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Creating a Resource
Efficient India

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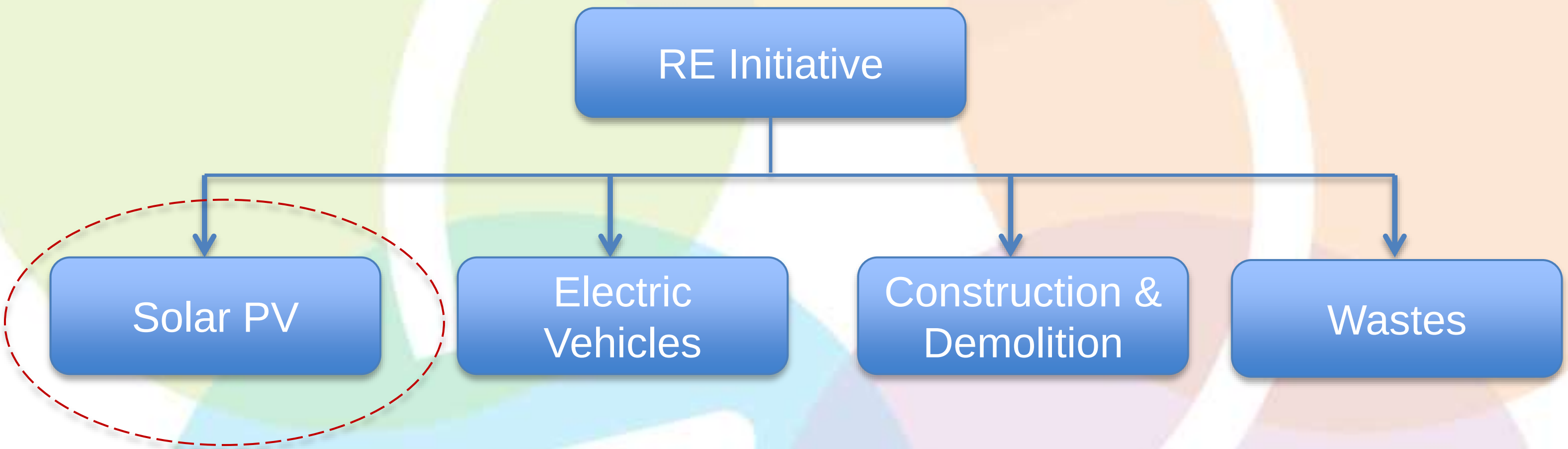
Greening the Solar PV value chain

adelphi | CII Confederation of Indian Industry | CII-ITC Centre of Excellence for Sustainable Development | giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH | teri

About the project

- Resource Efficiency Initiative (REI) is a EU commissioned project with the objective of introducing a resource efficiency framework for certain priority sectors for alleviating existing pressures on natural resources and take advantage of the economic benefits of resource efficient production



- **Key partners include**: GIZ (Consortium lead); TERI, Adelphi, CII-ITC Centre of Excellence for Sustainable Development

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Imperatives of RE in Solar PV

