Impact of Spectrum, Luminescent Coupling, and Temperature Coefficients on Tandem Device Performance

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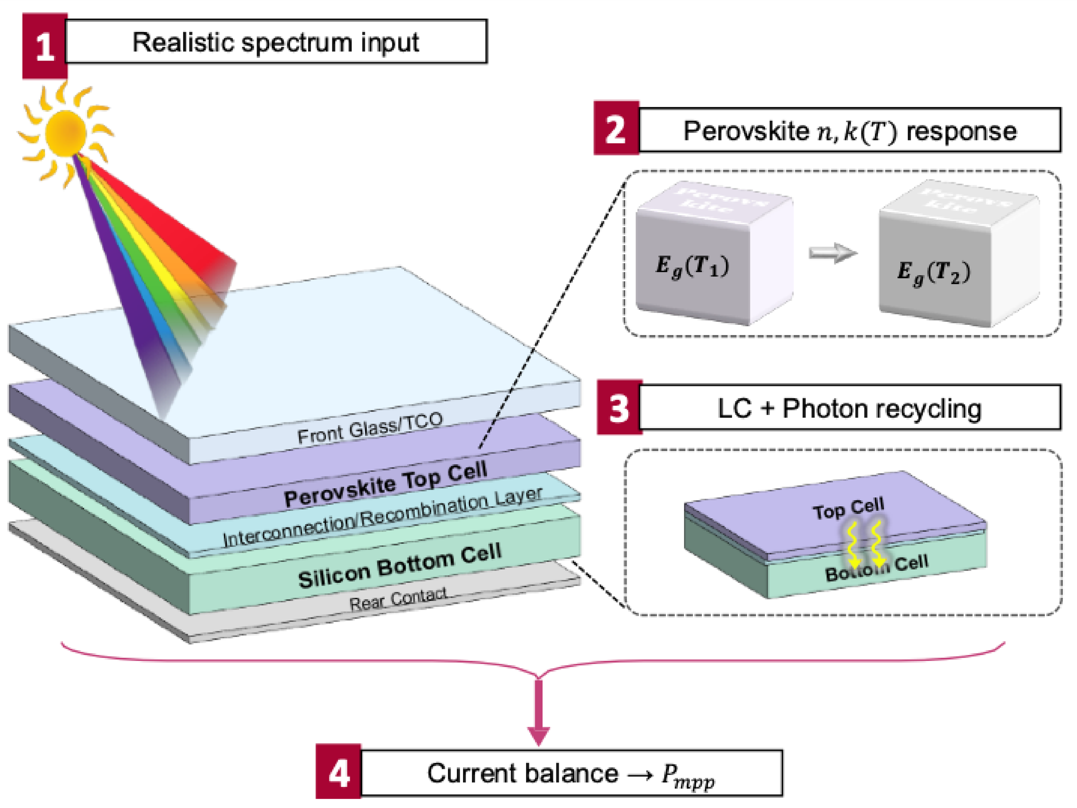
Abstract

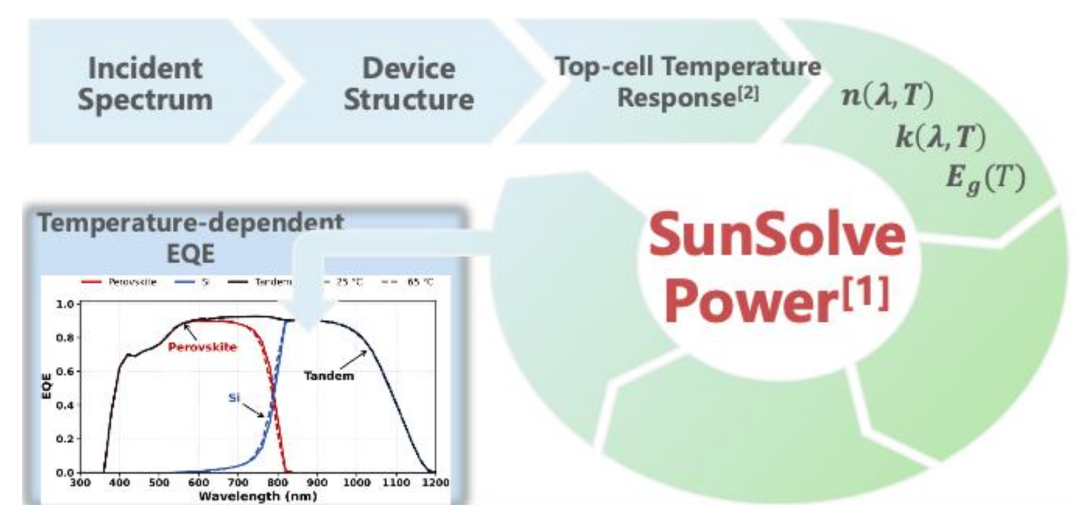
- Tandem solar-cell models require coupled optical treatment beyond single-junction assumptions.
- This work quantifies how spectrum, temperature-dependent bandgap, and luminescent coupling affect perovskite-silicon tandem performance predictions.
- Simplified assumptions can shift predicted output and bias bandgap selection.

