HZB Helmholtz Zentrum Berlin

Achievements of Perovskite PV during the last years

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HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

- Material quality and conversion effiency
- Upscaling and Industrialization
- Long term stability
- Sustainability profile
- Opportunities for the technology

Efficiency Race …

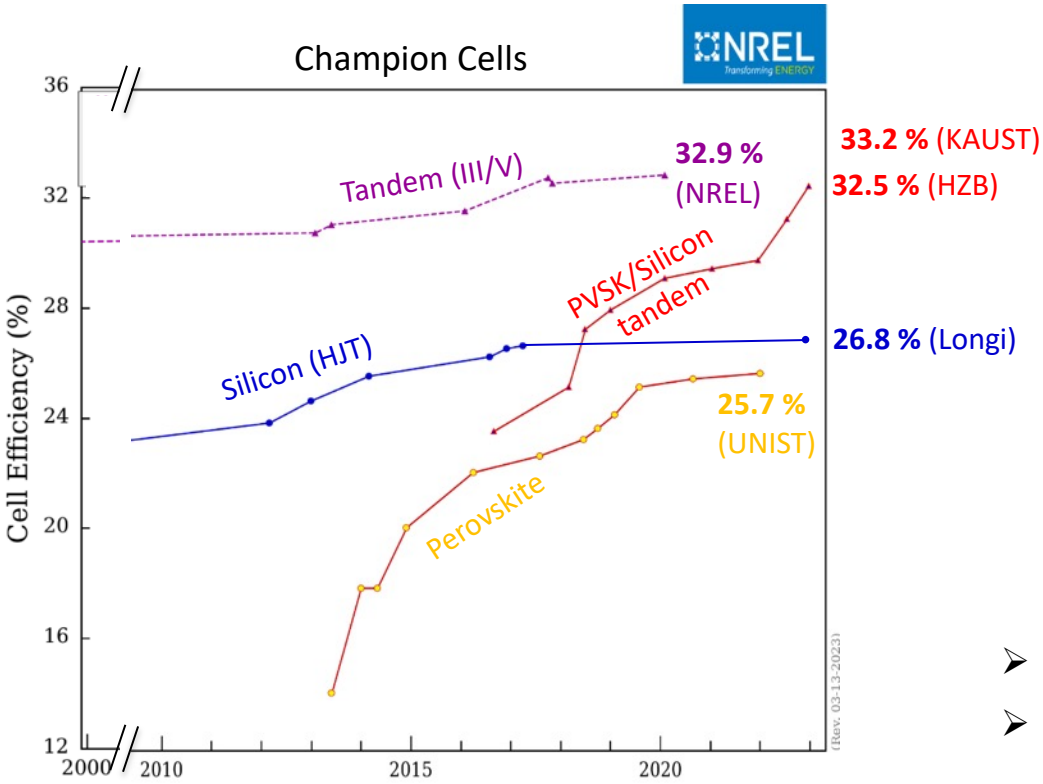
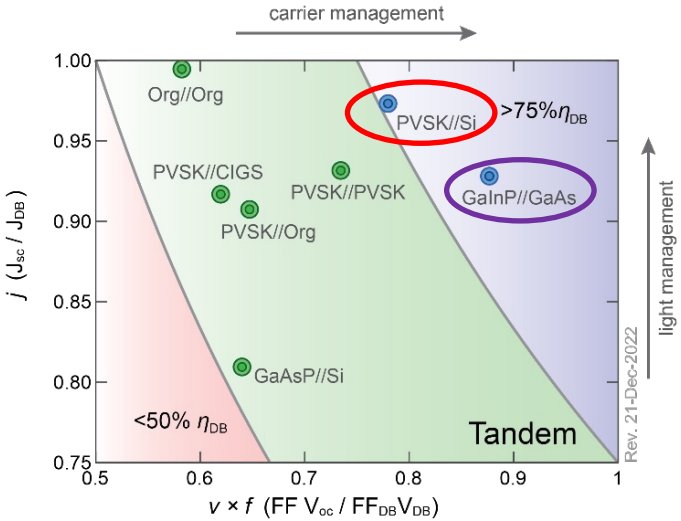


Image: https://www.nrel.gov/pv/interactive-cell-efficiency.html

Detailed-Balance efficiency limit:



- PVSK/Si Tandem entered the „75% club“
- PVSK/Si Tandem >20% better than Silicon

