



Integrated
Photovoltaic
Conference

25 – 26 November 2025
Chamber of Commerce
Florence, Italy



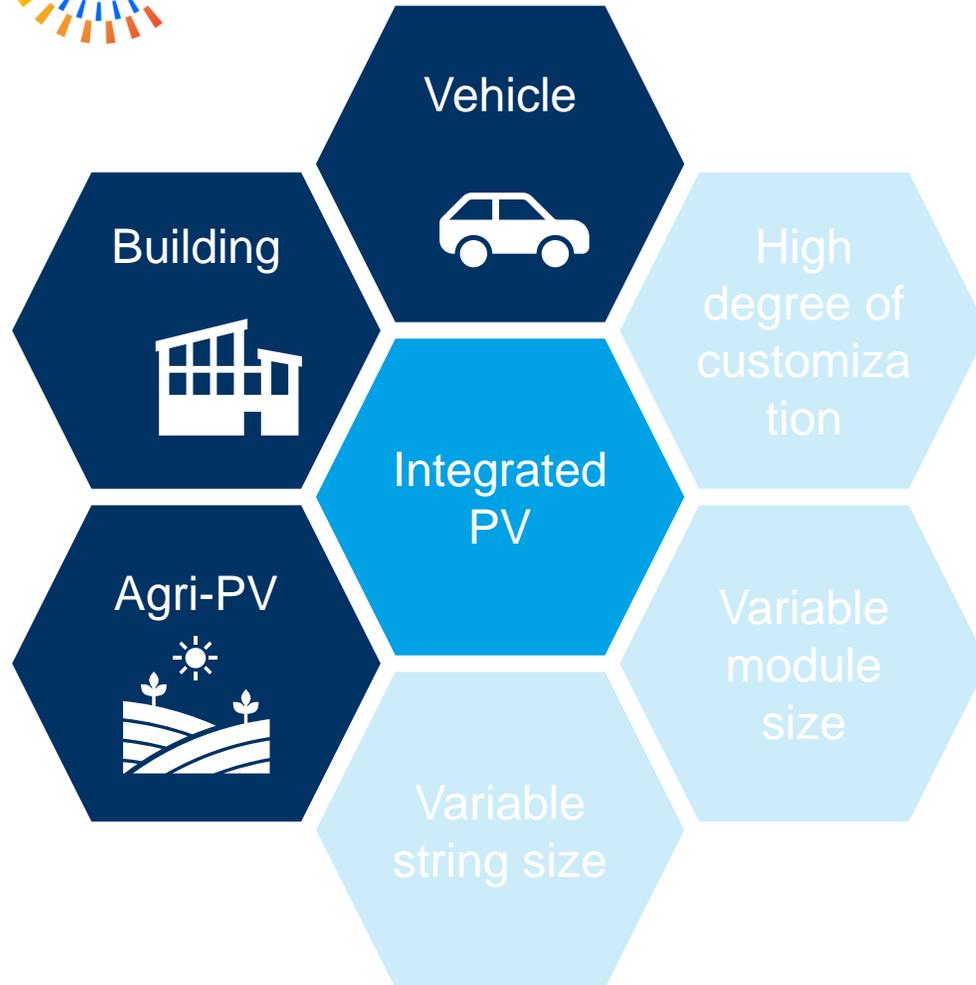
Lison Marthey, Alessandro Virtuani, Hengyu Li, Loann Baume, Matthieu Despeisse

