Reduction of silver usage in ECA based interconnection

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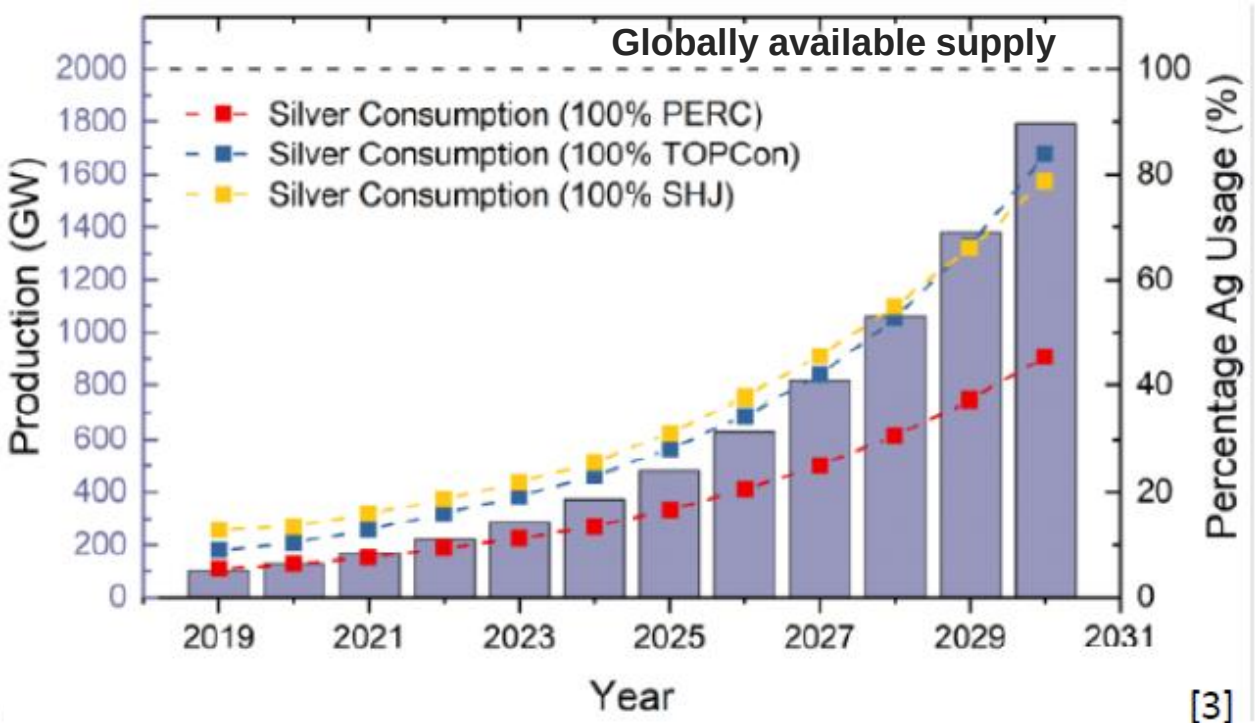
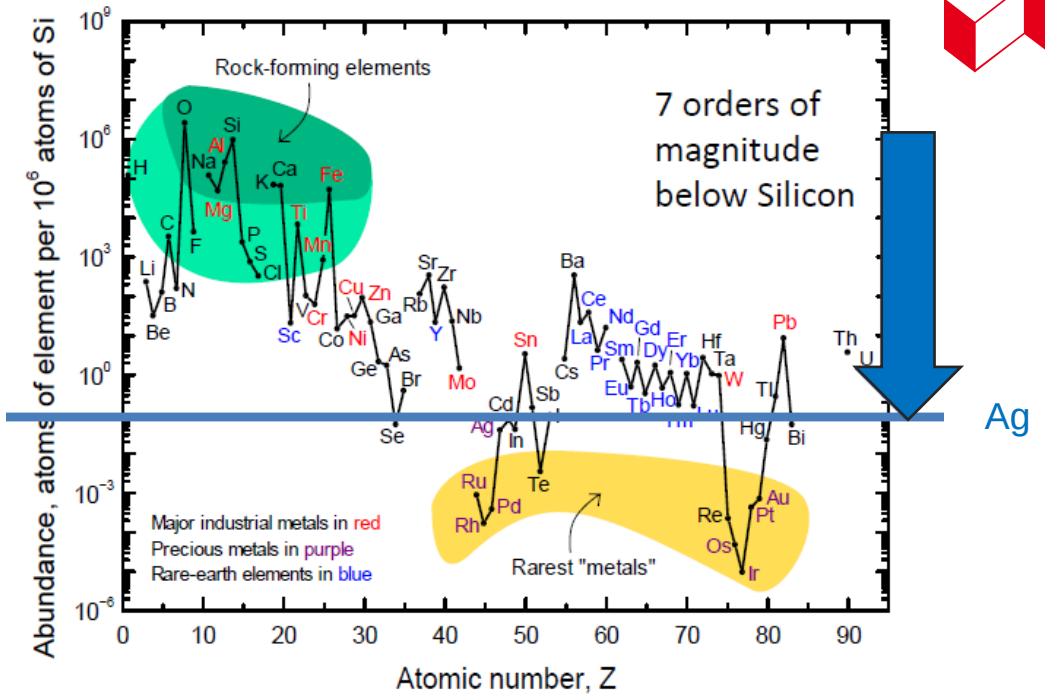
Challenges of TW scale PV manufacturing



https://science.sciencemag.org/content/364/6443/836.full
Solar Power Europe , Global PV market Forecast, 2022, B. Hallam et al. 2022



