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CLEAN ENERGY AS ECONOMIC STATECRAFT

Ten Strategies for Powering Viksit Bharat 2047

Nikit Abhyankar • Amol Phadke • Samir Saran • Gopalika Arora

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Editorial and Production Team: Vinia Mukherjee, *Editor and Producer;* Monika Ahlawat, *Assistant Editor;* Rahil Miya Shaikh, *Design and Layout.*

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Executive Summary

India has crossed a structural threshold: clean energy is no longer a climate choice; it is now economic statecraft. Handled strategically, it can halve economy-wide energy costs and halve fossil-fuel imports by mid-century, converting over US$200 billion per year currently spent on fuel imports into domestic capital formation and infrastructure investment. This would deliver a decisive boost to industrial competitiveness, energy security, and trade stability. Managed poorly, however, it risks remaining a fragmented sectoral transition, leaving India exposed to import volatility, fuel-price shocks, and stranded capital.

This report frames the current moment as a decisive economic opportunity. It identifies ten technologies and industrial platforms capable of translating India's energy transition into tangible outcomes of lower energy costs, reduced import dependence, improved air quality, and high-value employment, while positioning the country for leadership in emerging global markets.

India's position at this juncture is unique among major economies, combining four structural advantages rarely aligned at scale. First, solar-plus-storage prices have fallen to record lows, enabling near-24×7 clean power for under ₹4/kWh. At this price point, clean electricity extends beyond the power sector, making industrial and transport electrification economically viable while offering long-term tariff stability through 12–25-year contracts. Second, an integrated national electricity grid, together with open-access and captive procurement frameworks, allows large industrial consumers to directly source low-cost clean power, accelerating green manufacturing and electrification across sectors such as data centres, metals, and industrial heat. As carbon-linked trade measures—including the

European Union's (EU) Carbon Border Adjustment Mechanism (CBAM)—take effect, these low-carbon production pathways can unlock new export opportunities. Third, rising fuel imports—now approaching 4 percent of GDP—create a clear pathway for clean energy to strengthen energy security and macroeconomic stability. For example, electric freight trucks, already around 50-percent cheaper than diesel on a per-kilometre basis, offer a credible route to reducing oil dependence. Fourth, global capital is increasingly seeking scalable clean-energy platforms in emerging markets just as India is poised to become the world's second-largest clean-energy market, supported by a strong manufacturing base and deep engineering talent.

Against this backdrop, India's strategy should focus not on dispersing effort across many sectors but on deliberately cultivating a small set of high-impact technologies capable of delivering three simultaneous outcomes: rapid economic growth, large-scale job creation, and deep emissions reductions. The ten priorities identified in this report form a coherent growth strategy anchored in low-cost, firm clean electricity—positioning clean energy as a driver of competitiveness, investment, and trade rather than solely an environmental objective.

Rather than evaluating strategies through a narrow decarbonisation lens, the report applies an integrated economic and industrial framework. It prioritises areas where India's structural advantages—low-cost power, domestic market scale, institutional credibility, and a growing talent base—intersect with expanding global demand. These opportunities share three defining characteristics: they are energy-intensive and benefit disproportionately from low-cost clean electricity; they are globally scalable with rapidly expanding markets; and global leadership has not yet been irreversibly established, creating a strategic window for India to enter and scale.

Strategic timing now matters as much as ambition. The ten priorities identified here focus on areas where clean energy can deliver large domestic dividends—halving energy costs and imports, improved air quality, and high-value employment—while positioning India for exports in rapidly expanding global markets. Crucially, these are sectors where global leadership is not yet locked in and where India's comparative advantages—low-cost power, domestic market scale, institutional credibility, and a growing talent base—can shape outcomes.

The following tables provide a detailed analysis of each strategy, examining how India's structural strengths translate into domestic economic benefits and emerging global competitiveness.

Table 1a. Strategic Opportunity Mix: Deployment and Scale-Ready Engines

Strategies	Comparative Advantage	Domestic Dividend	Export Opportunity & Addressable Market	Policy Levers
Fast RE Deployment to Reach 1,000 GW by 2035	Record-low solar + storage prices implying near 24x7 clean power at Rs 4/kWh ($45/MWh); integrated national grid and favourable open access and captive procurement framework; strong institutional capability and innovative auctions; robust electricity demand growth.	Reduce electricity cost by 15%; maintain grid reliably while offering a long runway to existing fossil capacity; new construction jobs; utilise domestic solar panel and battery manufacturing.	Double the RE deployment rate from ~40-50GW/year to 80-100 GW/yr, including storage; Create 50 RE zones of 20-30 GW each to integrate 1,000 GW RE by 2035.	Expand non-utility demand, co-locate RE with storage, and use surplus transmission interconnection at existing plants to double annual deployment to 80-100 GW/yr.
Electric Trucks	Strong auto manufacturing sector; capabilities; battery manufacturing is also increasing; strong economic and industrial growth implies a large freight truck market that can offer scale.	Imported crude oil substitution; reduce & inflation-proof freight transport cost.	Each year ~400,000 new freight trucks are sold in India with ~4 million globally. Electric truck sales are already ~10-15% of the new truck sales in China.	Implement technology-agnostic zero-emission vehicle (ZEV) sales mandates for trucks, paired with corridor charging infrastructure.

Strategies	Comparative Advantage	Domestic Dividend	Export Opportunity & Addressable Market	Policy Levers
Advanced Grid Technologies	Strengths in manufacturing electrical equipment; strong domestic demand and power sector institutional capability that can offer scale to reduce costs.	Doubling grid capacity within existing right of way at low cost to integrate large amounts of RE in the grid.	Increasing global demand for critical grid equipment including advanced conductors and transformers from a trustworthy partner; Target building 100,000 circuit km of advanced conductors to integrate 1,000 GW of RE by 2035.	Mandate total-cost-of-ownership–based transmission planning and deploy advanced conductors and reconductoring as default options.
Data Centres and Digital Energy Infrastructure	Low-cost 24x7 clean electricity for data centres; global leadership & scale with UPI and Energy Stack; smart demand, distributed solar and storage.	Reduce energy costs and improve infrastructure utilisation; deepen energy markets	Green data centres can attract new FDI; new business models in energy markets enabled by smart financial technologies could be scaled globally	Create green data-centre enclaves with assured 24×7 clean power and enable new markets using energy-linked digital services built on India's digital public infrastructure.

Strategies	Comparative Advantage	Domestic Dividend	Export Opportunity & Addressable Market	Policy Levers
Advanced Cooling Technologies	Strengths in manufacturing; massive domestic demand of room ACs that can offer scale for cost reduction; strong standard-making institutions and momentum due to recent revisions; announcements at COP-28 and CEM of doubling energy efficiency by 2030	Reduce consumer energy bills by 20-40%; help adopt to heat stress due to rising temperatures; make grid integration of solar energy more economical by lowering the electricity demand during non-solar hours	India's room AC market is 14 million units/ yr, doubling every 10 years. Efficient ACs could reduce 60GW of peak demand by 2035 or so. Global room AC market is ~150 million/ yr, with nearly half in China. Significantly increasing room AC demand, especially from the global south.	Commit to an aggressive and long-term MEPS trajectory—2030 MEPS set at today's best technology sold in India; 2035 MEPS set at today's global best.

Table 1b. Strategic Opportunity Mix: Market Building Platforms

Strategies	Comparative Advantage	Domestic Dividend	Export Opportunity & Addressable Market	Policy Levers
Green Steel and Fertiliser	Strong steel manufacturing capacity; seasonally consistent solar resources critical for continuous green H2 production; growing capability to manufacture low-cost electrolysers; large domestic demand providing scale (steel ≈140 MT/yr, doubling every decade; urea ≈ 25–30 MT/yr).	Substitute expensive coking coal and imported natural gas with domestic solar resources; inflation-proof steel and fertiliser production; reduce exposure to volatile fossil fuel imports; lower and stabilise fertiliser subsidy burden (≈$20 billion/yr).	Global steel market is ~2 billion tons/yr (~$1 trillion/yr); 50% produced by China. Demand for green steel rising due to net-zero goals & import policies like CBAM. Global urea market is $150 billion/yr, impacted by gas market volatility. Inflation-proof green fertiliser is a big opportunity.	De-risk first projects through long-term offtake guarantees and time-bound public procurement mandates with price caps.
Industrial Heat Electrification	~50% of the final energy use in industrial processes is heat, offering robust domestic demand for scale. Open access and captive procurement makes low-cost clean electricity available to all large consumers. Strong heat battery manufacturing capability.	Electric heat pumps and thermal batteries can substitute imported oil gas used for industrial heat by clean electricity; give industries a global edge due to low & inflation-proof energy costs; large air quality benefit	Heat electrification tech would be a strong export market as countries face volatile fossil fuel markets and tightening climate regulations; clean electrified manufacturing clusters could unlock a new channel for FDI	Aggregate demand at industrial clusters, remove open-access barriers, and provide accelerated depreciation for high-capex electrification equipment.

Strategies	Comparative Advantage	Domestic Dividend	Export Opportunity & Addressable Market	Policy Levers
Sustainable Aviation Fuel	Potential use of crop residue that is otherwise burned & causes air pollution; India is the third largest aviation market in the world	Imported crude oil substitution; potential commercial use of biomass/crop residue to boost farmers' incomes and avoid biomass burning related air pollution	Global aviation fuel market is over $300 billion/ yr and nearly doubling in the next decade. Most major airlines have SAF and net-zero goals.	SAF blending mandates at major airports; fiscal & offtake support for first few plants.

Table 1c. Strategic Opportunity Mix: Frontier Technology Bets

Strategies	Comparative Advantage	Domestic Dividend	Export Opportunity & Addressable Market	Policy Levers
Storage Technologies Beyond Lithium	Strong manufacturing base: large auto and grid markets can offer scale to reduce the cost of new technologies	Diversify storage supply chains and leverage domestic mineral / material availability such as zinc or iron etc. Cross-seasonal grid balancing support requires long duration storage under $10-20/kWh.	Global battery demand is over 1,000 GWh/ yr (auto, grid, and consumer electronics), doubling by 2030. 80% of the lithium-based battery supply chain is dominated / controlled by China.	Fund RD&D, pilots, and early procurement through VGF and tax incentives.

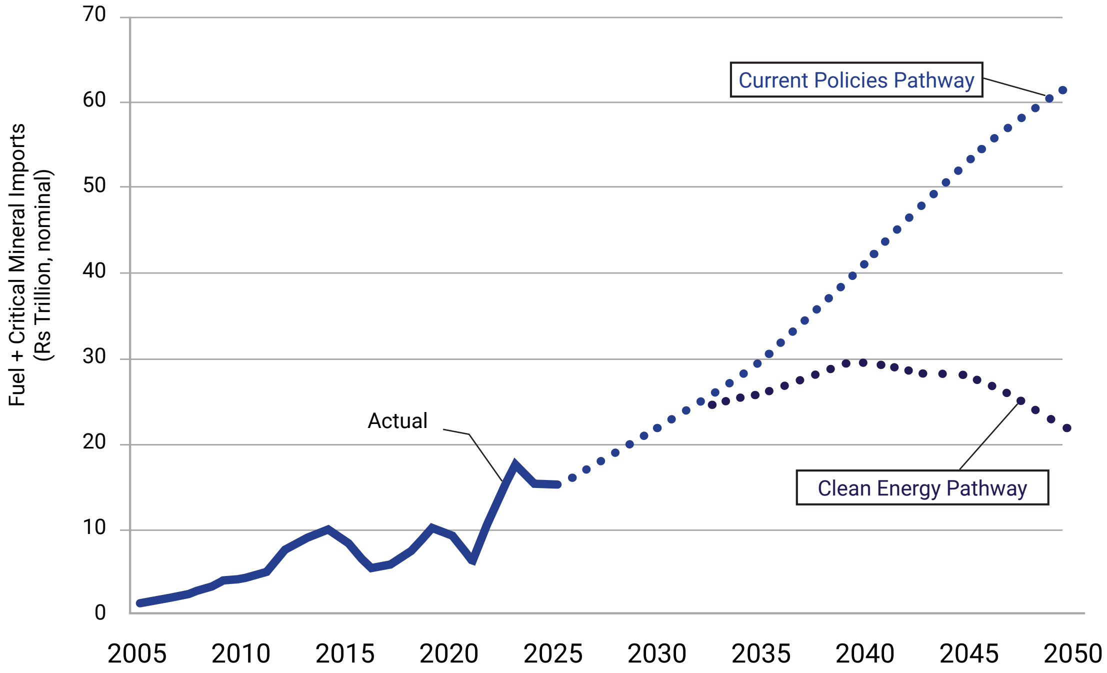
Strategies	Comparative Advantage	Domestic Dividend	Export Opportunity & Addressable Market	Policy Levers
Electrolysers	Strengths in manufacturing; Green hydrogen mission targets 5 MT of green H2 by 2030; long-term green H2 demand from steel and fertiliser sectors offer scale to reduce costs; encouraging initial auction results	Reducing the cost of electrolysers under $300/kW is critical for economical production of green H2 (and thus green steel, fertiliser, and other products); reduce import dependence	PEM electrolyser cost in the US & EU is >$1000/kW. Very high global demand for good quality, low-cost electrolysers. Solar capital cost in India is half that in the US, which can be replicated for electrolysers.	Electrolyser manufacturing linked green hydrogen auctions and VGF support.

