrogen that is blended with natural gas (for CNG/PNG) provided for a limited period • Capital incentives and subsidies are very specific to green hydrogen rather than the entire cleantech industry
	Power tariff & surcharge waivers	Leading	• 100% exemption from Cross Subsidy Surcharge and Additional Surcharge as per MERC Open Access Guidelines for power used in green hydrogen projects. • Standalone RE plants receive a 50% exemption on wheeling and transmission charges for 10 years, while hybrid RE plants receive a 60% exemption on both for 10 years • Green hydrogen plants get 100% electricity duty exemption for 10 years (standalone) and 15 years (hybrid)
	Other concessions and waivers	Emerging	• 100% exemption of stamp duties on land acquisition for green hydrogen projects.
Investment facilitation & support	Single window clearance system for cleantech	Leading	• Has the single window clearance Maharashtra industry trade and investments (MAITRI) facilitation cell. As per the green hydrogen policy 2023 the manufacturers of green hydrogen / ammonia and other renewable energy plant shall be given priority for grid connectivity to avoid any procedural delays.
	Dedicated investment facilitation agency	Leading	• Maharashtra energy development agency (MEDA) is the state nodal agency for renewable energy and conservation. MEDA spearheads the promotions, development and implementation of clean energy technologies and conservation measures. • MAITRI which conducts road shows and investor outreach to increase participation for investments in the state

ODISHA

Policy & Investment Support Mechanism		Relative Assessment	Key Evidence
Policy Support	Manufacturing-focused cleantech policy	Leading	• The state has a dedicated RE Policy & EV Policy
	Industrial clusters, parks or land for cleantech	Developing	• Multi sector parks and standalone industries. Example: - Gopalpur SEZ/ DTA Park consists of hydrogen/ solar panel/ cleantech companies • There are no existing or planned cleantech specific industrial clusters like other states
Infrastructural Support	Access to utilities (i.e. open access/grid connection & industrial water supply	Leading	• 24/7 power available for existing Industrial Estate with 4 units of 400/220/33Kv GSS and 2 PGCIL GSS projects in progress • Industrial water supply available from river sources
	Access to ports, logistics infrastructure & corridors	Emerging	• The state has around 130 Industrial Estates which are well connected to 3 ports operational out of 14, 2 operational airports out of 6, and the railway network (ECR, SER, ECR) etc. • Very few clusters are connected to ports, example: Dhamra Port and Gopalpur Port • Has existing and planned Multi-Modal Logistics Hubs (MMLHs) and an integrated approach to logistics, with Paradip Port being a key hub for road, rail, and sea connectivity. • Allows the transport of oversized/heavy equipment wind blades, transformers & nacelles on the interconnecting NH-5, 5A, NH-57, NH-655, along with the recently approved six-lane Capital Region Ring Road that will connect these highways.
Fiscal Incentives	Capital incentives & subsidies	Leading	• 20% capital investment subsidy on actual investment in plant & machinery (excluding land and building) for new units in Priority Sectors, disbursed over 5 years, with no upper limit. • 30% capital investment subsidy on actual investment in plant & machinery (excluding land and building) for new units in Thrust Sectors, disbursed over 5 years, with no upper limit. • Land in industrial areas at concessional rates, • 100% exemption from land registration premium, • Land at 50% of the industrial rate for large job creating projects in thrust sectors, and • Reimbursement of land conversion premium where applicable.
	Power tariff & surcharge waivers	Emerging	• Reimbursement of power tariff of ₹2.00 per unit for power purchased from DISCOMs and consumed by new units in Priority Sectors for 7 years.
	Other concessions and waivers	Developing	• No other explicit concessions & waivers
Investment facilitation & support	Single window clearance system for cleantech	Emerging	• The Industrial Policy covers all sectors including clean tech
	Dedicated investment facilitation agency	Emerging	• GRIDCO is the nodal agency for RFP in-house expertise • The state conducts roadshows / investor outreach to increase participation