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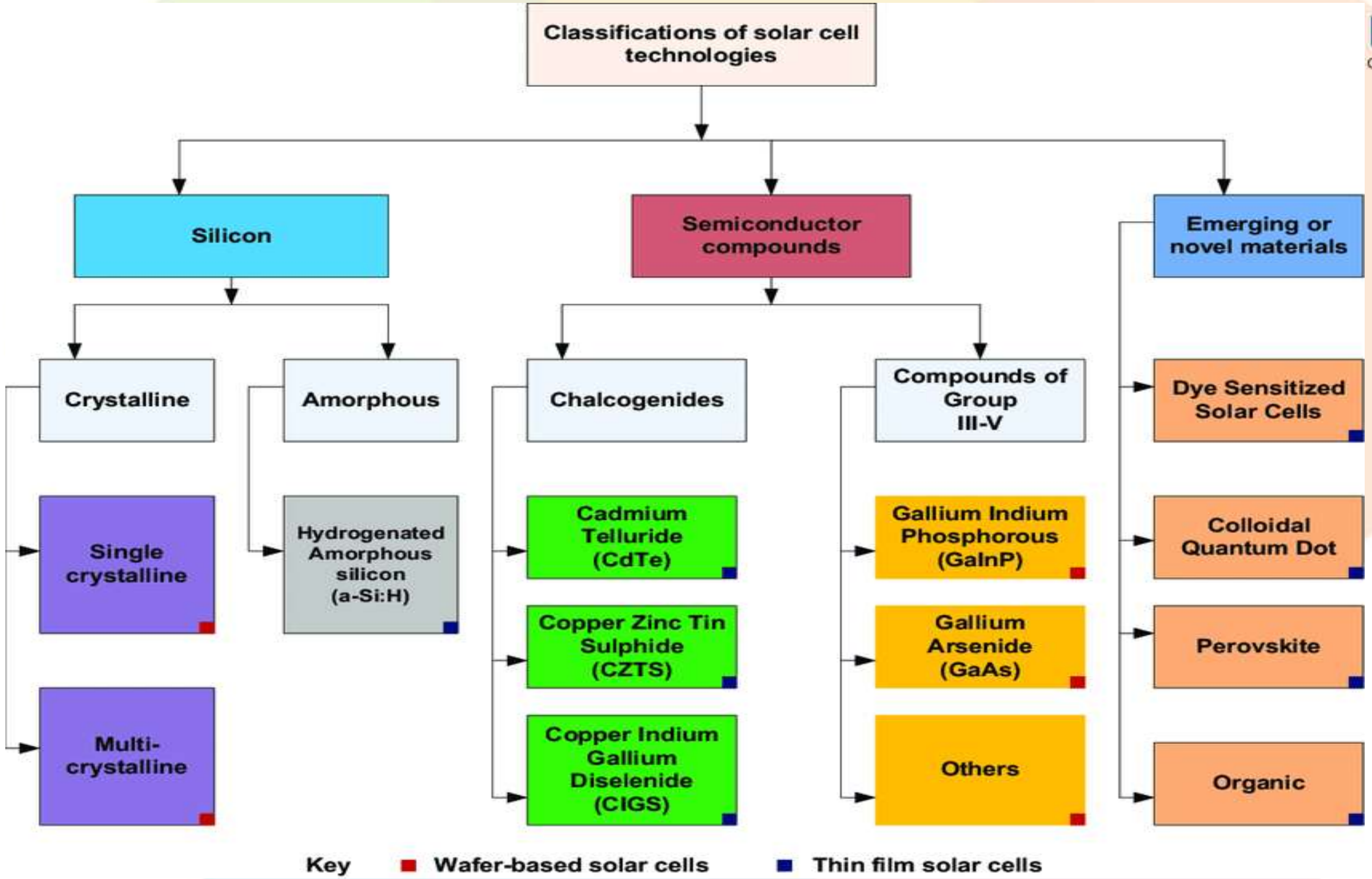
- India has one of the largest renewable capacity expansion programme.
- While it is a significant step towards meeting our NDC, there are challenges that need solutions with regard to tariff discovery, grid integration, storage, and human resources.
- Issues associated with material requirement is often ignored. Under the 'make in India' initiatives making panels may get affected due to issues on solar PV material availability at affordable prices.
- Further, issues related to end of life management of Solar PVs and battery modules would be critical
- An integrated assessment covering
  - ✓ material flow analysis,
  - ✓ review of good practices (product and process innovations) in India and abroad on Secondary Resource Management (SRM) on solar PV
  - ✓ end of life polices for better management of wastes

Research questions

- What are the major resources that find use in solar PV technologies and how will the demand for these resources evolve in the near future?
- To what extent can secondary material management be achieved under the current scenario?
- What are the current policies (if any) and legislative framework (in India and abroad) that can promote material use efficiency in the sector and the kind of learning that can be drawn for the Indian context?
- What are the different best practices (including those related to technological interventions and use of standards) along the value chain in the solar PV sector existing across the globe and if and how they can be replicated in India?
- How to enhance consumer awareness on the need and role of resource efficiency in solar sector?
- How the issue of circularity and product standards and end of life management be addressed through existing and new policies?
- What would be the essential elements of a resource efficient PV policy roadmap for India?