Source: Authors' own

Together, these strategies distinguish where rapid execution is possible today, where market design must unlock scale next, and where sustained innovation is essential for long-term competitiveness.

The combined effect of such clean energy strategies on India's energy imports is illustrated in Figure 1. Under a Clean Energy Pathway, characterised by rapid deployment of low-cost clean energy, total fuel and critical mineral imports decline by more than 60 percent by 2047 relative to a Current Policies Pathway, which assumes continuation of existing policies and limited clean-energy uptake. Importantly, projected lithium and other critical mineral imports account for only about 10 percent of the avoided fossil-fuel imports through 2050.

Figure 1: Total Fuel and Critical Mineral Imports (in Nominal INR, Under Two Scenarios)



Source: Authors' estimates based on Abhyankar et al (2023).[1]

Note: The two scenarios are: A Current Policies Pathway, assuming continuation of existing policies and limited clean-energy uptake, and a Clean Energy Pathway, assuming rapid deployment of low-cost clean energy enabled by the ten strategies outlined in this report.

These advantages, however, will not automatically translate into domestic economic gains or global export leadership. Markets can accelerate what already exists, but they cannot by themselves resolve coordination failures, manage transition and supply-chain risks, or create stable demand signals. The government's role, therefore, is not to provide indefinite subsidies or shield legacy systems, but to shape markets, steer the transition, and reduce strategic vulnerabilities across supply chains. If executed well, this approach can position clean energy as a cornerstone of a resilient, competitive *Viksit Bharat* by 2047.

Introduction

India's pursuit of development and its low-carbon transition are no longer separate objectives. Together, they will define India's growth trajectory over the coming decades, and the direction and credibility of the global climate transition. As India pursues the path toward *Viksit Bharat* by 2047 while committing to net-zero emissions by 2070, the real challenge lies in aligning economic growth with decarbonisation. The choices made today will influence not only economic resilience but also India's industrial edge and strategic autonomy in a rapidly evolving global order.

Energy lies at the core of this alignment. As India's economy expands, electricity demand is expected to grow faster than overall energy demand, driven by industrialisation, urbanisation, digital infrastructure, cooling needs, and transport. With greater electrification across sectors, including industry, transport, and cooking, electricity demand is projected to increase 4–5x by 2050 and 6–8x by 2070 compared with 2025 levels.[2] India's per-capita electricity consumption is also expected to rise significantly, from about 1,400 kWh in 2025 to roughly 7,000–10,000 kWh by 2070, approaching levels seen in advanced economies such as France and South Korea.[3]

India's experience already shows that climate action and development can move in tandem. Between 2005 and 2023, the country reduced the emissions intensity of its Gross Domestic Product (GDP) by 36 percent,[4] while sustaining one of the world's fastest growth rates. In the power sector, India achieved 50 percent non-fossil fuel capacity five years ahead of its Nationally Determined Contribution (NDC) target,[5] an early milestone that underscores both policy intent and implementation capacity.

At the same time, the economics of clean energy have shifted decisively. Over the past decade, the costs of renewable energy, particularly solar have fallen sharply, while rapid advances and cost declines in Battery Energy Storage Systems (BESS) have begun to address concerns around variability and reliability.[6] Through innovative competitive procurement mechanisms, India has consistently achieved record-low tariffs for both standalone solar and solar-plus-storage projects. These trends have fundamentally altered what is feasible at scale. Renewable energy (258 GW) already accounts for nearly 52 percent of India's total installed power capacity.[7] Globally, India now ranks third in solar power installed capacity, fourth in wind power capacity, and fourth in total renewable energy capacity.[8] Looking ahead, India is projected to become the world's second-largest solar market in 2026, overtaking the United States with annual solar additions expected to exceed 50 GW, far surpassing most other industrialised economies.

These developments mark a structural shift in India's energy landscape. Clean energy is no longer confined to climate policy or power-sector reforms; it is increasingly shaping the economics of growth itself. Falling costs, domestic availability, and long-term price certainty position clean energy as a central input to industry, infrastructure, and services—one with implications for inflation, trade competitiveness, and energy security.

However, this transition is not automatic. While technologies have matured rapidly, their economy-wide impact will depend on how effectively they are integrated into the energy system and linked to rising electricity demand. Grid infrastructure, storage deployment, market design, and large-scale electrification of industry and transport will determine whether clean energy remains a sectoral success or becomes a foundation for broader economic transformation.

India's position at this juncture is unique. Few large economies combine rapidly growing electricity demand, globally competitive clean-energy costs, an integrated national grid, and a strong domestic manufacturing and engineering base. Global conditions further sharpen this opportunity: fuel import dependence remains high, carbon-linked trade measures are beginning to reshape export markets, and international capital is increasingly seeking scalable clean-energy and industrial platforms in emerging economies.

This report is framed around this moment of opportunity. It identifies ten strategies and platforms that are critical to translating India's energy transition into tangible economic outcomes, including but not limited to lower energy costs, reduced import dependence, improved air quality, and high-value employment, while positioning India for leadership in emerging global markets. Rather than treating the energy transition as a standalone climate challenge, the report approaches it as a system-level transformation at the core of the Viksit Bharat mission.

Chapter 1

India's Energy Transition: A Strategic Opportunity

India's energy transition has reached a pivotal point as it is increasingly shaped by a convergence of economic fundamentals, institutional design, and geopolitical realities that together create a strategic opportunity unmatched by any other major economy.

Four structural conditions define this moment.

1.1 Record Low Solar and Storage Prices

India has leveraged the global declines in clean-energy technology costs, translating them—through scale and innovative competitive procurement—into record-low prices for solar and solar-plus-storage power. Recent solar-plus-six-hour storage auctions have cleared at approximately US$34/MWh (INR 3.1/kWh) for GW-scale projects, among the lowest prices globally for dispatchable renewable power.[9] These outcomes imply that near-24×7 clean power can be supplied at around ₹4/kWh (~US$45/MWh). At this price point, the benefits of clean electricity spill well beyond the power sector, making industrial and transport electrification economically viable. Importantly, these contracts lock-in fixed nominal tariffs for 12–25 years, making clean power effectively inflation-proof and providing long-term cost certainty for industry.

Equally important, firm solar-plus-storage configurations operate at approximately 80–90 percent capacity factors, dramatically improving transmission utilisation relative to standalone solar. Higher utilisation allows the same transmission assets to deliver three to four times more energy, reducing effective grid costs by an estimated 60–70 percent. Even after paying full interstate and intrastate transmission charges, this translates to a delivered cost to large industrial and commercial consumers of roughly US$ 55/MWh (INR5/kWh)—around half of prevailing industrial tariffs—establishing a new baseline for electricity pricing.[10]

1.2 A Market Framework Without Global Parallel

India's clean-energy advantage is not only technological; it is institutional. A unified national grid, combined with open-access and captive procurement frameworks, allows large consumers to procure clean electricity from anywhere in the country by paying regulated network charges to utilities.[11] This degree of supply-side flexibility at scale does not exist even in most advanced economies, and it ensures that declines in clean-power costs are transmitted directly to industry rather than being absorbed within traditional utility tariffs. In an economy exposed to global fuel price volatility, access to stable, long-term electricity prices becomes a durable source of industrial competitiveness.

1.3 Import Dependence Meets Rapid Demand Growth

India is the world's third-largest energy consumer, and rising industrialisation, urbanisation, and incomes are set to drive a sharp increase in energy demand over the coming decades. Relative to 2024 levels, India's total energy consumption is projected to roughly double by 2050, making it the single largest contributor to incremental global energy demand between 2020 and 2040.[12,13] Meeting this growth will require US$1–2 trillion of new investments in energy infrastructure over the next two decades.[14]

This demand growth coincides with deep import dependence. Fossil fuels account for a large share of India's energy supply, making the country one of the world's largest net energy importers. Crude oil import dependence exceeded 88 percent in 2024 and is expected to rise further as transport and industrial demand grow.[15,16] Over the past five years, the average oil import bill has been around INR 4.7 lakh crore in 2011 prices, with crude oil imports contributing roughly 23 percent of India's total import bill.[17] In 2024 alone, India's crude oil import bill exceeded US$132 billion (INR 1.15 lakh crore)—around 3.5 percent of GDP—exposing the economy to international price volatility.[18] Import reliance extends to key industrial inputs: over 90 percent of coking coal used in iron and steel production, 20 percent of coal used in power generation, and 50 percent of natural gas used in multiple sectors including fertilisers are imported.[19] This embeds global market and geopolitical risks directly into India's industrial cost structure.

The macroeconomic implications are significant. Fluctuations in international fuel markets and geopolitical disruptions translate quickly into consumer inflation, higher industrial energy costs, and pressure on the trade balance and currency.[20] Fossil fuel use also remains a major contributor to outdoor air pollution, imposing substantial health and productivity costs. Against this backdrop, clean energy offers a rare opportunity to turn rapid energy demand growth from a source of macroeconomic vulnerability into a stabilising force while simultaneously reducing import exposure, inflation risk, and long-term industrial cost uncertainty.

1.4 Momentum, Capital, and Trade Alignment

India is projected to become the world's second-largest solar market in 2026, overtaking the United States and far exceeding other industrialised economies, with annual solar additions expected to exceed 50 GW—a 6 percent year-on-year increase driven by strong domestic demand, supportive policy signals, and continued cost declines.[21] This sustained deployment momentum places India firmly on track to meet its 500 GW non-fossil electricity target by 2030.

This scale is increasingly aligned with global capital and trade dynamics. International investors are actively seeking exposure to scalable clean-energy and clean-industry platforms in emerging markets, and India's market size, cost structure, and institutional credibility position it among the most attractive destinations. At the same time, evolving European trade arrangements and the Carbon Border Adjustment Mechanism (CBAM) create a credible pathway for exporting green industrial products at a premium, further turning clean energy from a compliance obligation into a source of durable trade and competitiveness advantage.

Chapter 2

Scale and Strategic Timings: Lessons from China

Speed and sequencing matter in industrial transitions. The global clean-energy shift is opening large new markets in transport, power, and manufacturing—but these opportunities are time-bound. Countries that create scale early shape supply chains, cost curves, and trade patterns; those that move later face higher costs and thinner margins.

China's experience across electric vehicles (EVs), solar manufacturing, and batteries illustrates this dynamic. By combining early demand creation with supply-side scale, China converted emerging clean-energy technologies into engines of export growth and energy security. The result was not permanent subsidy dependence, but rapid cost reduction, global market leadership, and reduced exposure to imported fuels.