CSEM

PRE-LAMINATES: ENHANCING FLEXIBILITY IN INTEGRATED-PHOTOVOLTAIC (IPV) MANUFACTURING LINES

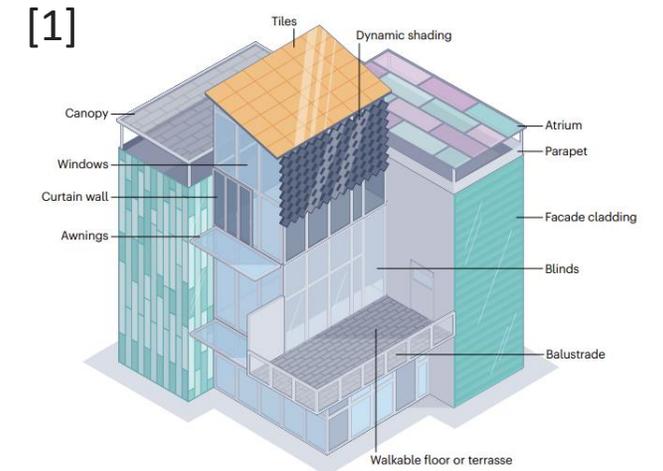
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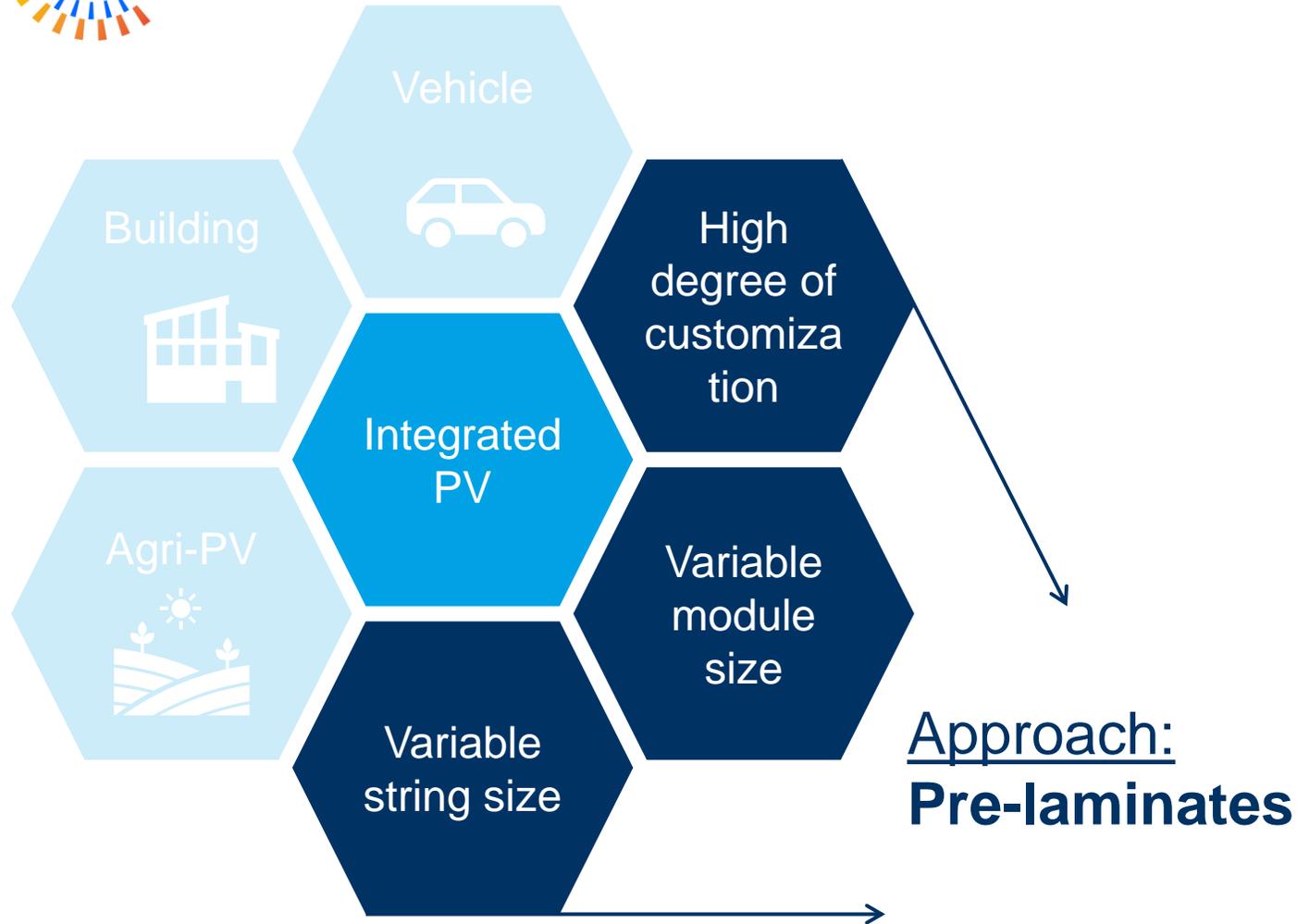
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Integrated PV:

- Both functional and architectural roll
- Local electricity production
- Increase aesthetics





Definition:

Intermediate assembly of strings and encapsulant, designed for storage prior to final PV module lamination

Advantages:

- Flexibility
- Buffer process
- Storage in air
- Mechanical and environmental protection (O₂ & moisture)

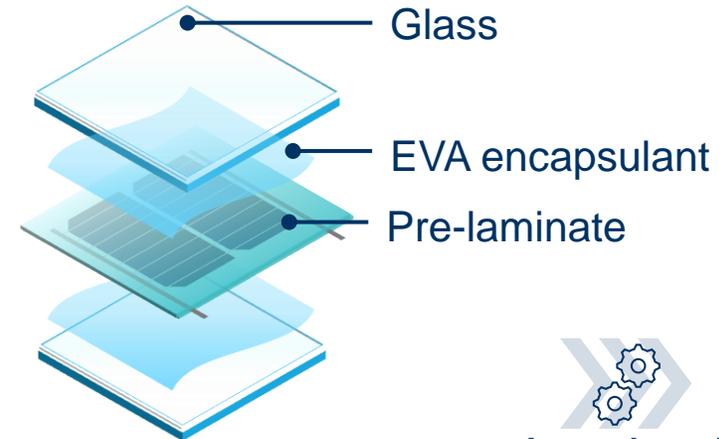
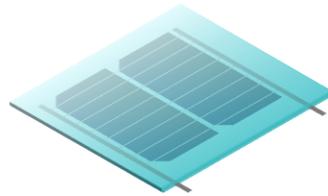
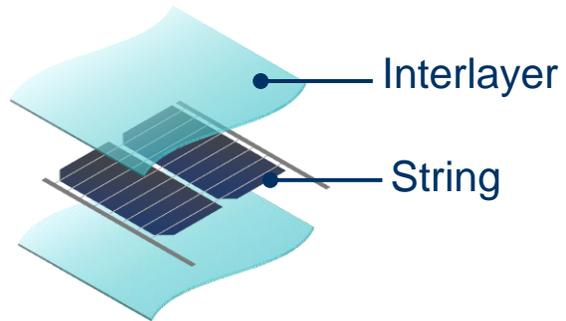
Approach:
Pre-laminates

Pre-laminate stack

Pre-laminate

Module stack

Final module



? *What is the most adapted material?*

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? *What is the impact of the storage at material level?*

? *What is the impact of storage at module level?*



APPROACH

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What is the most adapted material?



Interlayer requested properties:

- High transmittance
- Provide environmental barrier
- Stability with storage
- Mechanical protection (high stiffness)
- Compatibility with PV materials & processes

Commercial **POE** encapsulant

- ✓ Commercially available
- ✓ Known material
- ✓ Compatible with PV materials
- × Sticky (difficult to stack)

V/S

Developments at CSEM:

- Material formulation
- Characterization protocol
- Materials & module processing
- Several iterations

CSEM developed interlayer PO (**iPO**)

- ✓ Formulated on purpose
- ✓ Good barrier properties
- ✓ Rigid
- ✓ Non sticky (easy stacking)
- ✓ 180um thin
- × UV blocking → lower perf



What is impact of the storage at material level?

