

## Solar Cells Reporting Summary

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### ► Experimental design

#### Please check: are the following details reported in the manuscript?

##### 1. Dimensions

- Area of the tested solar cells  Yes  No Page 2 in SI: "The active area of tested cells was 12 mm<sup>2</sup>".
- Method used to determine the device area  Yes  No Page 2 in SI: "as defined from the area of overlap of the electrodes."

##### 2. Current-voltage characterization

- Current density-voltage (J-V) plots in both forward and backward direction  Yes  No Reported in Supplementary Fig. S8.
- Voltage scan conditions  Yes  No Page 2 in SI: "The temperature of the cell was fixed to 25 °C and a voltage ramp of 20 mV/s was used. "  
*For instance: scan direction, speed, dwell times*
- Test environment  Yes  No Page 2 in SI: "The temperature of the cell was fixed to 25 °C and a voltage ramp of 20 mV/s was used. "  
*For instance: characterization temperature, in air or in glove box*
- Protocol for preconditioning of the device before its characterization  Yes  No No pre-conditioning protocol was used.
- Stability of the J-V characteristic  Yes  No Reported in Figure 2e (stabilized current at fixed voltage) and Figure 3c (evolution of MPP).  
*Verified with time evolution of the maximum power point or with the photocurrent at maximum power point; see ref. 7 for details.*

##### 3. Hysteresis or any other unusual behaviour

- Description of the unusual behaviour observed during the characterization  Yes  No We typically observe a dip in the PCE in the initial 10 seconds which we attribute to current losses related to ion movement in the perovskite absorber layer, ref. 44,45.
- Related experimental data  Yes  No Figure 2e and the corresponding description in the manuscript.

##### 4. Efficiency

- External quantum efficiency (EQE) or incident photons to current efficiency (IPCE)  Yes  No Figure 2f in the manuscript.
- A comparison between the integrated response under the standard reference spectrum and the response measure under the simulator  Yes  No Figure 2f, the integrated product of EQE and solar cell spectrum matches the current under the sun simulator within 2%.
- For tandem solar cells, the bias illumination and bias voltage used for each subcell  Yes  No Not applicable here .

##### 5. Calibration

- Light source and reference cell or sensor used for the characterization  Yes  No An Oriel class AAA Xenon lamp-based sun simulator was used for illumination. The intensity of the solar simulator was monitored during the JV scans using a Si diode.
- Confirmation that the reference cell was calibrated and certified  Yes  No The intensity was calibrated with a KG5-filtered silicon solar cell calibrated by Fraunhofer ISE.

Calculation of spectral mismatch between the reference cell and the devices under test	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	The spectral mismatch factor ( $S_M$ ) was calculated to be 0.982 for the optimized devices with EQE spectra presented in Figure 1f, however, the obtained current has not been upscaled by $1/S_M$ .
6. Mask/aperture		
Size of the mask/aperture used during testing	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	Page 2 in SI: "An illumination mask with an area of 9 mm <sup>2</sup> was used to measure the JV-characteristics."
Variation of the measured short-circuit current density with the mask/aperture area	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	JV results in main text are reported with illumination mask. We note, the unmasked current is typically ~5% higher.
7. Performance certification		
Identity of the independent certification laboratory that confirmed the photovoltaic performance	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	No certification was carried out since no new efficiency record is reported.
A copy of any certificate(s) <i>Provide in Supplementary Information</i>	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	Not applicable.
8. Statistics		
Number of solar cells tested	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	Figure 2a-c in the manuscript.
Statistical analysis of the device performance	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	In caption in Figure 2 in the manuscript.
9. Long-term stability analysis		
Type of analysis, bias conditions and environmental conditions <i>For instance: illumination type, temperature, atmosphere humidity, encapsulation method, preconditioning temperature</i>	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	Long term stability tests were carried out as shown in Figure 3c (evolution of MPP at 26 °C, inert atmosphere in glovebox, white light LED) and repeated in Supplementary Figure S12 (evolution of MPP at 40 °C, ~30% RH outside, unencapsulated, white light LED).