ESR nº9:
Investigation on PV Module degradation mode indicators

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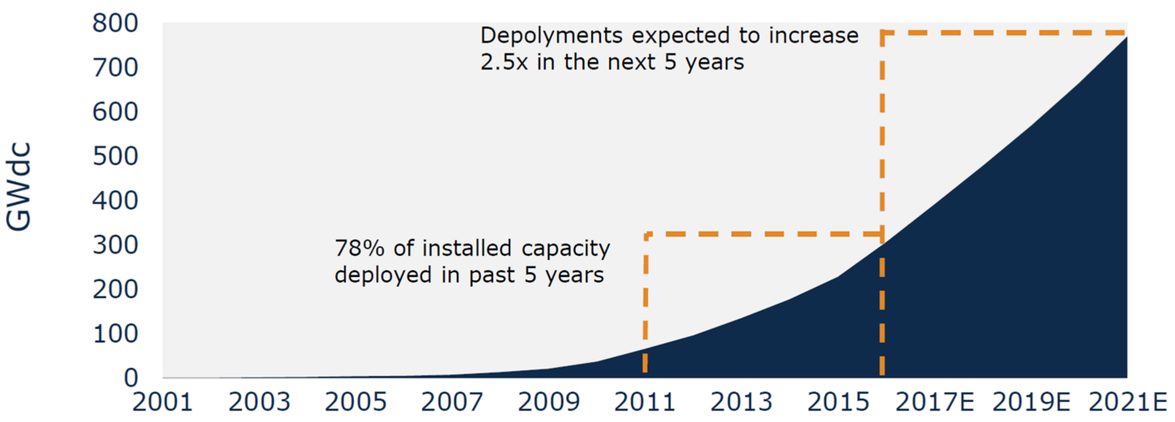
A young, but fast growing industry.



Source: GTM Research

Cumulative installed global PV capacity

Uncertainty and lack of maturity:

- Industry took off in late 2000's, more than 80% of the installed panels in the world experienced less than 5 years of in-field stress. There is a lack of experimental infield data.
- Link indoor results to in field lifetime, very complex due to degradations processes interactions.

Large amount of parameters and data to take into account, need to focus on some failure modes/panels technologies

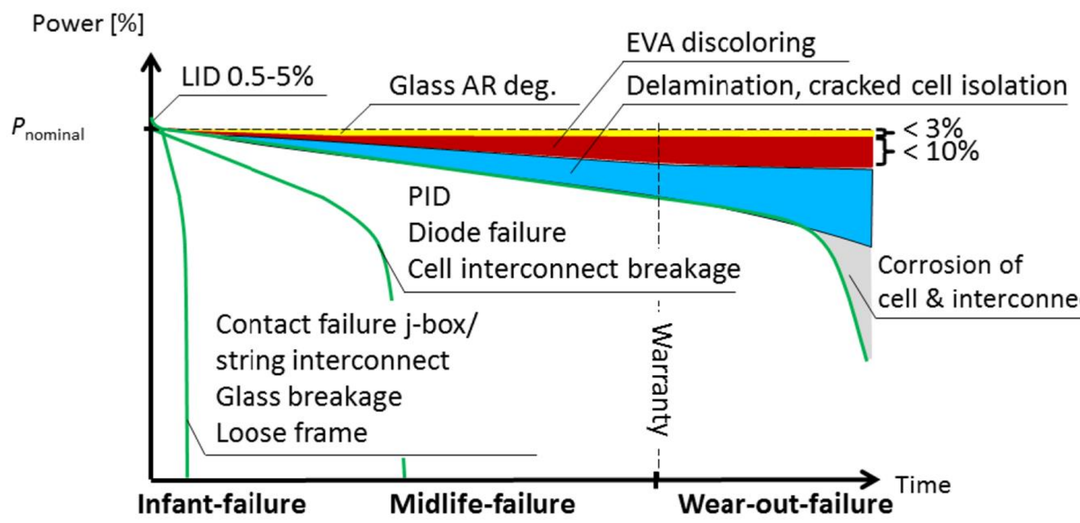
- Although C-Si is the dominant technology today, several panel technologies cohabits, this multiplies the quantities of specificities to take into account
- Climate specificities, several and completely different kind of stress due to climate specificities, may requires adaptations to panels, no unique proposition/solutions

Business aspect :

- To obtain more credibility , industrials must be able to give warranties to their clients.