Goal: evaluate materials properties change with storage time

Bill of Material:
Prelaminated iPO or POE

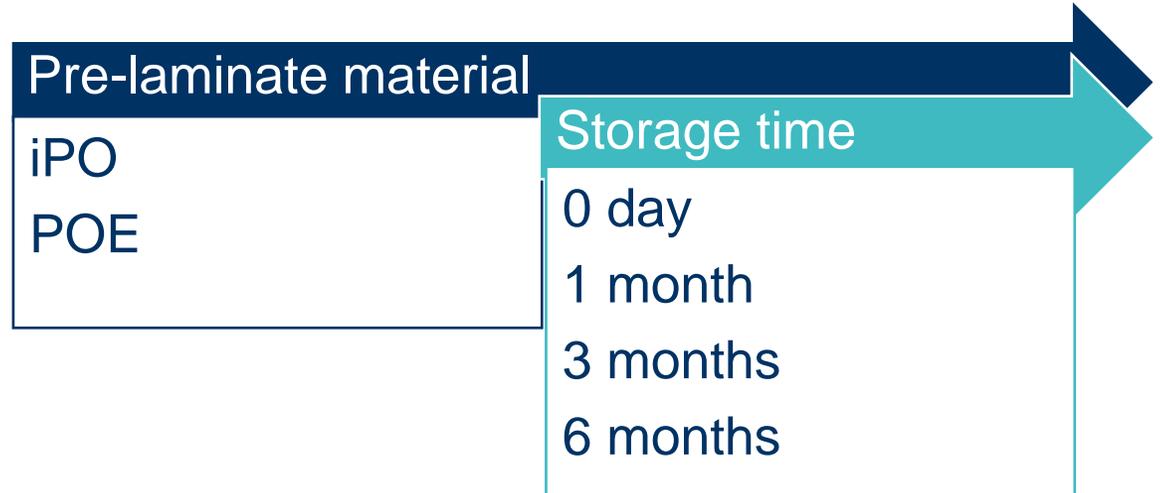


Storage conditions: 20°C, ~70% RH

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Experiment parameters:



Characterizations:

- 180° adhesion to EVA & solar cell
- Differential scanning calorimetry (DSC)
- Fourier transformed infrared spectroscopy (FTIR)
- Rheology

Adhesion:

- To cell: **>100N/cm** independently of storage time
- To EVA : high for iPO and POE (samples slipping out of clamps)
- Adhesion to cell remains good

Rheology:

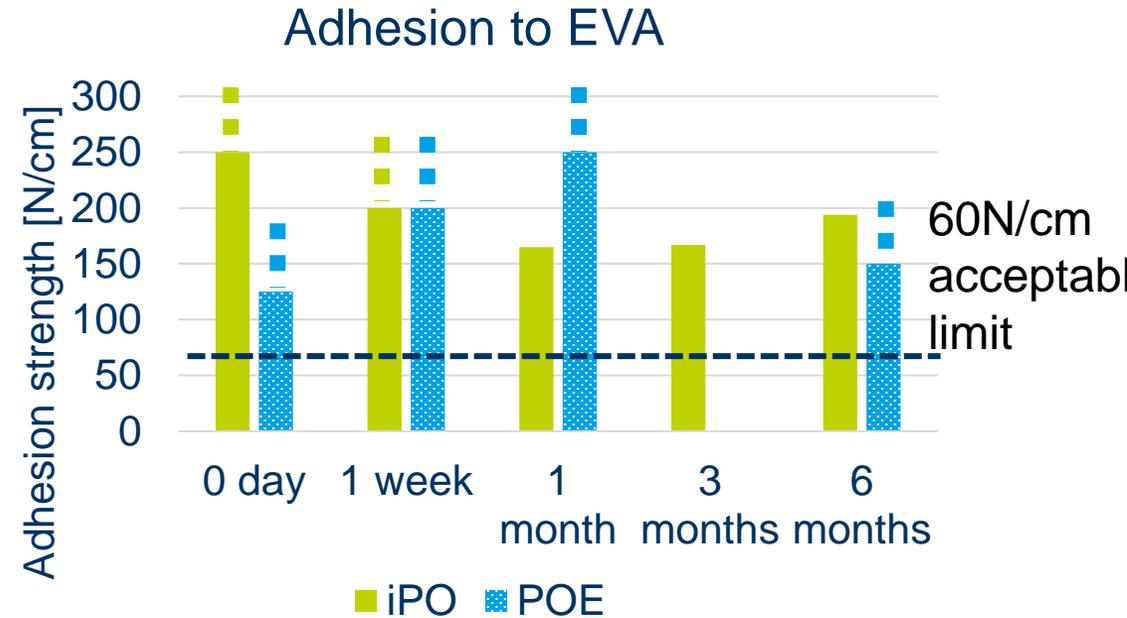
- Viscosity is increasing after 6 months
 - Max Tan δ iPO: -30%
 - Max Tan δ POE: -50%
 - Can still be processed

DSC:

- No pronounced variations in enthalpy reaction

FTIR:

- No pronounced peak change

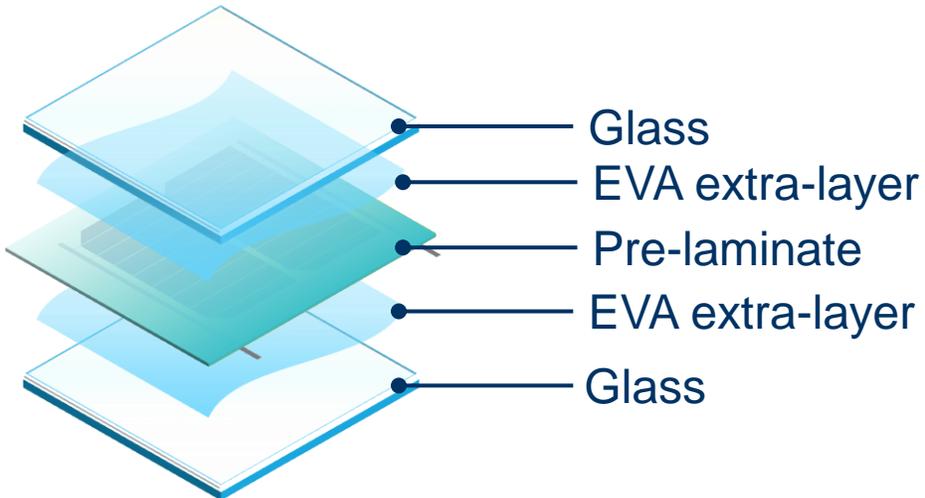


- Increase in viscosity with increasing storage time
- No pronounced variations in other properties
- **Material can still be processed**

What is impact of the storage at module level?

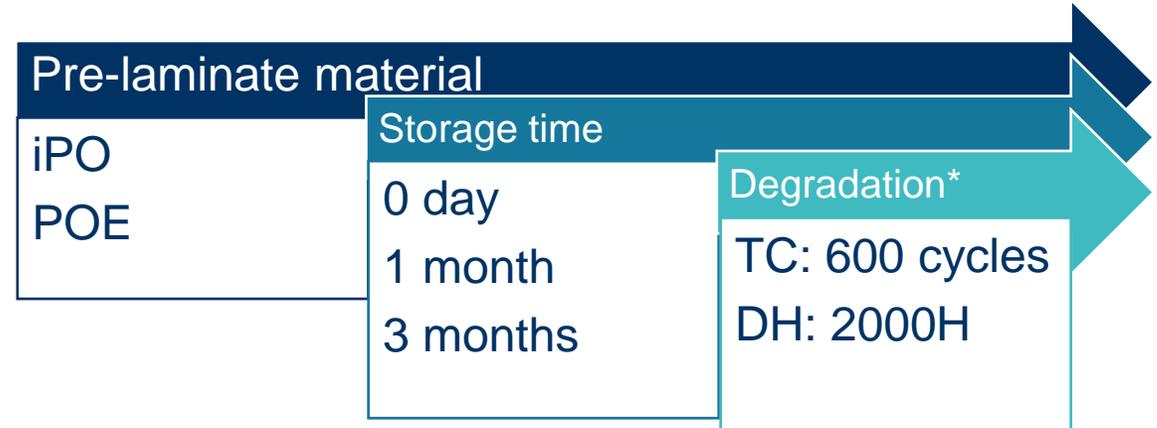
Goal: Evaluate performance and reliability of modules with iPO and POE pre-laminates at different storage time

Bill Of Material: Final stack ≈ EPE



Compared with reference module **GG/EVA**
conventional structure: **Reference EVA**
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Experiment parameters:



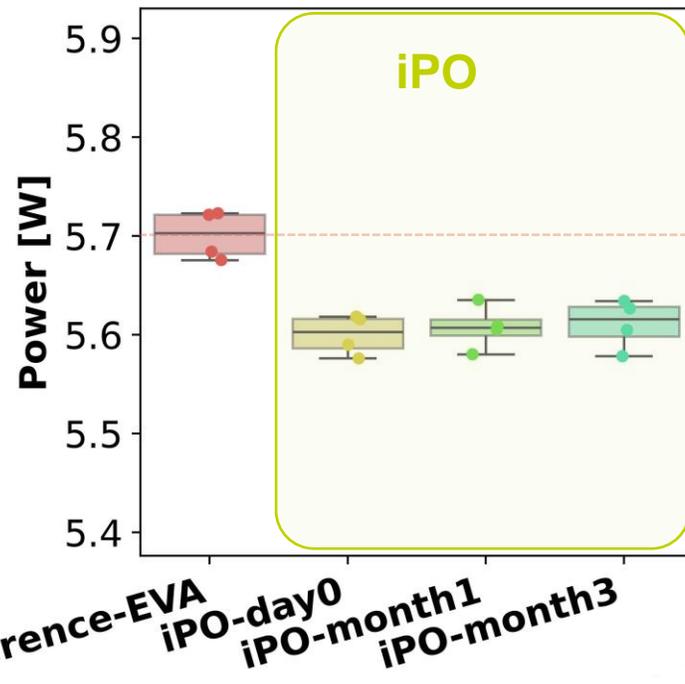
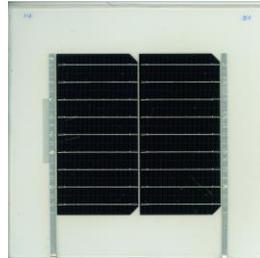
Characterizations:

LIV
EL
VI (visual inspection)

*Extended degradation: IEC standard 63209-1-2021 (sequences 1 & 4)

iPO:

- -1% power (I_{sc}) compared to EVA- ref
- UV-blocking property of iPO → can be improved
- Slightly yellow
- Good EL