RAJASTHAN

Policy & Investment Support Mechanism		Relative Assessment	Key Evidence
Policy Support	Manufacturing-focused cleantech policy	Leading	• The state has the formal definition of cleantech under 'Rajasthan Integrated Clean Energy 2024' (wind, battery energy storage, solar energy, biomass, energy efficiency, pump storage, green hydrogen, solar pumps, e-chargers)
	Industrial clusters, parks or land for cleantech	Leading	• The state has a fully operational solar park spanning 5700 hectares including the 2245 MW solar park in Bhadla (Thar desert). The state also has significant hubs and clusters for solar and wind energy. • RIICO (Rajasthan industries investment development corp) has so far developed 429 industrial area by acquiring 95000 + acres in the state. It has set up 33 regional offices and management of industrial areas including physical infrastructure developed includes roads, power, streetlight, water supply, drainage etc. as plug & play.
Infra-structural Support	Access to utilities (i.e. open access/grid connection & industrial water supply	Emerging	• Has 24/7 power availability. The state has 415 industrial zones / parks with other industrial infra projects are designed and provided with adequate sub stations and grid corridors. There are 610 grid substations (765 KV- 5, 400 KV -28, 220 KV - 122, 132 KV - 455) and transformers / substations of 1571 (765 KV - 33, 400 KV - 66, 220 KV - 259, 132 KV - 1213). • Rajasthan has a gap of 30% between demand and availability of ground water in the state which makes industrial water supply less available.
	Access to ports, logistics infrastructure & corridors	Leading	• The state is well connected to major ports such as Mundra Port and JNPT, has 9 inland container depots, 1 air cargo complex, and 7 airports (both international and domestic) with heavylift capability and railheads. • Rajasthan has 1 functional multi-modal logistics park with export facility in Kathuwas, Alwar. • It has the 3rd largest network of national highways, with 20 major national highways, and the 5thlargest railway network, and all industrial clusters, SEZs, and industrial parks are well connected. About 58% of the state's industrial areas lie within the Delhi–Mumbai Industrial Corridor (DMIC). • The national /state highways connected to all industrial clusters and industrial estate access roads allow / cater transport of oversized/heavy equipment wind blades, transformer and nacelles.
Fiscal Incentives	Capital incentives & subsidies	Developing	• The state has no explicit capex incentives or subsidies.
	Power tariff & surcharge waivers	Emerging	• 100% exemption from electricity duty for 7 years. • Under RIPS 2024 clause 3.1.3.2.3, enterprises availing the anchor booster (regional and sectoral anchors) receive 100% waiver/reimbursement of banking, wheeling, and transmission charges for captive power plants. • Power producers are exempted from payment of electricity duty for captive use within the state.
	Other concessions and waivers	Leading	• 75% exemption from stamp duty and reimbursement of the remaining 25%. • 75% exemption from land conversion charges and reimbursement of the remaining 25%. • 100% reimbursement of mandi/market fee for 7 years. • Waiver of Pollution Control Board fees for Consent to Establish (CTE) and Consent to Operate (CTO). • Priority allocation of water supply for eligible industries.
Investment facilitation & support	Single window clearance system for cleantech	Leading	• Rajnivesh portal provides a single point online interface and time bound clearance system by acting as a single platform for approval /tracking centre for clearances and approval. • Rajasthan electricity regulatory commission (RERC) has unveiled the green energy open access (GEOA) to fast-track renewable energy and green energy adoption addressing grid reliability and affordability.
	Dedicated investment facilitation agency	Leading	• Rajasthan renewable energy corporation (RREC) is the nodal agency as per the Rajasthan Clean Energy Policy 2024. • Rajasthan state under 'Invest Rajasthan 2022' has done road shows in Gujarat, Maharashtra, Tamil Nadu, Karnataka, Calcutta, Telangana and overseas in Dubai in 2022. Investment facilitation activities were subsequently conducted under 'Rising Rajasthan'. • The state doesn't have a major summit but instead the nodal agency is built into the clean energy framework unlike other states