Image: A. Polman, M. Knight, E.G. Garnett, B. Ehrler, and W.C. Sinke, „Photovoltaic materials – present efficiencies and future challenges“, Science **352**, 307 (2016). DOI: 10.1126/science.aad4424. (lmpv.amolf.nl/db)

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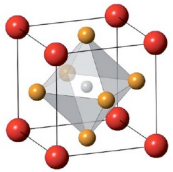
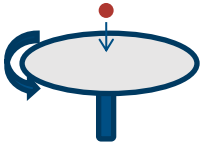
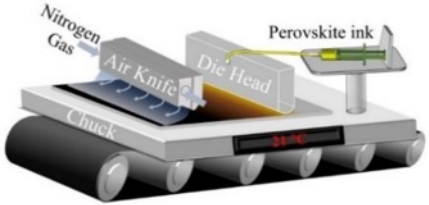
Routes for Perovskite upscaling



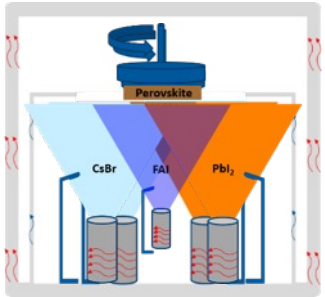
Lab process: Spin coating



(1) Slot-Die Coating:



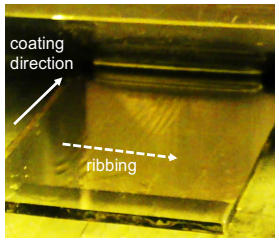
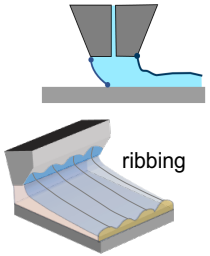
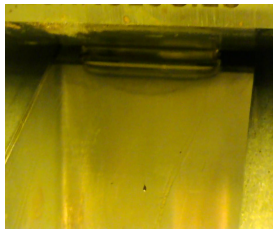
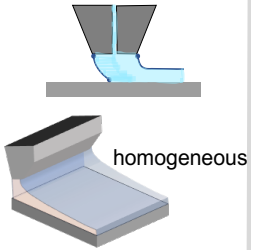
(2) Co-evaporation:



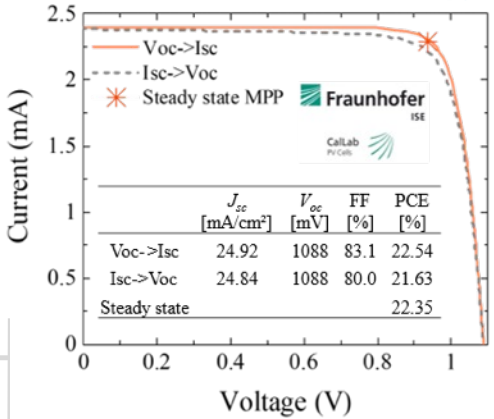
(3) Hybrid:
Evaporated anorganics + solution-processed organics

Slot-die Coated Perovskite PV devices

- **Ink optimization for the fabrication of slot-die coated $FAPbI_3$ perovskite solar cells with MACl additive to reduce large area non-homogeneity (ribbing)**

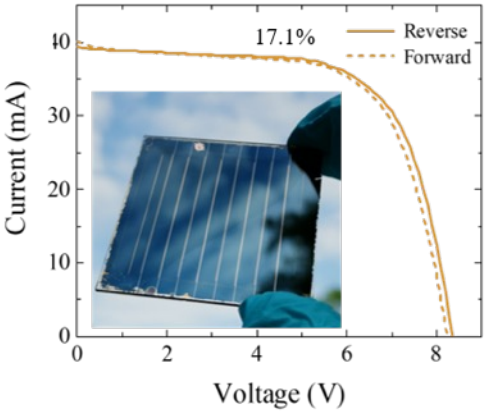
i) Ink composition	ii) Wetfilm after coating	iii) Illustration: ribbing
a) 2-ME ink 1 M $FAPbI_3$ 10 mol% MACl in 92 vol% 2-ME 8 vol% NMP		
b) 46% ACN 1 M $FAPbI_3$ 10 mol% MACl in 46 vol% 2-ME **46 vol% ACN** 8 vol% NMP		