Methodology

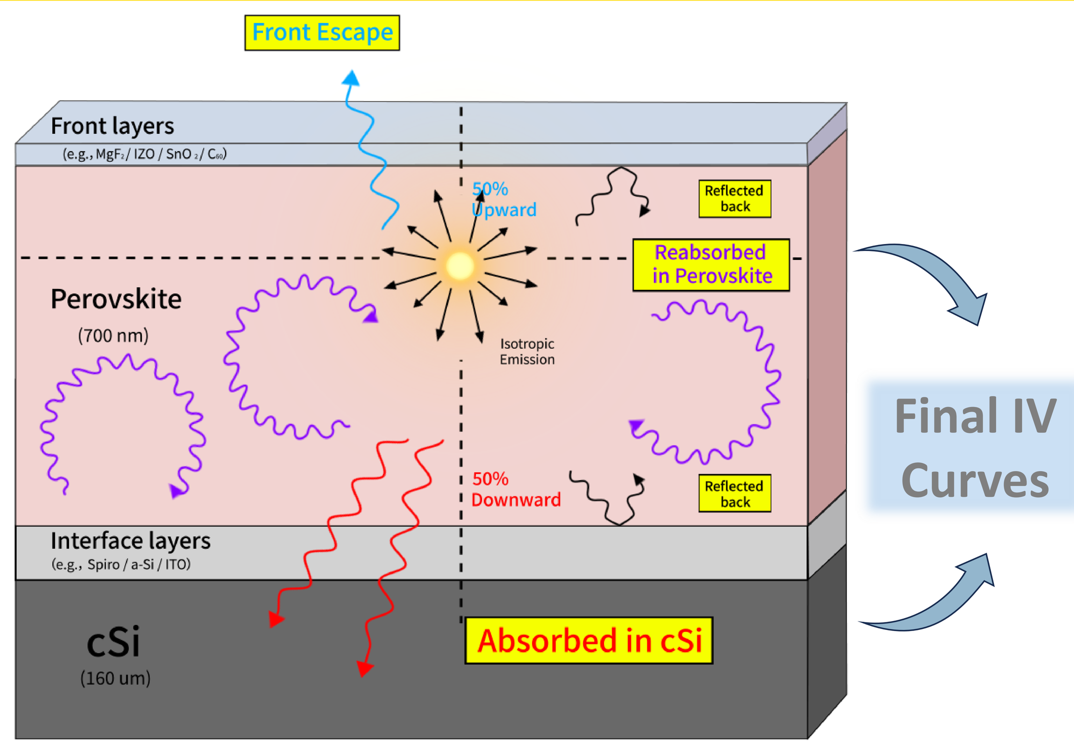


Parameter	Cases
Bandgap (eV)	1.58, 1.70, 1.77
Temperature (°C)	25, 35, 45, 55, 65, 75
Spectrum	AM1.5G (baseline), Clear-sky high, Clear-sky low, Intermittent high, Intermittent low, Cloudy high, Cloudy low
Radiative recombination η_{rad} (%)	0, 10, 30, 50, 100