TAMIL NADU

Policy & Investment Support Mechanism		Relative Assessment	Key Evidence
Policy Support	Manufacturing-focused cleantech policy	Emerging	• Promotes cleantech and clean energy through initiatives such as the Solar Policy 2019 and the Green Energy Open Access Regulations 2025, with manufacturing currently concentrated primarily in the EV segment.
	Industrial clusters, parks or land for cleantech	Emerging	• There are clusters for wind in Nagerkoil, Tuticorin, Nagapattinam, Thirunelveli, Cuddlore, Kumbakonam and Tanjore • Preliminary clusters planned for solar and BESS in Virudhunagar district and EV parks in Manallur • Most cleantech clusters are still planned with existing cleantech clusters only existing for wind. • 3500 acres and 21400 acres available under SIDCO and SIPCOT respectively for manufacturing
Infrastructur-al Support	Access to utilities (i.e. open access/grid connection & industrial water supply	Leading	• 24/7 power availability across industrial zones as the state has a surplus in power generation. • Roundtheclock water supply ensured by the Tamil Nadu Water Supply and Drainage Board, local authorities, and SIPCOT
	Access to ports, logistics infrastructure & corridors	Leading	• All clusters integrated with port/industrial corridors • The access road to the industrial parks allows transport of heavy equipment like transformers, blades and nacelles
Fiscal Incentives	Capital incentives & subsidies	Leading	• EV, battery, and component manufacturers are eligible for a 15% capital subsidy, with additional capital support for MSME EV component and charging infrastructure players • Land cost subsidies range from 15% to 50% in southern districts
	Power tariff & surcharge waivers	Leading	• Manufactures setting up EV/battery/components get an electricity tax exemption of 100%
	Other concessions and waivers	Leading	• Full SGST reimbursement on EVs manufactured, sold and registered till 2030. • Fixed employeebased incentive (₹48,000 per employee for one year). • Exclusive EV parks with common facilities
Investment facilitation & support	Single window clearance system for cleantech	Leading	• There is a single window clearance for cleantech under the Green Energy Open Access (GEOA) regulation 2025
	Dedicated investment facilitation agency	Emerging	• Tamil Nadu Infrastructure Development Board (TNIDB) acts as a nodal infrastructure agency and in-house RFP expert, with the state e-procurement portal serving as the bidding support platform • Investor outreach is led by Guidance Tamil Nadu through domestic and international roadshows, including Hanoi and district-level cluster-focused engagements across the state. However, they have not hosted cleantech specific summit similar to other states like Gujarat

TELANGANA

Policy & Investment Support Mechanism		Relative Assessment	Key Evidence
Policy Support	Manufacturing-focused cleantech policy	Leading	• The state adopts a layered policy stack rather than a single cleantech policy, with sector coverage across the Clean & Green Energy Policy (solar, wind, BESS, green hydrogen), EV & Energy Storage Policy, Electronics & IT Hardware Policy, and TG-iPASS • Auto components and battery materials are explicitly recognized and incentivized, while chemicals and metals are supported under broader industrial and chemical policies.
	Industrial clusters, parks or land for cleantech	Leading	• The state has dedicated cleantech clusters at Zaheerabad (EV manufacturing), Divitipally (energy storage systems), Yenkathala (innovation and testing), and Ramagundam (green hydrogen), with multiple solar parks supporting generation. • These clusters are designed as plug-and-play ecosystems, particularly for EV and electronics manufacturing.
Infrastructur-al Support	Access to utilities (i.e. open access/grid connection & industrial water supply	Leading	• 24x7 reliable power supply available for industrial consumers • Water supply is assured through a combination of surface water, groundwater, and recycled water sources
	Access to ports, logistics infrastructure & corridors	Emerging	• While the state has no port access, it is well connected via national highways and the Outer Ring Road (ORR), supported by two rail-linked logistics parks at Chityal and Nalgonda. • Road infrastructure on NH-44/65 and the ORR enables movement of oversized and heavy equipment such as wind blades, transformers, and nacelles.
Fiscal Incentives	Capital incentives & subsidies	Emerging	• Capital investment subsidy available at 20% of investment capped at INR 30 Cr for Mega Enterprises
	Power tariff & surcharge waivers	Emerging	• Power tariff discount of 25% for 5 years capped at INR 5 Cr for Mega Enterprises. • Electricity Duty Exemption of 100% for 5 years capped at INR 0.5 Cr
	Other concessions and waivers	Leading	• Mega enterprises receive 100% net SGST reimbursement, capped at INR 5 crore annually and INR 25 crore over seven years
Investment facilitation & support	Single window clearance system for cleantech	Emerging	• The TG-iPASS single window clearance system is available for various industries including cleantech and guarantees approvals in <30 days
	Dedicated investment facilitation agency	Leading	• Has in-house RFP expertise via TGREDCO (solar, wind, EV charging) and partners such as GIZ and Deloitte for green hydrogen. • Investor outreach is driven through roadshows and facilitative frameworks like "meet or beat" and the TS-iPASS Act.