Certified PCE of 22.3%

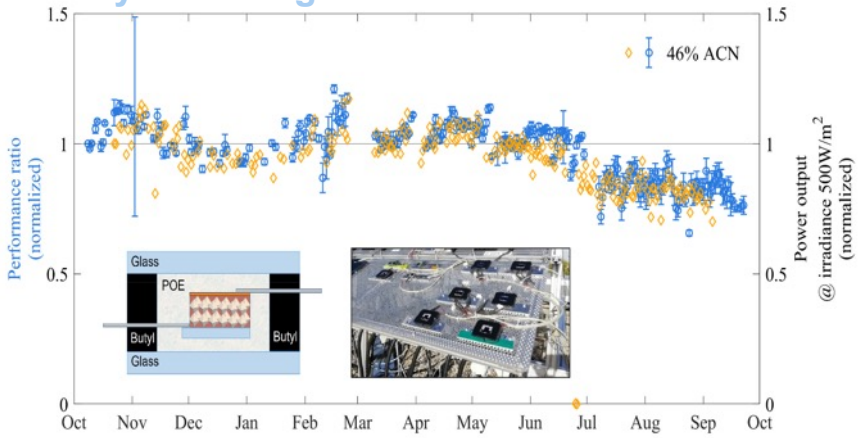


	J_{sc} [mA/cm²]	V_{oc} [mV]	FF [%]	PCE [%]
Voc->Isc	24.92	1088	83.1	22.54
Isc->Voc	24.84	1088	80.0	21.63
Steady state				22.35

Modules with 17% PCE



1 year testing outdoors



J. Li et al. *Adv. En. Mater.* (2023).

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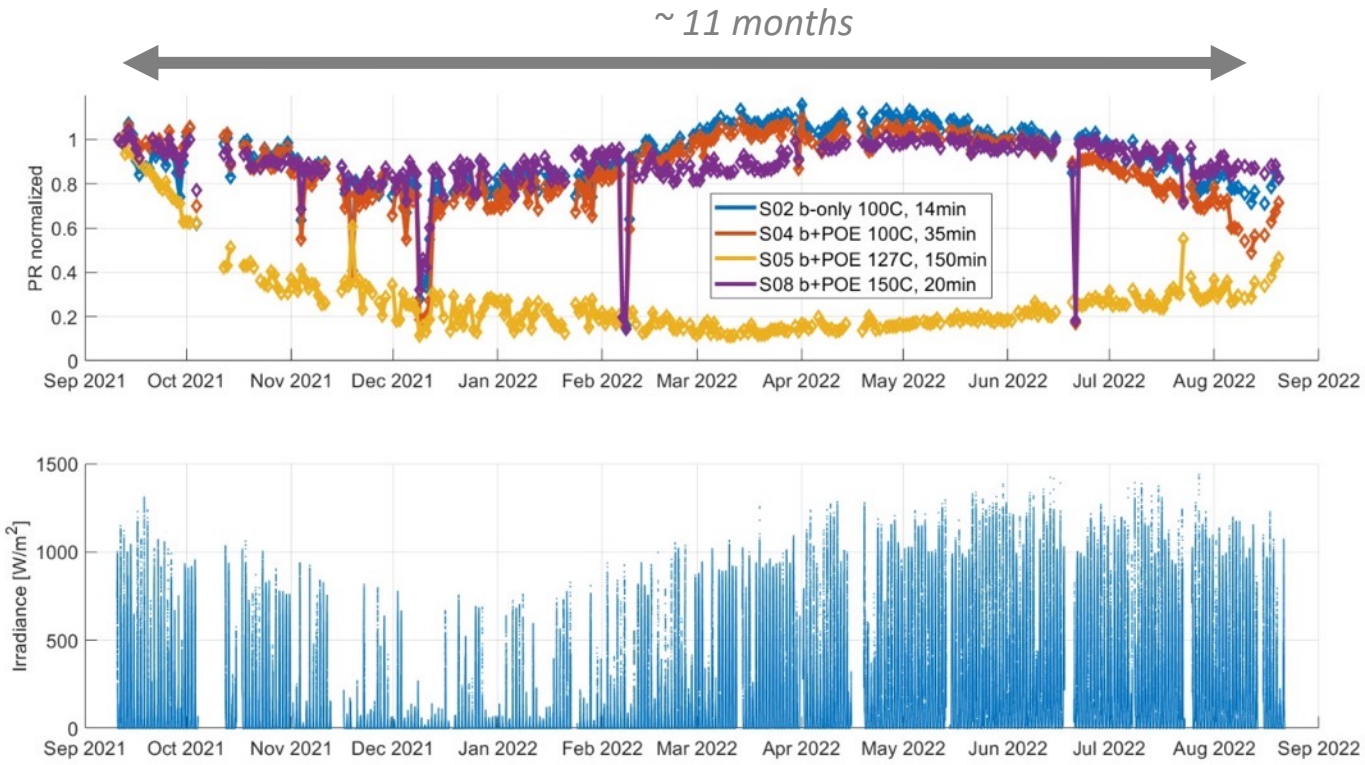

