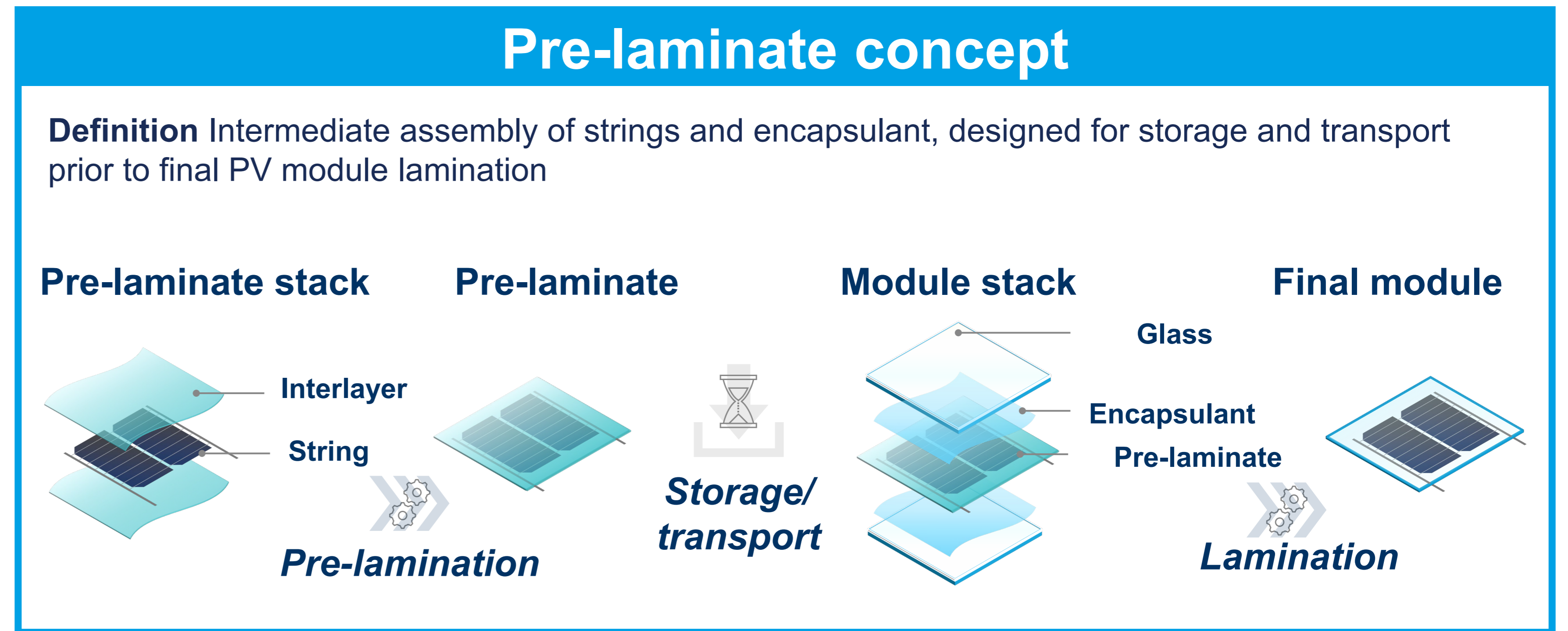
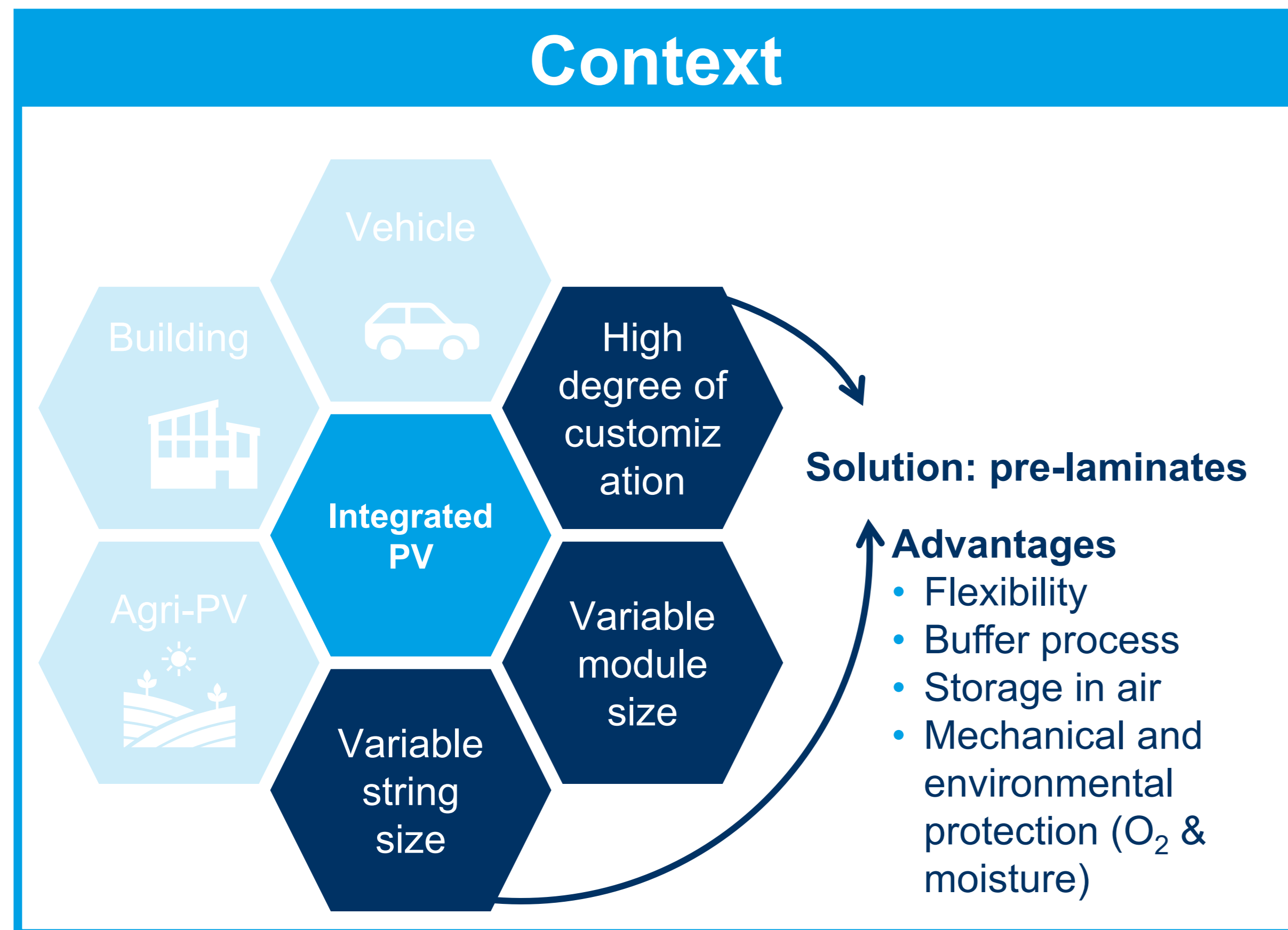