UTTAR PRADESH			
Policy & Investment Support Mechanism		Relative Assessment	Key Evidence
Policy Support	Manufacturing-focused cleantech policy	Emerging	• Has multiple sector-specific policies - EV Manufacturing & Mobility Policy, Green Hydrogen Policy, Solar/Renewable Energy Programs (Invest UP)
	Industrial clusters, parks or land for cleantech	Emerging	• The state is going to establish INR 700 cr EV Park in Kanpur (planned), spread across 500 acres implemented by (UPSIDA). Similar clusters are planned under vision 2047.
Infrastructural Support	Access to utilities (i.e. open access/grid connection & industrial water supply	Leading	• Provides 24x7 power supply to industrial consumers. UP is connected to national grid backbones, including HVDC corridors passing through the state. All industrial parks of 155 are well covered with sub stations and grids. • Water is predominantly sourced from surface water (rivers, canals) and groundwater. Also, several industrial areas also use treated/recycled water from STPs. Under 20% of the water is used by the industries in UP state.
	Access to ports, logistics infrastructure & corridors	Emerging	• Most industrial clusters lie within 2–10 km of national highway corridors, industrial estates are generally 5–15 km from railheads, and, as a landlocked state, connectivity is primarily via Delhi IGI and Jewar international airports and domestic airports in Lucknow, Kanpur, and Varanasi, which are typically 10–25 km from the main industrial areas. • Multi-modal logistics parks are planned near DFC nodes typically 0-10km from expressway, and 5-20km from rail freight terminals. • NH (Yamuna, Purvanchal, Bundelkhand, Agra-Lucknow, Gange) are access-controlled and have 6 to 8 lanes suitable for wind blades, nacelles, large transformers, and heavy reactors.
Fiscal Incentives	Capital incentives & subsidies	Emerging	• Capital subsidy on charging infrastructure • Capital subsidy up to 40% and land at concessional rates for green hydrogen • Capital subsidies are not available for all sectors of cleantech
	Power tariff & surcharge waivers	Developing	• No explicit power tariff or electricity duty incentives
	Other concessions and waivers	Developing	• Stamp duty exemptions on EVs & Batteries • There are no broad stamp duty exemptions or EPF benefits like other states
Investment facilitation & support	Single window clearance system for cleantech	Emerging	• There is a general single window system (Nivesh Mitra) for all industrial approvals including environmental and power.
	Dedicated investment facilitation agency	Leading	• In-house RFP support is decentralised as UPNEDA takes care of renewables & hydrogen, UPEIDA takes care of industry in the broader perspective, and Invest UP covers investment structuring. • The state has hosted UP Global Investors Summit along with various international and national roadshows under Vision 2047 (Invest UP).

Annexure B

An indicative, non-exhaustive list of priority technologies to strengthen cleantech manufacturing in India across sectors through technology transfer, commercialization, or indigenous development

Developed through consultations with industry and academia, the list provides a basis for further refinement of India's cleantech priorities over the coming decade.

