Testing of lightweight PV modules based on glass-fiber reinforcement

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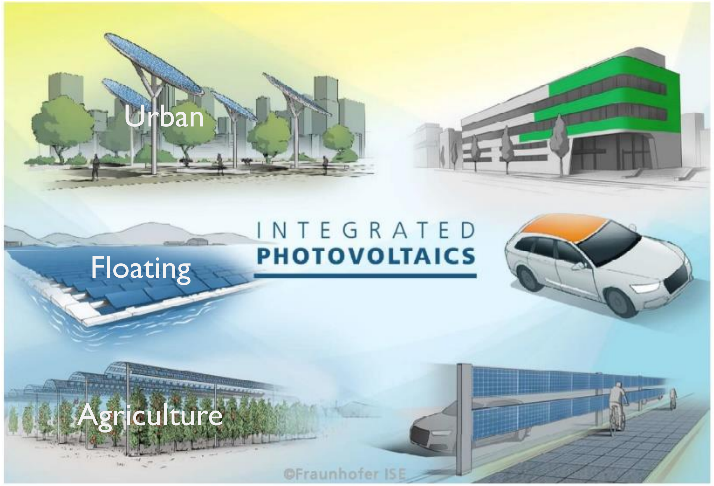
Background rationale

Away from 1 size fits all and PV-centric modules

➔ PV everywhere: application-centric integration of PV functionality in existing surfaces



Building

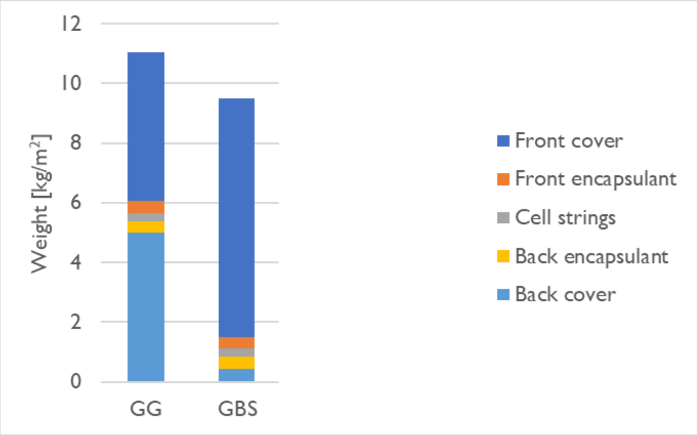
Vehicle

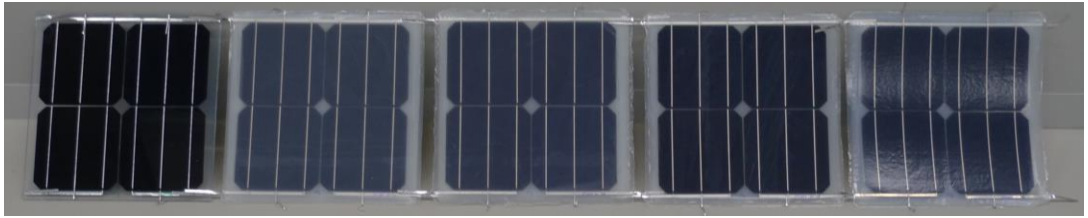
Infrastructure

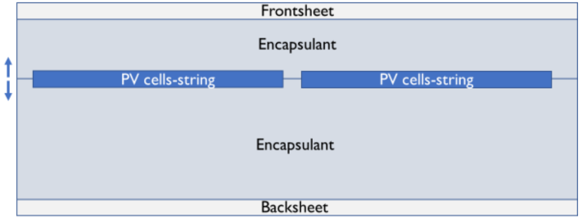
Source: Fraunhofer ISE

- Lightweight
- Curvature
- Customization
- Odd forms/shapes
- Safety, aesthetics, (in)visibility, ...