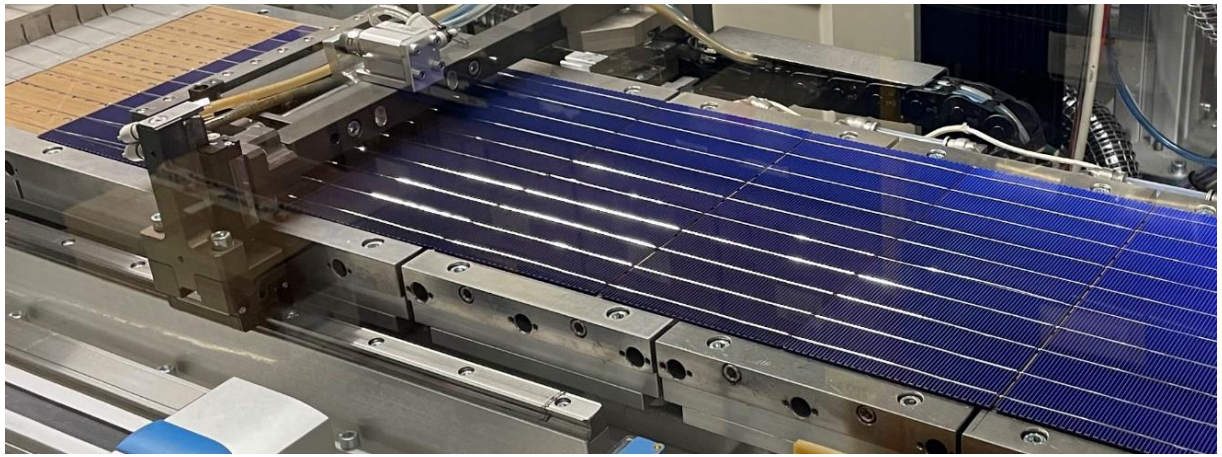
Abundance of elements in the Earth's upper crust (G. Haxel 2018)

- Silver availability is one of the most alarming concerns for the expansion of the PV industry at the TWp scale
- Currently the PV industry is using more than 15 % globally available Ag
- Current projection indicate that latest cell technologies of TOPCON and SHJ technologies would require the entire supply of Ag **-> Ag reduction is a must !**

Gluing with ECAs for HJT and TANDEMS

Electrically Conductive Adhesive (ECA)

- Conductive particles (approx 40-70 w% Ag)
- Epoxy or Acrylate Matrix



- Reliability proven process
- Lead and Bismuth free
- Low T process < 200°C
- Copper based ECA available now

ECA Mondragon TABBER STRINGER

- Multi-ribbon handling up to 20 wires & ribbons
- G12 cells compatible @ INES
- Thin cell handling down to 110 µm
- Independent printing of the 2 cell sides
- Provide developed curing profiles
- Gapless and Paving compatible

MONDRAGON ASSEMBLY

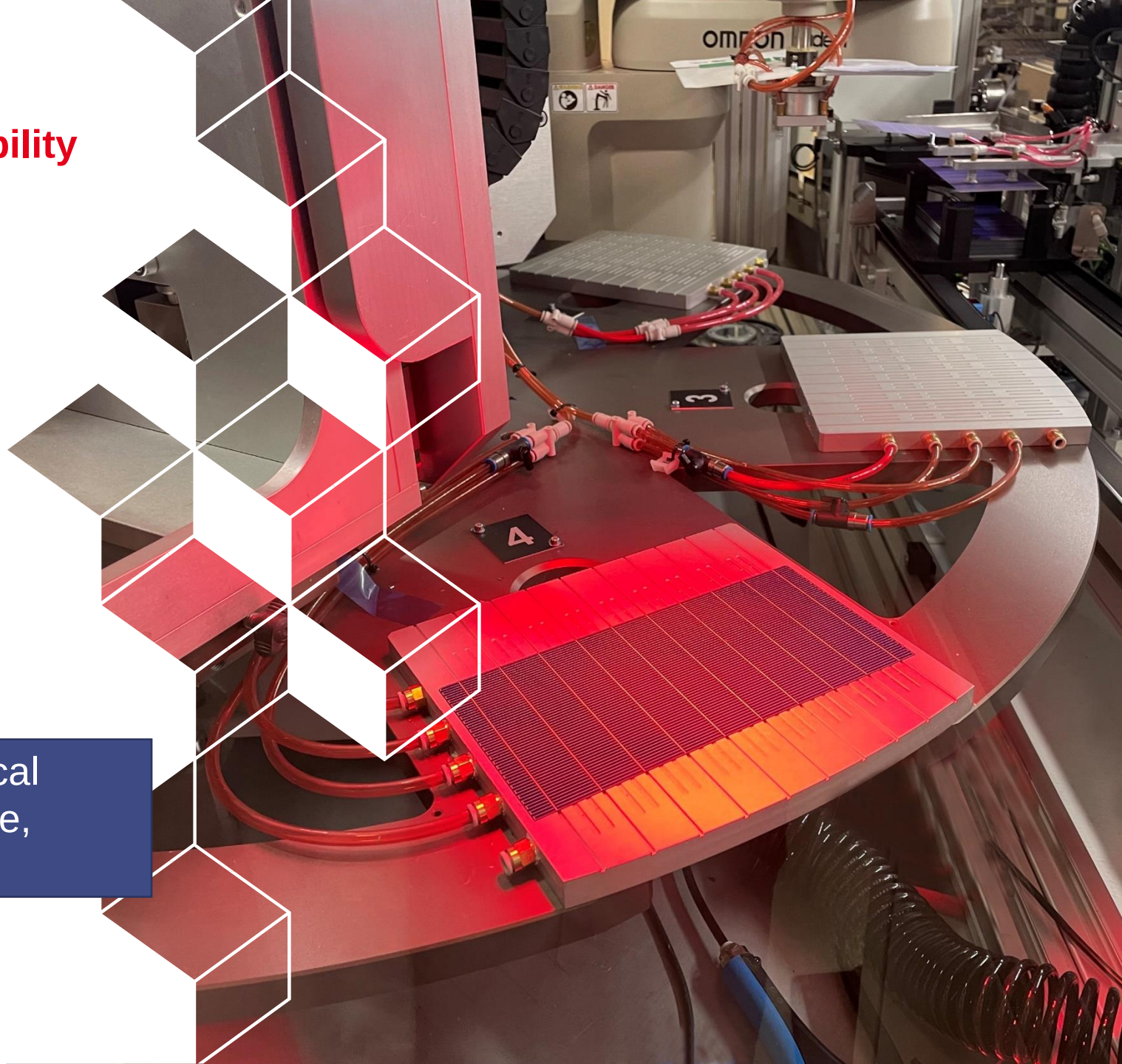
Duality of
increasing performance & reliability
and
reducing Ag consumption