Temperature-dependent bandgap workflow



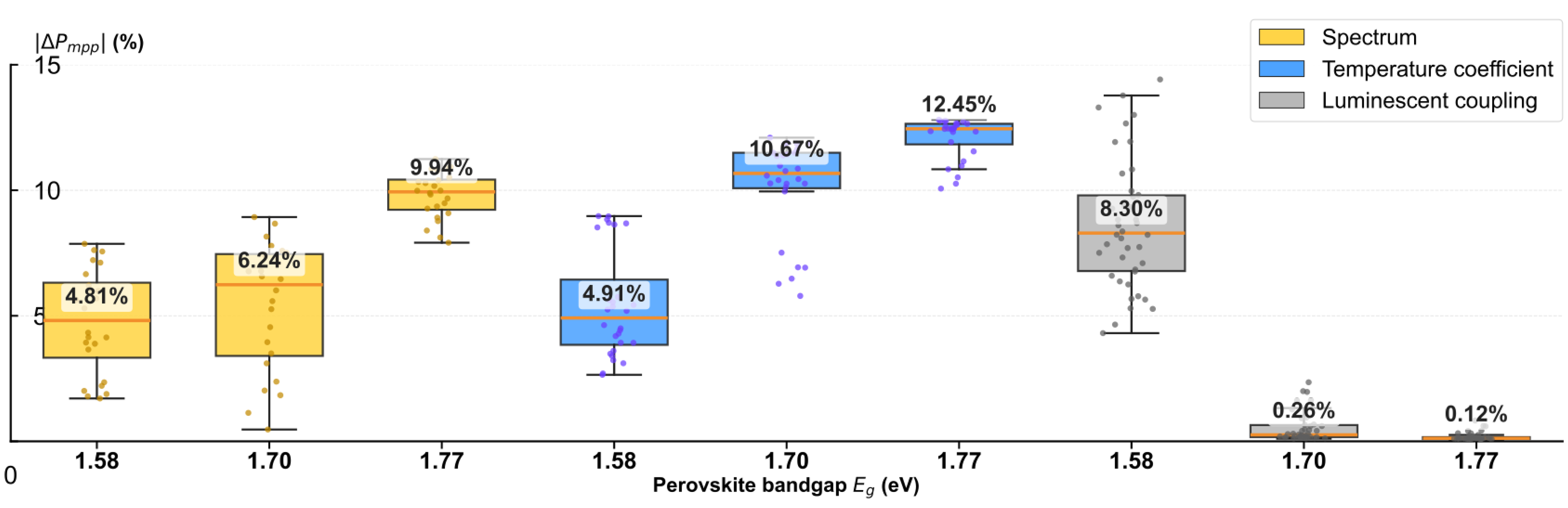
Luminescent Coupling Model[3]



Single-pass
- **69.02%** reabsorbed in Perov
- **27.06%** collected in Si

With recycling ($\eta_{rad} = 0.5$)
- **52.69%** reabsorbed in Perov
- **41.32%** collected in Si