MODULES INITIAL PERFORMANCE

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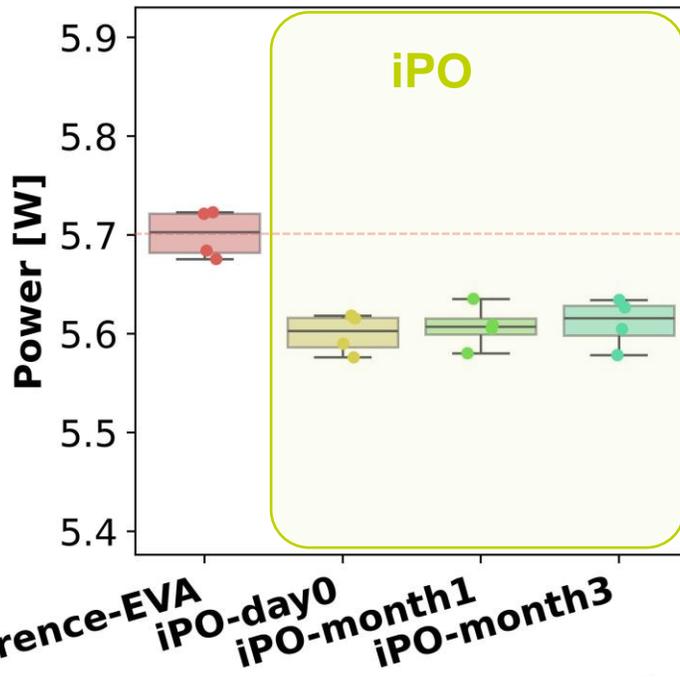
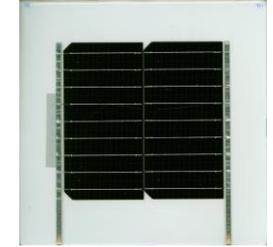
iPO:

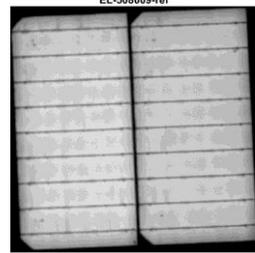
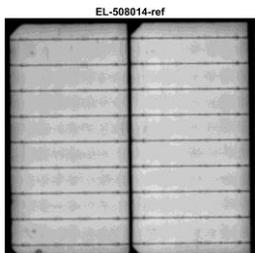
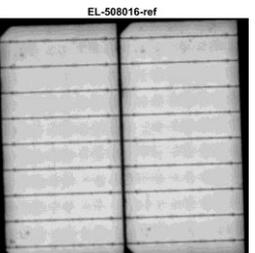
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POE:

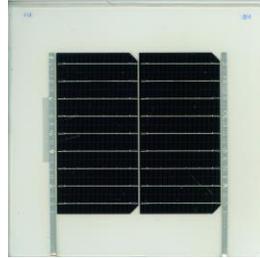
- Performs better than iPO
- Few interconnection losses → related to double lamination?