Ag weigth
Cost

$$\frac{mg}{Wp}$$

Performance

Finding a balance between critical material usage and performance, while maintaining reliability



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Experimental workflow

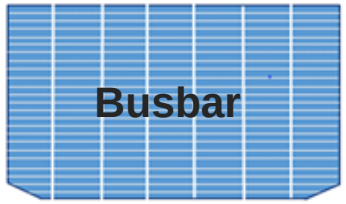
SHJ Cells
INES

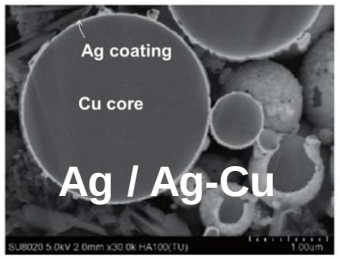
→ Stringing

→ Mini-modules

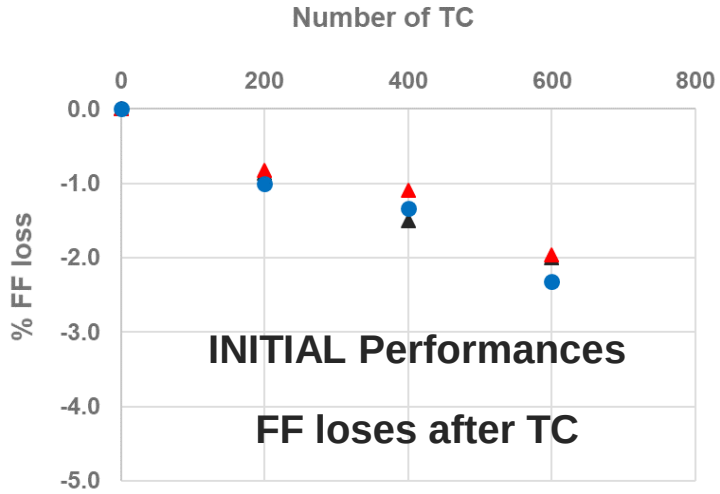
→ Thermal Cycling
-40/+85°C

→ 1 SUN IV Curve
EL





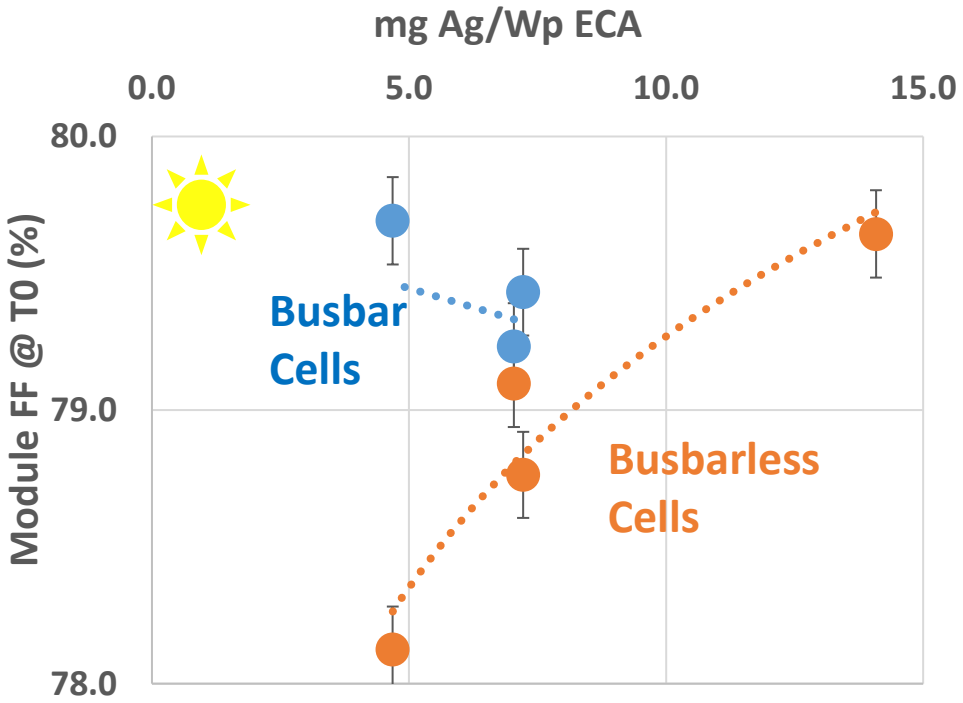
- *Variation of line width*
- *Variation of line thickness*
- *Different ECA formulations with reduced Ag*