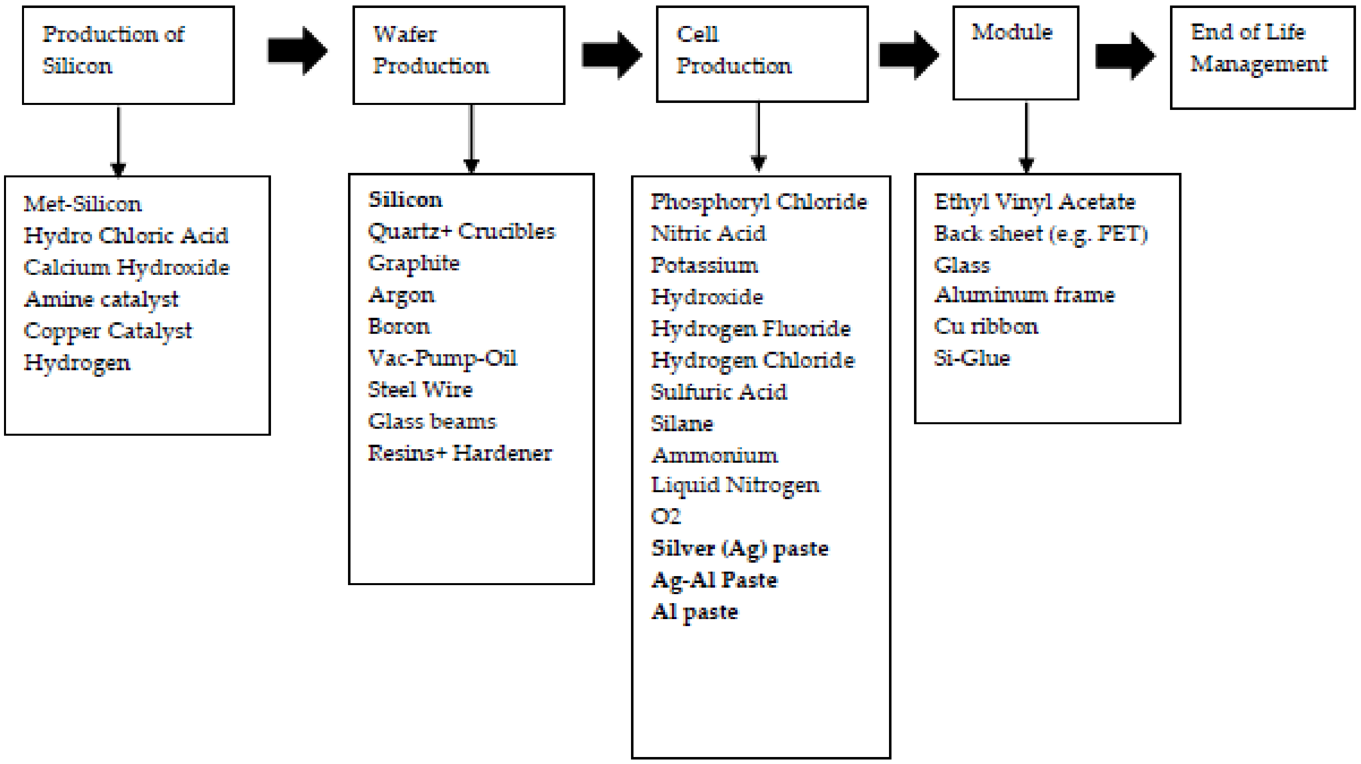
Classification of Solar PV technology



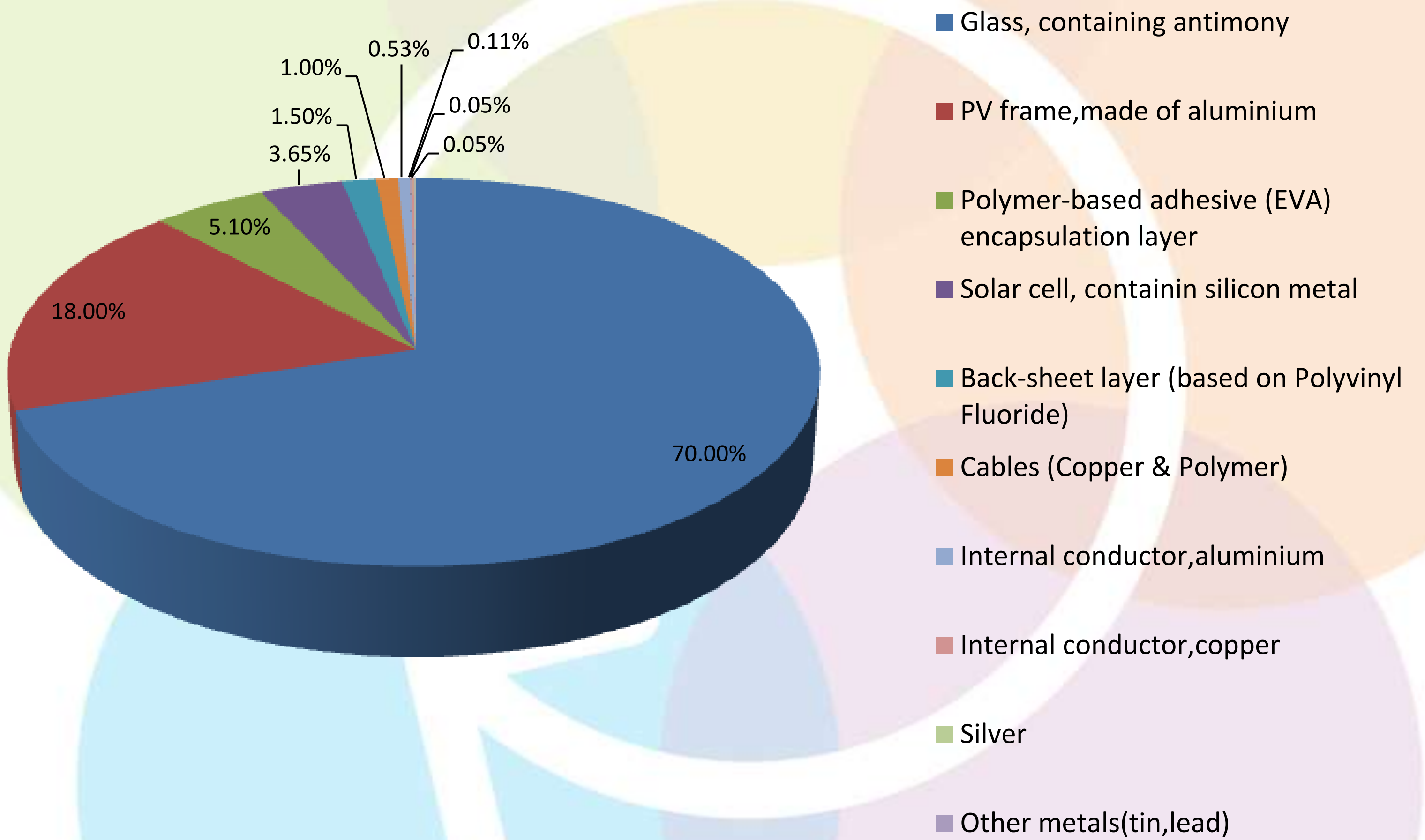
Global market share of Solar PV technologies in 2015

- Crystalline silicon (c-Si) modules represented 85-90%** of the global PV market in 2015 whereas Thin-films accounted for 10% to 15%** of global PV market
- C-Si modules are subdivided in two main categories:
  - Single crystalline (sc-Si), and
  - Multi-crystalline (mc-Si)
- Thin-film modules are subdivided in three main categories:
  - Amorphous (a-Si),
  - Micromorph silicon (a-Si/µc-Si), and
  - Cadmium-Telluride (CdTe)