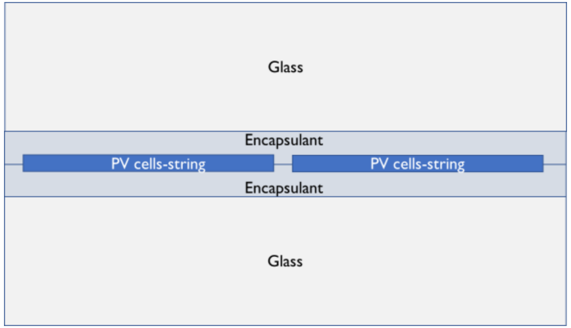
Focus on light-weight

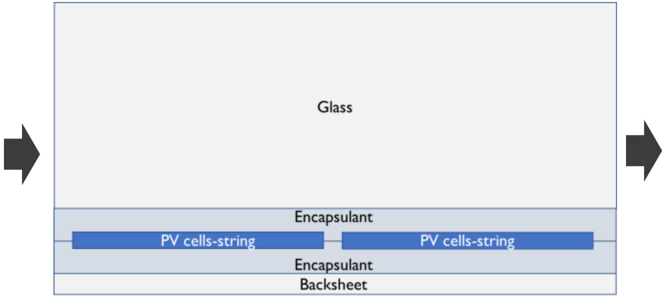


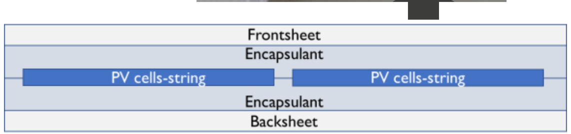




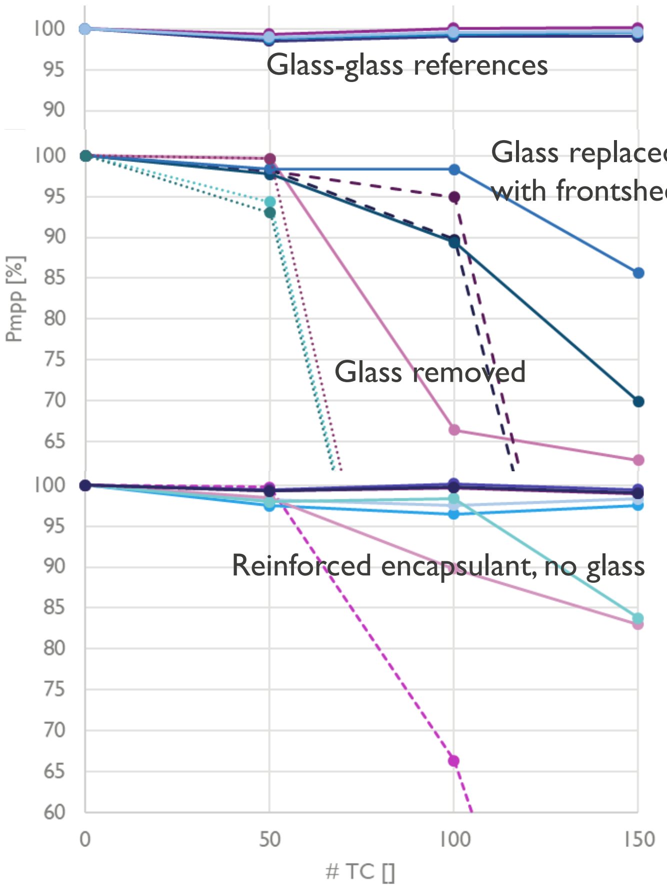
→ **Positioning strings inside thicker encapsulant**