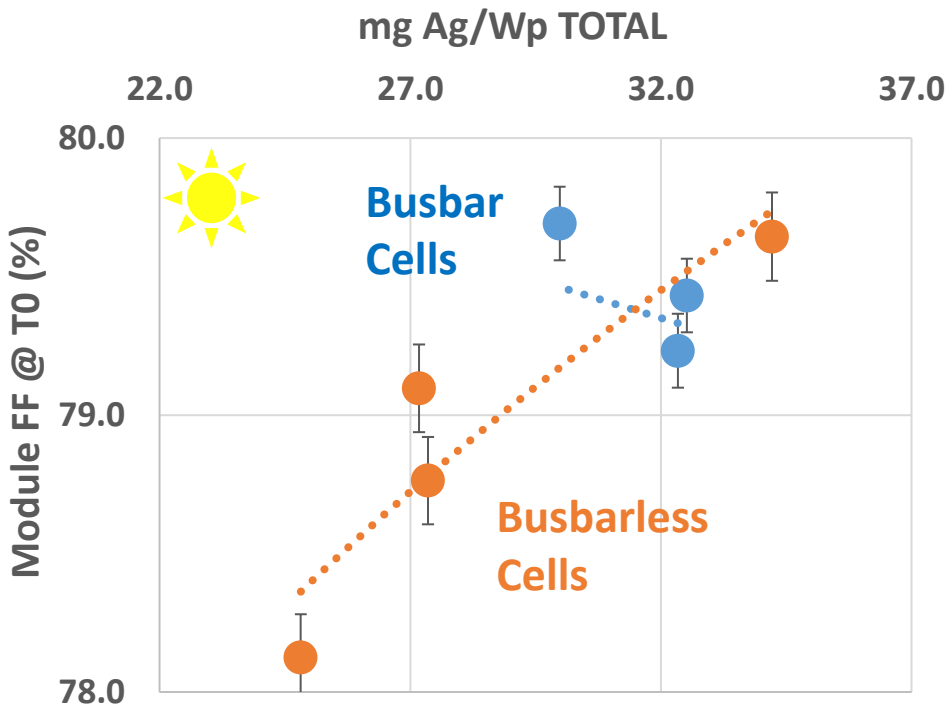
Influence of reduction of Ag Weight on performances & reliability

INITIAL Performances (T0)

- **FF according to the Amount of deposited ECA**



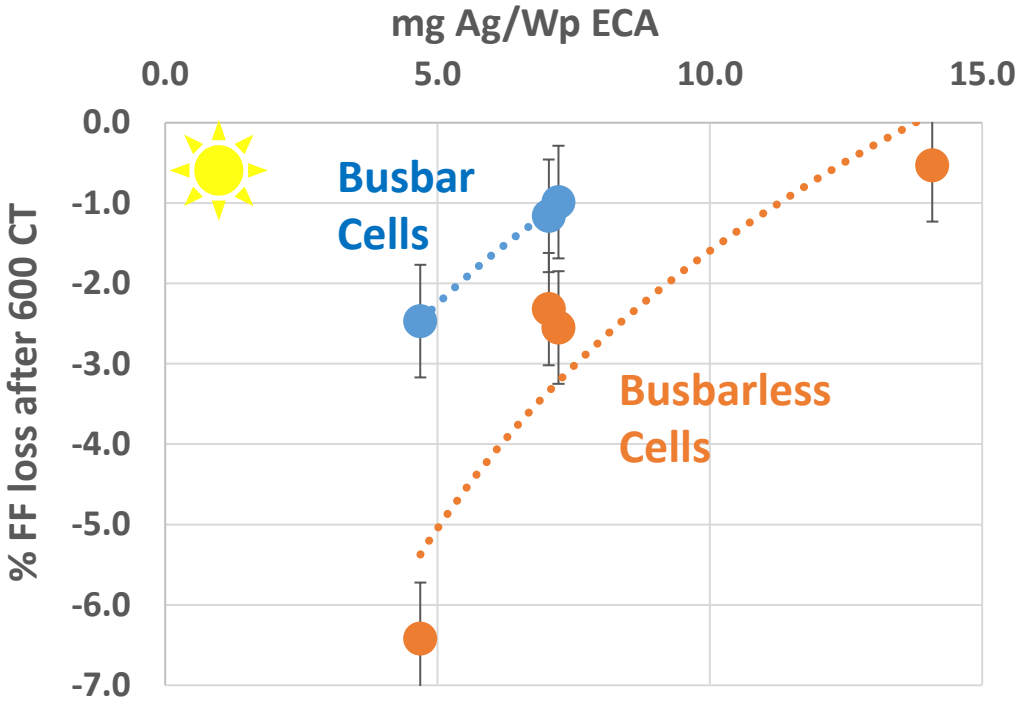
- **FF according to the total Ag weight /Wp (Total Ag : ECA + Ribbon + Cells)**



