Strengthening R&D for Solar Manufacturing: Indian context

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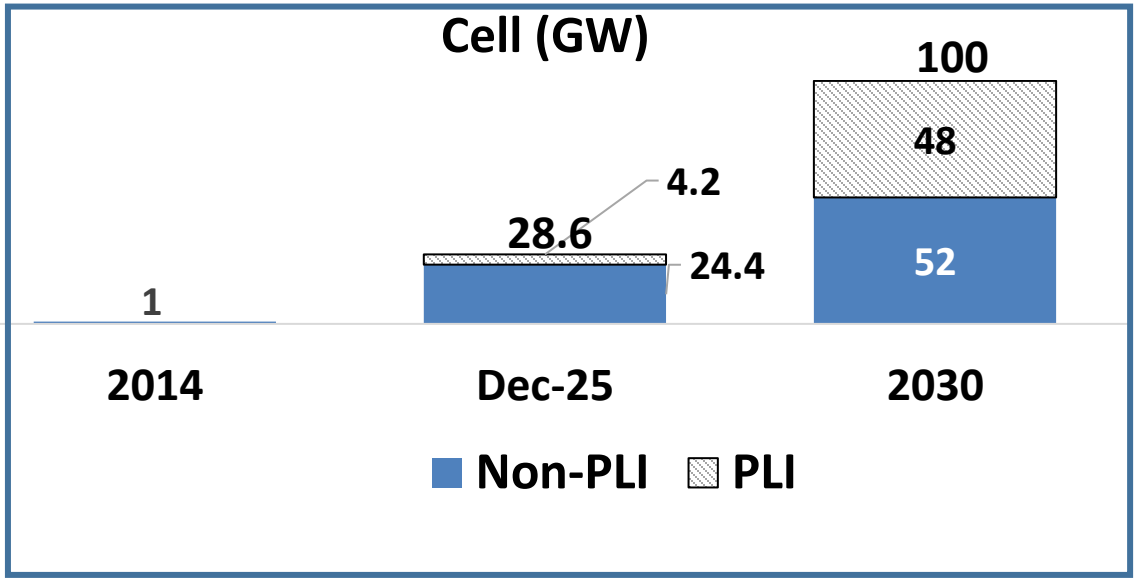
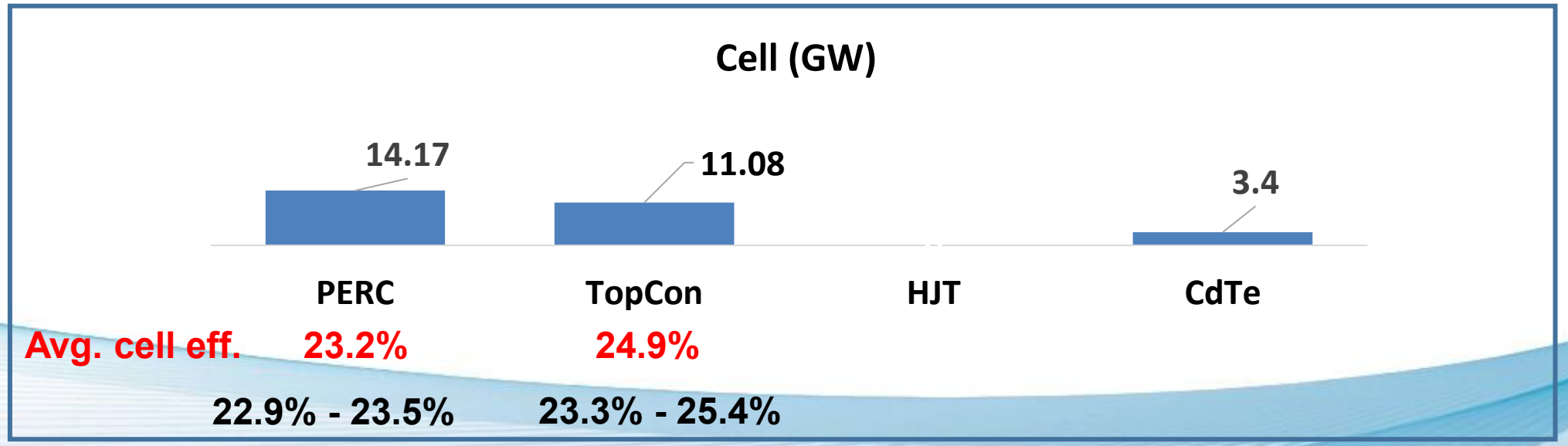
Solar Cell Manufacturing status in India

- ~ **28.6 GW** domestic cell manufacturing capacity (December 2025).
- Expected to reach 100 GW by 2030.
- HJT manufacturing will be operational, soon.





