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Importance of Solar PV module Quality Assurance & Quality Control

Mapping Solar PV Supply Chains & Risk Assessment of Technology Roadmaps



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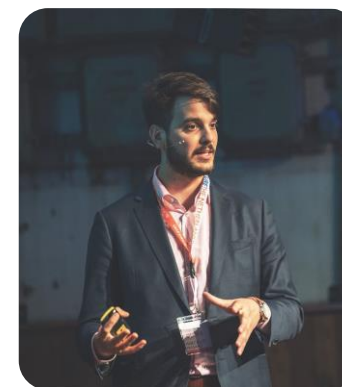




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Market Developments

- ☐ New technologies with yet unknown risks
- ☐ Sellers market & price hikes (quality concerns)
- ☐ Upcoming EU legal demands
- ☐ Concerns about forced labor modules
- ☐ 1 in 7 projects underperforming



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Executive Summary

Risks

- 1 Business case is not met & lower than expected secondary market prices
- 2 Executive team is held legally liable for not implementing mitigation tactics in their CSR policy

Solar investments do not meet expectations

Mitigation Measures

- ✓ *Budget an amount of initial CAPEX for quality assurance in business case to mitigate financial losses*
- ✓ *Review and evaluate CSR and traceability reports of module suppliers*

Solar investments meet & exceed expectations



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Quality driven, informed and transparent

Sunzest Solar is your advisor in procuring ethical, sustainable, financial & technical bankable PV modules.

Email us at marcello@sunzestsolar.com to learn more about the data and how we can help your team.





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Global Market PV Module Developments

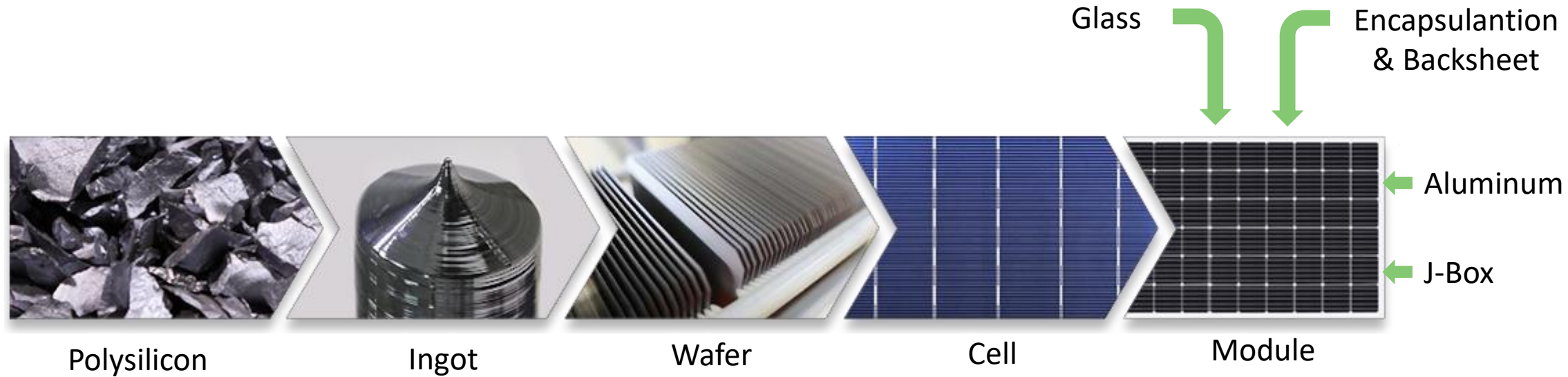
- **Global climate crisis increasing frequency & severity of severe weather events**
 - EPCs and Advisors need factor in higher wind & snow loads and the thermomechanical stresses of higher consistent temperatures (in particular with larger module sizes)
- **Wild-growth of new technologies & bill of material combinations**
 - Availability of PERC, PERC+, TOPCON, HTJ in different wafer/cell/module sizes in both monofacial and bifacial applications; raise concerns about their thermomechanical duress and reliability long term.
 - Variations of different bill of materials strongly influence the lifetime of a module as it has an influence of the module's susceptibility to UV stability, water ingress, electrical resistivity, acetic acid formation, delamination, browning, yellowing and PID.
 - New technologies require a steep learning curve. PI Berlin, Sinovoltaics & STS have seen higher non-conformity with new technologies at production sites.
 - PV Evolution labs shows a resurgence of PID. Moreover, that of PID polarization in bifacial modules.