- Co-evaporated perovskite/SHJ Tandem
- Glass/POE/Glass + butyl
- Pronounced increase in March-May, likely due to higher irradiance

Jona Kurpiers, Stefanie Severin, Marko Remec, Marcel Roß, Mark Khenkin – to be published

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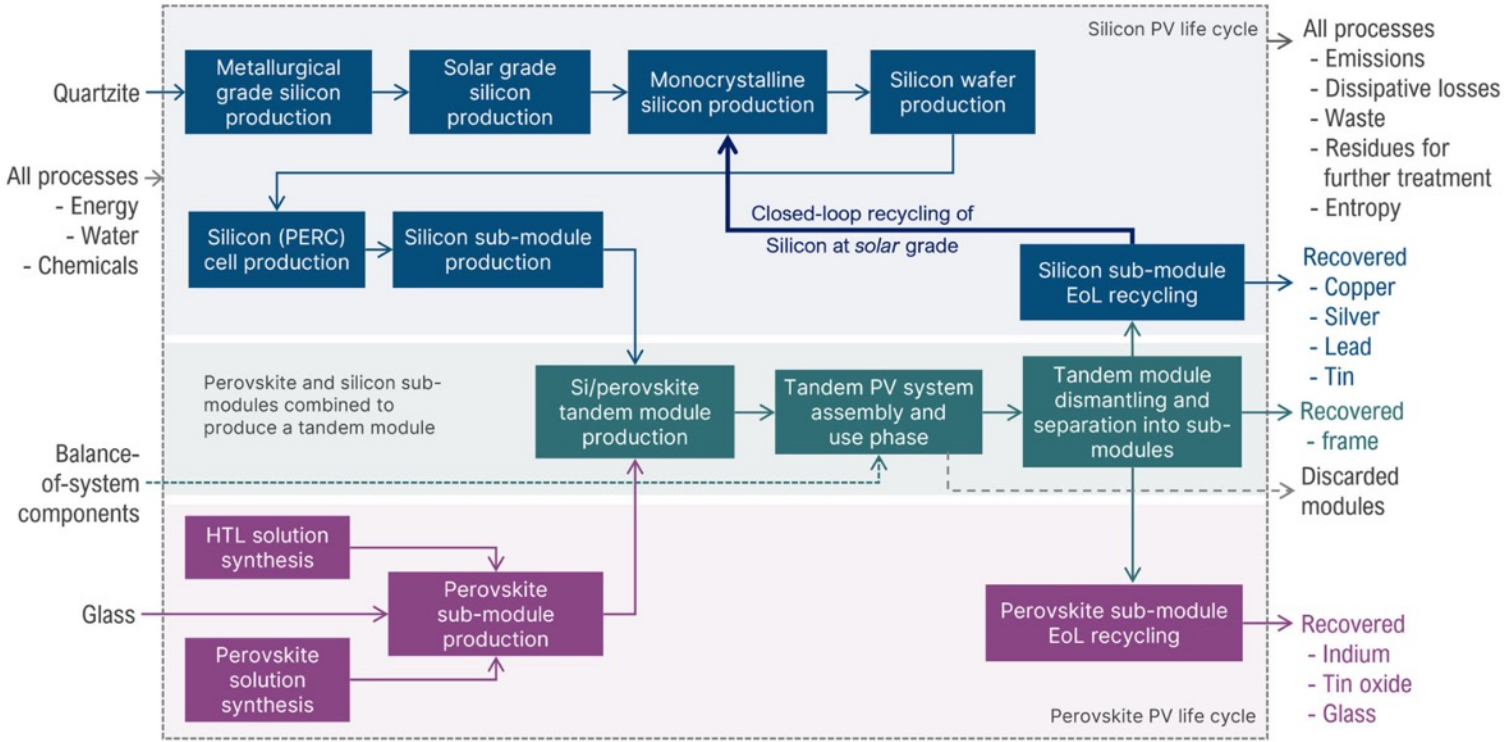