Government Schemes and Roadmap for high efficiency cells

- Support for high efficiency cell and modules while being technology agnostic.
- Push towards domestic manufacturing of high efficiency cell and modules
  - **Introduced module efficiency cutoff for ALMM enlistment:**

Application/Use	c-Si PV modules	CdTe thin film
Utility/Grid Scale Power Plants	20.0%	19.0%
Rooftop and Solar Pumping	19.5%	18.5%
Off-grid applications (Module wattage < 200 Wp)	18.0%	18.0%

  - MNRE proposed phased increase in efficiency to phase out obsolete technologies:
    Utility-Scale: Proposed to rise to **21.0%** by January 2027, and **21.5%** by January 2028.

  - **Introduced ALMM for Solar cell:** Mandatory ALMM enlistment for cell from June 2026.

Government Schemes and Roadmap for high efficiency cells

- Production Linked Incentive (PLI) Scheme for high efficiency cell & modules
  - Focus on high efficiency & vertical integration
  - Higher PLI for improved cell efficiency
  - Base PLI Rate increases with module efficiency **to motivate and incentivize manufacturers for high efficiency cells** & modules -> higher R&D investment.
  - Planned solar cell manufacturing capacity: **~48 GW (Tranche-I & II)**
  - **~ 4.2 GW operational**

PERFORMANCE MATRIX TABLE for P+W+C+M Basket							
	Module Efficiency* (%) →	During five Year period after commissioning					
		Base PLI Rate (₹/W_p)					
		≥20.50% & <21.00%	≥21.00% & <21.50%	≥21.50% & <22.00%	≥22.00% & <22.50%	≥22.50% & <23.00%	≥23.00%
Module's Temperature Coefficient of P_{max}** (in % per degree Celsius)↓	Position	U	V	W	X	Y	Z
-0.40 to -0.30	A	0.00	1.45	1.65	1.85	2.00	2.20
Better than -0.30	B	1.45	1.65	1.85	2.00	2.20	2.20

Strengthening Solar Manufacturing R&D Ecosystem

- **Challenges in mass Solar manufacturing**
  - Availability of Technology/Tool for mass manufacturing (most tools are imported)
  - Issues with cell line optimization, capacity utilization
  - Skilled workforce for manufacturing and R&D

- Although c-Si is matured technology, India still needs **dedicated Research efforts** towards mass manufacturing, capacity utilization of manufacturing facilities, green manufacturing,

- MNRE formed a committee to identify R&D required in solar and possible pathways. NISE is leading the efforts in this direction jointly with NSEFI and other stakeholders.

Strengthening Solar Manufacturing R&D Ecosystem

- MNRE has dedicated R&D division to fund the next generation R&D technologies
  - NCPRE has received funding for Perovskite/Si Tandem cell/module development.
- **Proposed Industry–Government funded Solar R&D Consortium**
  - Industry & Government supported Solar manufacturing R&D consortium led by the research/academic institutions with pilot R&D line/tool for the technology like TopCon, HJT, IBC, Perovskite/Si, Tandem, etc.
  - The Industry can get support for efficiency improvement, yield enhancement, indigenous equipment/process development, reliability enhancement, new material adoption, etc.
  - Execution should leverage shared pilot manufacturing lines, testing facilities, and qualification labs, enabling rapid translation from lab to fab.