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Birds eye view of Solar PV Value Chain



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Made in China



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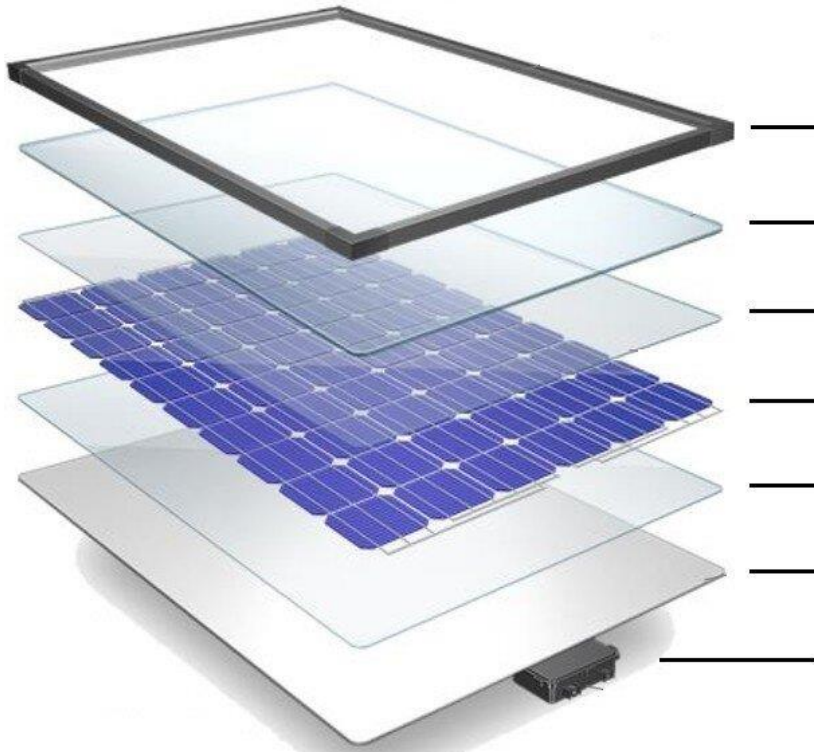


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Module Bill of Material Variations



Frame: *Aluminum, frameless*

Frontsheet: *3, 2-3mm, 2mm rolled/structured glass*

Cell Interconnect: *multibusbar (Cu ribbons, Cu wires), shingled*

Cell Tech: *PERC, PERC+, TOPCON, HTJ [monofacial or bifacial]*

Cell Size: *G1, M10, M6, M4, G12, Half cut, Full Cell*

Encapsulant: *TPO, POE, EVA*

Backsheet: *PVDF, PVF, PET, PP, f-coating, 3, 2-3mm, 2mm rolled/structured glass*

Junction Box: *smart or non-smart*

Module Sizes: *<2.5m², 2.5 – 3.0m², >3.0m²*

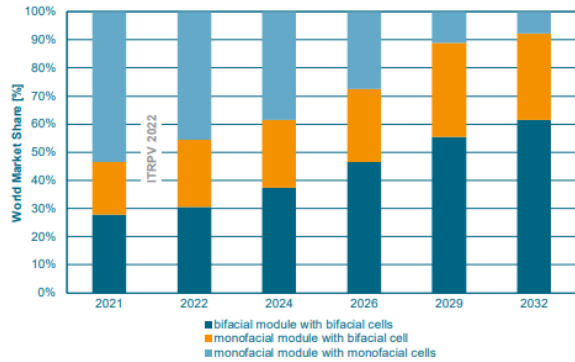




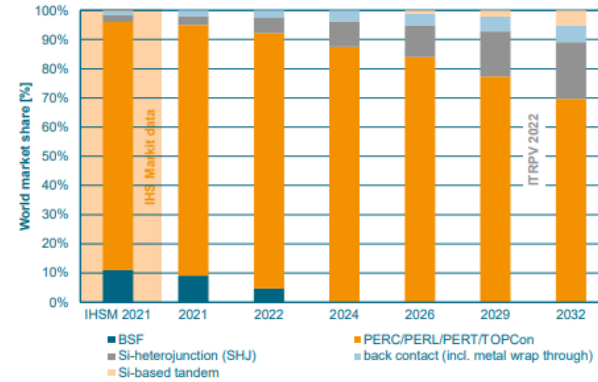
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Technology Roadmaps

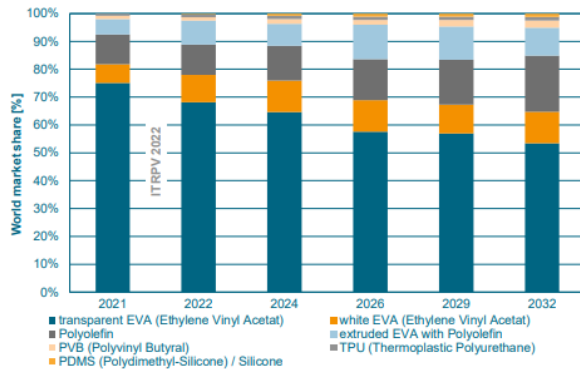
World Market Share of monofacial and bifacial modules