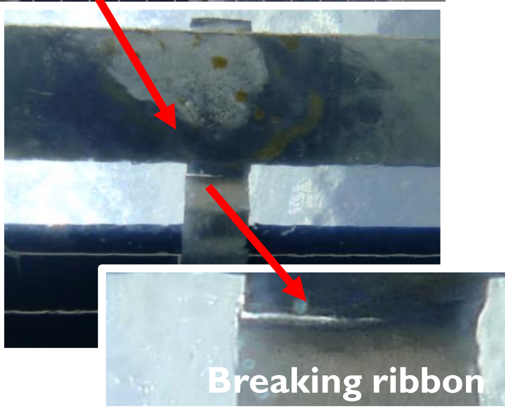


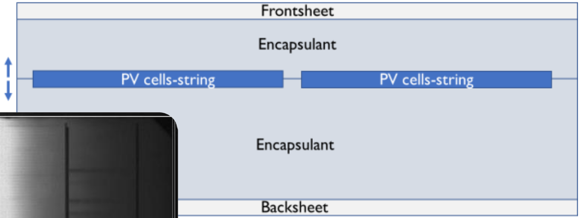




Evaluating the absence of outer glass

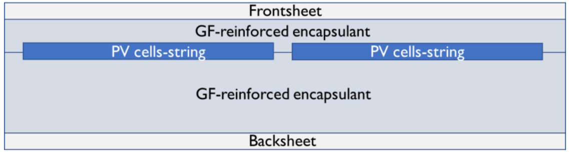




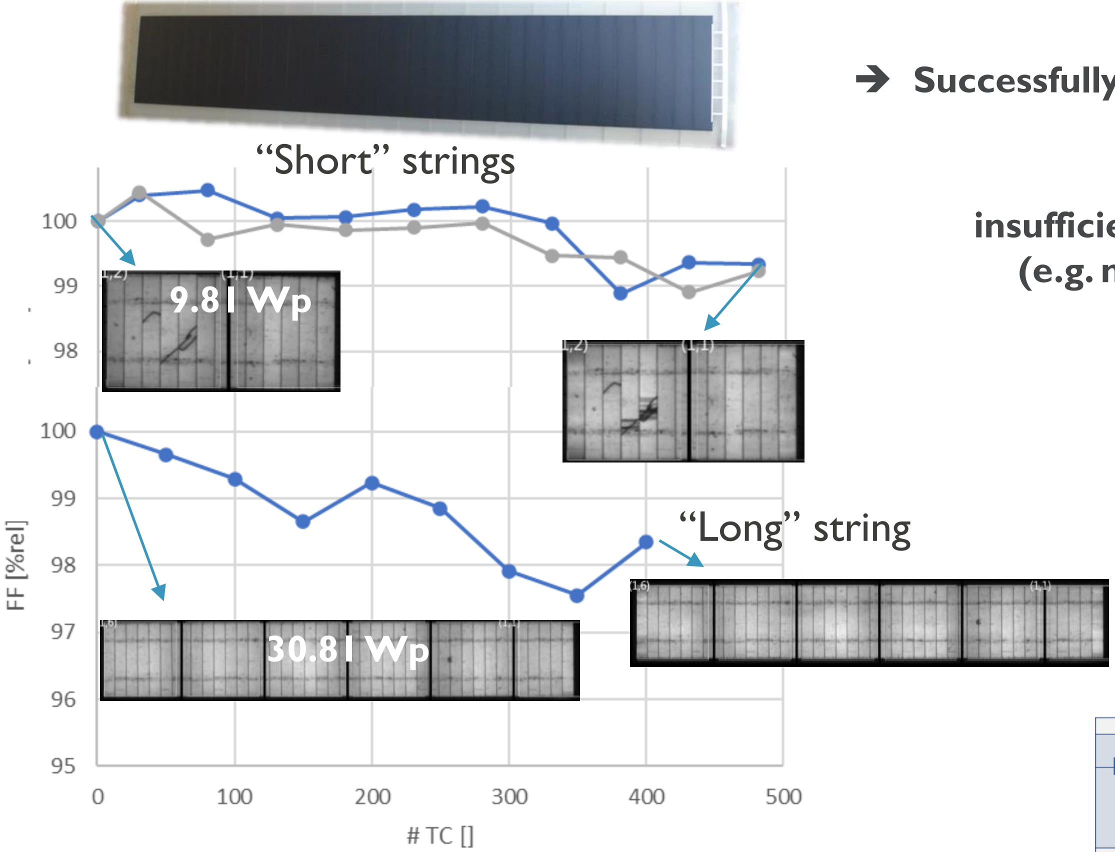


➔ **Ribbon breakage due to fatigue (CTE-induced deformation)**

➔ **Significant improvement by integrating glass fibre**

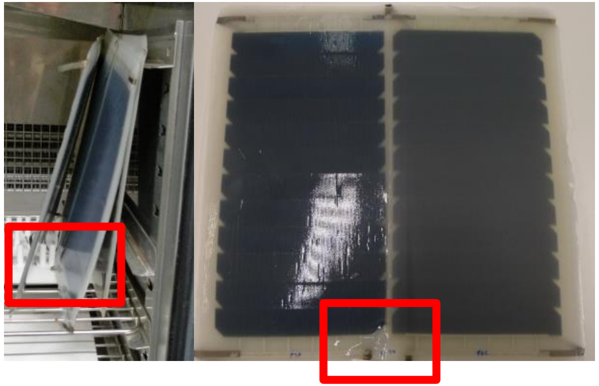


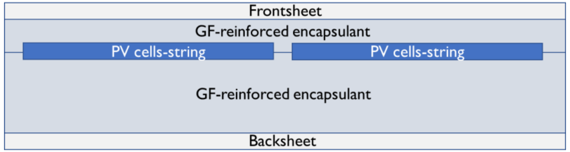
Evaluating the absence of outer glass ➔ GFRE



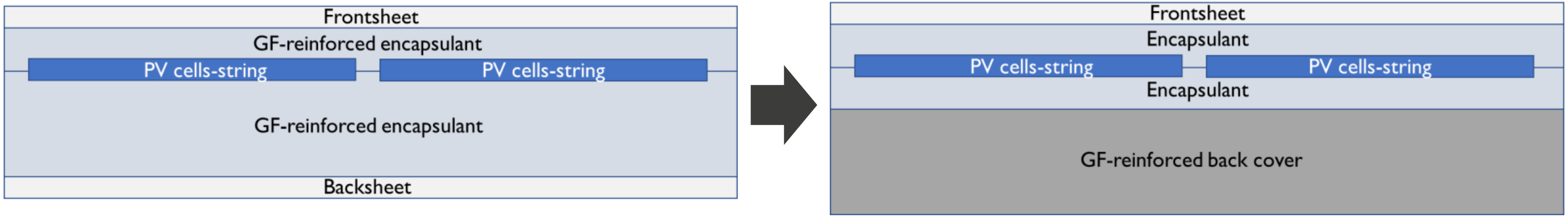
➔ **Successfully passed thermal cycling of shingled strings**

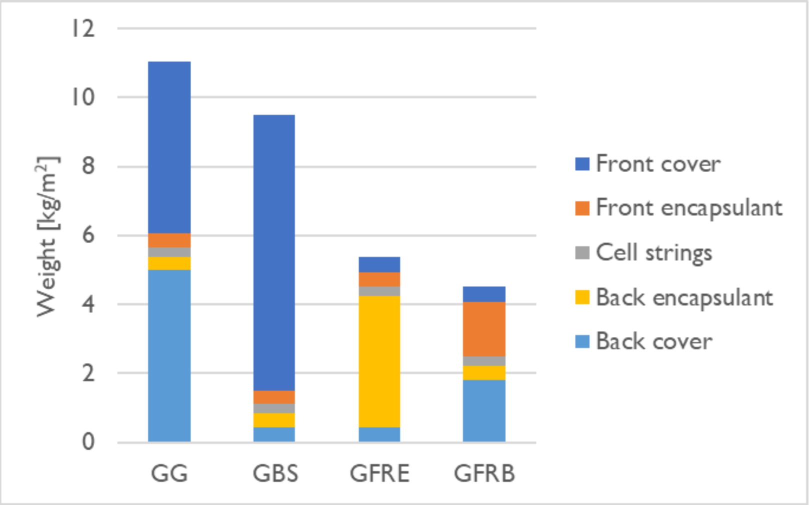
BUT:
insufficient stability at higher temperatures
(e.g. not self-supporting in damp heat)



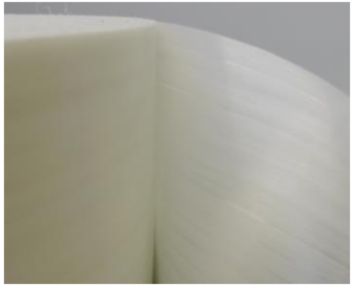


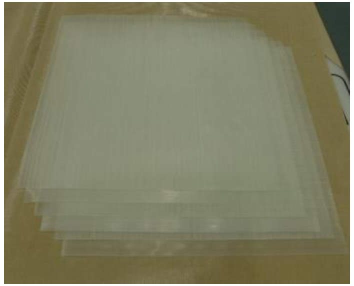
Fibres into the (higher melting) back cover to address stability: GFRB