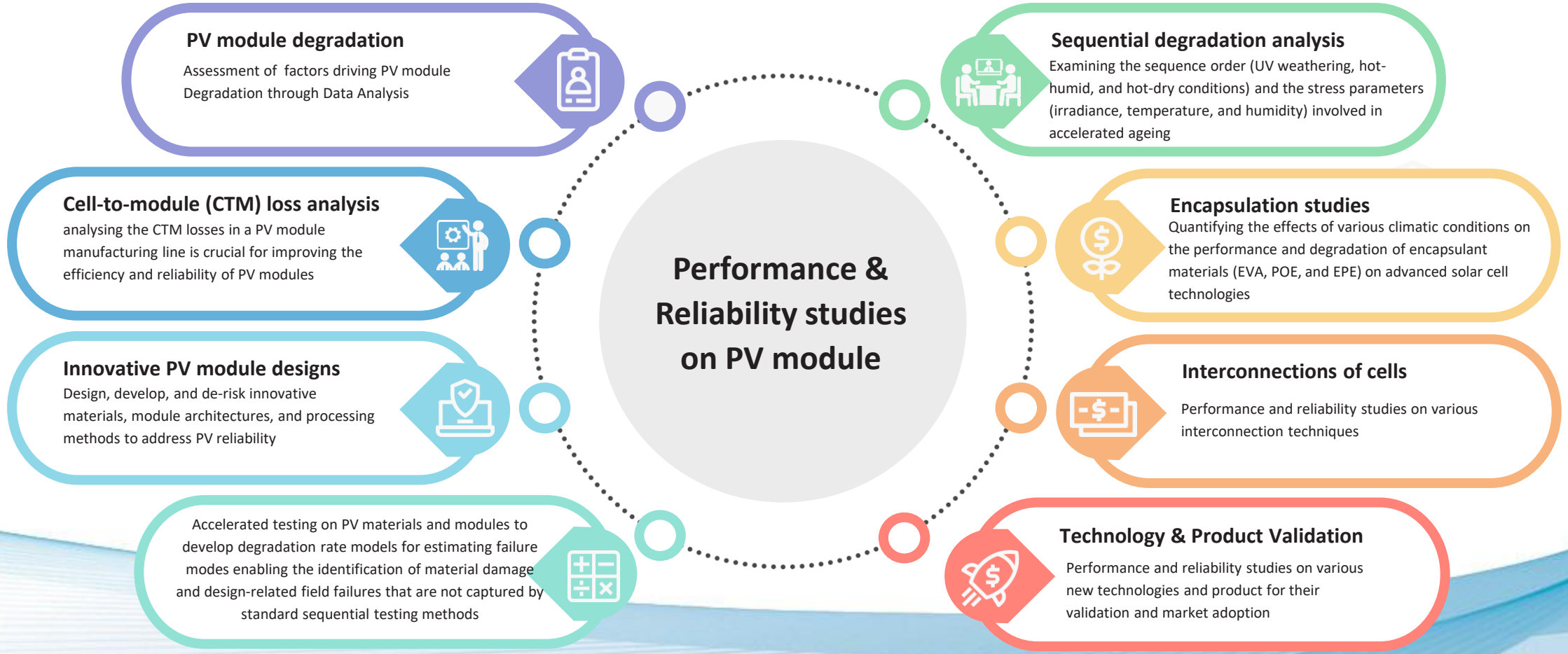
Strengthening Solar Manufacturing R&D Ecosystem

- Promote Collaboration of Indian research institutes with International R&D institutions/technology providers.
  - Jointly, the institutions may support research activities to Indian manufacturers.
  - Manufacturers may engage Indian academia and research institutes during the technology evaluation phase and later for R&D support.

- **Skilled workforce for manufacturing and R&D needs**
  - New Training programs focused on TOPCon, HJT, Perovskite, tandem, advanced interconnection and module fabrication, etc.
  - Implementation of training through partnership with Manufacturers with hands-on exposure to pilot and commercial lines.
  - **NISE has started a 2.5 months training course on “Cell and Module Manufacturing” in Sept. 2025 .**
  - We need to do more. Industry should support and join hands with institutions like NISE, NCPRE, IITs, and other foreign institutes.

Performance & reliability of new cell/module technologies

- **Module performance and Reliability should also be considered as Core R&D Pillar.**
- NISE involved in R&D on modules including Measurement, standardization and reliability of Perovskite/Si Tandem modules (jointly working with P3C Ltd.)



Sustainability in Solar PV Manufacturing

Are current PV deployments sustainable?

- ❖ Design for recycling
- ❖ Greener Production

Greener Production

- Energy-efficient manufacturing with **lower carbon footprint**
- Adoption of **eco-friendly technologies** for minimal environmental impact

Longer Module Lifespan

- High-efficiency solar modules designed for **durability & affordability**
- Improved performance ensures **sustained energy generation**

Smarter Material Use

- Silicon consumption **cut from ~16 g/Wp (2006) to <2.5 g/Wp today**
- Achieved through **thinner wafers, diamond wire sawing & larger ingots**

Faster Energy Payback

- Energy Payback Time (EPBT) **now < 1 year**, reducing further with advancements

End-of-Life Management: What's Next?

- How do we ensure **effective recycling & re-use**?

Thank you!

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