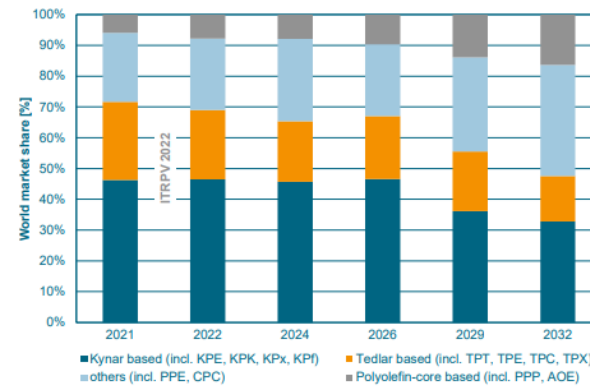
Different cell technology



Different encapsulation material



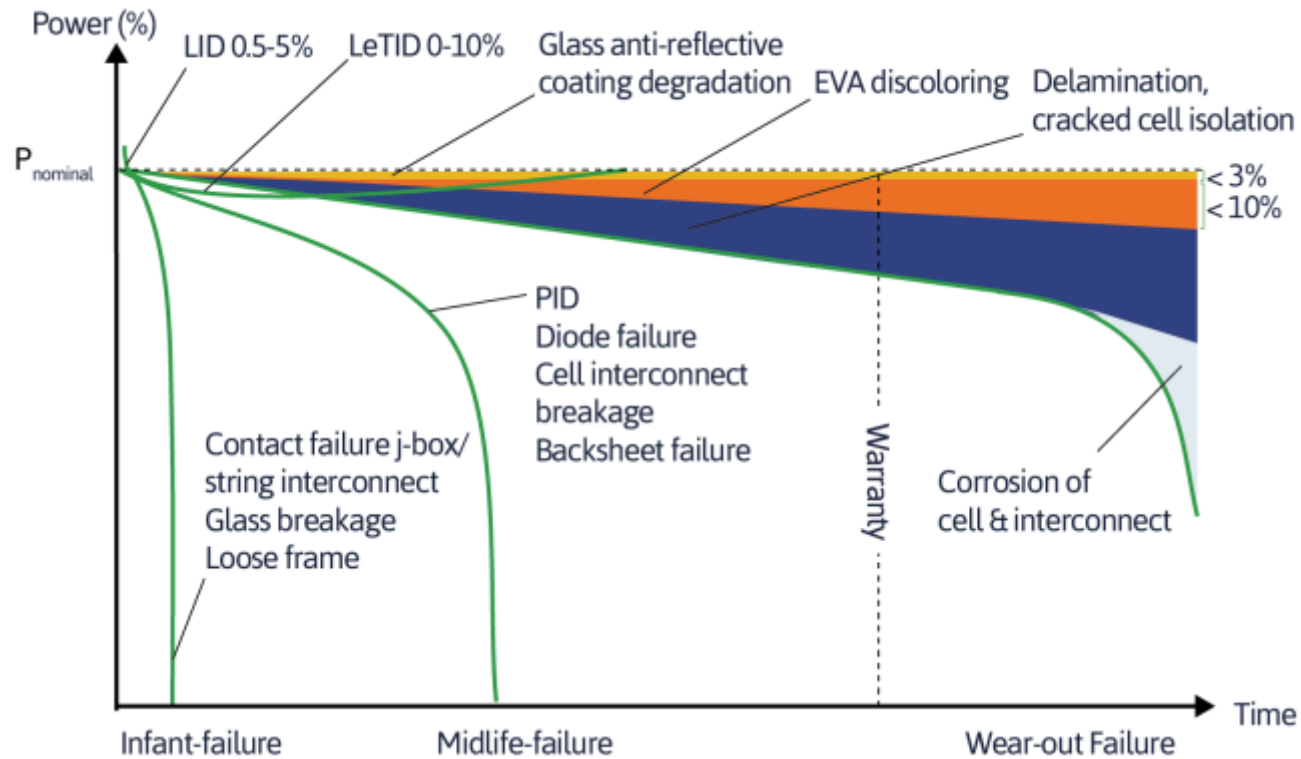
Different backsheet foil materials





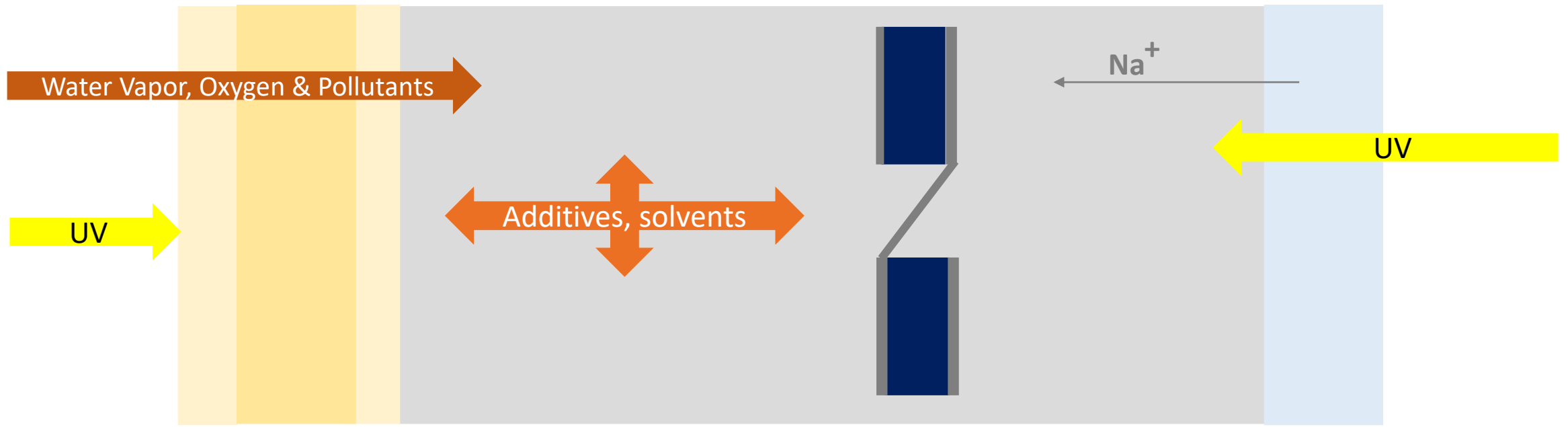
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Known Failure modes & Degradation Rates to Date





BOM in field



Backsheet

Encapsulant

Solar Cell

+ fingers/busbars/wires/ribbons

Encapsulant

Glass

Challenges

Yellowing, cracking, delamination

Browning, delamination, snail trails, PID

LID, UVID, LETID, PID-s, PID-p, microcracks, metastability, hotspots, peeling, corrosion, IC failure

Browning, delamination, snail trails, PID

Glass breakage, anti-reflection coating degradation



Reliability Risks to be tackled by Cell Tech. Type

Cell Technologies	ESG concerns [polysilicon]	PID-s*	LID	LETID	UVID	Metastability	PID-p	Learning Curve**
PERC (Boron Doped)	X	X	X					Low
PERC+ (Gallium Doped)	X	X		X				Low-Medium
n-type TOPCON	X	X			X			Medium-High
n-type HTJ	X	X				X		High
Bifacial	X	X					X	Medium-Low

*dependent on BOM combination

**dependent on workshop quality procedures, training, equipment, staff and familiarity

Learning curve will depend level of non-conformity and potential for future reliability issues. PI Berlin, STS and CEA see higher non-conformity with new technologies.





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Reliability Risks to be tackled by Cell Tech. Type

	Glass	Polymer Backsheet A	Polymer Backsheet B	Polymeer Backsheet C	Polymeer Backsheet D	Polymeer Backsheet E