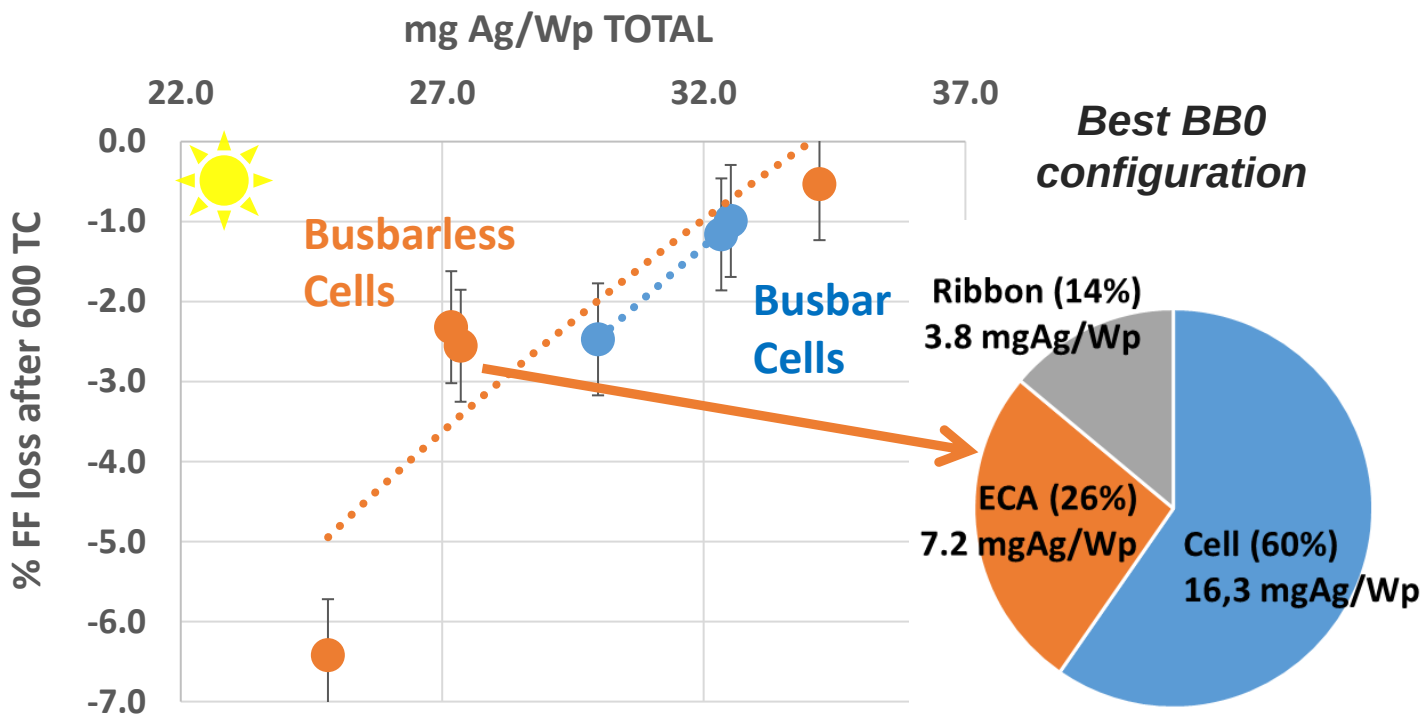
- **Busbar cell**: Initial performance independent of the amount of ECA
- **Busbarless configuration:** Initial performance is closely related to the amount of ECA
- **Good initial performances around 27 mg/Wp Ag total consumption**

