

SOLAR PANEL MANUFACTURING

ADVANCED PV MANUFACTURING • UTILITY-SCALE ELECTRIFICATION



PREPARED FOR CORPORATE LEADERS & CLIMATE-TECH STAKEHOLDERS

Solar & Wind

Solar Panel Manufacturing

This section provides key inputs on the Indian Solar Panel Manufacturing Opportunities for corporate leaders

Highlights

- Structural demand certainty driven by India's long-term solar targets, ALMM enforcement, and corporate decarbonization commitments
- Technology transition cycle underway, with TOPCon and HJT becoming mainstream and rapid obsolescence risk for legacy lines
- Manufacturing economics remain volatile, influenced by Chinese pricing, input cost swings, and scale-dependent margins
- Clear gap between capacity creation and capability creation, favoring players with execution depth, quality control, and upgrade readiness

Key recommendations for corporate leaders include:


- Back scale with flexibility, not static capacity — plants must be designed for fast tech upgrades
- Prioritize bankability over price, including warranties, degradation profiles, traceability, and supplier balance-sheet strength
- Build differentiation beyond cost, via performance, automation, and downstream integration
- Secure long-term demand visibility, through multi-year module supply agreements

Opportunity Snapshot: Solar Panel Manufacturing

Assembling solar PV cells into modules to be used for power generation.

((o))	Market Signals		What Makes or Breaks It?
	<ul style="list-style-type: none"> • Strong policy push; ALMM+ customs duty on imports; domestic demand protection • Export potential driven by US/EU supply chain diversification • Annual Market size by 2030: ₹75,000-80,000 Cr 		<ul style="list-style-type: none"> • Scale ($\geq 3-5$ GW) to achieve cost competitiveness • Backward integration (cells) to protect margins • Strong EPC/utility relationships for consistent offtake
	Why It Matters NOW?		Well Aligned Opportunity for
	<ul style="list-style-type: none"> • Domestic manufacturing push reducing import dependence from countries like China • Strong pipeline of utility scale+ rooftop+C&I solar projects • India becoming an alternate hub, as global buyers diversify sourcing 		<ul style="list-style-type: none"> • Existing module manufacturers scaling capacity • EPC players / developers integrating manufacturing for supply security • Industrial players with assembly-line manufacturing capabilities
	Key Challenges		Business Models
	<ul style="list-style-type: none"> • Thin margins due to high competition + commoditization • Price volatility in inputs (glass, EVA, cells) 		<ul style="list-style-type: none"> • Greenfield large-scale plants (leveraging domestic demand + exports) • Backward integration: module \rightarrow cell manufacturing • Contract manufacturing / OEM supply for developers & EPC firms

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Introduction and Business Case

Solar panels are the backbone of renewable power and India has been depending heavily on Chinese imports for modules and cells. Scaling domestic panel manufacturing captures value across the supply chain, reduces forex outflows and ensures energy security. These reasons have spurred strong policy support for solar power gear manufacturing in India through schemes such as PLI & ALMM).

With such tailwinds supporting it, India has a chance to emerge as a global solar hub, meeting both domestic demand and export solar power plant markets, while creating jobs and economic growth.

Market Potential for Solar Panel Manufacturing in India

Year	Market Size (₹ Cr)	Capacity Outlook	Drivers
2025	60,000-65,000	90 GW module capacity	PLI-backed expansion; ALMM enforcement.
2030	75,000-80,000	120 GW approx capacity	Domestic demand + exports; integrated fabs scaling.
2040	110,000-120,000	150 GW approx capacity	Net Zero demand; India as a global export hub.

Market Segments and Applications

Segment	Applications	Business Model	Key Drivers
Utility-scale solar power plants	Large ground-mounted solar parks (50 MW–5 GW+)	Bulk supply contracts, tenders	Largest volume driver; scale economics
Onshore wind–solar hybrid projects	Co-located solar + wind plants	Hybrid EPC supply	Improves grid utilization; growing segment
RTC / firm renewable projects	Dispatchable solar with storage	Utilities, DISCOMs	Premium demand for high-quality modules
Commercial & Industrial (C&I)	Factories, warehouses, campuses	Corporates, ESCOs	Higher margins than utility-scale
Floating solar projects	Reservoirs, dams, water bodies	Utilities	Specialized niche with growth
Data centers & hyperscalers	24x7 clean power supply	Tech companies	High-credit, premium segment