Increasing the flexibility and versatility of Integrated-Photovoltaics (iPV) manufacturing lines through the adoption of pre-laminated strings

Lison Marthey¹, Albin Servais¹, Hengyu Li¹, Matthieu Despeisse¹, Bénédicte Bonnet-Eymard¹, Christophe Ballif¹, Tonio Buonassisi¹, Alessandro Virtuani¹

¹Swiss Center for Electronics and Microtechnology (CSEM), CH-2002 Neuchâtel, Switzerland

This work introduces a pre-lamination concept to enhance flexibility and robustness in integrated-PV (iPV) manufacturing. Interconnected cell strings are encapsulated using a newly developed interlayer polyolefin (iPO) prior to final module lamination, creating mechanically stable pre-laminates that can be safely stored and transported. Mini-modules fabricated with PERC and TOPCon cells show performance and reliability comparable to, or better than, conventional modules. Storage of pre-laminated strings in air for several weeks has no measurable impact on electrical performance or stability under damp-heat and thermal-cycling tests. Pre-lamination also benefits moisture-sensitive cell architectures (such as perovskites and TOPCons) by providing additional humidity protection during storage and within the module stack. Finally, this approach decouples stringing and pre-lamination from final lamination, enabling greater manufacturing flexibility and new pathways for customized integrated-PV products.



CSEM Interlayer PO

CSEM interlayer polyolefin (iPO) :

- Formulated on purpose
- Good barrier properties
- High stiffness providing mechanical stability during storage
- Non sticky (easy stacking)
- 200µm thin
- Excellent compatibility with EVA

Material stability

Material stability within storage time up to 6 months:

- Adhesion > 100N/cm to cell & EVA
- Viscosity is increasing but can still be processed
- No visible changes in FTIR

✓ Can be processed after 6 months of storage

Scale up evaluation

Concept scale up currently under evaluation

Challenges:

- Strings interconnection post pre-lamination
- iPO shrinkage/ overflow during pre-lamination
- Occasional cell cracking

Modules performance and reliability

Method

- iPO pre-laminates of 2-cell strings stored in air from 0 to 3 months before implementation into mini-modules
- Module evaluation: initial performance and reliability (damp heat & thermal cycling)

Modules initial performance

- UV through iPO : no measured initial performance loss compared to reference
- Storage time does not affect module initial performance

Reliability

Damp Heat

Thermal cycling

✓ UV through iPO: no measured performance losses compared to reference
 ✓ Pre-laminate storage has no negative impact on module performance or reliability (tested up to 3 months)
 ✓ Using pre-laminates with TOPCons improve module reliability under TC & DH

Conclusions & next steps

Conclusions

- Pre-laminate concept enables flexible, robust iPV manufacturing.
- No final module performance loss up to 3-6 months storage.
- Comparable or improved reliability (DH & TC), especially with TOPCon.
- Mechanical stability allows safe handling, transport, and customization.

Next steps:

- Additional reliability testing including mechanical load, UV, PID etc..
- Scale-up ongoing; focus on bussing, iPO shrinkage, and occasional cell cracks
- Evaluate the technology on perovskite-based solar cells