Encapsulant A	Low-Medium	Low-Medium	Medium – Low	Medium - Low	Medium - Low	Medium-High
Encapsulant B	Medium	Medium	Medium-High	Medium-High	Medium-High	High

*Risk profile dependent on

- Climate of Install Site
- Module Assembly Quality
- Product Conformity
- Encapsulant Production Quality & Storage
- Backsheet Production Quality & Storage
- System Installation Quality





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Example Mitigation Tactics

Criteria	+ 40 year lifetime	30 year lifetime	25 year lifetime	<15 year lifetime
TIER 1	X	X	X	X
IEC 61215 & 61730	X	X	X	X
Site Testing	X	X	X	X
CSR review (ethics, toxicity, LCA & reuse, reduce & recycle approach)	X	X	X	
IEC63209 or equivalent (RETC, PVEL)	X	X	X	
Site Considerations	X	X	X	
Spare Parts	X	X		
BOM Review	X	X		
Module Testing	X	X		
Production Monitoring	X			
Risk Profile	Medium - Low	Medium	Medium-High	High

Sunzest has tailored solutions for your project size and budget needs to reduce technical, CSR and financial risks associated with module procurement.





Sunzest Solar Added Value

	Sunzest Solar	Competitor A	Competitor B	Competitor C
Datasheet review	X	X	X	X
Warranty Review	X	X	X	X
Financial Bankability	X	X	X	X
Durability & BOM Review	X	X		
Risk Asses + QA/QC Strategies.	X	X		
Testing Project Management	X			
Testing partnerships	X			
CSR/ESG review	X			

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Thank you for your attention!

Any questions, reach out to:

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