Energy storage-linked solar plants	PV + BESS plants	Utilities, IPPs	Storage increases module performance value
Government & public-sector programs	National solar missions	Governments	Volume stability
OEM/EPC strategic supply	Long-term EPC partnerships	EPC majors	Predictable demand
Downstream integrated platforms	Developer-owned projects	In-house IPPs	Margin protection strategy

Typical Project Capacities & Investments Required in India

Project Type	Typical Capacity	Indicative CapEx (₹ Cr)	Notes
Module Assembly (PERC/TOPCon/HJT-ready)	0.5-2.0 GW/yr	80-350	Stringers, laminators, EL/Hi-POT/IV testers;
Cell Line (mono PERC → TOPCon-ready)	1.0-2.5 GW/yr	800-2,000	Diffusion, PECVD/ALD, metallisation, firing; cleanroom + utilities heavy.
Ingot & Wafer (mono, G9/M10/M12)	1.0-2.0 GW-eq/yr	1,200-2,500	CZ pullers, wire saws; power-quality and consumables
Thin-Film (CdTe/ μ -Si) Pilot	100-300 MW/yr	300-800	Niche; IP/licensing; BOS advantages in hot climates.
Solar Glass (textured, 3.2 mm)	300-800 TPD	700-1,500	High gas/power use; benefits from cluster siting.
EVA/POE Encapsulant Plant	10-30 KTPA	120-300	Polymerisation + coating lines; quality consistency key.
Backsheet/Coating Line	5-15 KTPA	90-220	Fluoro/non-fluoro laminates; adhesion and UV stability.
J-Box, Ribbon, Frame (Al) Units	5-15 GW BOM/yr	40-150	Tooling- and inventory-light; fast to localise.

Underlying Technologies & Processes

Element	Options	Key Traits
Cell technologies	Mono-PERC, TOPCon, HJT, thin film (CdTe)	Higher efficiency drives competitiveness; HJT/TOPCon scaling.

Module types	Polycrystalline, monocrystalline, bifacial	Shift toward high-efficiency mono & bifacial.
Manufacturing processes	Ingot → wafer → cell → module	Vertical integration improves margins and reliability.
Materials ecosystem	EVA sheets, backsheets, glass, junction boxes	Critical to localisation under PLI.
Automation & digitalisation	Robotics, AI-driven QC, inline testing	Boosts yield, reduces defects.
Recycling & circularity	Panel recycling, silver & silicon recovery	Aligns with circular economy, reduces waste.

Key Challenges

Challenge Area	Key Issues	Business Impact	India Specific	Strategic Implications
Upstream Supply Chain Dependence	Heavy reliance on imported polysilicon, wafers, and cells; global price volatility	Margin pressure, uncertain costs, delayed production planning	China dominates upstream manufacturing; India still building backward integration	Need for integrated manufacturing (polysilicon → wafer → cell) and domestic ecosystem development
Capital Intensity & Financing Risks	High capex for integrated facilities, technology upgrades (TOPCon/HJT)	Long payback periods; pressure on ROI and balance sheet	PLI schemes help but large upfront investment still required	Strategic partnerships, JV models, and scale are critical for competitiveness
Pricing Pressure & Global Competition	Aggressive pricing from global manufacturers; cyclical module prices	Reduced margins; risk of overcapacity	Anti-dumping duties and BCD policies support domestic players but pricing remains competitive	Differentiation via efficiency, warranties, and niche markets (C&I, high-efficiency modules)
Demand Volatility & Offtaker Risks	Policy shifts, DISCOM payment delays, tender cancellations, price renegotiations	Revenue uncertainty affecting cash flow and planning	Utility-scale projects dependent on govt auctions and DISCOM financial health	Diversification into rooftop, C&I, exports reduces risk concentration

Technology Transition & Operational Challenges	Rapid shift from PERC to TOPCon/HJT; skill gaps; yield optimization	Risk of stranded assets; continuous reinvestment required	Indian players scaling technology capabilities rapidly but still catching up	Focus on R&D, automation, and long-term technology roadmaps
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Prominent Players in the Indian Market

Company / Entity	Focus Areas
Adani Solar	India's largest integrated solar cell & module maker; >4 GW capacity, scaling to 10 GW+ underway.
Tata Power Solar	~4 GW module manufacturing; expanding under PLI.
Vikram Solar	Leading module exporter; >3.5 GW capacity.
Waaree Energies	India's largest module maker; ~16 GW module capacity.
RenewSys India	Integrated modules, EVA & backsheets manufacturing.
Premier Energies	Expanding cell + module manufacturing footprint.
Jakson Group / Goldi Solar	Module makers with EPC integration.