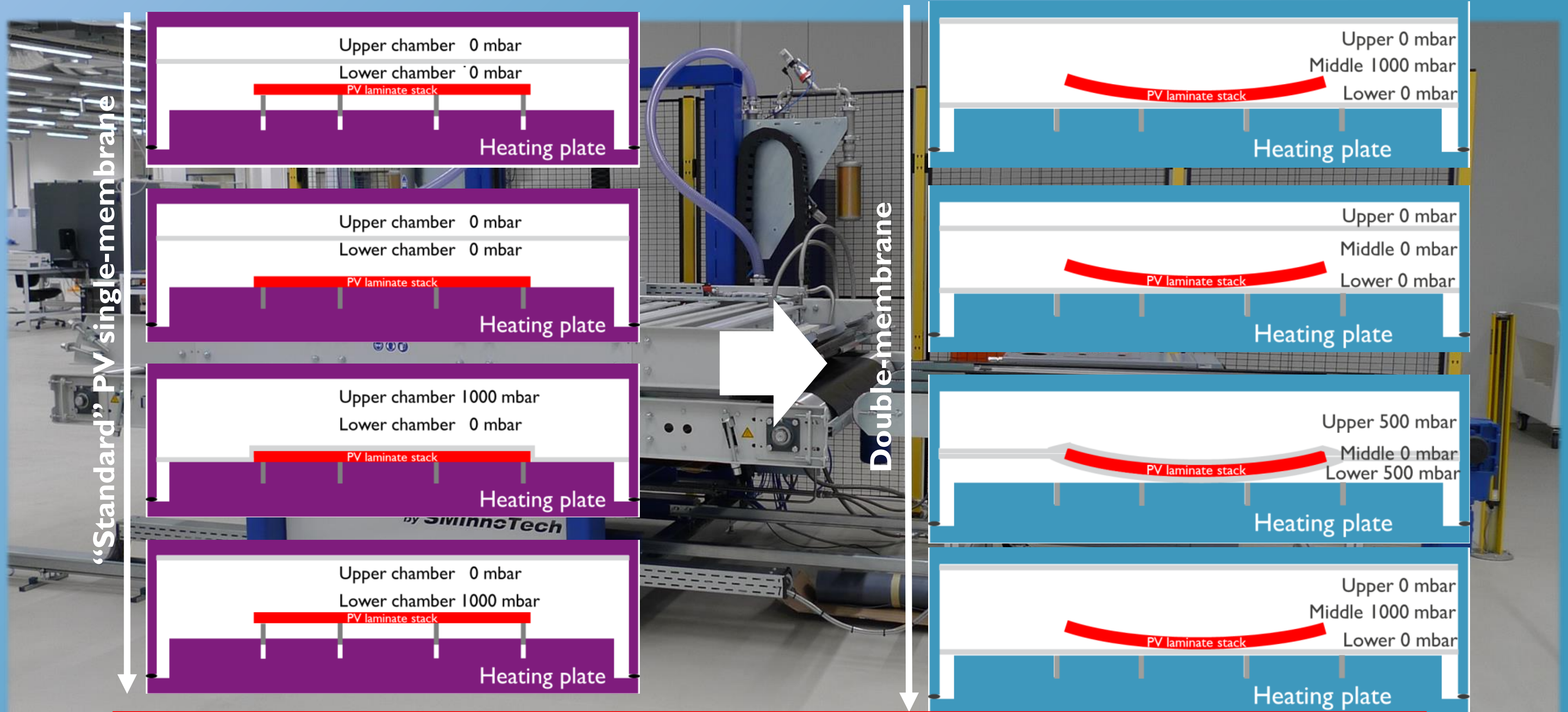


BÜFA



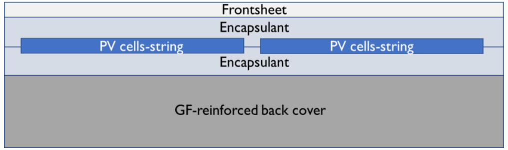


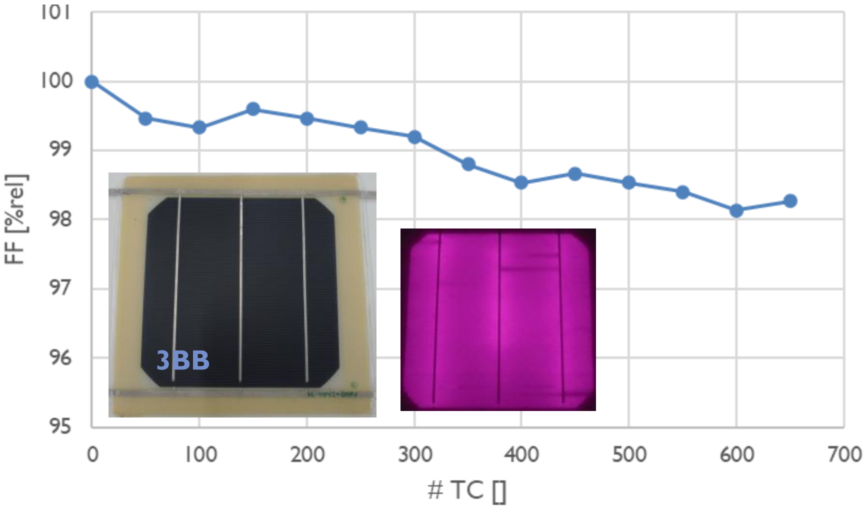
Intermezzo on lamination technology

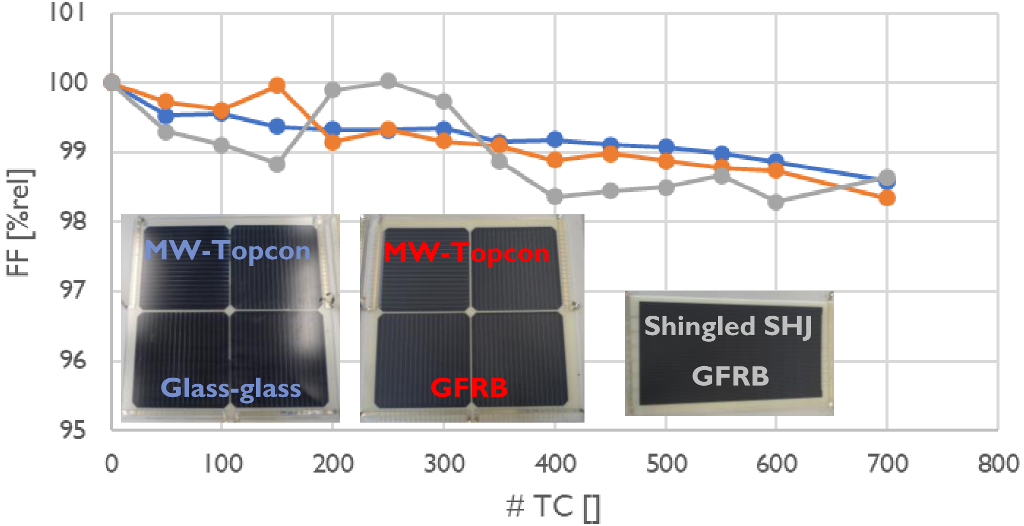


Further out from PV (~30 min, 150 °C, 0.8 bar)
but closer to glazing industry vacuum bagging and autoclaving (>2h, ~130 °C, >5 bar)