Value chain of PV and material requirement

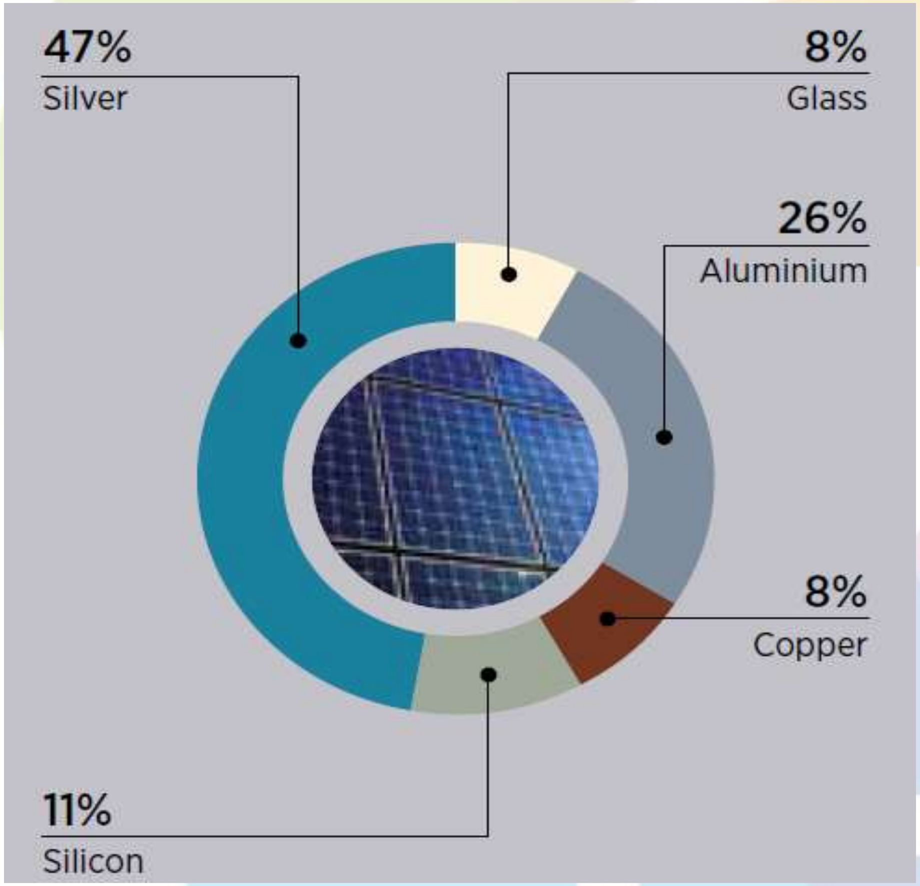


Share of key materials used in manufacturing solar PV modules (mc-Si) (by weight)



Source: Latunussa, et.al (2017)

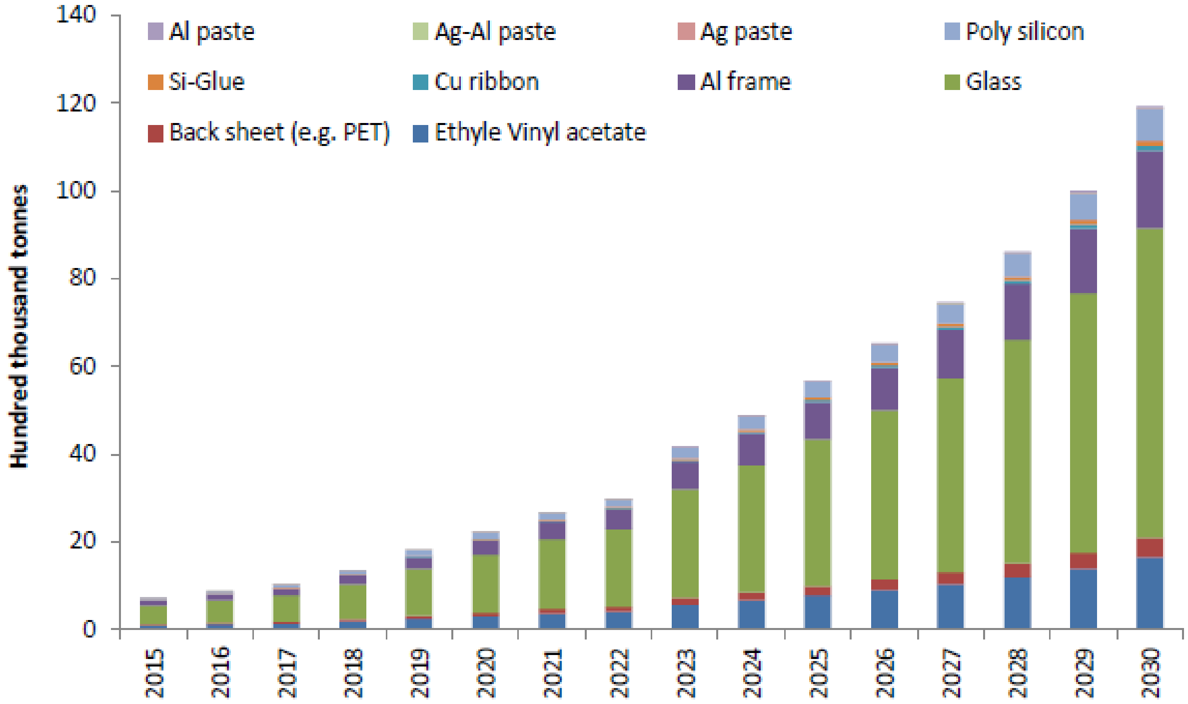
Share of key materials used in manufacturing solar PV modules (mc-Si) (by cost)



Source: IRENA 2017

- From a value standpoint, silver is by far the most expensive component per unit of mass of a c-Si panel, followed by copper, silicon, aluminium, glass and polymer.
- The PV industry consumes about 10% of global silver production

Estimated consumption of materials



- ➢ Heroic solar deployment scenario (~ 170 GW) is assumed to be installed by 2030.
- ➢ Material requirement for manufacturing of C-Si solar PV estimated to increase from nearly 0.7 million tonne to almost 12 million tonnes.