Innovation Perspectives

Innovation	Business Opportunity	For Senior Management
From module seller to energy-solution partner	Bundle modules with storage, EMS, warranties	Moves revenue from transactional to recurring
Technology-led segmentation	Segment-specific products (utility, rooftop, premium)	Enables margin optimization by segment
Fast tech-transition leadership	Rapid scale-up of next-gen technologies	Prevents margin erosion
Vertical integration (upstream & downstream)	Polysilicon/wafers or captive IPP projects	Margin stabilization
Storage-optimized & hybrid-ready modules	Modules optimized for BESS & hybrids	Differentiation in RTC projects
Performance-guaranteed modules	Output-guarantee-backed modules	Premium pricing
Digital modules & data monetization	Smart modules with monitoring & analytics	New revenue layers

Repowering & replacement solutions	Retrofit-focused module offerings	New demand stream
New demand stream	Joint product development with EPCs	Faster market adoption
Financing-linked module sales	Vendor-backed financing	Expands addressable market

Concentric & Satellite Opportunities

- Line integrators: India-ready stringers, laminators, ALD/PECVD upgrades and MES packages for fast PERC→TOPCon/HJT transitions.
- BOM localisation hubs: Solar glass, EVA/POE, backsheets, sealants and AI frames with cluster utilities and recycled cullet/aluminium streams.
- Silver-paste & metallisation innovation: Low-Ag pastes, copper plating pilots and paste-recycling services to cut cell cost/watt.
- End-of-life recovery networks: Glass/Al/silver/polymer recycling with EPR credits and refurbished-module secondary markets.
- Skilling & certification academies: Cleanroom operations, tool maintenance and quality-engineering programs to deepen the talent bench.
- Junction box potting stations: Automated silicone dispensers for IP68 waterproofing.

Key Takeaway for Senior Management

Takeaway	Details
Bankability and quality drive long-term value more than cost	<ul style="list-style-type: none"> • Lowest-cost modules often lead to higher lifetime project risk. For eg: A ₹0.30/W cheaper module can wipe out project IRR if early degradation exceeds assumptions • Developers and lenders increasingly prioritize warranties, degradation, and traceability <p>Take-away:</p> <ul style="list-style-type: none"> • Long-term performance guarantees (25–30 years) • PID, LID, LeTID resistance and field performance data • Manufacturer balance sheet strength <p>Key message: Senior management must align manufacturing KPIs with project-level bankability, not just factory gate pricing</p>
Demand visibility is as critical as manufacturing efficiency	As oversupply cycles quickly destroy margins in commoditized manufacturing, plants without secured offtake face utilization and pricing risk. For e.g., manufacturers with in-house IPP portfolios or anchor buyers maintained margins even during global module price crashes

	<p>Take-away: <i>Focus on the following:</i> Captive demand from IPP/EPC pipelines Long-term offtake or strategic buyer agreements Export optionality and geographic diversification</p>
<p>Integration and ecosystem control will separate winners from survivors</p>	<p>Value addition occurs across polysilicon, wafers, cells, modules, logistics, and financing. Thus, for a panel maker, at least a partial integration improves cost control, supply security, and risk resilience. Cell-module integrated players absorb price shocks better than pure module assemblers during supply disruptions</p> <p>Take-away: <i>Focus on the following:</i></p> <ul style="list-style-type: none"> ● Cell-module or wafer-cell integration ● Strategic raw material sourcing (glass, silver, backsheets) ● Digital quality control and yield analytics <p>Key message: Competitive advantage increasingly comes from ecosystem orchestration, not isolated assets</p>

Next Steps for Corporate Leaders

Solar panel manufacturing in India is entering a scale-up phase driven by domestic capacity targets, import substitution, PLI incentives, and growing demand from utility-scale, C&I, and export markets. While capacity addition is accelerating, value creation is increasingly determined by technology choices, supply-chain integration, and the ability to deliver bankable, high-efficiency modules at globally competitive costs.

This could be an attractive climate tech opportunity for industries and firms in specific sectors and industries keen on catering to this fast growing market.

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