2.1 Electric Vehicles

China's rise as the world's largest automobile exporter underscores the decisive role of early scale creation in industrial transitions. As recently as 2019, India exported more automobiles than China, while Japan and Germany exported several times more. By 2023, however, China had overtaken both Japan and Germany to become the largest automobile exporter globally, shipping over 5 million vehicles, an increasingly large share of which were electric vehicles.[22] By contrast, India's auto exports have grown more gradually despite a strong domestic manufacturing base.

China's EV leadership was not accidental. Coordinated and sustained policies—such as early support for battery manufacturing, EV sales mandates, and rapid charging infrastructure build-out—created guaranteed demand at scale, driving rapid cost reductions and enabling subsidies to be phased out. As a result, electric vehicles now account for more than half of new passenger car sales in China, significantly reducing oil import exposure while building globally competitive firms.[23] In 2025, BYD surpassed Tesla to become the world's largest EV manufacturer, delivering about 2.3 million vehicles compared to Tesla's 1.6 million, signalling a decisive reordering of global EV leadership.[24]

2.2 Solar Panels

A similar pattern has played out in solar panels. China aligned domestic deployment with manufacturing scale, enabling firms to move rapidly down the cost curve. By 2024, China controlled over 80 percent of global manufacturing capacity across key segments of the solar value chain, including polysilicon, wafers, cells, and modules.[25] India, despite strong deployment and excellent solar resources, was forced into a catch-up position in manufacturing. While recent policy and investment momentum has enabled India to build over 100 GW of domestic module manufacturing capacity, most upstream segments remain concentrated elsewhere.[26]

2.3 Batteries

China treated batteries as a platform technology, spanning transport, grid storage, and consumer electronics. As of 2024, China accounted for roughly 70–80 percent of global lithium-ion battery manufacturing capacity, shaping global supply chains and trade dependencies.[27] India has begun to respond through production-linked incentives and planned gigafactories, but large-scale manufacturing is still at an early stage.

China's experience underscores a central lesson: strategic timing is as important as comparative advantage. Where India has moved decisively, most notably in utility-scale renewables, it has helped reset global cost benchmarks. Where it has hesitated or moved later, such as in EVs and batteries, it has been compelled into catch-up mode. The objective is not imitation, but selective replication of scale-creation mechanisms in sectors where India's fundamentals—market size, cost competitiveness, and institutional capacity—are strongest.

2.4 Strategic Implication for India

Taken together, these conditions reposition clean energy in India from a sectoral transition to a strategic economic platform—one that intersects energy security, industrial competitiveness, trade policy, and geopolitical alignment. The question is no longer whether India can afford to pursue clean energy at scale. It is whether India can move fast enough to convert its cost and institutional advantages into durable leadership in the next generation of energy-intensive industries.

The rest of this report identifies ten such strategies and areas where India can create large domestic dividends while positioning itself as a global supplier in a rapidly transforming world economy.

Chapter 3

Methodology and Framework

India's clean-energy strategy should focus not on spreading effort thinly across many sectors, but on deliberately cultivating a small set of high-impact technologies that can simultaneously deliver four outcomes: rapid economic growth, large-scale job creation, expanded export competitiveness, and deep emissions reductions. This report identifies ten such strategies. Together, they form a coherent growth strategy, anchored in low-cost clean electricity that can power India's development while contributing meaningfully to global climate goals.

Rather than evaluating strategies solely through a decarbonisation lens, this report applies an integrated economic and industrial framework. The goal is to identify opportunities where clean energy becomes a driver of competitiveness, investment, and trade, not only emissions reduction.

These strategies share three defining characteristics. First, they are energy-intensive and therefore stand to benefit disproportionately from India's access to low-cost, firm clean electricity. Second, they are globally scalable, with rapidly expanding international markets driven by decarbonisation, energy security, and digitalisation. Third, clear global leadership has not yet been irreversibly established, creating a window for strategic entry and scale.

3.1 Analytical Framework: Four Evaluation Lenses

Each technology is evaluated using three consistent lenses:

1. **Comparative Advantage:** Where India possesses structural strengths that enable cost leadership or rapid scale.
2. **Domestic Dividend:** The extent to which deployment reduces imports, creates jobs, improves affordability, or strengthens resilience.
3. **Global Market Opportunity:** The size and trajectory of international demand and India's potential positioning within emerging value chains.

Together, these lenses connect national economic priorities with global market dynamics, ensuring that technology selection reflects both domestic development goals and export competitiveness.

3.2 Understanding India's Comparative Advantages, Domestic Dividends, and Export Opportunities

The global energy transition is reshaping where value, jobs, and trade will accrue over the next two decades. This section examines how India's unique combination of resources, institutions, capital, and talent can be converted into domestic dividends and competitive export positions in clean-energy-driven industries.

3.2.1 India's Comparative Advantages

India's clean-energy strategy rests on five reinforcing categories of comparative advantage that together create conditions for scale, competitiveness, and export leadership.

Geopolitical and Supply-Chain Realignment

Shifts in global geopolitics and growing reluctance among many economies to rely on China-centric supply chains for critical energy technologies are creating space for alternative suppliers. India is well positioned to emerge as a trusted source of advanced grid technologies, transformers, power electronics, and electrolysers, leveraging its manufacturing base and geopolitical credibility.[28]

Renewable Resource Endowment

India possesses one of the highest-quality and most seasonally consistent solar resources globally, complemented by robust onshore wind potential.[29] This resource advantage translates directly into structurally low electricity costs, improving affordability for domestic consumers while enhancing the global competitiveness of energy-intensive products manufactured in India.

Distinctive Institutional Framework

India's electricity market architecture, anchored by a unified national grid and open-access and captive procurement frameworks allows large consumers to source power directly from anywhere in the country. This institutional flexibility is rare at scale globally and enables rapid transmission of clean-power cost declines into industrial competitiveness.

Momentum and Capital Attraction in Clean Energy

India's clean-energy sector, particularly power generation, has built strong deployment momentum. At the same time, India remains a major destination for global capital and attracted over US$12 billion in foreign direct investment in renewable energy in FY 2024–25,[30] reflecting growing investor confidence in the country's clean-energy transition. This combination of scale and capital availability accelerates learning, deployment, and cost reduction.

Demographic and Talent Advantage

India's large and expanding workforce provides a deep pool of talent for design, engineering, manufacturing, construction, and operations—skills that are increasingly in demand across the global energy transition. This demographic advantage supports not only domestic deployment but also the export of energy-related services and system-level expertise.

3.2.2 Domestic Dividends: Import Substitution, Jobs, and Air Quality

India's heavy reliance on imported oil and coal poses persistent energy security and macroeconomic risks, while also representing a missed opportunity for domestic value creation. Substituting imported oil and gas through electric mobility, electrified industrial heat, and sustainable aviation fuels, and replacing coking coal in steelmaking with green hydrogen, can significantly reduce import dependence while anchoring new domestic industries.

At the same time, this shift reduces and inflation-proofs energy expenditure. Renewables, EV batteries, and hydrogen infrastructure are capital-intensive assets with rapidly declining costs, reducing exposure to global fuel price volatility. For example, a transition to electric transportation is estimated to generate US$2.5 trillion (INR 190 lakh crore) in net consumer savings through 2047.[31] According to a forthcoming study by the India Energy and Climate Centre, UC Berkeley, in the power sector, scaling 800–1,000 GW of low-cost renewables by 2035 could lower wholesale electricity prices by approximately 15 percent relative to 2024, yielding US$30 billion (INR 2.5 lakh crore) in annual savings while shifting a majority of power expenditure to fixed, inflation-proof costs.

Clean energy also offers a pathway for job creation at scale, with over 1.3 million jobs already in renewables and over 3 million additional jobs by 2030 tied to achieving the 500 GW non-fossil target, with further upside from downstream clean-industrial applications.[32,33]

These shifts would deliver substantial co-benefits in air quality, reducing public-health and productivity losses. An aggressive clean-energy transition could avoid over 4 million premature deaths from air pollution between 2023 and 2047.[34] Additionally, it will also enable India's carbon emissions to peak in the early 2030s and decline to ~800 Mt/yr by 2047, placing the country 85–90 percent on the way to a net-zero trajectory.[35] In parallel, the deployment of low-cost, high-efficiency cooling technologies and improved thermal practices can moderate peak demand, reduce household energy bills, and enhance heat resilience, creating a large, recurring domestic dividend that extends well beyond the energy sector.

3.2.3 Anticipating and Cultivating Future Global Markets

A critical element of this strategy is identifying technologies and products that will experience rapid demand growth as the global energy transition accelerates, but where durable leadership has not yet been established. Unlike lithium-ion batteries where supply chains and market power are already highly concentrated, several emerging clean-energy markets remain fluid, creating an opportunity for early movers to shape cost curves, standards, and trade flows.[36]

Sustainable aviation fuel (SAF) illustrates this dynamic. Global demand for aviation fuel and for SAF in particular is expected to grow sharply, yet no country or firm has established clear dominance. According to recent estimates by NITI Aayog, India's Aviation Turbine Fuel (ATF) demand is projected to reach 43 million tonnes of oil equivalent (Mtoe) in 2050, creating a large domestic market and export potential.[37] As aviation is one of the hardest sectors to decarbonise rapidly, sustainable aviation fuel is expected to be an essential decarbonisation pathway.

SAF is a high-value, premium product, and India has unique advantages in its production: combining low-cost electrolytic hydrogen with biomass-based pathways can increase SAF output by up to three times while lowering costs and lifecycle emissions. Given that India currently burns around 100 million tonnes of crop residue annually,[38] contributing to severe air pollution, redirecting this biomass into SAF production presents a rare opportunity to convert an environmental liability into a globally competitive clean fuel.

A similar opportunity exists in green fertilisers and green steel. Recent auctions in India have demonstrated that India can produce green ammonia at near-competitive prices with the global ammonia/urea market price, reflecting the rapid decline in both solar electricity and electrolytic hydrogen costs. These outcomes imply green hydrogen production costs in the range of US$3/kg, a threshold at which green ammonia and steel start becoming competitive with fossil-based counterparts in key markets. By linking low-cost solar power with electrolysis, India can not only reduce reliance on imported feedstocks such as natural gas but also build exportable green fertiliser or green steel supply chains. This dynamic illustrates how emerging markets that are not yet dominated by incumbent players can be opened through strategic scale creation and targeted industrial integration.

As mechanisms such as the EU's CBAM and the EU Deforestation Regulation (EUDR) begin to reshape global trade by penalising the embedded carbon and environmental footprint of industrial products, early scale in these technologies can help India avoid future trade penalties and potentially capture price premiums in decarbonising global markets. Together, these evolving regulatory frameworks could affect nearly US$9.5 billion of Indian exports, around 12.9 percent of India's total shipments to the EU, highlighting the strategic importance of accelerating low-carbon industrial transformation.[39]

Chapter 4

Ten Clean Energy Strategies for Powering *Viksit Bharat* 2047

India's pathway to clean industrial growth will be shaped not by incremental change across many sectors, but by targeted investment in a small set of technologies capable of transforming energy systems, industry, and global trade positioning simultaneously. Building on the analytical framework outlined in Chapter 3, this section examines ten strategies that combine India's comparative advantages with large domestic dividends and rapidly expanding global market opportunities. Together, these strategies form a coherent strategy for leveraging low-cost clean electricity to drive economic growth, enhance energy security, and strengthen India's role in emerging clean-energy value chains.

Strategic timing now matters as much as ambition. The ten strategies identified here focus on areas where clean energy can deliver large domestic dividends—halved energy costs and imports, improved air quality, and high-value employment—while positioning India for exports in rapidly expanding global markets. Crucially, these are sectors where global leadership is not yet locked in and where India's comparative advantages—low-cost power, domestic market scale, institutional credibility, and a growing talent base—can shape outcomes.