- ➢ Materials that would experience substantial increase in demand include Al, glass, Ag, and Cu (mc-Si).
- ➢ Many of these materials have competing application, experience price volatility, and relatively high import dependency. (Ag, Cu)

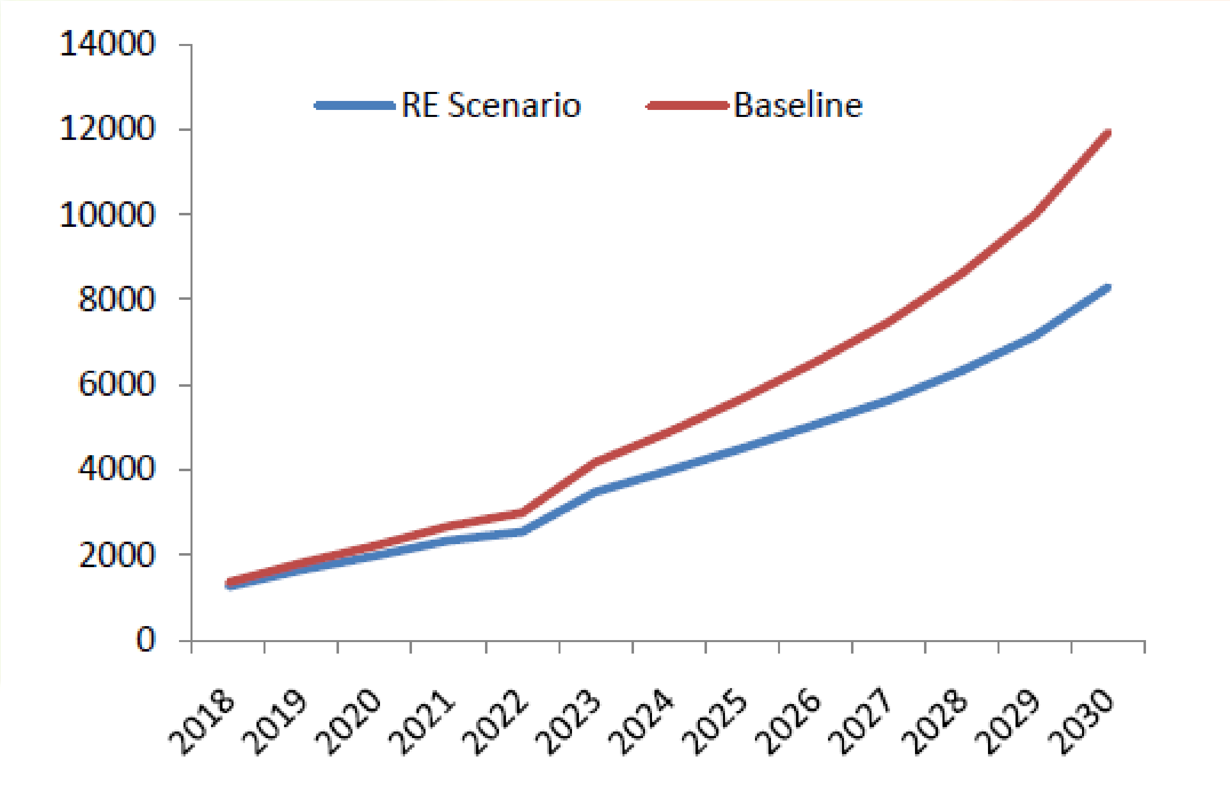
Achieving RE through

RE Attribute	Definition	Indicators
Product Design	• Next generation solar cell technologies • Use of alternatives	• Product composition • Newer materials with high efficiency • Material concentration • Cost effective alternatives
Process innovation	• Material restriction • Material streams • Use of alternatives	• New technology to avoid usage of toxic process materials • Waste reduction during cell processing • Cost effective alternatives
End of Life	• Reusability • Recyclability • Recoverability	• Take back share • Reduction of toxic components in waste streams • Silicon recycling