Fill Factor losses after 600 TC

- FF loss according to the amount of deposited ECA

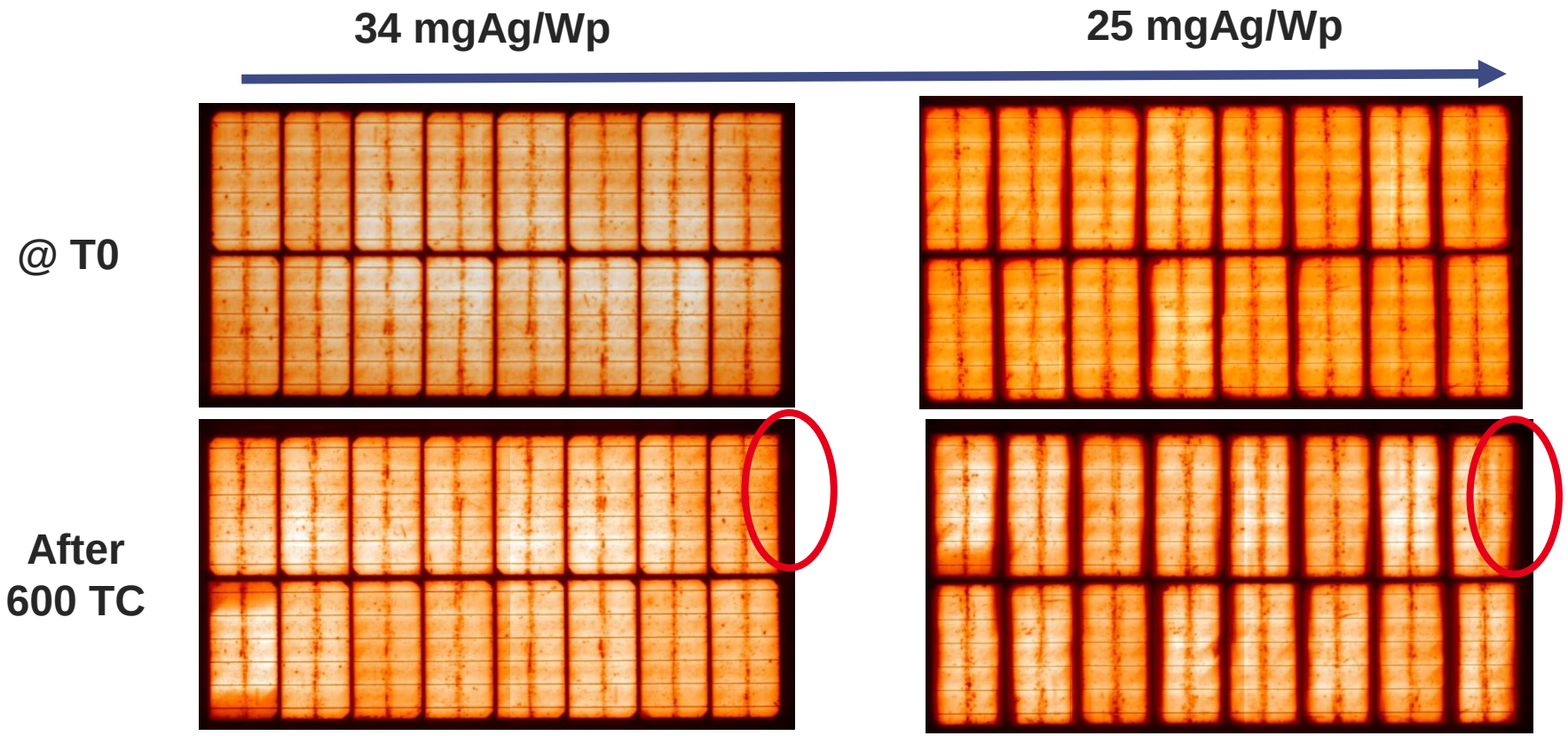


- FF loss according to the total Ag weight /Wp (Total Ag : ECA + Ribbon + Cells)



- Decrease of power mainly due to FF
- In the both configurations, the FF losses are closely related to the amount of deposited ECA
- Same tendencies as after 200 & 400 TC
- **Less than 2.5 % degradation after 600 TC with 27 mgAg/W in the module**

EL characterization : Busbarless Cells

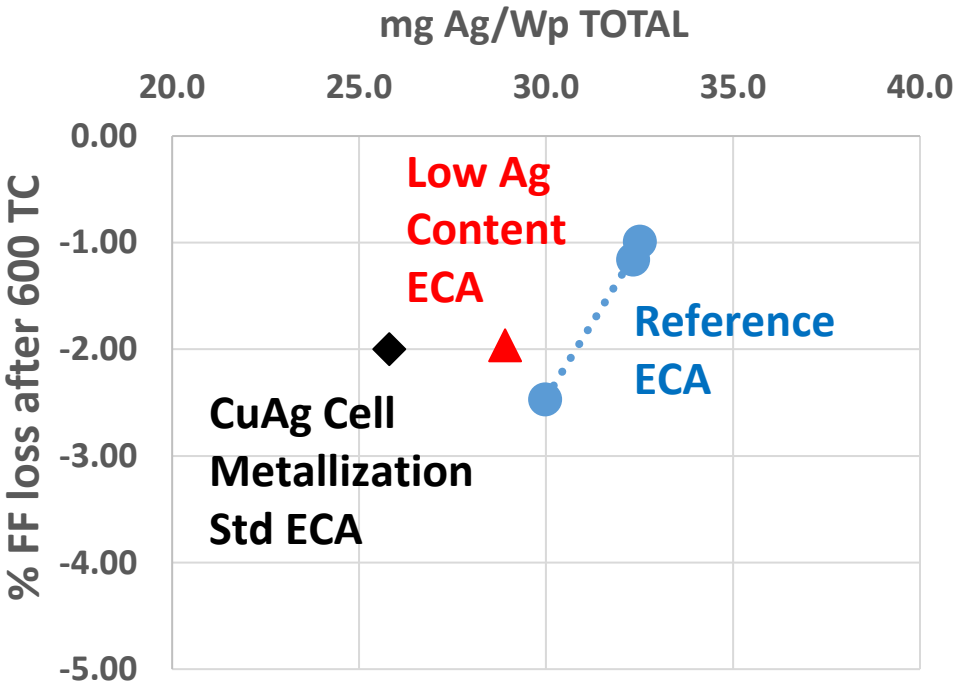


- EL degradation on the borders after 600 TC and depends on the amount of deposited ECA
- Higher degradation observed than on Busbar Cells
- No Isc and Voc degradation after TC (1 SUN I-V)