	TECH TRANSFER / COMMERCIALIZATION	INDIGENOUS R&D FOCUS
Solar	POE encapsulants; Busbar-less solar cells; Advanced tracking systems; TOPCon–IBC hybrid cell architectures; Perovskite–silicon tandem cells	Nano-coatings; Self-healing coatings; Advanced solar cell materials for higher efficiency
Wind	Split-path gearboxes; Spiral-welded tall towers; 3D-printed tall towers; Advanced bearings	AI-based wake steering & wind farm control; Self-healing polymer blade coatings; Wooden laminated veneer lumber (LVL) blades
Bess	Solid polymer electrolyte batteries; Tab-less electrode design; Thermal adhesives; Advanced BMS technologies; Improved battery cooling systems	Sodium-ion batteries; Lithium-sulphur batteries; Zinc-air batteries; Direct immersion cooling; Solvent-based battery recycling & separation technologies
E-Mobility	Ultra-fast DC charging; Megawatt Charging Systems (MCS); Synchronous reluctance motors; Phase-change thermal materials	Ferrite magnet motors (REE-free); In-Rotor Inductively Excited Synchronous Motors (I2SM); Pushbelt CVT (Continuously Variable Transmission); Electronically controlled CVT
Green Hydrogen	Advanced polymer electrolyte membranes; Bipolar plate coating technologies; PEM electrolyser stacks; Alkaline electrolyser stacks	Alternative low-PGM alloy catalysts; Porous transport layers (PTLs); Indigenous electrolyser component materials; Biomass-to-hydrogen pathways
Transmission	Hybrid Modular Multilevel Converter (MMC); Clean Air + Vacuum GIS; Polymeric UHV insulators (>800 kV)	DC filter elimination; Hybrid HVDC breakers; Advanced MMC architectures; Indigenous HVDC insulation technologies