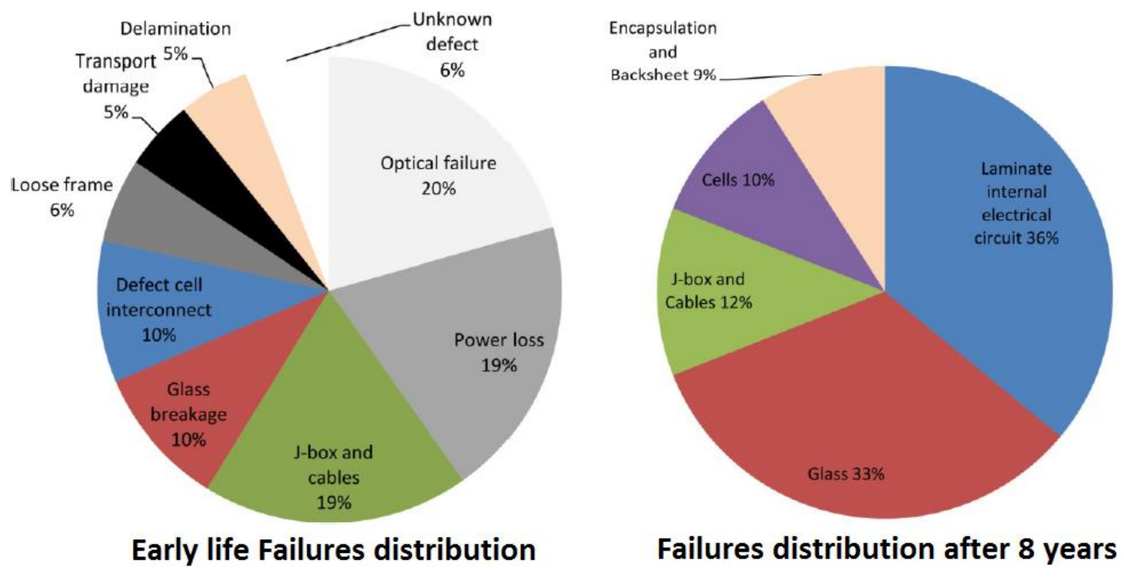
The 3 great categories of failures

1. **Early life - Infant failure (within the 2 first years)**
   - Mostly dependent on fabrication processes
2. **Midlife failures**
   - 2% of the PV modules
3. **Wear-out failures:**
   - Safety problems or Power falls under < 80% of Initial Power



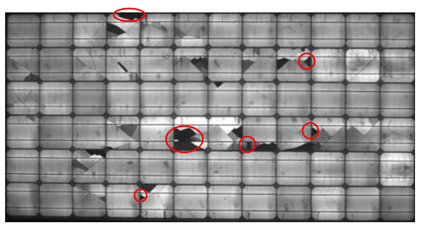
Aging mechanisms leading to PV module degradation

Source: IEA PVPS 2014

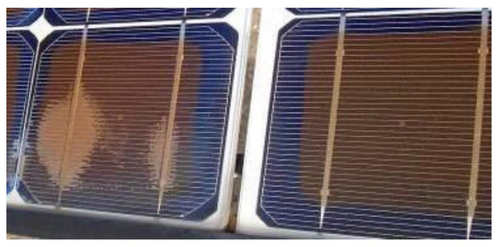


Early life Failures distribution **Failures distribution after 8 years**

Source: IEA PVPS 2014



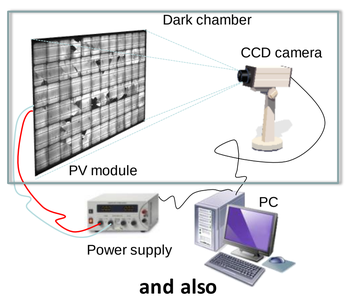
Cracks observation by Electroluminescence (CENER)



Encapsulant delamination and yellowing (M. Köhl, ISE)

Full degradation modes study capability at CENER

CENER lab is fully equipped to preform IEC61215 test sequences.

Failure mode	Ageing		Characterization tools Available devices at CENER
	Accelerated stress	Available devices at CENER	
Broken interconnect Broken Cell Solder bond Failure Junction box adhesion Module connection open circuits Open circuits leading to arcing	**Thermal Cycling**	**2 Climatic chambers** (-40ºC to 185ºC) 0% to 100% Relative Humidity Capacity of 10 panels of 2x1 meters Electric circuit to test Potential Induced degradation during the thermal cycle 1 Smaller climatic chamber (<1^3 meter)	Electro Luminescence  **and also** Optical microscopes Thermography (Steady / Lock-in) I-V curve measurements at specific temperatures SEM EFM Spectral reflectance/transmitance Spectral response
Delamination of encapsulant Junction box adhesion Inadequate edge deletion	**Humidity Freeze**		
Corrosion **Delamination of encapsulant** **Encapsulant loss of adhesion and elasticity** Junction box Adhesion **Electrochemical corrosion of TCO** Inadequate edge deletion	**Damp Heat**	Above Climatic chambers **+1 Damp heat dedicated machine** **+ 1 Salt Spray chamber**	
Delamination of encapsulant **Encapsulant loss of adhesion and elasticity** **Encapsulant discoloration** **Ground fault due to backsheet degradation**	**UV exposure**	**UV chamber** Accepts 2x1 meters panels Two type of lamps - UVB/UV = 33% - 3% UVB/UV < 10%	

Accelerated ageing/weathering devices

Multi-Usage climatic chamber at CENER

Salt spray chamber at CENER

In-field installations

Built-in PV panels at CENER, (Installation in 2005)

Two-axes trackers on the roof

Step stones, expected results and collaborations

- **To identify degradation patterns of PV module performance.**
  - ➢Material properties that are most sensible to climatic conditions.
- **To develop non-destructive tests for degradation risk detection.**
  - ➢For "a priori" diagnosis of degradation mechanisms.
- **To trace-back degradation patterns to individual degradation mechanisms**
  - ➢Define figures of merit for PV modules testing.
- **Tfff**
  - ➢ vvv

Host institution	Purpose
PCCL - Austria (Dr. Oreski)	Advanced materials processing and characterization
FRAUNHOFER - Germany (Dr. Köhl)	Combinatory testing
ATERSA - Spain (Mr. Daroqui Raga)	Influence of the production on degradation effects

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