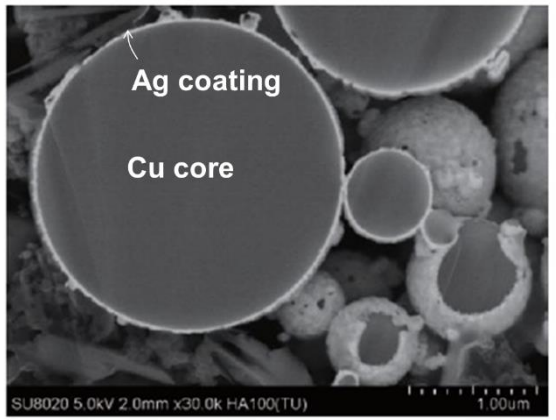
-> FF degradation is linked to an increase of the series resistance on BB0 and Busbar Cells

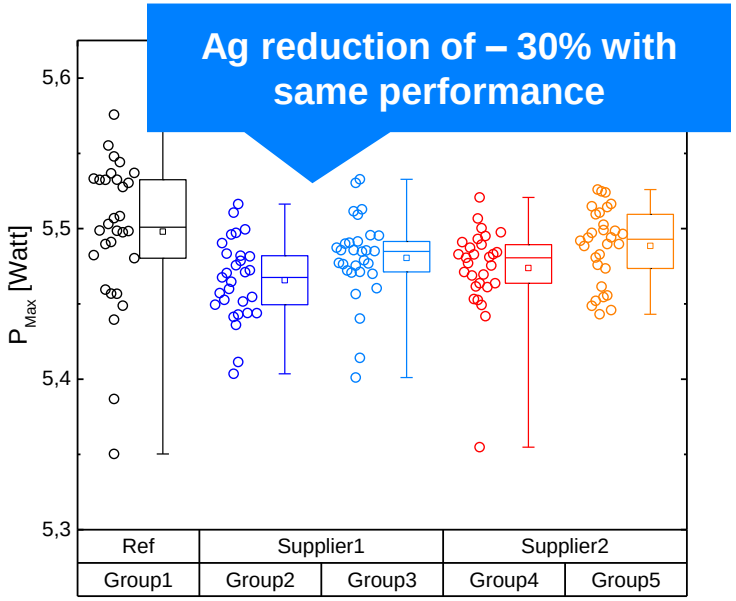
Low Ag content ECA and Ag/Cu Cell Metallization

- **FF loss in function of Ag weight /Wp (Total Ag : ECA + Ribbon + Cells)**
- **1 Busbar configuration**



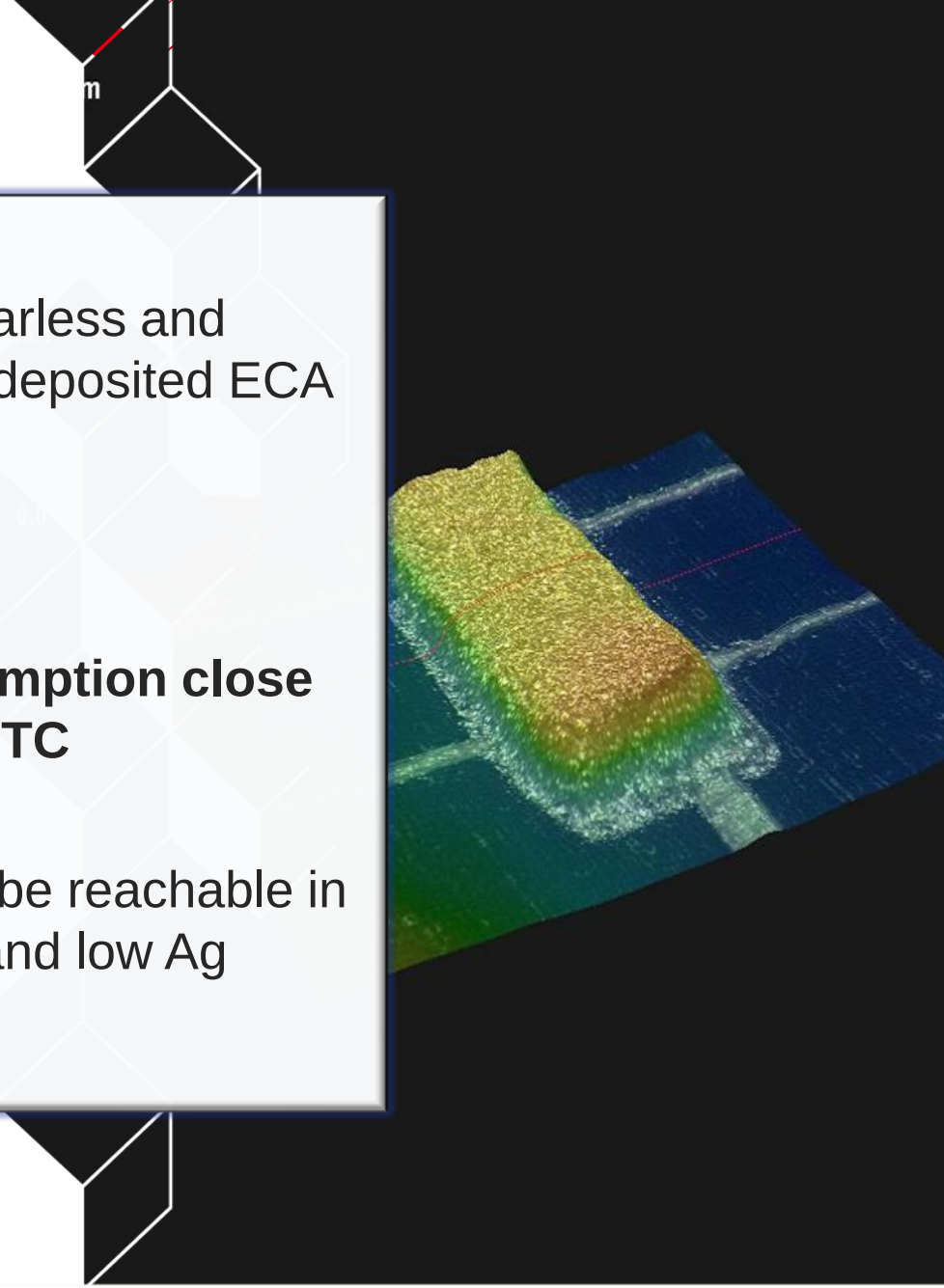
- ECAs with reduced Silver content (< 40 %) show impressive results : - 2 % FF loss after 600 TC
- Silver-Copper metallized cells allows to reach a low total Ag consumption close to 25 mg/Wp with a degradation of 2 % after 600 TC