Key Results



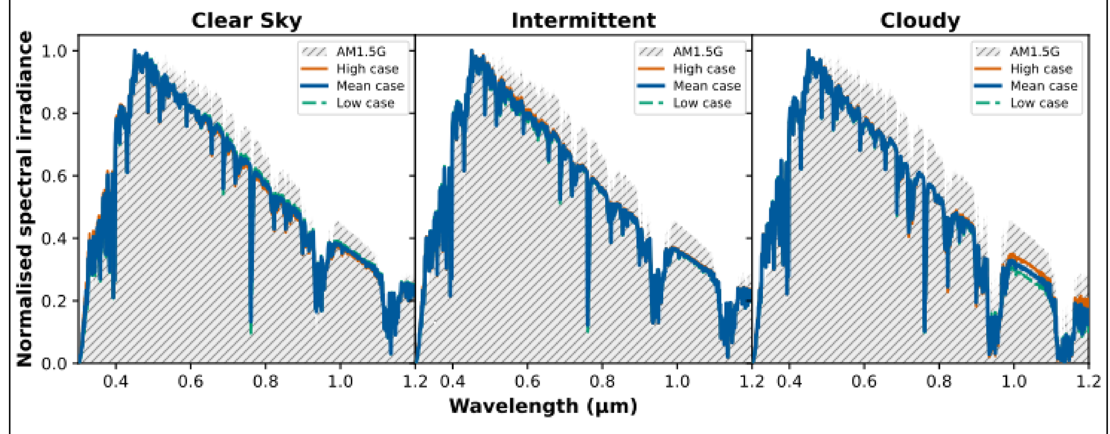
Impact of Incident Spectrum

Spectra Used

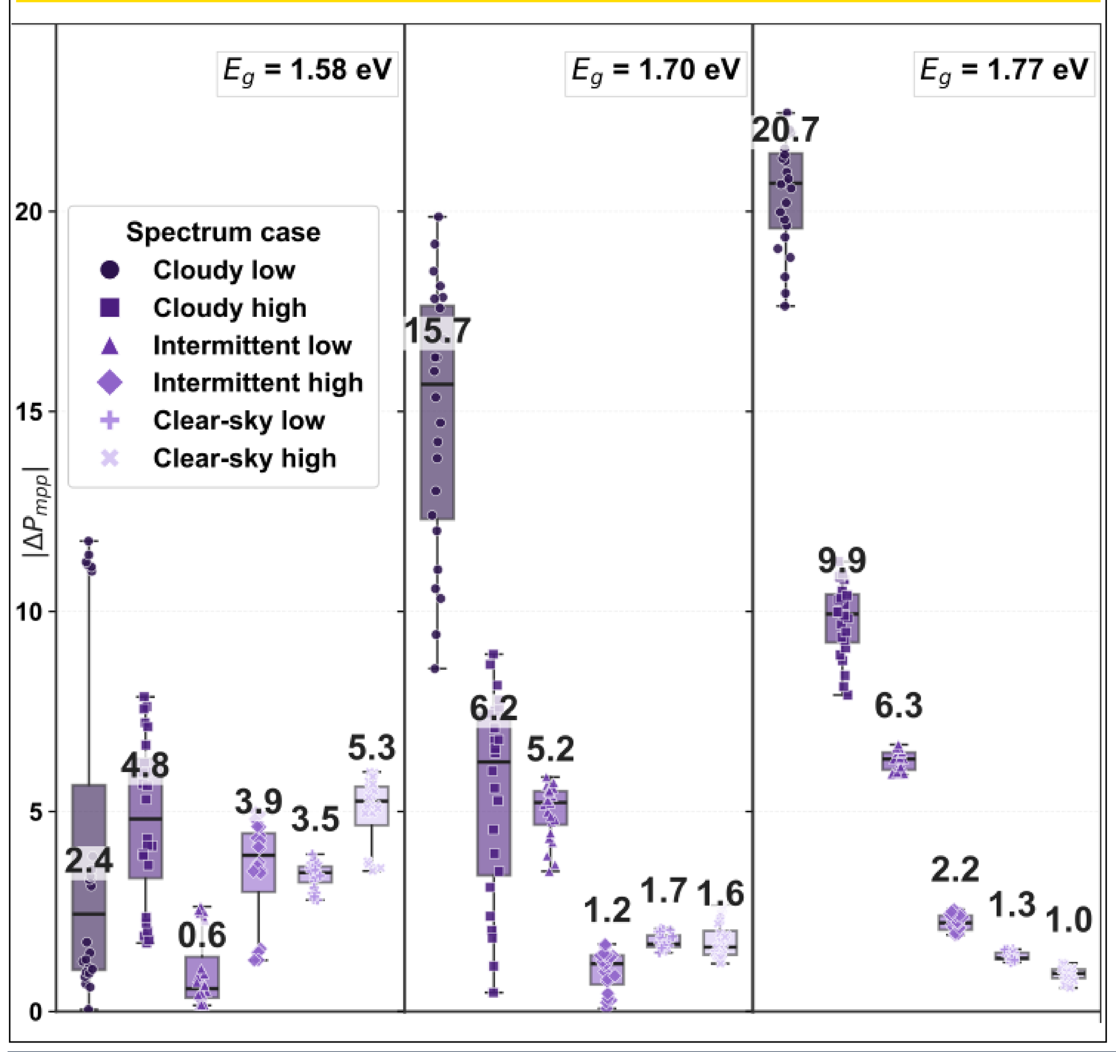
We use 2024 hourly spectral irradiance data from Albuquerque and classify sky conditions using (K_t)

Clear Sky	Intermittent	Cloudy
$K_t \geq 0.95$	$0.5 < K_t \leq 0.95$	$K_t < 0.5$

We define the high and low case as the 90th and 10th percentile from each classification. All spectra were normalized to a GHI of 1000 Wm^{-2}.