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52 Dalberg analysis based on "RE Supply Chain Report 2024", MEC+, 2024; "Feasibility Analysis for c-Si PV Manufacturing in India", CSTEP, 2018, and industry consultations
53 National Institute of Public Finance and Policy, 2025
54 India announced USD 2 Bn support to solar projects in ISA member countries in 2018 of which only USD 250 Mn has been allocated, USD 1.75 Bn remains unused
55 "Africa Renewable Energy Manufacturing – Opportunity and Advancement", SE for All, 2022
56 Academia and industry experts
57 Cell efficiency for Utility scale solar for c-Si modules compared to 20% today (target efficiency for other applications, e.g. rooftop/ off-grid could be adjusted in-line)
58 Grant estimates based on USA's Small Business Innovation Research (SBIR) program – "America's Seed Fund Powered by the SBA – Annual report 2022", US Small Business Administration, 2022
59 Dalberg analysis, assuming announced capacities have already been funded
60 "India's wind energy soars past 51 GW, but 2030 targets face turbulence", Down to Earth, 2025
61 "Renewable Consumption Obligations", Bureau of Energy Efficiency, 2025
62 Dalberg & MEC+ analysis
63 MEC+ analysis based on "India Wind Outlook", Global Wind Energy Council, 2022
64 "Materials used in US Wind Energy Technologies", NREL, 2023, MEC+ analysis
65 "RE Supply Chain Report, 2024", MEC+, 2024
66 Dalberg and MEC+ analysis based on "RE Supply Chain Report 2024", MEC+, 2024; and industry consultations
67 National Institute of Public Finance and Policy, 2025
68 PLI is considered as ~25% of CAPEX requirement to get breakeven in ~8 years and the 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
69 MEC+ analysis based on "Green Jobs Report", Council on Energy, Environment and Water (CEEW) & NRDC, 2022, "Global Wind Workforce Outlook", Global Wind Energy Council (GWEC), 2024, "The EU Wind Energy Sector Skills Gap", European Wind Energy Technology Platform, 2013
70 Dalberg analysis based on projected conservative and optimistic demand scenarios
71 "India mandates collocating energy storage with solar projects", PV Magazine, 2025, "India targets 30% EV sales by 2030, pushes for infrastructure expansion", ET Energy World, 2024
72 Our analysis also assumes co-located stationary storage for incremental Wind energy deployments.
73 "Batteries and Secure Energy Transitions", IEA, 2024.
74 Dalberg analysis based on consultations with industry experts and key battery manufacturers
75 Dalberg analysis based on bill of materials split between Battery components, and current component level import reliance – inputs collected from industry experts.
76 "Advanced Chemistry Cell Batteries and Domestic Capacity", Press Information Bureau, 2025
77 Dalberg analysis based on "Lithium-ion Batteries: State of the Industry 2024", BloombergNEF, 2024; "Lithium-ion Battery Pack prices fall to USD 108 per kWh", BloombergNEF, 2025; and industry consultations
78 Dalberg analysis based on mineral demand estimations, domestic mineral availability and global share of resources and refining capacities - "Indian Minerals Yearbook – 2023", Ministry of Mines and Indian Bureau of Mines, 2025; "Mineral Commodity Summaries", USGS, 2025; "Global Critical Minerals Outlook", IEA, 2025
79 Dalberg analysis on cost competitiveness of domestic battery-grade graphite refining – inputs collected from expert inputs
80 Dalberg analysis on battery circularity considers battery waste from mobility (EV 2W, 3W, and 4W segments) and stationary applications (Consumer electronics – cellphones and laptops, telecom towers and stationary storage systems – both small and large scale). Further, the analysis assumes an 95% waste collection rate for mobility applications, 30% for consumer electronics and 50-60% for other stationary storage systems by 2030. Of the collected waste, 50% of EV-4Ws, 15% of EV-2Ws and 3Ws, and 70% of telecom tower and large-scale stationary storage system batteries are expected to be refurbished. Refurbished batteries are expected to sustain another 3-5 years of second-life application (across E-rickshaws, last mile EV-2/3Ws, solar street lamps and stationary storage systems), before they undergo recycling.
81 "Unlocking Supply Chains for Localizing Electric Vehicle Battery Production in India", IISD, 2024
82 Analysis includes ~2,000 R&D profile jobs spread across the battery value chain
83 Dalberg analysis; refer chapter 5 for more details
84 Dalberg analysis based on industry and academia input
85 Estimated requirement: 9-12 small labs (TRL 4–5) at INR 50–100 crore each, and 3-4 large labs (TRL 5–8) at INR 250–300 crore each, amounting to total INR 1,200-2,400 crore capex requirement for infrastructure development. Public investment of INR 600-1,200 crore could mobilise the requisite investment.
86 Public grant investment of INR 300-600 crore could mobilise additional INR 300-600 crore R&D investment from the private sector, via instruments such as grant matching.
87 Subsidy outlay to support development of 85kTPA domestic graphite refining capacity till 2030 (potentially operating at 85% capacity utilisation).
88 VGF - Viability Gap Funding based on assumption of 50% coverage of price difference between domestic, imported cells, covering domestic OEM share of E-4Ws demand, estimated from 2027 to 2030
89 Dalberg analysis based on a conservative and optimistic estimates of annual EV registrations by 2030 across vehicle segments
90 Dalberg analysis based on industry consultations and workshops, "Driving self reliance – localizing EV components in India", Praxis Global Alliance, 2025; "Magazine-2025", EV Reporter, 2025
91 Dalberg analysis suggests that increasing localisation will lead to an increase in the ex-factory price of EVs in India as upfront capex investments will be needed from manufacturers
92 Dalberg analysis of charging infrastructure requirement for the existing EV fleet volume suggests that ~220K charging points are needed. However, as of Aug 2025, only ~29K charging stations, equivalent to ~120K charging points are available.
93 "Comprehensive Guide to Financing the ZET Transition in India", RMI and CoEZET, 2024
94 India does not have any sizable estimates of heavy rare earth ores. Heavy rare earth oxides are a key material for production of permanent magnets that are at the core of EV traction motors.
95 Based on number of machines that are imported amongst all relevant machines to manufacture a component
96 Includes approximately 400,000 indirect workers. Dalberg analysis based on "EV Talent Landscape in India: Bridging the Skill Gap for 2030", SIAM, 2025