Table 2: Categorisation of Strategies

Strategic Opportunity	What It Means	Primary Objectives	Strategies
Deployment & Scale-Ready Engines	Markets, institutions, and technologies are already mature. The main challenge is execution and scaling existing momentum.	Rapid deployment, cost reduction, and near-term economic dividends.	• Fast RE Deployment to 1,000 GW by 2035 • Electric Trucks • Advanced Grid Technologies • Data Centres & Digital Energy Infrastructure • Advanced Cooling Technologies
Market-Building Platforms	Technologies are commercial but need coordination, offtake certainty, aggregation, and market design to scale.	Build demand, reduce risk, and unlock new industrial markets.	• Green Steel & Green Fertiliser • Industrial Heat Electrification • Sustainable Aviation Fuel (SAF)
Frontier Technology Bets	Strategic long-term technologies requiring sustained R&D, pilots, and ecosystem development.	Innovation leadership and future export positioning.	• Storage Technologies Beyond Lithium • Electrolysers

Source: Authors' own

4.1 Strategy Deep Dives

The following subsections provide detailed analyses of each strategy, examining how India's structural strengths translate into domestic economic benefits and emerging global competitiveness.

4.1.1 Deployment and Scale-Ready Engines

These technologies are already mature and supported by established market frameworks and institutional capacity. The primary challenge is not innovation, but accelerating deployment through coordinated execution, infrastructure expansion, and investment alignment. Rapid scaling in these areas can deliver immediate domestic economic dividends while reinforcing India's competitiveness in emerging clean-energy markets.

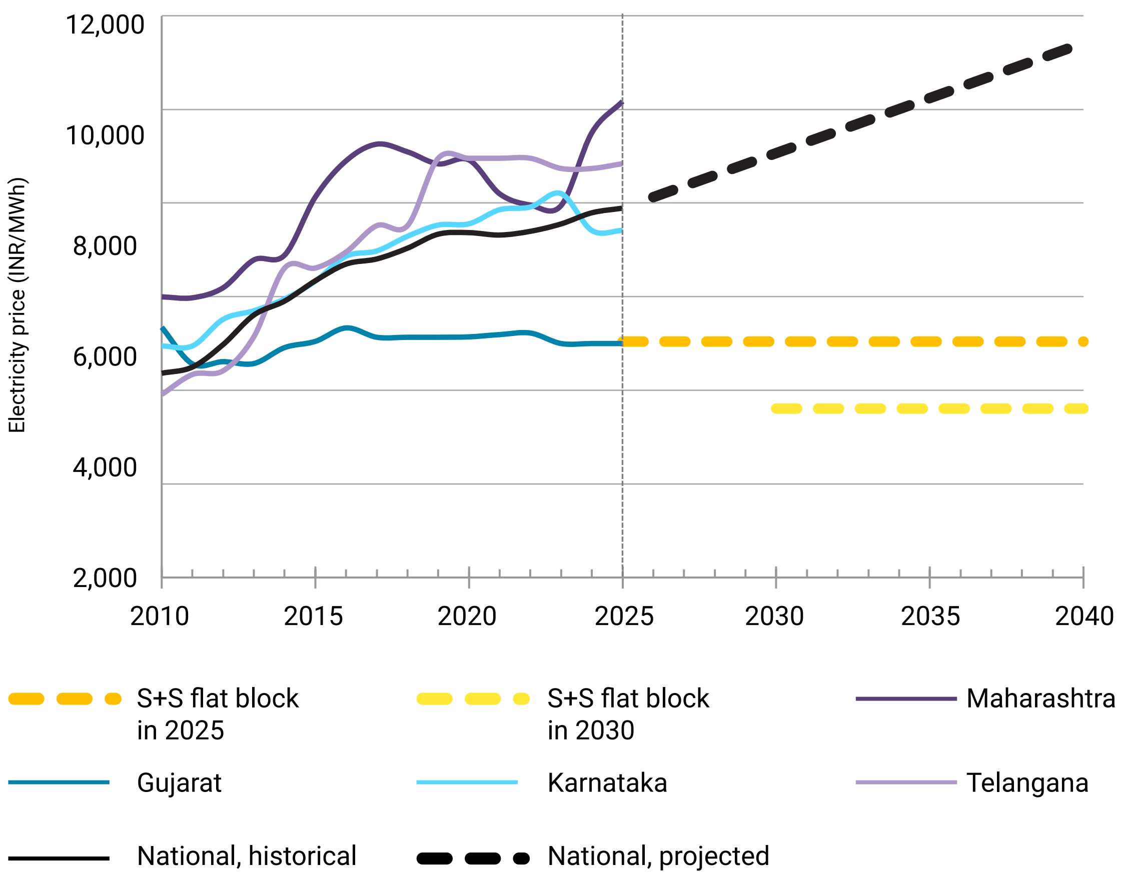
Strategy 1: Fast RE Deployment: Solar + Storage Round-the-Clock Power

Falling solar and battery storage costs are creating a new paradigm for electricity generation in India. Standalone solar is paving the way for more advanced solar-plus-storage models. The Government of India's recent decision to significantly expand Viability Gap Funding (VGF) for Battery Energy Storage Systems to INR 1,000 crore in the latest Union Budget further reinforces this momentum.[40]

Estimates based on recent reverse auctions in India demonstrate that, solar-plus-storage systems can now deliver round-the-clock clean power at over 95 percent availability at prices below INR 4/kWh.[41] This is 20-30 percent cheaper than prevailing industrial tariffs in many states and also competitive with the cost of electricity from new coal plants.[42]

Figure 2 shows that the costs of a solar-plus-storage flat block are projected to remain constant through 2040 in nominal terms, whereas national electricity prices for industrial consumers are likely to increase based on historical trends. A solar-plus-storage (S+S) flat block is also competitive with industrial electricity prices in several major Indian states, which have exhibited significant variability over the past 15 years.

Figure 2: Industrial Electricity Prices Vs Solar-Plus-Storage Flat-Block Costs in India



Source: Choikiewicz et al. (2025)[43]

The study also highlighted that unlike conventional industrial tariffs, which typically rise with inflation, long-term solar-plus-storage contracts can offer fixed prices for up to 25 years, providing cost certainty for utilities and industrial consumers while reducing exposure to fuel price volatility.[44] This shift has significant economic implications, positioning renewable power not only as a decarbonisation pathway but also as a tool for stabilising energy costs and supporting long-term industrial competitiveness.

India's existing manufacturing ecosystem strengthens this opportunity. The country already has over 100 GW of solar module manufacturing capacity and more than 6 GW of solar cell manufacturing capacity, with continued expansion underway.[45] At the same time, growing interest in domestic battery manufacturing and system integration is creating the foundations of a vertically integrated solar-plus-storage supply chain, enabling

India to capture value across project development, equipment manufacturing, and energy services.

To unlock this potential, policymakers will need to enable technology-neutral, all-source competitive bidding for firm 24×7 power, allowing solar-plus-storage projects to compete directly with thermal generation. Co-locating renewable generation with battery storage should be prioritised. Physically, it is easier to co-locate solar and battery storage and is also the most cost-effective option as it offers 15–20 percent cost savings from shared inverters, grid access, and balance of system (BOS) components.[46] Additionally, deployment can also be accelerated by enabling new solar-plus-storage projects to utilise surplus transmission interconnection capacity at existing plants, reducing land, permitting, and grid-upgrade bottlenecks.

Strategy 2: Advanced Grid Technologies

India's transmission system is facing growing strain as electrification accelerates, renewable capacity expands, and urban electricity demand continues to rise. Meeting this demand efficiently will require a reliable grid that can integrate large-scale renewable generation. Much of today's transmission infrastructure continues to rely on conventional Aluminium Conductor Steel Reinforced (ACSR) technology, a design that has remained largely unchanged for decades. Over the past two decades, however, a new class of advanced transmission conductors have emerged and are gaining momentum.

Reconductoring existing transmission corridors using advanced composite-core conductors, particularly high-temperature low-sag (HTLS) technologies, offers a transformative opportunity to expand India's grid capacity without requiring extensive new rights-of-way.[47] These technologies can double the power transfer capability of existing lines, and when combined with energy storage deployment and incremental renewable additions at existing interconnection points, they can deliver a 4–5x increase in effective capacity within current corridors.[48] Such upgrades could enable the transmission system to integrate nearly 1,000 GW of renewable energy, positioning advanced grid infrastructure as a critical enabler of India's long-term clean energy strategy.[49]

Economically, India's planned US$100-billion transmission expansion through 2032, representing a roughly 40-percent increase in network length creates a unique opportunity to future-proof grid investments.[50] A recent study by UC Berkeley argues that while deploying HTLS conductors on all planned greenfield lines could increase upfront capital costs by approximately US$22 billion, or about 22 percent compared with conventional ACSR conductors, this additional investment is expected to be recovered within roughly four years through reduced transmission losses alone.[51] Beyond cost savings, HTLS technologies also enhance grid resilience during extreme heat events by maintaining high transfer capacity even at elevated operating temperatures, an increasingly important consideration as climate risks intensify.

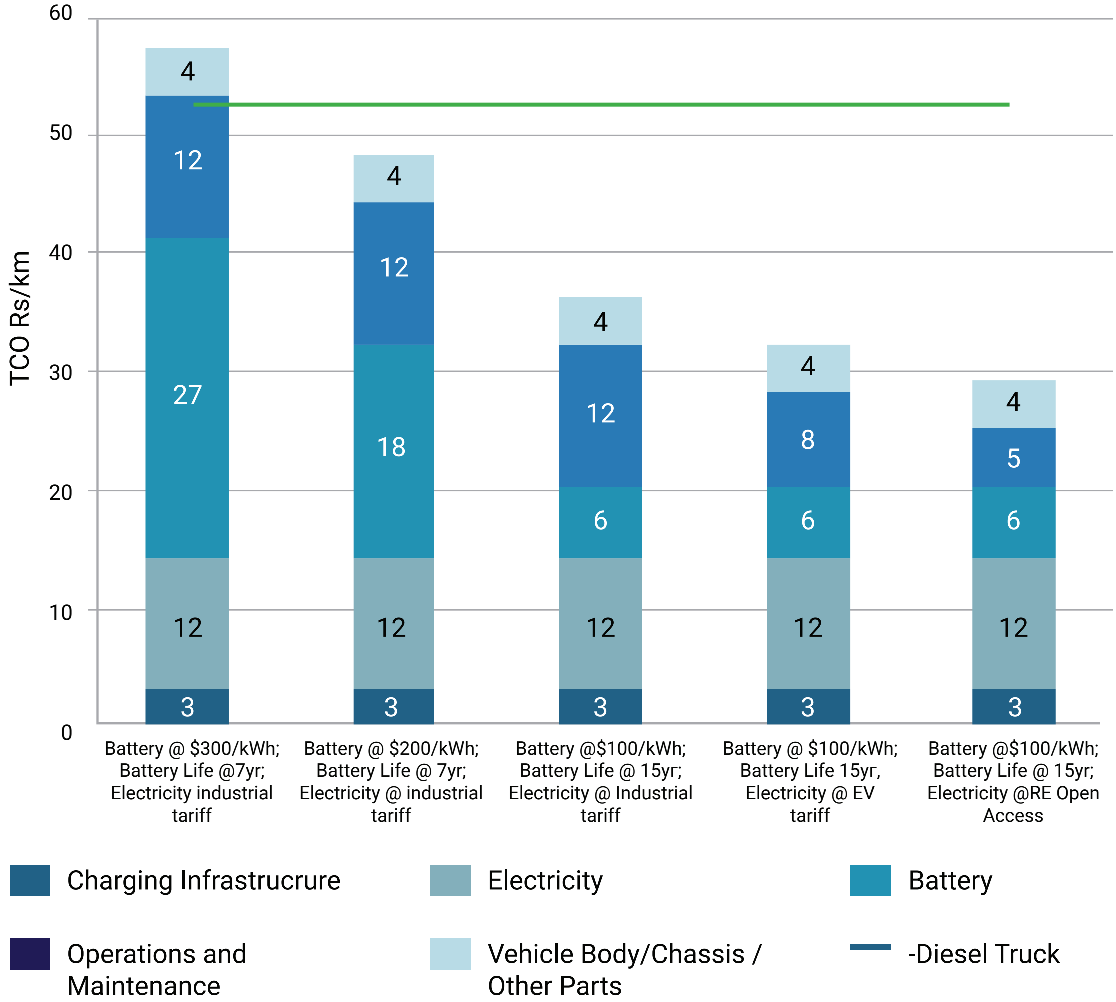
A coordinated national approach to doubling the effective capacity of existing transmission networks by 2030 will be critical. As India moves toward finalising the National Electricity Policy 2026,[52] grid expansion and investment frameworks can evolve to account for advanced technologies such as HTLS conductors in new transmission lines, alongside regulatory mechanisms that enable and support such investments at both central and state levels. India already possesses growing domestic manufacturing capacity for advanced conductors, and leveraging the country's strong electrical-equipment industry could position it as a global supplier of next-generation transmission technologies. Realising this potential will require regulatory and planning reforms that shift transmission evaluation toward a total-cost-of-ownership approach, accounting for long-term efficiency gains rather than only upfront capital expenditure.