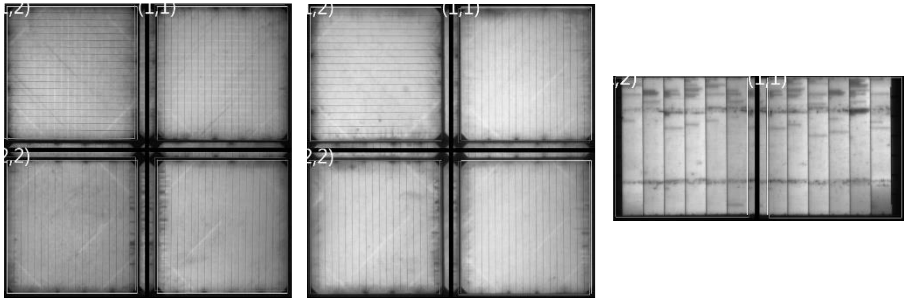
GFRB reliability: thermal cycling (TC: -40 <> 85 ° C)



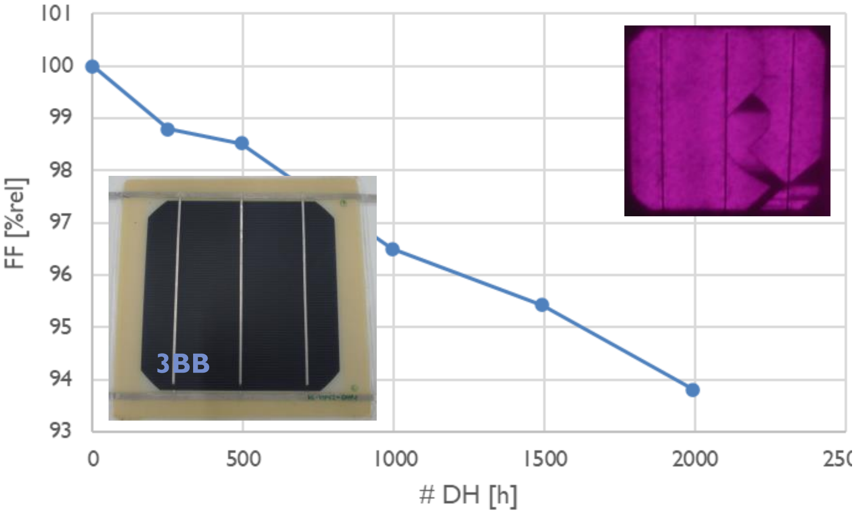


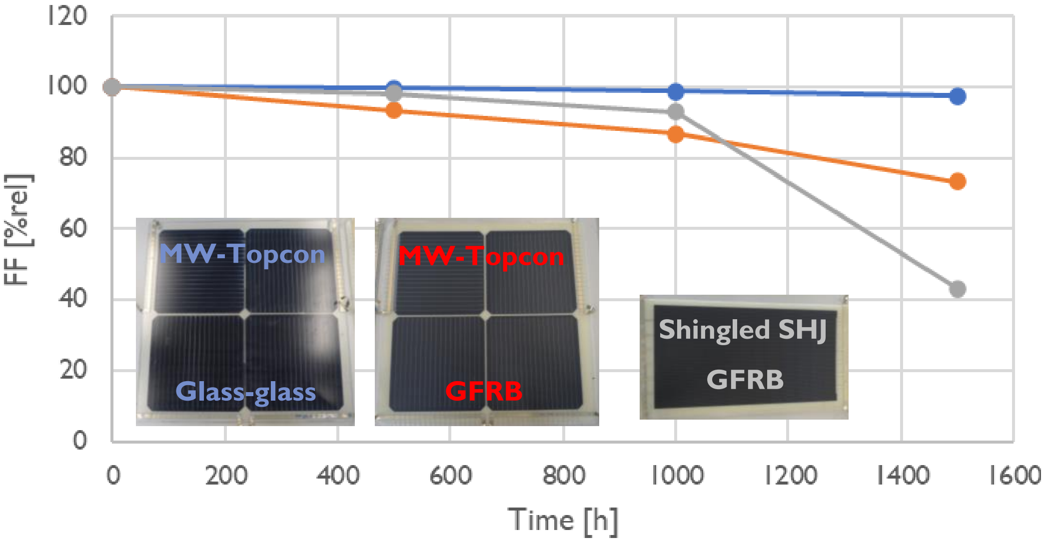


➔ **Minimodules pass thermal cycling**

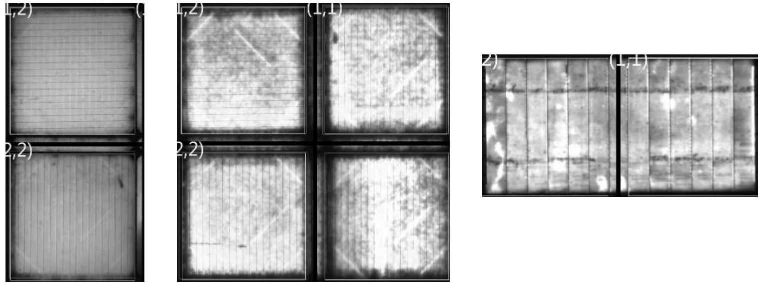


GFRB reliability: damp heat (DH: 85 ° C / 85%RH)