EL	Day0	Month1	Month3
iPO			

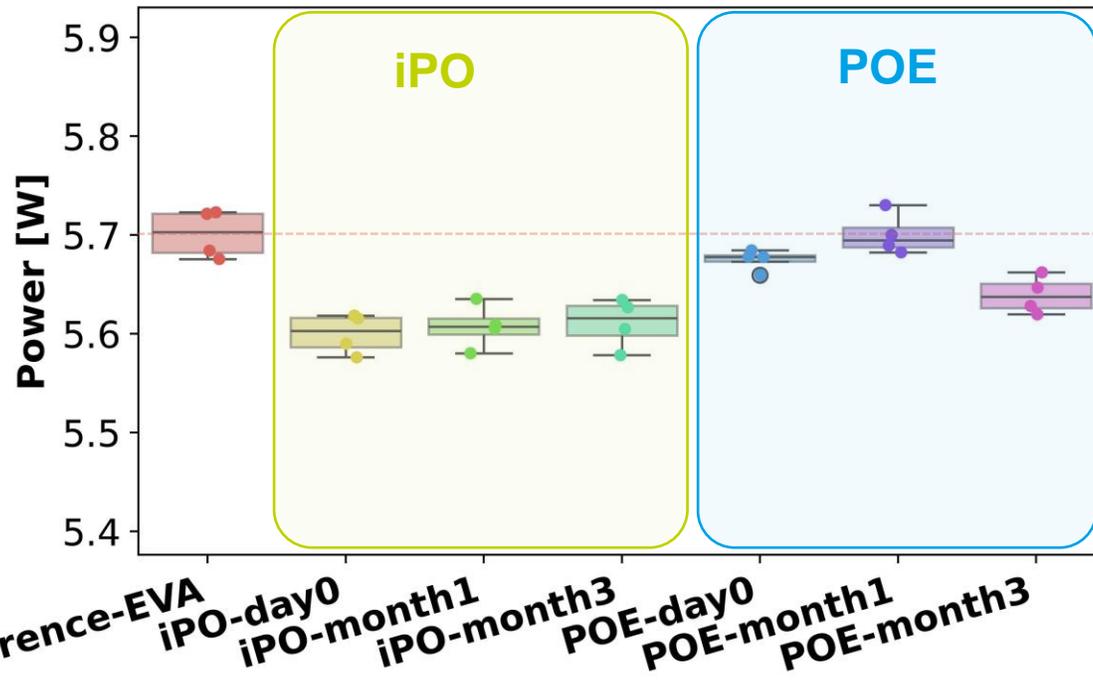
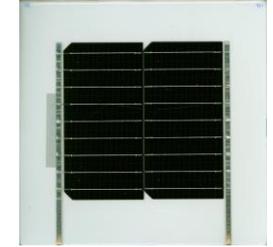
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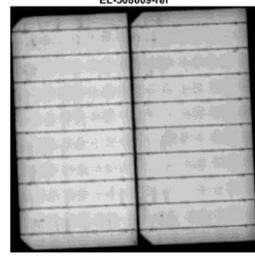
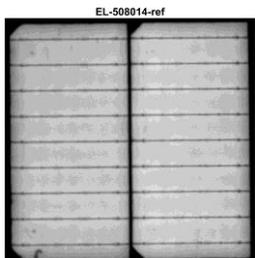
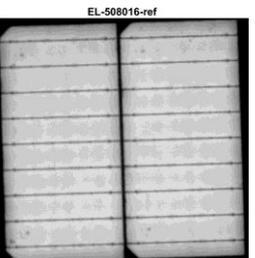
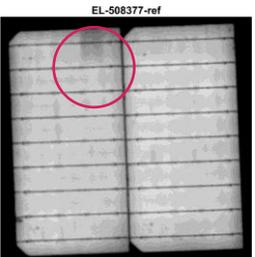
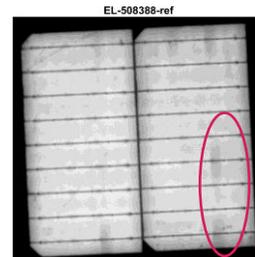
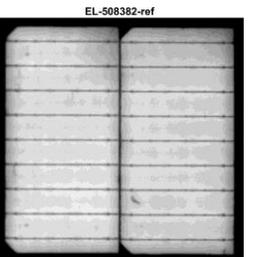
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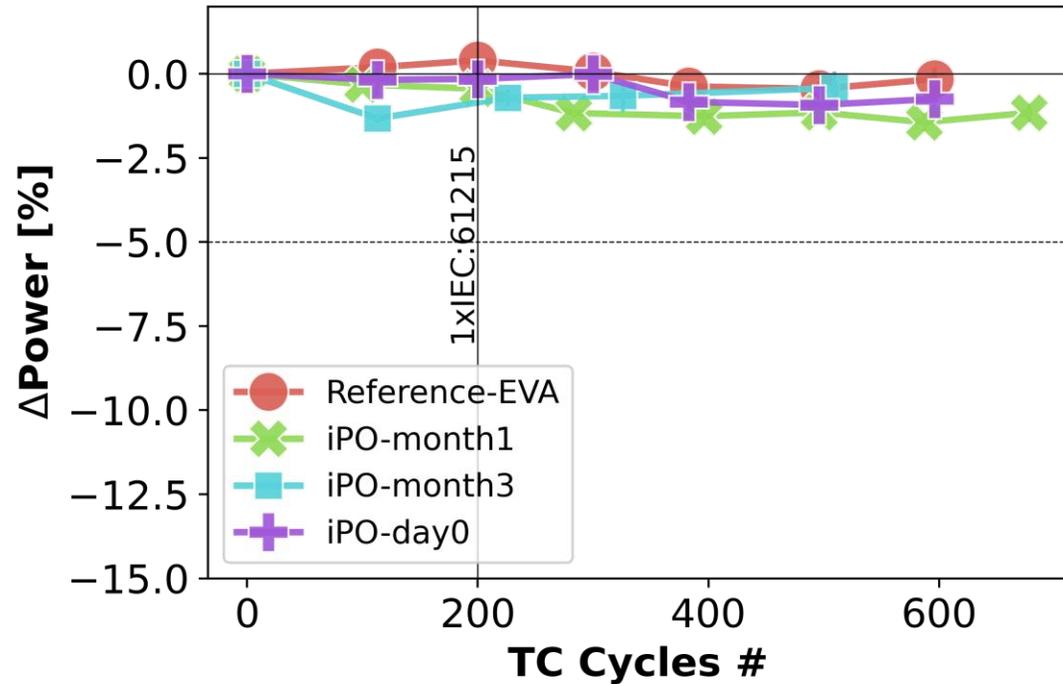
POE:

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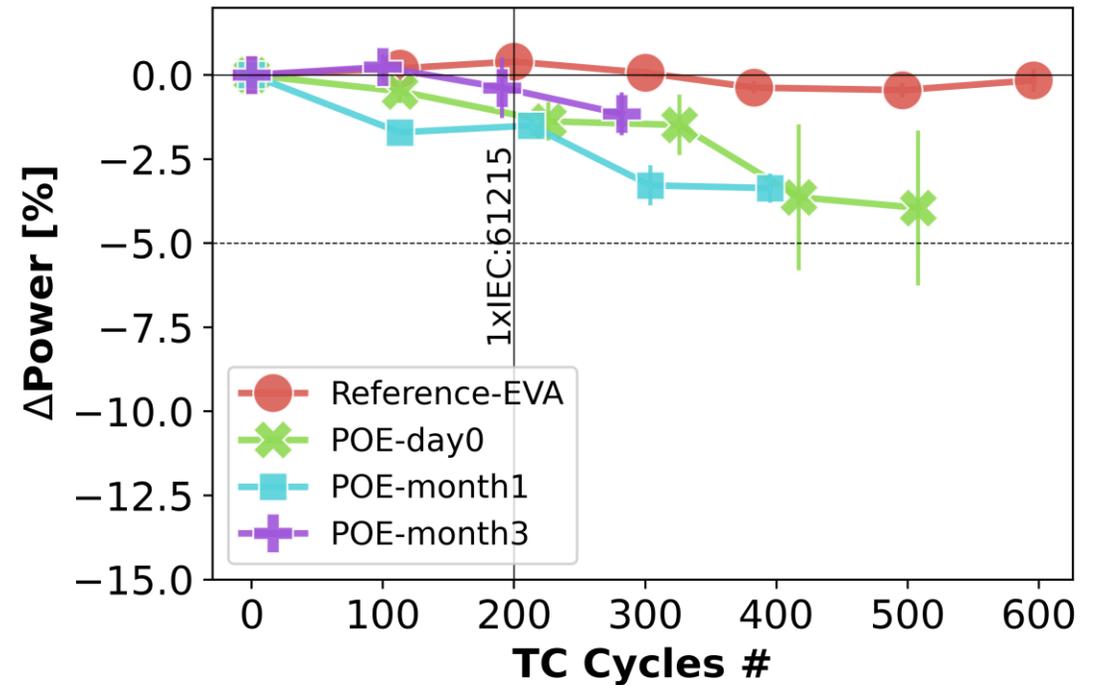


