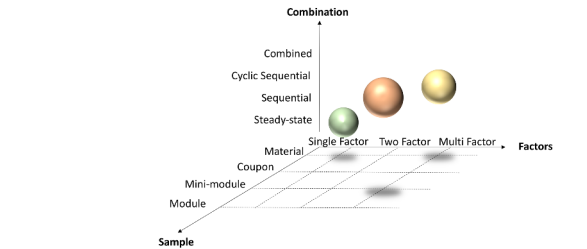


EXAMINING LIGHT-INDUCED DEGRADATION WITH COMBINED-ACCELERATED STRESS TESTING

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Combined-Accelerated Stress Testing (CAST) is Representative and Comprehensive Durability Testing

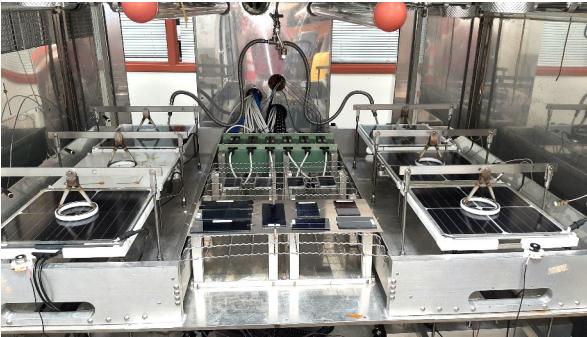


"Combination": representation of the actual combination of stress factors as in the natural environment and their balance (exceeding vs not exceeding real-world stress levels)

"Factors": extent of inclusion of the stress factors of the natural environment

"Sample": representation of the materials interfaces, boundary conditions of the shipping module

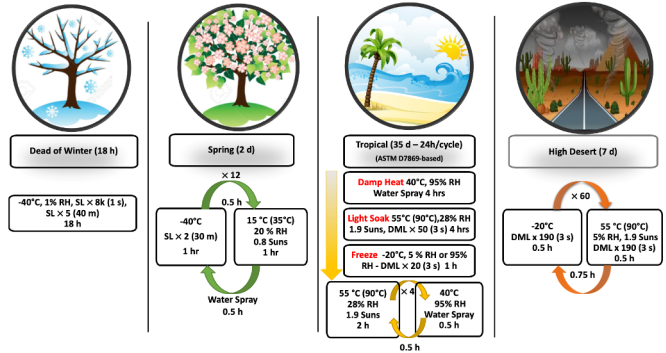
CAST is designed to discover potential weaknesses in module designs, both known and not *a-priori* recognized, reduce risk, accelerate time to market, bankability and reduce costly overdesign, to lower the leveled cost of electricity.



- Stress Factors**
- Heat
 - Light
 - Humidity
 - Condensing
 - Non-condensing
 - Mechanical pressure
 - System voltage

In-situ Metrology

- I-V, EL

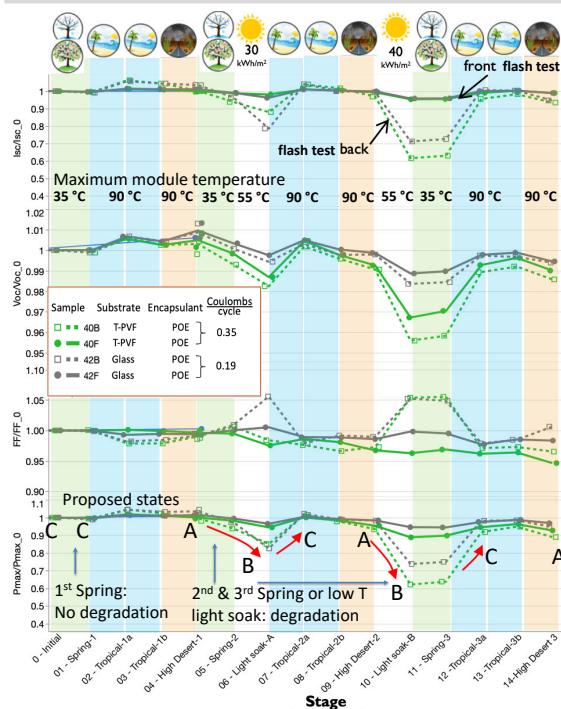


The four stress sequences (climates) performed sequentially in combined-accelerated stress testing (C-AST). Undergoing the four stress sequences in the order shown is defined as one C-AST cycle. Temperatures indicated as Tchamber (Tmodule). -1000 V System voltage applied to cell circuit only when irradiation is applied. DML refers to Cyclic Dynamic Loading to produce radius of curvature that would be seen on a full-size module with 1000 Pa loading. SL is static loading with 2400 Pa equivalent

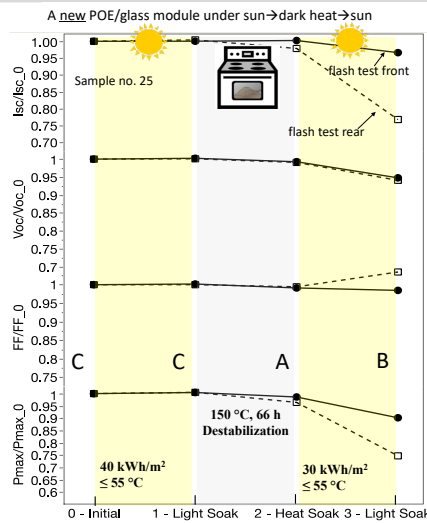
Samples

No.	Substrate	Encapsulant	Cell type	Stress testing performed
			(Mono-Si PERC)	
40	transparent PVF	POE	Bifacial	3-cycles of CAST with two interspersed ex-situ light soaks; two light soaks after CAST with 1 st light soak under UV absorbing acrylic
42	glass	POE	Bifacial	3-cycles CAST with two interspersed ex-situ light soaks; two light soaks after CAST
The mini modules below did not go through CAST but went through tests indicated in the right-hand column				
25	glass	POE	Bifacial	Light soaking, heat soaking, light soaking
27	transparent PVF	POE	Bifacial	Two light soaks with 1 st light soak under UV absorbing acrylic

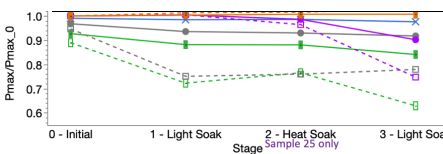
Results



Effect of light soak



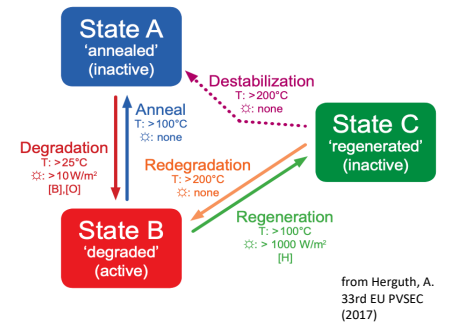
Effect of light soak, dark heat, and a second light soak on module power. The results indicate cells are shipped in the C state and destabilization with respect to LID occurring during the heat soak.



Final diagnostic testing:

- Post-CAST samples degrade during first light soak.
- New sample degrades only in 2nd light soak, only after dark heat soak.

Framework for light-induced degradation



Summary

While further understanding is sought, the results suggest that a module can show no degradation in performance through a qualification test light soak, (IEC 61215: 2021 MQT 19.1 requirement of 10 kW minimum on one side) as per samples 25 and 27. Yet, such cells may degrade significantly by LID under conditions within the statistical extremes of the natural environment applied in CAST, as seen in samples 40 and 42.

Acknowledgements

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