Bartie et al., J. Ind. Ecol. 2023

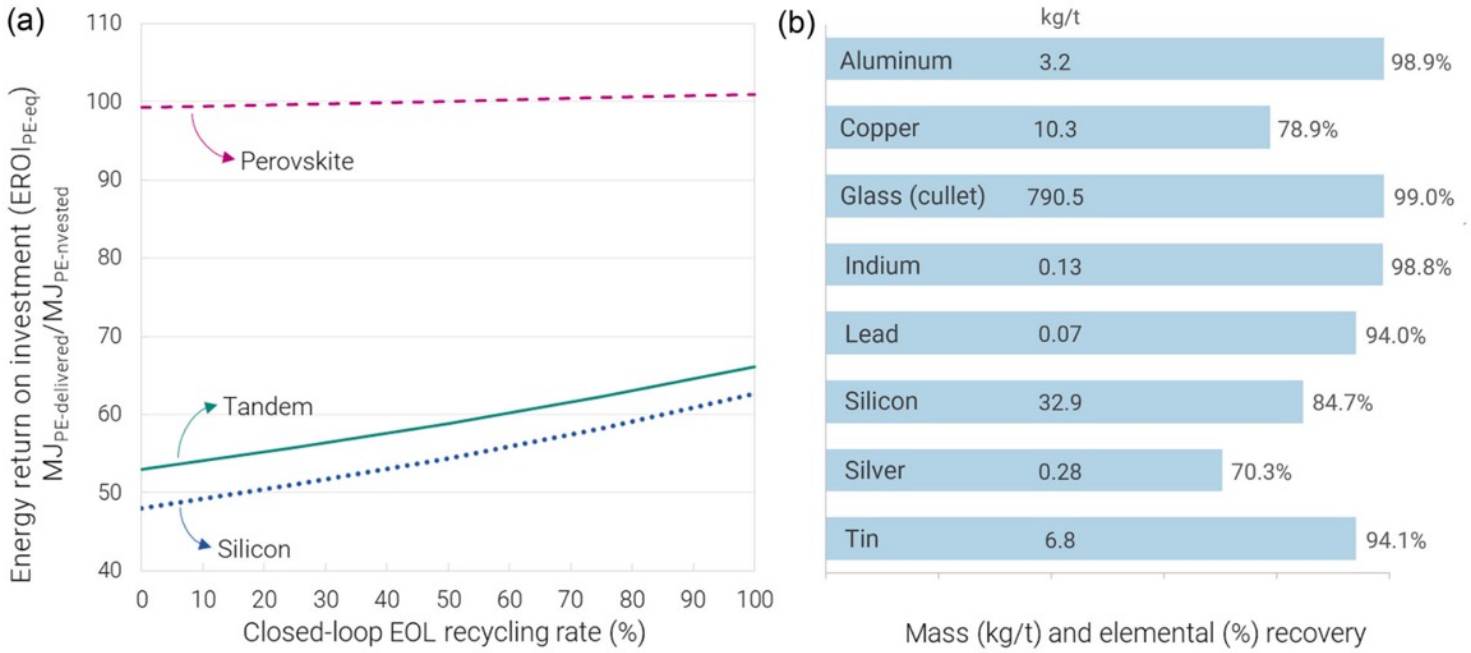

FIGURE 3 (a) Energy return on energy investment (EROI$_{PE-eq}$) and (b) end-of-life (EoL) recoveries as a percentage of the element entering the recycling process and as the mass recovered per tonne of EoL modules recycled. Note that the recoveries are independent of the recycling rate. Tin and lead are recovered as oxides. EROI$_{PE-eq}$ values have been normalized to an average irradiation of 1700 kWh/(m^2 year), PR of 0.75, lifetime of 30 years, and a grid efficiency (η_{grid}) of 0.30. Underlying data can be found in Supporting Information S2.

Bartie et al., J. Ind. Ecol. 2023

- Material quality and conversion effiency ✓
- Upscaling and Industrialization ✓
- Long term stability ✓ *but open*
- Sustainability profile ✓
- *Opportunities for the technology* ✓✓