EL	Day0	Month1	Month3
iPO			
POE			

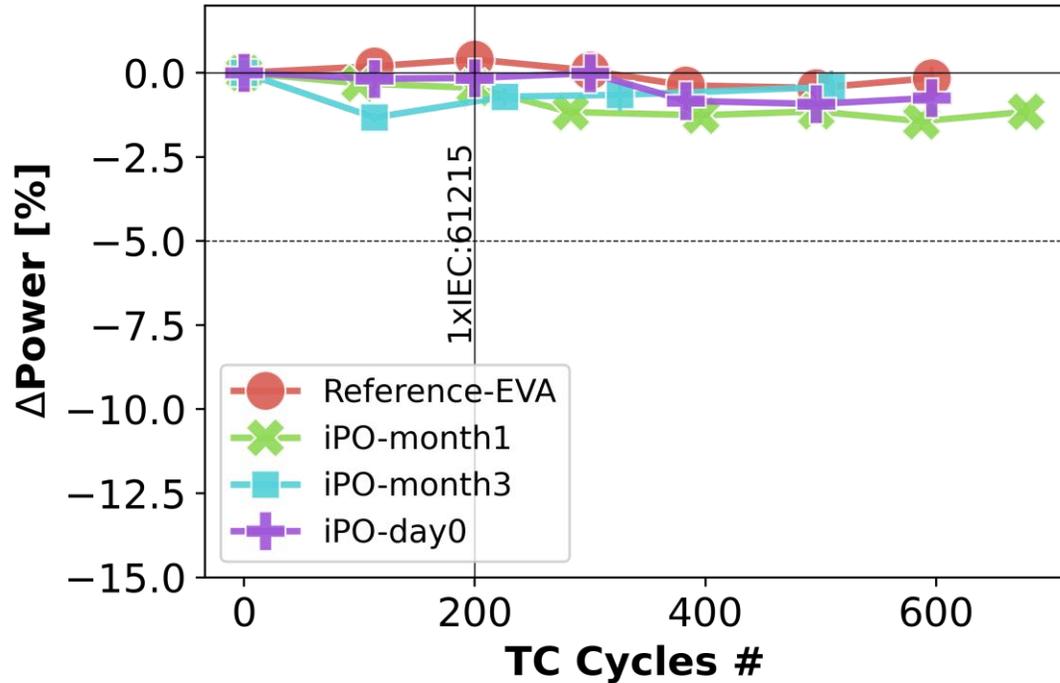
iPO: Modules stable in TC



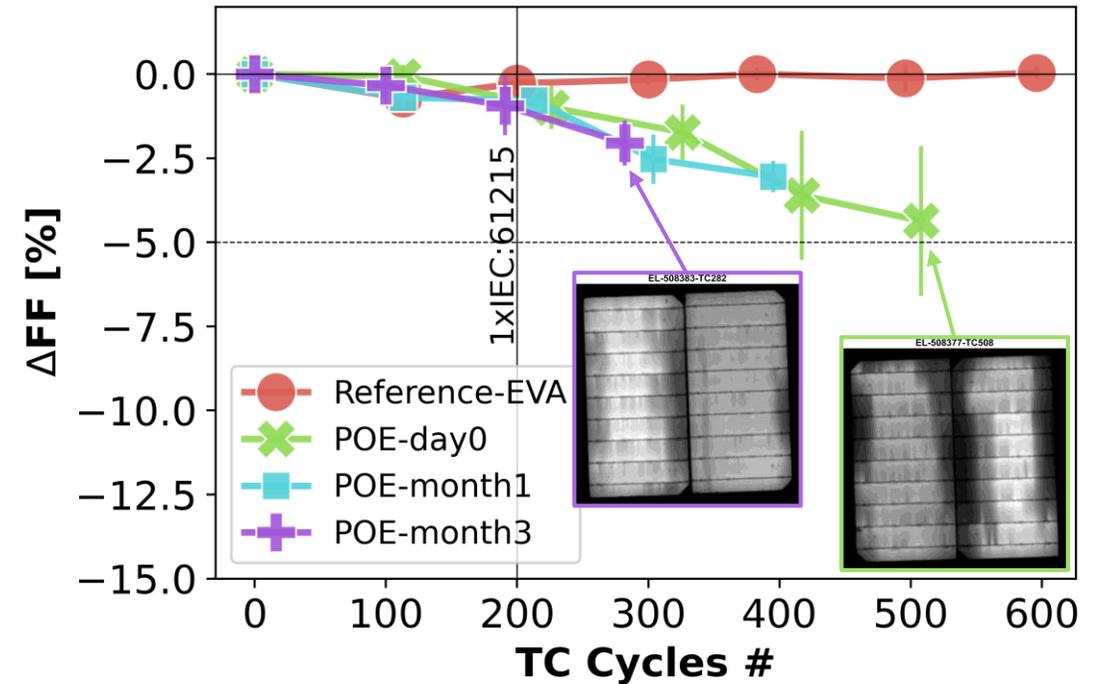
POE: losses in FF → interconnection losses