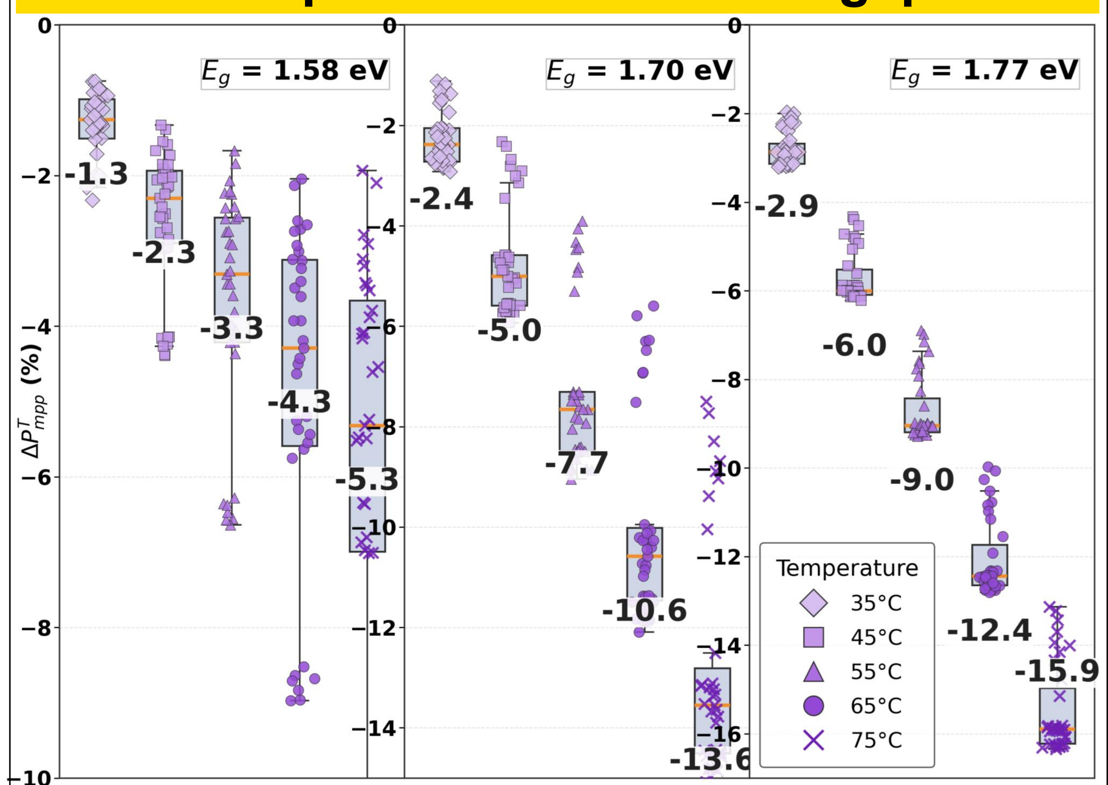


Comparison to simulation with AM1.5G



Temperature-dependent bandgap

Comparison to 25°C bandgap



Linear Approximations

Linear approximations can greatly simplify yield simulations for tandem devices.