Key resource saving opportunities

- Use of Diamond Wire Sawing leading to 15% less consumption of Si, due to better cutting.
- Reduction of silver use at the cell manufacturing level is already practiced; Cu, as less expensive material, (or other alloys) applied with plating technologies, is the envisioned substitute.
- Reduce of thickness of glass; use of antireflective (AR) coatings has become common in recent years as a mean of improving the transmission of the front cover glass.
- Currently, more than 97 percent of the modules use Al as major frame materials Frameless modules are expected to increase market share to above 20% in 2028. Plastics frames are expected to enter slowly into the market.
- Others include, extending life of PVs; efficient reverse logistics; etc

Comparative estimates for Resource consumption



- Total estimated material demand under baseline has been estimated at nearly 12 million tons
- Under RE scenario the estimated demand for materials is estimated at 8.2 million tons
- This leads to an efficiency of more than 30 percent by 2030, from as low as 6 percent from 2018

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Assessing good industry practices of RE in PV across selected stages of solar PV value chain

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Wafering technology

Cutting and wafering of silicon ingots

- Crystallized silicon → silicon ingots → silicon wafers
- Significant amount of silicon is lost in the process.
- Recycling of kerf loss (loss of silicon in the form of sub micron powder) → reduction in polysilicon consumption + reduction in waste generation
- Garbo has patented its silicon recycling process, known to remove contaminants and purify silicon.
- Purified silicon → dried and packed under vacuum → powder so obtained goes through high temperature oxygen degassing → used for producing ingots

Cell processing

- Converting silicon wafers to cells involves wet chemical etching and cleaning processes.
- Reduce/avoid use of certain chemicals and metals such as silver, hydrogen fluoride, lead etc. + increase use of less pure and/or recycled chemicals → waste generation can be reduced.

i. **Silver** : ISC- Konstanz is conducting experiments to reduce silver use.

ii. **Hydro fluoric and nitric acid:** ISC-Konstanz and SoliTek are in the process of developing an alkaline method for saw damage removal and cleaning, that is intended to replace the use of these concentrated mixtures.

> The innovations are expected to save 60 % silver and 90% chemicals used

iii. **De-ionized water:** water once used to clean silicon wafers is discarded. ISC Konstanz is studying the viability of recycling waste water.

> Saving 90 % of used water is expected.

iv. **Minimize area cut off from wafer edges :** An advanced laser treatment technology is being developed by AIMEN.

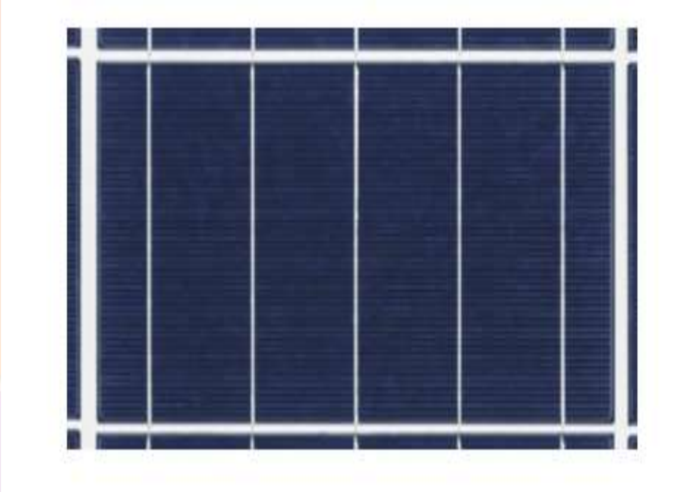
New Industrial Cell Encapsulation

- Apollan Solar is a R & D firm set up in 2001.
- Scientific, technical and technological solutions are offered by it for reducing the cost of solar PV.

- NICE module designed to facilitate **easy dismantling**.
    - Makes use of pressure contacts instead of soldering to connect the cells.
    - Poly-Isobutylene (PIB) sealing used instead of EVA (Ethyl Vinyl Acetate) like encapsulation.
    - Modules can be **opened and disassembled** into various components (facilitating **recovery**)
    - Degraded or malfunctioning components can be **repaired** or **replaced**.