Strategy 3: Electric Trucks

Recent declines in battery costs and rapid technological advancements have accelerated the global shift toward electrified freight transport, resulting in the availability of more than 800 electric truck models worldwide, including nearly 300 electric heavy-duty vehicles (HDVs) such as the Tesla Semi Truck. These vehicles offer 3–4x better fuel economy than conventional diesel trucks, fundamentally reshaping the economics of freight movement.

Falling battery costs, extended useful life, and low-cost inflation-proof clean power reduce both upfront vehicle costs and the ongoing charging costs. Our preliminary analysis demonstrates that, at scale, electric trucks not only can achieve cost parity with diesel trucks, but also potentially deliver up to 50-percent lower total cost of ownership (TCO), as illustrated in Figure 3.

Figure 3: Total Cost of Ownership (TCO) of 25-Ton Electric Trucks in India



Source: Authors' own estimates

Note: Estimated for varying assumptions on battery costs, battery life, and electricity cost. The black line shows the TCO of a 25-ton diesel truck.

India's experience in the power sector illustrates how scale can unlock rapid and sustained cost reductions. Through large-scale renewable energy and storage auctions, the country has driven grid-scale stationary battery storage prices down by more than 80 percent between 2021 and 2025. Although comparable cost reductions have not yet been realised in the transport sector, similar dynamics should be achievable if the MDV/HDV market leverages global battery cost declines and applies lessons from the power sector's scale-driven transition.

India's broader electric-mobility transition is already underway across several vehicle segments. According to recent estimates, electric two-wheelers have grown from just 0.1 percent of new registrations in FY2020 to 5.38 percent in FY2024, while electric four-wheelers increased from 0.1 percent to around 5 percent over the same period. The three-wheeler category has seen particularly rapid electrification, rising from 17.6 percent to 54.2 percent of new registrations, highlighting how policy support and falling battery costs can quickly transform segments where total cost of ownership becomes favourable.[54] The Government of India has also introduced targeted financial incentives for electric trucks under the PM E-DRIVE initiative, aimed at accelerating the adoption of zero-emission freight transport. The programme is expected to support the deployment of around 5,600 e-trucks nationwide, including a dedicated allocation of approximately 1,100 vehicles in Delhi, backed by an estimated ₹100 crore outlay to help address the capital's severe air-quality challenges. Diesel trucks, though constituting only 3 percent of the total vehicle population, contribute to 42 percent of transport-related greenhouse gas emissions and significantly worsen air pollution.[55]

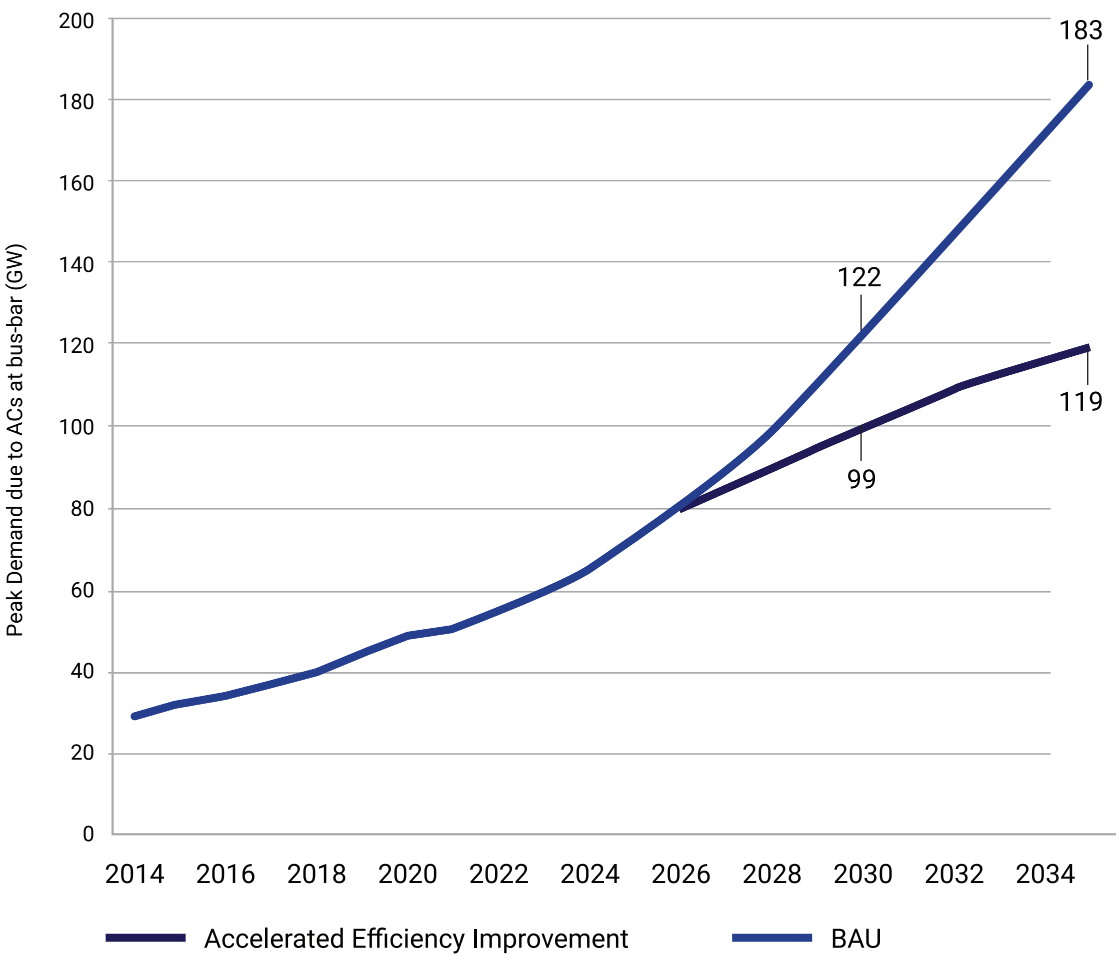
At scale, the transition to electric HDVs could deliver substantial economic benefits for India by reducing oil import dependence, insulating logistics costs from fuel price volatility, and protecting the broader economy from goods inflation. Lower operating costs and improved energy efficiency also create opportunities for long-term consumer savings and enhanced supply-chain resilience. India's large commercial vehicle market and strong automotive manufacturing ecosystem position it well to capture domestic manufacturing and export opportunities as global demand for electric freight vehicles grows.

While national-level policies provide an important foundation for accelerating freight electrification, state-level action will play a decisive role in scaling electric trucks given the sector's diverse operating conditions and use-cases. Policy frameworks are most effective when tailored to industrial clusters, freight corridors, and regional trucking patterns. Several states, including Madhya Pradesh and Maharashtra, have begun advancing supportive measures by aligning incentives, infrastructure planning, and regulatory approaches with local transport needs.[56] Subnational zero-emission vehicle mandates can further help align vehicle supply with deployment targets, while coordinated planning for charging infrastructure along major freight routes remains critical to enabling reliable operations. For example, Maharashtra's EV policy identifies the Mumbai–Pune and Mumbai–Nagpur expressways as priority corridors for charging deployment, helping ensure seamless e-truck movement across high-traffic industrial routes.[57] Similar corridors can be identified to expand charging infrastructure for each state.

Strategy 4: Advanced Cooling Technologies

Rapid growth in cooling demand, driven by rising incomes and increasing temperatures, presents both a challenge and an opportunity for India's energy system. It is technically feasible and economically advantageous to significantly accelerate improvements in air-conditioner efficiency, potentially doubling the current rate of performance gains. Recent revisions to India's room air-conditioner minimum energy performance standards (MEPS), set to take effect from 2028, represent an important step forward. However, globally best-available technologies remain substantially more efficient than products currently available in India and even beyond the planned MEPS trajectory, indicating considerable headroom for sustained efficiency improvements well beyond 2030.[58] Advancing toward this higher efficiency benchmarks can transform cooling from a major driver of peak electricity demand into a strategic lever for reducing system costs and supporting renewable integration.

Figure 4: Projected Peak Demand (National) Due to Room ACs



Source: Abhyankar et al (2025)[59]

The projection is made for two scenarios: BAU and Accelerated Efficiency Improvement Under the Accelerated Efficiency Improvement scenario—where MEPS are tightened aggressively starting in 2027—AC-driven peak demand can be reduced by 23 GW by 2030 and over 60 GW by 2035. This is equivalent to avoiding the need for 120 large (500 MW) thermal power plants (~US$60-70 billion in generation capacity investments), along with US$25–30 billion in additional transmission and distribution infrastructure.

The economic benefits of accelerated efficiency improvements are substantial. Over the next decade, enhanced AC performance could generate net consumer savings exceeding INR 225,000 crore (approximately US$25 billion), while reducing national peak demand by as much as 60 GW by 2035—equivalent to avoiding the construction of dozens of large thermal power plants and associated grid investments.[60] Improved efficiency would also strengthen distribution utilities' financial health by lowering peak procurement costs and enabling greater integration of solar power into the grid.

At the same time, Indian manufacturers stand to benefit from expanding global markets and technology upgrades, supported by nearly US$1 billion available through the Montreal Protocol Multilateral Fund for HFC phase-down–linked manufacturing improvements[61] and an additional US$700 million in World Bank–supported financing under the AHEAD programme.[62] These resources can help modernise production lines, accelerate adoption of high-efficiency technologies, and diversify global supply chains.

Realising this opportunity will require sustained and predictable policy support. Continued aggressive tightening of MEPS, coupled with clear long-term efficiency targets and interim milestones aligned with commercially available technologies, will provide industry with the investment certainty needed to scale innovation. By combining strong standards with manufacturing support and international financing, India can position advanced cooling technologies as a cornerstone of both domestic energy savings and global clean-technology competitiveness.

Strategy 5: Data Centres and Digital Energy Infrastructure

The rapid expansion of India's digital economy is driving a structural surge in demand for reliable, low-cost electricity. Data centres now sit at the strategic intersection of clean power, industrial growth, and global competitiveness. As cloud computing, digital public infrastructure, fintech, e-commerce, and artificial intelligence scale across government and industry, electricity demand from digital infrastructure is rising sharply.

India's cloud data-centre capacity currently stands at approximately 1,280 MW, supporting critical sectors such as banking, power systems, telecommunications, and public digital platforms. Capacity is projected to grow four- to five-fold by 2030.[63] Looking further ahead, India's data centres could consume nearly 390 TWh of electricity by 2070, underscoring the urgency of aligning digital infrastructure expansion with long-term carbon-neutral power planning.[64]

At the same time, hyperscale operators and global technology firms have adopted ambitious net-zero and 24×7 carbon-free electricity commitments. This is intensifying demand for firm, round-the-clock clean power. In advanced economies such as the United States and parts of Europe, however, delivered prices for firm clean energy remain high due to elevated EPC costs, land constraints, transmission bottlenecks, lengthy interconnection queues, and fragmented electricity markets. Regions capable of delivering reliable clean power at scale and at predictable prices may therefore acquire a structural advantage in attracting digital infrastructure investment.