97 VGF pool calculated based on the projected number of E4Ws. Other EV segments (buses, trucks, etc.) have been excluded as they have separate, targeted financing interventions. This intervention is consistent with the VGF proposed under BESS sector, and doesn't require additional allocation in the E-mobility sector.
98 The subsidy amount has been calculated based on the already announced INR 2,000 crore for 72K charging stations under PM E-DRIVE Scheme.
99 The guarantee fund amount has been calculated based on the existing outlay of INR 3,435.33 crore under PM E-Bus Sewa PSM Scheme to support 38,000 buses by 2029.
100 Investments to drive Charing infrastructure installation, Bus and Truck adoption are over and above available and undisbursed INR 31,700 crore funds under PM E-DRIVE and PM E-Bus Sewa schemes.
101 Calculated based on an estimated budget for R&D and pilot manufacturing by the Office of the Principal Scientific Adviser to the Government of India. "eMobility R&D Roadmap for India", PSA Office, 2024
102 Includes an outline of INR 3,500-6,500 crore for training costs, INR 3,000-5,000 crore for demo facilities setup and upgradation of ITIs.
103 Refers to public funding required (@10% capex subsidy), to expand EV component manufacturing (for Battery Management Systems, Power Electronics and Motors), vehicle assembly and charging infrastructure manufacturing facilities. etc.
104 Interest costs have been calculated on total capex investments estimated to expand the domestic EV ecosystem (including upstream mineral and circularity facilities). Estimations assume 11% annual interest rate, a 7 year loan tenure and 70% Debt share in capex investments. 20% of estimated interest cost can be provided as concessional finance by the government.
105 "How can Hydrogen Electrolysers be made in India," CEEW, 2024
106 2030 cumulative domestic electrolyser capacity considers 75% utilisation of current electrolyser factories with 2.1 GW/year capacity, between 2026-2030. An additional 25.9 GW/year manufacturing capacity is planned or announced, but may all not come live by 2030 due to meek demand and slow investments
107 "How can Hydrogen Electrolysers be made in India," CEEW, 2024; CEEW and Dalberg analysis; NGHM website, MNRE, Accessed 2025; "RfS Document for Selection of EM for Setting up Manufacturing Capacities for Electrolysers in India under SIGHT Scheme (Tranche-II)," SECI, 2024
108 Dalberg and CEEW analysis based on industry and academia expert inputs
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111 Dalberg and CEEW analysis
112 Dalberg and CEEW analysis; "Harnessing Green Hydrogen," NITI Aayog, RMI, 2022; Financing Green Hydrogen in India, BNEF, CEEW, 2024; Charting the future: Green hydrogen expansion and PNGRB's pivotal role, ICF, The World Bank, PNGRB, 2024
113 Initial analysis suggests that top 10 states for CGD blending could be Gujarat, Delhi, Haryana, Uttar Pradesh, Maharashtra, Karnataka, Punjab, Rajasthan, Tamil Nadu and Telangana.
114 "SIGHT Scheme 2A Guidelines," MNRE, 2024; "SIGHT 2A Amendments," MNRE, 2024
115 Dalberg analysis based on industry and academia expert inputs
116 Assumes that green ammonia tender prices can be extended to remaining fertilizer demand for 2030 and that marginal cost increase in refinery sector will be absorbed by the sector
117 Absorbing the cost differential of domestically manufactured electrolysers vs. those that are imported as prices are not going down enough through existing PLIs
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119 "National Electricity Plan Vol II - Transmission", CEA, 2024
120 Estimated based on industry expert input
121 Domestic value addition considered only for the substation components of the transmission system and does not include line components (towers, conductors and insulators) which are largely indigenised
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143 Dalberg and Blue Lotus Partners analysis
144 Dalberg and Blue Lotus Partners analysis
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146 Includes assets under management (AUM) for mutual funds, pension funds, provident fund and insurance companies. Mutual fund assets are as per AMFI (Nov 2025); pension assets reflect NPS and APY corpus reported by the Ministry of Finance (Oct 2025); EPFO corpus is based on Government of India investment statistics (Mar 2024); insurance assets are derived from publicly reported insurer investment data.
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