Split junction box

- REC's solar cells have **5 bus bars** (instead of 3). Facilitates faster electron flow and improves panel reliability.
- **Split junction box**
  - Makes use of lesser metallization, reduces internal resistance & takes up lesser space.
  - Freed up space can be used for **greater spacing between cells** → increased internal reflection of light from backsheet to cell surface.



5 Bus bars

Crystallization of silicon feedstock

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- Two areas identified for reducing carbon footprint
  - <u>Argon Gas Recovery</u>
    - Gas Recovery and Recycling Limited (cleantech company) has developed a technology for recycling argon gas.
    - The recovered gas has a 99.9999% purity level.
    - “ArgonØ”- product developed by them, recycles more than 95 % of furnace exhaust gas.
    - Savings of > 95% can be realized if argon gas is purified and reused.
  - <u>Reusing Crucibles</u>
    - STEULER has come up with a concept for reusable silicon nitride crucibles.
    - SINTEF has studied the technical potential of these crucibles for crystallization of multi crystalline silicon
    - Savings of more than 85 % are expected.

Extending life of Solar PV

- U.S based company established in 2007.
- World's first **upgradeable** solar energy system : **40 Year Upgradable Solar**
  - Can generate power at a cost of $0.01/kWh.
  - Makes use of High Concentrating Photovoltaic (HCPV) technology
  - Generates 40% more power per installed kW
  - Multi-junction cells used
  - Upgradation of cells helps **increase service life to 40-50 years**
  - direct cell upgradation can take place in the field at a low cost
- **Unique features**:

  -Glass concentrating lenses

  -Upgradeable, hermetically sealed modules

  -Secondary alignment that ensure 0.1degree sun tracking accuracy

  -A tracker structure that operates in a variety of challenging climatic conditions (including during 200 km/hr winds).

- Can benefit fully from any technological improvement that comes about, without having to worry about current technology becoming obsolete.

End of Life Management of Solar PV (1/2)

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PV Cycle

- PV Cycle, a company based in Belgium, having global operations has achieved a record recycling rate of 96% for silicon-based PV modules.
- The remaining 4% that is not recycled tends to be made of some residues from the glass recovery and EVA foils (used for lamination).
- These are sent for energy recovery, which is a form of waste-to-energy technology.
- The company in association with EU recycling partners for silicon-PV modules uses new process that combines mechanical and thermal treatment to recycle silicon flakes as well as recycling a combination of EVA laminate, silicon-based semiconductors and metals.

End of Life Management of Solar PV (2/2)

Reclaim Solar PV Private Limited

- Reclaim PV Recycling operates an Australian Photovoltaic take back and reclaiming scheme, providing waste management and resource recovery services throughout Australia and Oceanic region
- The company provides a streamlined component recovery system that is said to be accessible for any manufacturer
- The company has developed a unique process of reclaiming efficient cells from damaged solar modules. By removing the good cells, it can reduce the amount of energy needed to effectively recycle solar cells.

Recommendations for a low carbon resource efficient Solar PV sector in India (1/2)

Objective	Actions	Outcome	Policy
Enhance raw material security of the country	Encourage standardized and easily dismantled product designs Encouraging manufacturers of solar PV systems to use recycled raw material Set up a proper solar panel recycling infrastructure	Reduced imports; Recovery of secondary raw material	Financial support; Set up a modest recycling targets; Investment in formal recycling, Cluster based approach recycling set ups; A cluster approach could be considered target of use of recycled material; Issuance of guidelines that specifically provide
Implementing Extended Producer Responsibility including that for end of life management	Developers should be made responsible for handling damaged and unusable modules broken during transit or installation.		Design of an agreement mandating the developers for collection

Recommendations for a low carbon resource efficient Solar PV sector in India (2/2)

Objective	Actions	Outcome	Policy
Resource efficiency standards	To strengthen and organize the used panels segment by recognizing specialized dealer network or manufacturers	Bring back used, remanufactured, and refurbished panels and sell them through organized channels	Introduction of appropriate functional criteria and labels Monitoring and supervision by solar developers
Capacity development	Support for R&D in PV end-of-life activities; Support for technology Innovations Industrial cluster cultivation between the PV and waste sectors as well as cross-cutting R&D programmes	Improved technological Performance and generation of greater value from the recycling output; Creation of high-value recycling processes for rare, valuable and potentially hazardous materials	Grants for organizing training and Workshops; Financial support for R&D

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Thank you for your attention

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