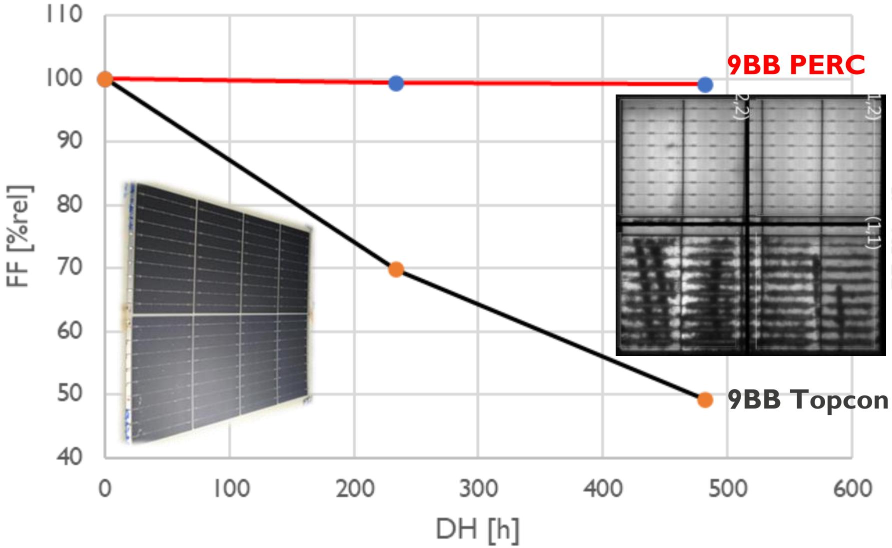
➔ **Minimodules are susceptible to damp heat (though not all to the same extent)**

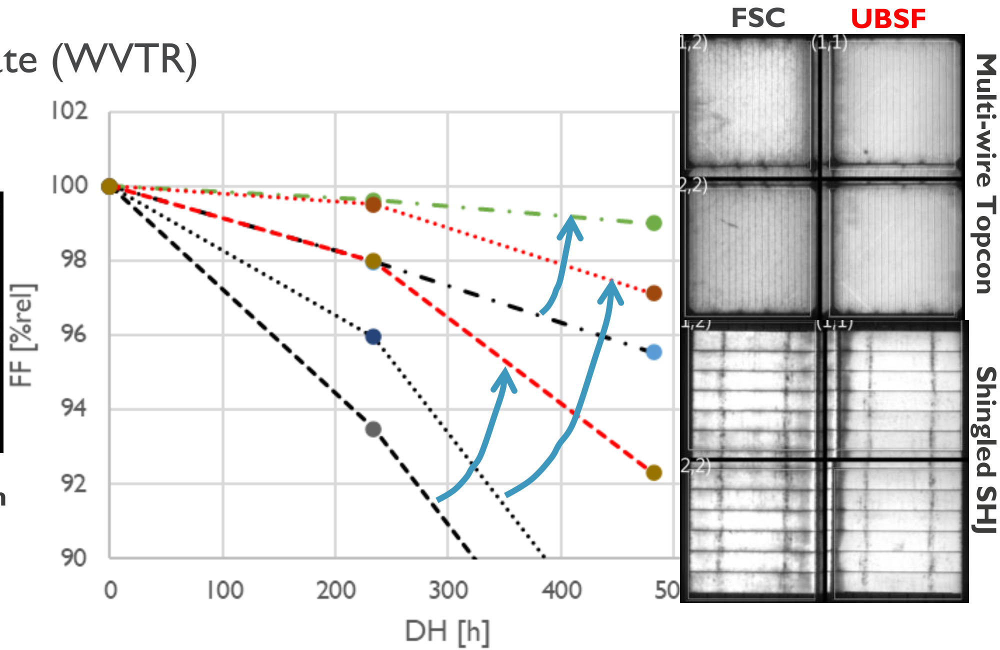


GFRB reliability: damp heat (DH: 85 ° C / 85%RH)

Damp heat resilience can be tuned

- Sensitivity of cell technology
- Encapsulation water vapour transmission rate (WVTR)

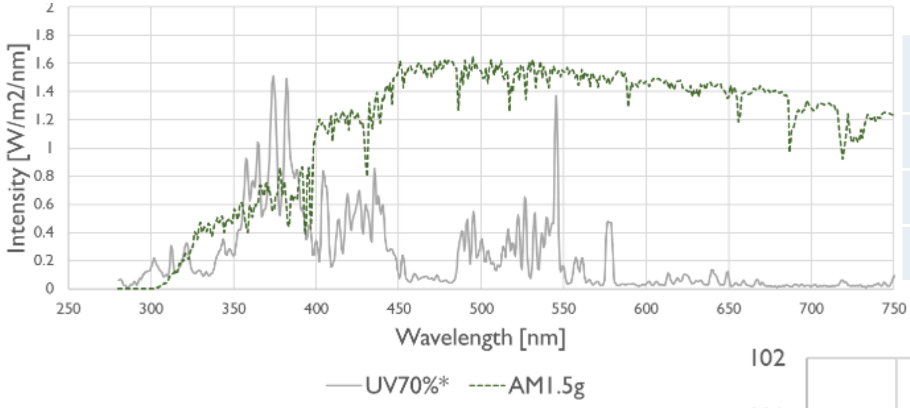




➔Topcon (as SHJ) performs much worse than PERC in this bill-of-materials (BOM)