India is uniquely positioned to supply inflation-resistant 24×7 clean electricity to data centres at globally competitive prices. Record-low solar-plus-storage auction tariffs, a nationally integrated transmission grid, and flexible open-access and captive procurement frameworks create a distinctive structural advantage. Renewable generation can be developed in high-resource regions such as Rajasthan or Gujarat and wheeled efficiently to urban load centres—where most data centres are located and land is constrained.

Preliminary analysis indicates that, even after accounting for network charges, losses, and balancing costs, delivered 24×7 clean power prices for Indian data centres could range between ₹5.5–7.0/kWh (approximately US$60–80/MWh). These prices are materially below prevailing firm clean energy contract prices in the United States and Europe, which frequently exceed US$100–150/MWh.

Importantly, more than 70 percent of delivered costs under long-term renewable contracts are fixed in nominal rupee terms over 25 years. In contrast, conventional utility tariffs in many Indian states have historically escalated at 4–5 percent annually in nominal terms. Moreover, given the historical trend of rupee depreciation relative to the US dollar (approximately 2–3 percent annually), effective dollar-denominated power costs under long-term rupee PPAs decline over time for globally reporting firms. Even under conservative exchange-rate assumptions, nominal dollar costs fall across the contract life, while real (inflation-adjusted) dollar costs decline even more substantially. This creates a powerful hedge against both fuel price volatility and currency risk.

Structural clean-power cost differentials may increasingly shape the geography of data-centre investment. India's ability to provide reliable, long-term, inflation-resistant 24×7 clean electricity at competitive prices has implications beyond energy economics—it strengthens industrial strategy, digital sovereignty, foreign direct investment flows, and global decarbonisation pathways.

Economically, renewable-powered data centres can reduce long-term energy costs, improve infrastructure utilisation, and deepen electricity markets by enabling new demand-response and smart energy management models. It can also potentially reduce their emissions by 88 percent, with transformative impacts for the country's overall decarbonisation targets.[65]

Additionally, India's leadership in digital public infrastructure, including large-scale digital payment platforms and emerging energy-market architectures, creates opportunities to develop exportable business models that combine digital finance with clean-energy procurement. The growth of green data centres also presents a significant opportunity to attract foreign direct investment, as global technology companies increasingly seek low-carbon infrastructure aligned with net-zero commitments.

Realising this opportunity will require enabling policy frameworks that facilitate direct procurement of 24×7 clean power, support renewable-powered data centre clusters, and encourage innovation in smart energy markets. Policies that integrate digital infrastructure planning with renewable energy deployment—alongside incentives for clean-power–supplied industrial and data centre enclaves—can help align India's digital growth with its broader clean-energy and industrial strategy.

4.1.2 Market-Building Platforms

These technologies are technically proven but have yet to achieve large-scale deployment due to fragmented demand, financing challenges, and coordination gaps across value chains. Scaling them requires deliberate market creation through standards, aggregation mechanisms, long-term offtake structures, and supportive market design. When aligned effectively, these platforms can unlock new industrial ecosystems and position India in emerging low-carbon export markets.

Strategy 6: Green Steel and Green Fertiliser

Declining costs of solar electricity and electrolysers, combined with India's abundant and seasonally consistent renewable resources, are creating a unique opportunity to produce green steel and green fertiliser at globally competitive prices.[66] Hydrogen is expected to play an important role in decarbonising the steel sector, as it can be applied across various stages of production including the Direct Reduced Iron (DRI) process. Using green hydrogen–based direct reduced iron (H2-DRI) technology and achieving sufficient manufacturing scale, our analysis suggests that there is a pathway in India to produce green steel below US$550 per ton and green fertiliser below US$400 per ton—price points that position these products competitively in emerging low-carbon industrial markets. Beyond emissions reductions, this transition carries significant economic benefits by reducing reliance on imported coking coal for steel production and natural gas for fertiliser manufacturing, thereby stabilising input costs and protecting key sectors from global fuel price volatility.

A study by EY estimates that India's steel sector could require approximately 9.82 million tonnes per annum (MMTPA) of green hydrogen by 2050 to support deep decarbonisation. Steel produced through the green hydrogen–based DRI-EAF pathway, capable of achieving up to a 90-percent reduction in emissions compared to conventional processes, is projected to become increasingly cost-competitive, with production costs expected to decline from around US$600 per ton in 2024 to approximately US$421 per ton by 2040, implying the cost premium of green steel over conventional BF-BOF steel to decline from 32 percent in 2025 to about 1 percent in 2030, reaching a discount of roughly 50 percent by 2050.[67] Several other studies, including a forthcoming one from IECC consistently indicate a rapid narrowing of the cost premium through the 2030s. These trends suggest that green hydrogen–based steelmaking could emerge as a commercially viable and sustainable alternative to traditional blast-furnace routes.

The shift toward green industrial production also presents a strong domestic manufacturing and export opportunity. As international markets increasingly adopt policies such as the EU's CBAM and global automakers commit to sourcing low-carbon materials, demand for green steel is expected to grow rapidly. India's ability to produce cost-competitive green commodities could therefore unlock substantial export potential while catalysing domestic supply chains, including electrolyser manufacturing, mirroring the country's success in scaling solar manufacturing.

Realising this opportunity will depend on a supportive regulatory environment that helps reduce early-stage investment risks and build market confidence. Long-term offtake arrangements for initial large-scale projects, along with targeted tax incentives or viability gap funding, can help accelerate deployment and lower financing barriers. The development of a carbon pricing framework such as the forthcoming Carbon Credit Trading Scheme (CCTS) could further strengthen investment signals for steel-sector decarbonisation. Additionally, public–private partnerships will be important for developing green hydrogen infrastructure, including production hubs, storage systems, and transport networks. Coordinated infrastructure planning can optimise supply chains and significantly reduce hydrogen delivery costs, with some estimates suggesting potential cost reductions of 70–90 percent between 2030 and 2040.

Strategy 7: Industrial Heat Electrification

Industrial heating represents one of the largest and most underexplored opportunities in India's clean-energy transition, accounting for approximately 44 percent of the country's final energy use, with nearly 80 percent currently supplied by fossil fuels, much of it imported and subject to price volatility. A significant share of this demand, particularly low- and medium-temperature heat in the range of 200–500 °C, is technically and economically suitable for direct electrification. Technologies such as industrial heat pumps, electric boilers, and thermal batteries, when powered by India's low-cost solar electricity offer a viable pathway to decarbonise industrial energy use while stabilising long-term heat supply. Electrified heat can be delivered at roughly ₹2–4 per kWh-thermal, making it over 30-percent cheaper than heating based on imported oil or gas and broadly competitive with coal-based systems, while eliminating exposure to fuel price fluctuations.

India's uniquely low solar tariffs and flexible open-access procurement framework give it a structural advantage in scaling industrial heat electrification ahead of many other economies. Early-adopter sectors such as food processing, dairy, textiles, chemicals, pulp and paper, and light manufacturing, many of which are MSME-dominated, stand to benefit from lower operating costs, improved workplace safety, and reduced compliance burdens. At the same time, the transition can stimulate domestic manufacturing of heat pumps, electric boilers, thermal batteries, and advanced control systems, anchor new clean-technology supply chains and generate broader air-quality and public-health benefits.

Realising this opportunity will require coordinated policy action, including industrial-cluster demand aggregation, removal of barriers to open-access electricity procurement, and targeted fiscal support such as accelerated depreciation for high-capex electrification equipment.

Strategy 8: Sustainable Aviation Fuel

Falling costs of solar energy and electrolysers, combined with India's 750 million tonnes of available biomass and nearly 213 million tonnes of surplus agricultural residue, creates a unique opportunity to produce sustainable aviation fuel (SAF) economically at scale.[68] By integrating biomass feedstocks with green hydrogen through the Fischer–Tropsch process, overall carbon and hydrogen efficiency improves substantially, enabling potential SAF production costs of around $6 per gallon with sufficient manufacturing scale. This pathway aligns India's renewable energy advantages with its growing aviation sector, positioning SAF as a strategic bridge between clean energy deployment and industrial innovation. According to recent estimates, SAF can reduce lifecycle greenhouse gas emissions by 60–80 percent compared to conventional jet fuel, while some pathways are capable of achieving reductions of up to 80 percent.[69]

From an economic standpoint, domestic SAF production could reduce reliance on imported crude oil for aviation fuel, stabilise long-term energy costs, and unlock a significant export opportunity. Global demand for SAF is rising rapidly as airlines adopt net-zero targets and blending commitments, with the European Union mandating SAF blending levels of 20 percent by 2035 and 70 percent by 2050. Such policy drivers, combined with India's rapidly expanding aviation market, create strong demand signals that could support early scale and investment. As a member state of ICAO, India will be required to comply with the mandatory phase of CORSIA beginning in 2027, creating additional momentum for domestic deployment. National targets already signal early market creation, with blending mandates of 1 percent SAF by 2027 and 2 percent by 2028, applicable initially to international flights, alongside a proposed pathway toward 10 percent blending by 2035. These policy signals are reinforced by early industrial activity: India's first SAF production facility is already producing approximately 3,200 tonnes per year, and public-sector refineries are preparing to scale output to nearly 32,000 tonnes by 2027, indicating the emergence of a domestic supply base.[70]

SAF also presents a compelling domestic manufacturing opportunity. As a high-value fuel in a fast-growing sector, it could anchor new supply chains spanning biomass aggregation, electrolyser manufacturing, and advanced fuel production—mirroring the industrial growth seen in India's solar sector.

Scaling cost-effective sustainable aviation fuel (SAF) adoption will depend on a coordinated policy framework that provides clear long-term direction and enables integration across the aviation value chain. This includes well-defined policy signals, supportive fiscal instruments, and market-based mechanisms such as carbon pricing or offset frameworks that help create stable demand and reduce investment risk. Structured blending mandates by major airports and leading airlines can play an important role in building early markets and accelerating industry confidence.

4.1.3 Frontier Technology Bets

These technologies hold significant long-term strategic potential but are still evolving in terms of cost, performance, and ecosystem readiness. Early investment in research, pilot projects, and demonstration-scale deployment is essential to accelerate learning and reduce uncertainty. Building capabilities in these frontier areas today can position India to capture future markets as technologies mature and global demand expands.

Strategy 9: Storage Technologies Beyond Lithium

The rapid expansion of renewable energy, accelerating adoption of electric vehicles, and the urgent need to modernise power grids are collectively driving extraordinary demand for advanced battery technologies across emerging markets. Within this broader global shift, India's energy storage transformation stands out as one of the most consequential opportunities to redefine global battery supply chains.[71] A recent study by the India Energy and Climate Centre, UC Berkeley estimated that the global demand for batteries has already exceeded 1,000 GWh per year, driven primarily by electric vehicles, which account for roughly 85 percent of demand, followed by grid-scale energy storage at around 8–10 percent and consumer electronics at about 5 percent. This demand is expected to nearly double by 2030 and triple by around 2035, yet the supply chain remains highly concentrated, with approximately 80 percent of lithium-based battery manufacturing dominated or controlled by China.[72] As the global energy transition accelerates, diversifying storage technologies and supply chains presents a strategic opportunity for India—particularly by leveraging domestic material availability in elements such as sodium, zinc, and iron to develop alternative storage chemistries.

From an economic perspective, lithium batteries have achieved significant technological maturity and manufacturing scale, with LFP battery pack prices reaching about US$82/kWh in 2025 and projected to fall to roughly US$60/kWh by 2030.[73] These cost declines make lithium technologies well suited for electric vehicles and short-duration grid storage. However, providing cross-seasonal grid balancing and supporting critical industrial loads will require long-duration storage solutions that can deliver energy at costs below US$10–20/kWh—thresholds that may be difficult for lithium technologies to achieve but could be feasible for emerging technologies such as iron-air batteries. Developing such systems could reduce system-level electricity costs while improving energy security in a deeply renewable power system.