iPO: Modules stable in TC

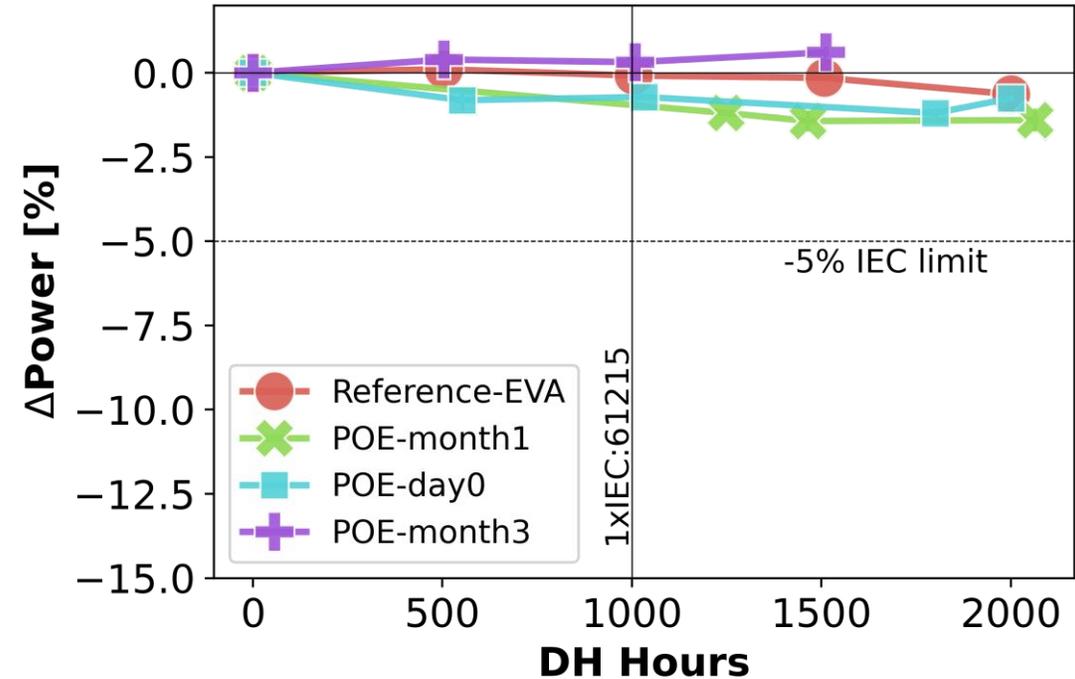
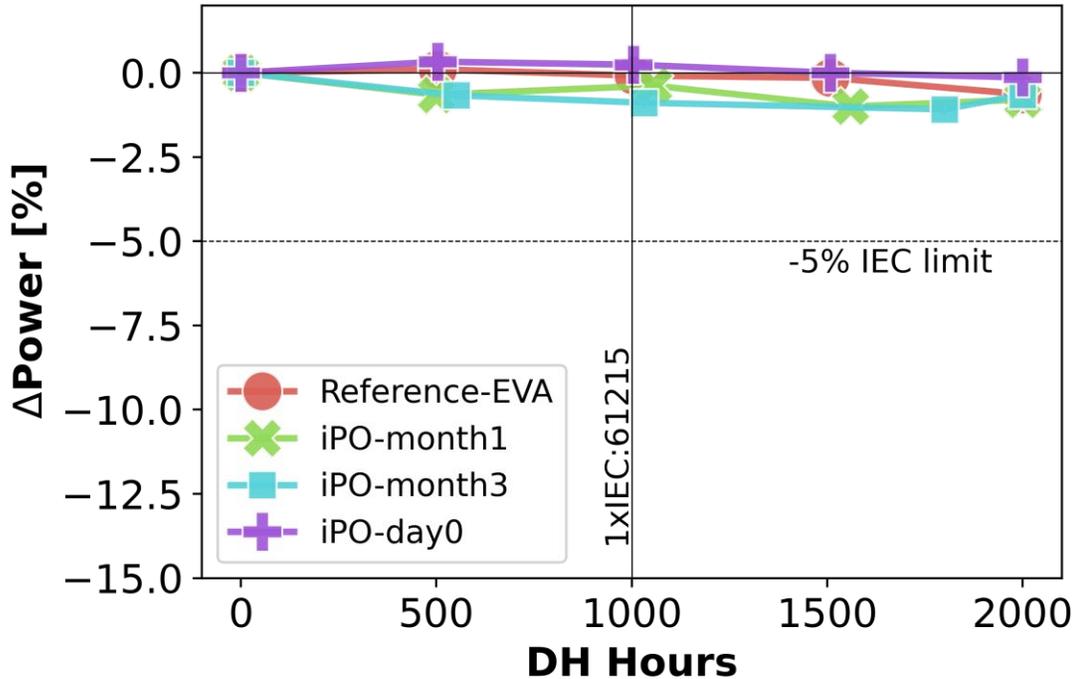


POE: losses in FF → interconnection losses



POE not adapted material or need of further process development

All modules <1% power loss but all of them are yellowing .. related to presence of EVA





CONCLUSIONS

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- **Feasibility & benefits:**
 - Prelaminates offer increased flexibility in PV module production
 - Early trials show promising results.
- **Technical findings:**
 - CSEM iPO interlayer is well-suited
 - Prelaminated stacks are easy to handle and store
 - Storage has no negative impact on module performance or reliability
- **Challenges:** Process and material optimization remain challenging
- **Outlook:** Focus on improved formulations (e.g., removing UV blockers), eliminating extra layers like EVA, refining processes, and testing with advanced cell technologies such as TOPCon and PK.



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