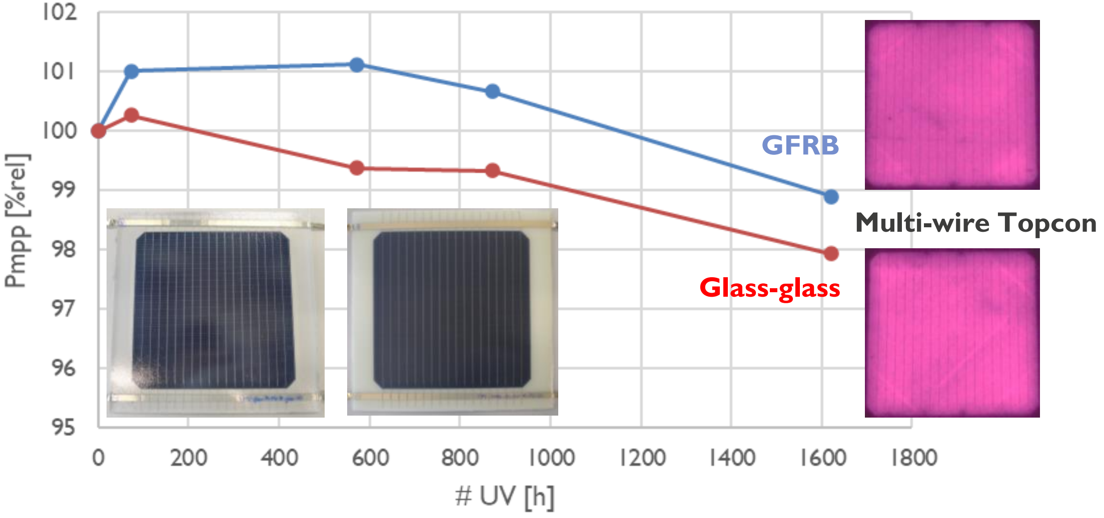
➔Including a low-WVTR barrier (UBSF vs FSC) reduces DH degradation (for both TC and SHJ)

GFRB reliability: UV exposure (@ 60°C)



Exposure intensity [W/m2]	AM1.5g	UV70%*
280-320 nm	1.1	4.5
280-385 nm	24.8	38.9
280-400 nm	32.9	47.0

→ **No degradation so far**



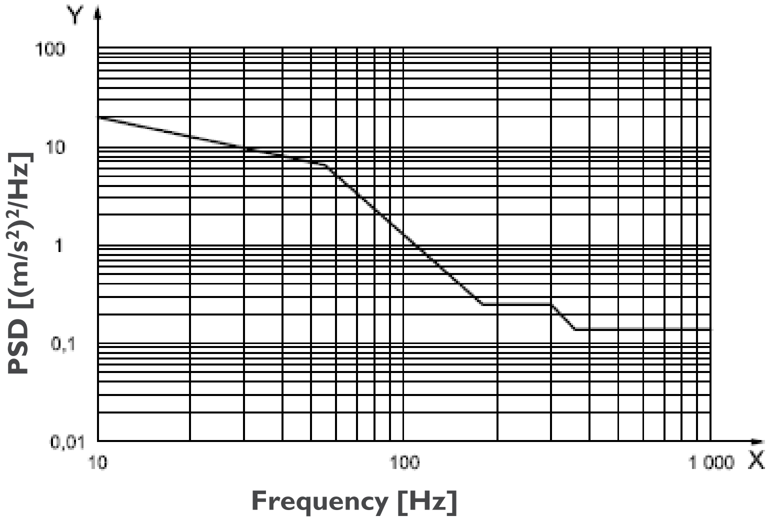
Automotive testing

Test conditions

ISO 16750

Vibrations

- Test IV: Passenger car, sprung masses (vehicle body)
- Specific Power Spectral Density (PSD)
- 8h testing
- Requirement: no breakage



Mechanical shock (devices on rigid points)

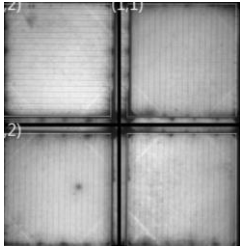
- 10 shocks of 6 ms
- Gradually increasing accelerations 50 → 500 m/s^2

Table 19 — Mechanical shock test for components on rigid points on the body and on the frame — Parameters

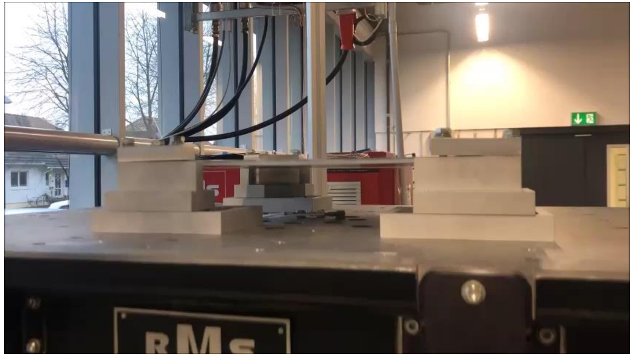
Operating mode of DUT (see ISO 16750-1)	3.2
Pulse shape	half-sinusoidal
Acceleration	500 m/s^2
Duration	6 ms
Temperature	Room temperature
Number of shocks	10 per test direction