Building on India's experience in scaling solar manufacturing, there is a clear pathway to reduce the cost of next-generation storage technologies through domestic innovation and manufacturing. Growing global demand for diversified, reliable, and cost-competitive energy storage solutions creates a potential export opportunity, particularly as countries seek alternatives to concentrated lithium supply chains.

Realising this potential will require targeted policy support, including tax incentives and subsidies for research, development, and demonstration (R, D&D) of low–technology-readiness-level technologies, along with pilot deployment programmes that provide real-world operating experience and accelerate commercialisation.

Strategy 10: Electrolysers

Electrolysers represent a critical enabling technology for India's emerging green hydrogen economy and broader clean industrial transformation. Under the National Green Hydrogen Mission, India has set a target of producing 5 million tons per year of green hydrogen by 2030, with production costs below US$3/kg considered essential for making green steel, green fertiliser, and sustainable aviation fuels economically viable. Recent green ammonia auctions conducted by SECI have already discovered prices in the range of ₹50–55/kg, implying green hydrogen costs of roughly US$3/kg, signalling rapid progress toward competitiveness. Achieving further cost reductions will depend significantly on lowering electrolyser capital costs to around US$300/kW, a threshold that could unlock large-scale deployment and enable globally competitive green hydrogen supply chains.

From an economic perspective, electrolyser manufacturing presents a major industrial opportunity. While typical PEM electrolyser systems in the US and EU currently cost around US$1,200–1,500/kW, alkaline electrolysers in China are available at approximately US$300–600/kW,[74] demonstrating the impact of scale and industrial policy on cost reduction. India's experience in reducing solar capital costs—now roughly 50-percent lower than in the US and about 20-percent lower than in China despite using similar hardware—suggests that a comparable cost trajectory could be achieved for electrolysers through innovative policy frameworks and manufacturing scale. Building domestic manufacturing capacity could position India as a trusted global supplier of affordable and reliable electrolysers at a time when international demand for diversified supply chains is rising rapidly.

Realising this opportunity will require targeted policy support, including tax incentives and manufacturing subsidies to accelerate domestic production, as well as procurement frameworks that encourage the use of locally manufactured electrolysers in green hydrogen auctions. Emulating the success of domestic manufacturing–linked solar auctions could help drive early scale while strengthening supply chains. In addition, expanded R&D funding will be essential to address operational challenges associated with alkaline electrolysers—such as performance under intermittent renewable power and high technical minimum load requirements—ensuring that India's electrolyser ecosystem remains both cost-competitive and technologically robust.

4.2 Strategic Opportunity Matrix

The preceding sections provided detailed analyses of each technology through the four evaluation lenses described earlier in this report. Table 4 synthesises these insights into a comparative matrix, enabling a cross-sector view of India's strategic positioning and policy priorities.

Table 3: Strategic Opportunity Matrix

	Strategies	Comparative Advantage	Domestic Dividend	Export Opportunity & Addressable Market	Policy Levers
Deployment and Scale-Ready Engines					
1	Fast RE Deployment to Reach 1000 GW by 2035	Record-low solar + storage prices implying near 24x7 clean power at Rs 4/kWh ($45/MWh); integrated national grid and favourable open access and captive procurement framework; strong institutional capability and innovative auctions; robust electricity demand growth.	Reduce electricity cost by 15%; maintain grid reliably while offering a long runway to existing fossil capacity; new construction jobs; utilise domestic solar panel and battery manufacturing.	Double the RE deployment rate from ~40-50GW/year to 80-100 GW/yr, including storage; Create 50 RE zones of 20-30 GW each to integrate 1000 GW RE by 2035.	Expand non-utility demand, co-locate RE with storage, and use surplus transmission interconnection at existing plants to double annual deployment to 80-100 GW/yr.
2	Electric Trucks	Strong auto manufacturing sector; capabilities; battery manufacturing is also increasing; strong economic and industrial growth implies a large freight truck market that can offer scale.	Imported crude oil substitution; reduce & inflation proof freight transport cost.	Each year ~400,000 new freight trucks are sold in India with ~4 million globally. Electric truck sales are already ~10-15% of the new truck sales in China.	Implement technology-agnostic zero-emission vehicle (ZEV) sales mandates for trucks, paired with corridor charging infrastructure.

	Strategies	Comparative Advantage	Domestic Dividend	Export Opportunity & Addressable Market	Policy Levers
3	Advanced Grid Technologies	Strengths in manufacturing electrical equipment; strong domestic demand and power sector institutional capability that can offer scale to reduce costs.	Doubling grid capacity within existing right of way at low cost to integrate large amounts of RE in the grid.	Increasing global demand for critical grid equipment including advanced conductors and transformers from a trustworthy partner; Target building 100,000 circuit km of advanced conductors to integrate 1000 GW of RE by 2035.	Mandate total-cost-of-ownership–based transmission planning and deploy advanced conductors and reconductoring as default options.
4	Data Centres and Digital Energy Infrastructure	Low-cost 24x7 clean electricity for data centres; global leadership & scale with UPI and Energy Stack; smart demand, distributed solar and storage.	Reduce energy costs and improve infrastructure utilisation; deepen energy markets	Green data centres can attract new FDI; new business models in energy markets enabled by smart financial technologies could be scaled globally	Create green data-centre enclaves with assured 24×7 clean power and enable new markets using energy-linked digital services built on India's digital public infrastructure.

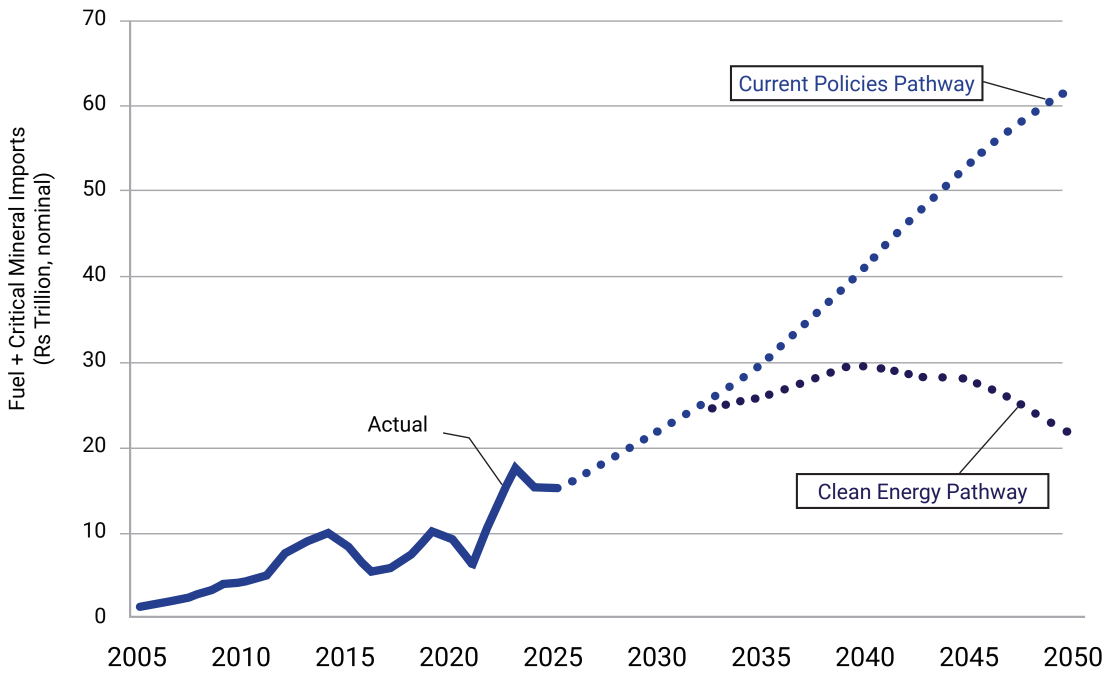
	Strategies	Comparative Advantage	Domestic Dividend	Export Opportunity & Addressable Market	Policy Levers
5	Advanced Cooling Technologies	Strengths in manufacturing; massive domestic demand of room ACs that can offer scale for cost reduction; strong standard-making institutions and momentum due to recent revisions; announcements at COP-28 and CEM of doubling energy efficiency by 2030	Reduce consumer energy bills by 20-40%; help adopt to heat stress due to rising temperatures; make grid integration of solar energy more economical by lowering the electricity demand during non-solar hours	India's room AC market is 14 million units/yr, doubling every 10 years. Efficient ACs could reduce 60GW of peak demand by 2035 or so. Global room AC market is ~150 million/yr, with nearly half in China. Significantly increasing room AC demand, especially from the global south.	Commit to an aggressive and long-term MEPS trajectory—2030 MEPS set at today's best technology sold in India; 2035 MEPS set at today's global best.
Market building platforms					
6	Green Steel and Fertiliser	Strong steel manufacturing capacity; seasonally consistent solar resources critical for continuous green H2 production; growing capability to manufacture low-cost electrolysers; large domestic demand providing scale (steel ≈140 MT/yr, doubling every decade; urea ≈ 25–30 MT/yr).	Substitute expensive coking coal and imported natural gas with domestic solar resources; inflation-proof steel and fertiliser production; reduce exposure to volatile fossil fuel imports; lower and stabilise fertiliser subsidy burden (≈$20 billion/yr).	Global steel market is ~2 billion tons/yr (~$1 trillion/yr); 50% produced by China. Demand for green steel rising due to net-zero goals & import policies like CBAM. Global urea market is $150 billion/yr, impacted by gas market volatility. Inflation-proof green fertiliser is a big opportunity.	De-risk first projects through long-term offtake guarantees and time-bound public procurement mandates with price caps.

	Strategies	Comparative Advantage	Domestic Dividend	Export Opportunity & Addressable Market	Policy Levers
7	Industrial Heat Electrification	~50% of the final energy use in industrial processes is heat, offering robust domestic demand for scale. Open access and captive procurement makes low-cost clean electricity available to all large consumers. Strong heat battery manufacturing capability.	Electric heat pumps and thermal batteries can substitute imported oil gas used for industrial heat by clean electricity; give industries a global edge due to low & inflation-proof energy costs; large air quality benefit	Heat electrification tech would be a strong export market as countries face volatile fossil fuel markets and tightening climate regulations; clean electrified manufacturing clusters could unlock a new channel for FDI	Aggregate demand at industrial clusters, remove open-access barriers, and provide accelerated depreciation for high-capex electrification equipment.
8	Sustainable Aviation Fuel	Potential use of crop residue that is otherwise burned & causes air pollution; India is the third largest aviation market in the world	Imported crude oil substitution; potential commercial use of biomass / crop residue to boost farmers' incomes and avoid biomass burning related air pollution	Global aviation fuel market is over $300 billion/yr and nearly doubling in the next decade. Most major airlines have SAF and net-zero goals.	SAF blending mandates at major airports; fiscal & offtake support for first few plants.

	Strategies	Comparative Advantage	Domestic Dividend	Export Opportunity & Addressable Market	Policy Levers
Frontier Technology Bets					
9	Storage Technologies Beyond Lithium	Strong manufacturing base: large auto and grid markets can offer scale to reduce the cost of new technologies	Diversify storage supply chains and leverage domestic mineral / material availability such as zinc or iron etc. Cross-seasonal grid balancing support requires long duration storage under $10-20/kWh.	Global battery demand is over 1,000 GWh/ yr (auto, grid, and consumer electronics), doubling by 2030. 80% of the lithium-based battery supply chain is dominated / controlled by China.	Fund RD&D, pilots, and early procurement through VGF and tax incentives.
10	Electrolysers	Strengths in manufacturing; Green hydrogen mission targets 5 MT of green H2 by 2030; long term green H2 demand from steel and fertiliser sectors offer scale to reduce costs; encouraging initial auction results	Reducing the cost of electrolysers under $300/ kW is critical for economical production of green H2 (and thus green steel, fertiliser, and other products); reduce import dependence	PEM electrolyser cost in the US & EU is >$1000/ kW. Very high global demand for good quality, low-cost electrolysers. Solar capital cost in India is half that in the US, which can be replicated for electrolysers.	Electrolyser manufacturing linked green hydrogen auctions and VGF support.