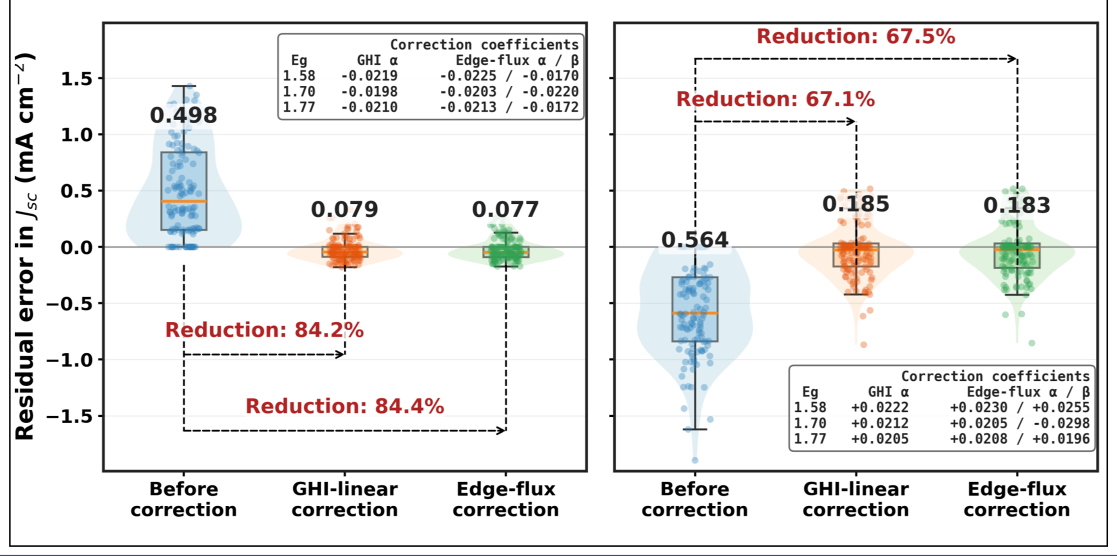
GHI-linear:

$$\Delta J_{sc}^{GHI}(T, S) = \alpha_{sc}^{GHI} \cdot G_{norm}(S) \cdot (T - T_0)$$

Edge-flux:

$$\Delta J_{sc}^{edge}(T, S) = \alpha_{sc}^{edge} \cdot \Phi_{edge}(S) \cdot (T - T_0),$$

where $T_0 = 25°C$, α_{sc} is the sub-cell temperature coefficient and $\Phi_{edge} = \int_{\lambda_g-80}^{\lambda_g+120} E(\lambda)\lambda \, d\lambda$