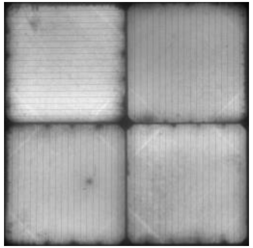
Automotive testing

Multi-wire Topcon

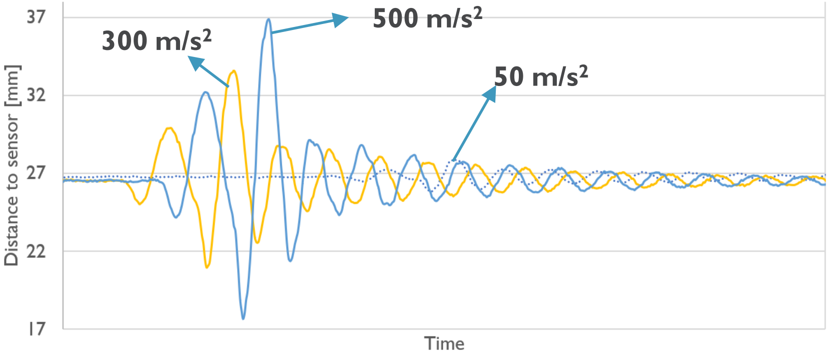


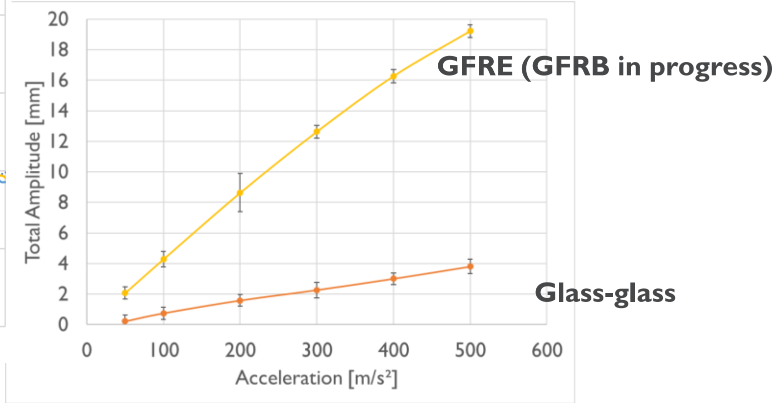
Shingled SHJ





- ➔ **No significant degradation so far for vibration or shocks**
- ➔ **Deflection linear with acceleration**



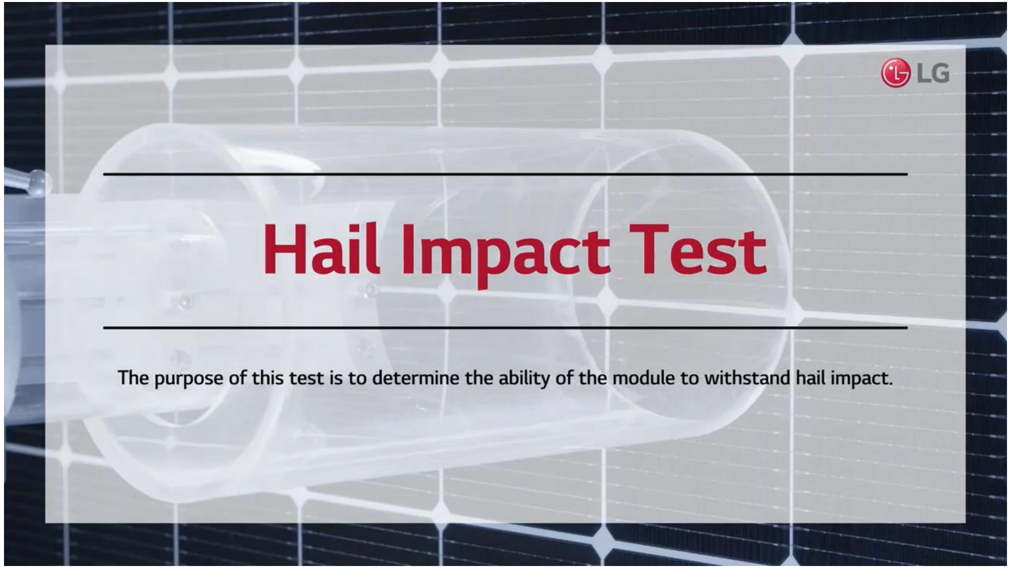


Hail impact testing
Test conditions

IEC 61215 -2005-04

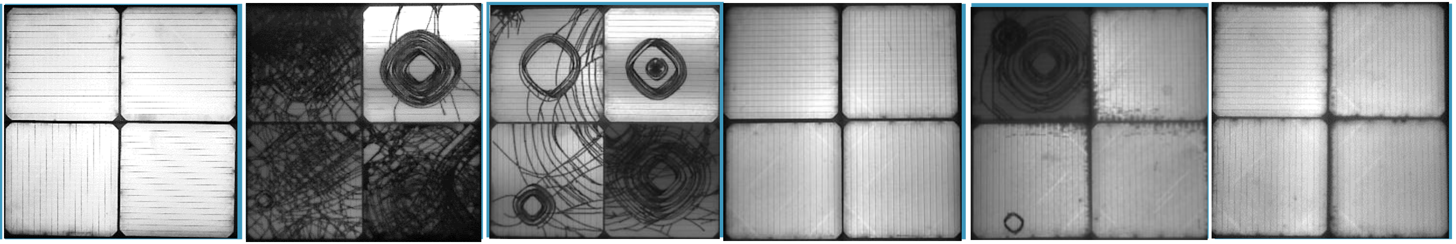
Hail impact

- 25 mm diameter ice ball at 23 m/s
- Requirements:
  - no visual defects
  - <5% power loss



Source: LG

Hail impact testing

EL inspection after test						
Front cover	Glass	Frontsheet	Frontsheet	Frontsheet	Frontsheet	Frontsheet
Front encapsulant	PO	PO	4xPO	PO	4xPO	4xPO
Strings	Multi-wire	Multi-wire	Multi-wire	Multi-wire	Multi-wire	MW
Back encapsulant	PO	PO	PO	PO	PO-GF	PO
Back cover	Glass	GFRB	GFRB	glass	GFRB	Thick GFRB

- ➔ **Glass-glass survives**
- ➔ **Slightly reduced damage with thicker front PO**
- ➔ **Glass only at the backside is sufficiently stiff**
- ➔ **Slight improvements with reinforced rear encapsulant (GF)**
- ➔ **Stiffening the backside improves the resilience to hail impact**

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Questions???

Thank you

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  - in particular AMAT and CEA-INES for providing cells and strings
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- BÜFA for GFRB material and discussions
- Technical lab support: Luc, Geert, Reinoud
- The organizers for the invitation

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