The combined effect of such clean energy strategies on India's energy imports is illustrated in Figure 5. Under a Clean Energy Pathway, characterised by rapid deployment of low-cost clean energy, total fuel and critical mineral imports decline by more than 60 percent by 2047 relative to a Current Policies Pathway, which assumes continuation of existing policies and limited clean-energy uptake. Importantly, projected lithium and other critical mineral imports account for only about 10% of the avoided fossil-fuel imports through 2050.

Figure 5: Total Fuel and Critical Mineral Imports (in Nominal INR, Under Two Scenarios)



Source: Authors' estimates based on Abhyankar et al (2023)[75]

4.3 The Role of India's Distinct Labour Market Dynamics

India's path will necessarily differ from China's. Given India's labour market dynamics, rising wages, and increasing automation, low-cost manufacturing for export alone is unlikely to deliver sufficient employment or durable advantage. While exports of high-tech services will remain important, it is unclear that services alone can absorb the scale of labour entering the workforce each year. Instead, the ongoing transformation of global energy, industrial, transport, and digital systems offers India an opportunity to build clean-energy-anchored industries that combine manufacturing, operations, services, and exports.

The labour-market context reinforces the urgency of this strategy. Between 2000 and 2022, employment growth in India continued to lag far behind Gross Value Added (GVA) growth, with employment expanding at well under half the pace of output growth, reflecting rising capital intensity and limited absorption of labour in high-productivity sectors.[76] Over this period, India's labour force expanded by over 100 million people, yet more than 80 percent of workers remain in informal employment, and manufacturing's share of GDP has remained largely stagnant at around 13 percent.[77,78] With India's working-age population (ages 15–64) projected to grow by nearly 10 million people annually through 2031, the challenge is not only growth, but the creation of productive, scalable employment pathways.[79]

Clean energy and its downstream applications offer such a pathway. According to the latest estimates, India's renewable energy sector employs over 1.3 million people, and achieving the 500 GW non-fossil electricity target by 2030 could create an additional 3–4 million jobs in construction, installation, operations, and maintenance alone, excluding upstream manufacturing and supply-chain employment.[80,81] According to the latest estimates by NITI Aayog, the Net Zero Scenario could expand energy-sector employment to nearly 7 million by 2050, around 1 million more jobs than under the current policy scenario, highlighting a structural shift toward clean manufacturing, renewable infrastructure, and emerging energy services across skill levels.[82] Expanding into green steel and fertiliser, electric freight, heat batteries, electrolysers, and data-centre infrastructure significantly amplifies these employment and industrial spillovers by anchoring long-lived domestic demand for clean power and associated manufacturing.

This urgency is reinforced by India's position in global trade and investment flows. India's share of global manufacturing exports remains below 2 percent, far lower than peers such as China and Vietnam, underscoring the need for new, competitive export engines.[83] At the same time, clean energy and related sectors are emerging as a major attractor of foreign capital: in India, equity foreign direct investment (FDI) in clean energy now exceeds US$4 billion per year.[84] Aligning clean-energy deployment with export-oriented manufacturing therefore offers a pathway to simultaneously expand India's trade footprint and attract long-term, productivity-enhancing investment.

Globally, the scale of opportunity is unprecedented. Transforming power, industry, transport, buildings, fuels, aviation, shipping, and digital infrastructure to meet climate and growth objectives is projected to require over US$50 trillion in cumulative investment by 2050.[85,86,87] This strategy adopts a multi-criteria framework—combining cost advantage, market scale, institutional capacity, and strategic relevance—to identify where India can capture a meaningful share of this investment, create large domestic dividends while positioning itself as a global supplier in a rapidly transforming world economy.

Chapter 5

From Comparative Advantage to Competitive Scale: Unlocking Domestic Dividends and Export Competitiveness

The preceding sections showed how India is entering the global energy transition with rare structural advantages: the world's lowest-cost firm clean power, a uniquely flexible electricity market architecture, large and growing domestic demand, and expanding access to global capital and trade. However, these advantages will not automatically translate into domestic economic dividends or export leadership. Markets can scale what already exists—but they do not resolve coordination failures, transition and supply chain risks, or demand uncertainty on their own.

The role of government in this phase is not to substitute for markets or provide permanent subsidies, but to convert India's comparative advantages into scale, ensure that domestic demand becomes an engine for industry creation, and manage the transition of incumbent institutions so that growth is not blocked by friction or instability.

5.1 Deepen Power-Sector Markets and Manage Utility Transition

India's low-cost clean-power advantage delivers value only if it reaches consumers and industry at scale as a stable, predictable input into manufacturing and services. This requires deepening power-sector reforms around open access for large consumers, while carefully managing the financial transition of distribution utilities. While open access is already operational for most large consumers (High Tension, or HT consumers, which account for roughly a third of electricity demand but less than 1 percent of consumers), in practice it faces significant barriers, including multiple additional charges introduced to protect utility revenues that were built around the assumption of captive industrial consumers. As recent discussions around amendments to the Electricity Act indicate, the direction of reform is toward open access by default for large consumers, reflecting the growing maturity of competitive power procurement and the scale of clean power now entering the system.

The challenge is not whether open access should expand, but how the transition is managed. Expanding open access must be accompanied by a transparent, time-bound transition and cost-recovery framework, rather than ad-hoc barriers. For example, the relevance of cross-subsidy revenues in DISCOM finances has declined sharply over the past decade, with state government subsidies now a more significant contributor to revenue than cross-subsidies in most states.[88] A study conducted by Prayas proposes replacing the current cross-subsidy and additional surcharge regime with a clearly defined Supply Obligation Charge that makes transition costs explicit, capped, and time-bound, alongside deregulation of HT supply and separation of carriage and content.[89] The objective is not to hollow out DISCOMs, but to enable their evolution into strong grid, reliability, and service platforms, while competitive procurement delivers lower and more predictable electricity prices to large consumers.

Handled well, this approach can strengthen rather than weaken the power system—allowing utilities to remain financially viable, improving system planning, and ensuring that clean-power cost declines translate into lower electricity prices, inflation-proof energy costs, and economy-wide domestic dividends directly supporting India's competitiveness and export positioning.

5.2 Use Domestic Demand as the Primary Scale Engine

India's greatest strength is domestic market scale. For technologies that are already commercially mature—such as electric vehicles, high-efficiency cooling, grid equipment, and renewable energy-based data-centre power supply—government intervention should focus on clear standards, obligations, and procurement mandates, rather than prolonged subsidies.

This logic mirrors India's solar success: credible demand first, competition second, incentives only as a bridge. Stronger vehicle electrification mandates, progressively higher appliance efficiency standards aligned with global benchmarks, and public procurement of clean products can rapidly move industries down the cost curve, enabling domestic manufacturing to scale and compete globally.

5.3 Resolve Coordination Failures in Emerging Clean-Industry Pathways

For emerging clean-industry pathways—such as green steel, green fertilisers, sustainable aviation fuels, and industrial heat electrification—the primary constraint is not the absence of underlying technologies, but the challenge of integrating them at scale. In most cases, key components are already commercially deployed in adjacent or early markets—including low-cost renewable power, electrolysers, storage, and electrified industrial heating. What remains difficult is coordinating these components into bankable, end-to-end projects with aligned timelines, contracts, and risk allocation across power supply, conversion technologies, and offtake.

Here, government's role is to facilitate coordination, not pick winners—through mechanisms such as bundled procurement, standardised contracts, shared infrastructure, and limited offtake support for the first few projects. Innovative auctions, such as SECI's green ammonia procurements that revealed near-competitive prices and implied green hydrogen costs of around US$3/kg, illustrate how price discovery and risk reduction can unlock scale. These tools should be applied selectively, as part of a broader market-creation approach.

5.4 Create Clean-Power Growth Zones to Anchor Investment and Exports

To accelerate learning and investment, India should enable clean-power growth zones, including data-centre and industrial enclaves, with assured access to 24×7 clean electricity. By streamlining land access, interconnection, transmission, and firm-power procurement, these zones can act as anchor demand for solar-plus-storage and flexibility services, attract global capital, and establish India as a preferred destination for energy-intensive digital and industrial infrastructure.

Such zones directly link domestic demand with export competitiveness, especially as global firms increasingly seek low-carbon supply chains.

5.5 Secure Supply Chains and Manage Strategic Risk

As electrification and storage scale, supply-chain resilience itself becomes strategic infrastructure. Government intervention is therefore warranted not to slow deployment, but to manage concentration risk while preserving the cost and scale advantages of clean energy. While clean energy can sharply reduce fossil-fuel import dependence in India, absent robust supply chains, it could create new vulnerabilities toward a narrower set of critical components—most notably batteries and upstream minerals. This mirrors global trends as solar PV and battery supply chains are highly concentrated, with China accounting for a dominant share of manufacturing capacity across cells, modules, cathodes, and battery components.[90,91]

A frequent counterargument is that while clean electricity may be inexpensive, key components—especially batteries—must be imported, often from China. The concern is understandable, but it points to the need for a more sophisticated clean-energy security strategy, not a retreat from deployment. India's experience with solar manufacturing demonstrates that scale, predictable demand, and policy certainty can rapidly reduce dependence on concentrated supply chains. As documented in the IEA's solar PV supply-chain assessments, manufacturing leadership followed deployment scale—not the reverse—and India has already begun replicating this trajectory in modules and balance-of-system components.[92]

Battery manufacturing can follow a similar path, but with additional instruments. IECC analysis indicates that under aggressive vehicle electrification, India's annual battery demand could approach 1,000 GWh by the 2040s, with 80–85 percent deployed in electric vehicles and roughly 10 percent in grid storage, underscoring the importance of domestic manufacturing and supply-chain planning in the transport sector.[93] Alongside domestic manufacturing and accelerated recycling, India should deepen critical-mineral partnerships with allied economies through long-term offtake agreements, standards harmonisation, and joint investment platforms—reducing exposure to upstream concentration while supporting export-oriented clean manufacturing.

In parallel, India could establish a strategic battery reserve through forward procurement—an instrument analogous to the Strategic Petroleum Reserve but designed for the clean-energy era. A reserve on the order of 200 GWh would require an investment of approximately US$10–12 billion, implying a modest ~1-2 percent premium relative to annual battery expenditure in the vehicles and grid sectors. Such a reserve would be a first-of-its-kind energy-security tool, providing insurance against supply disruptions, dampening price volatility, and reducing external leverage over the energy system—while allowing India to continue scaling clean energy at pace.

In sum, the government's role is to act as a market deepener, coordinator, and transition manager—ensuring that India's comparative advantages translate into lower and more stable energy costs, large domestic dividends, and globally competitive clean-energy industries. Done well, this approach minimises fiscal burden, preserves institutional stability, and positions domestic demand as the launchpad for sustained export leadership.

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About the Authors

Nikit Abhyankar is Associate Adjunct Professor, Co-Faculty Director, India Energy and Climate Center, Goldman School of Public Policy, University of California, Berkeley.

Amol Phadke is Faculty Director, India Energy and Climate Center, Goldman School of Public Policy, University of California, Berkeley.

Samir Saran is President, Observer Research Foundation.

Gopalika Arora is Deputy Director, Centre for Economy and Growth, Observer Research Foundation.

OBSERVER RESEARCH FOUNDATION

20 Rouse Avenue
New Delhi-110002
Ph: +91-11-35332000. Fax: +91-11-35332005
www.orfonline.org | contactus@orfonline.org

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UC Berkeley Goldman School of Public Policy

India Energy and Climate Center
Goldman School of Public Policy
University of California, Berkeley
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