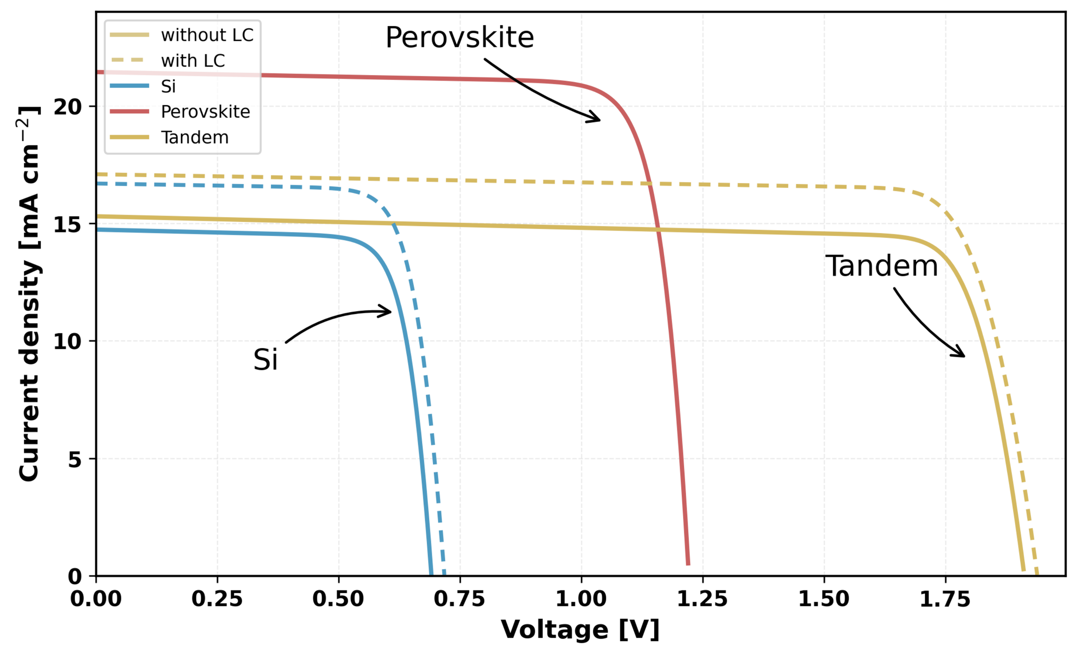


Luminescent coupling

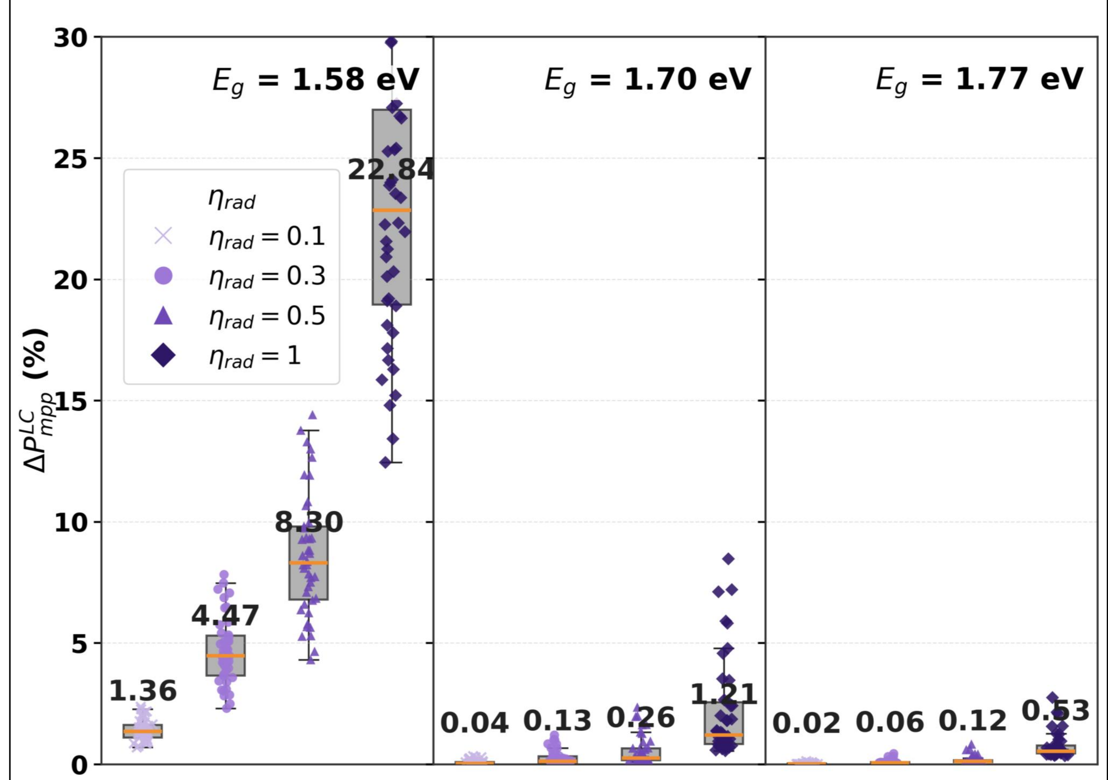
We incorporate LC by sweeping the radiative recombination fraction η_{rad}

Impact on IV Curves

Luminescent coupling introduces an additional term for the bottom cell photocurrent, which depends on the top cell voltage.



Comparison to η_{rad}=0



The impact of luminescent coupling is highly dependent on the photocurrents of both cells

Conclusion

- Spectrum variation introduces the largest P_{mpp} deviation with low dependence on other effects
- Losses due to bandgap widening increase with top cell E_g; gain from LC decreases with E_g.
- Neglecting these effects can bias bandgap selection toward higher E_g.

Leave us a Comment!

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References

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[2] Aydin, Erkan, *et al.* (2020) *Nature Energy* 5.11: 851-859.
[3] Zeder, S.J., *et al.* (2025), *APL Energy*, 3, 026110.

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