Conclusion of the study

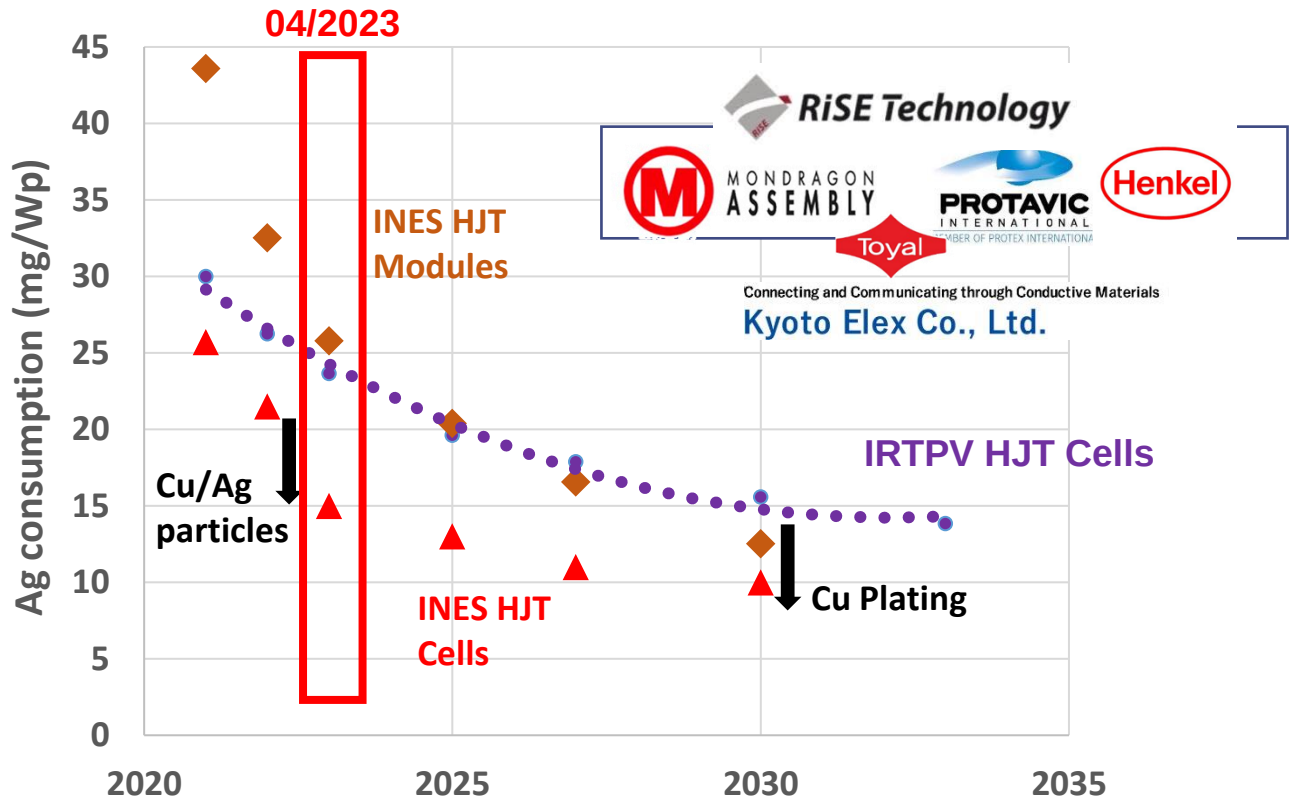
- Reliability of ECA gluing interconnection (in TC) in both busbarless and busbar cell configurations is closely related to the amount of deposited ECA
- Ag content in ECA can be lowered with no impact
- AgCu cell metallization allows to reach a low **total Ag consumption close to 25 mg/W** on modules with a degradation of **2 % after 600 TC**
- On BB0 cells (-5mg/W), a consumption of **16 mg/Wp** should be reachable in short term on HJT modules by coupling Ag/Cu metallization and low Ag content ECA



Strategies for further Ag reduction

- Improved deposition accuracy (< 100 µm)
- Ribbons with Ag-free coating
- Wire gluing
- Novel Cu-particle based ECAs
- Perovskite devices interconnection

Radical reduction of Ag metallization is a must for TW scale manufacturing in PV
We must target **5-10 mg/Wp by 2030**



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