Is IEC 61853-1 testing useful for predicting the energy yield of tandem solar cells?

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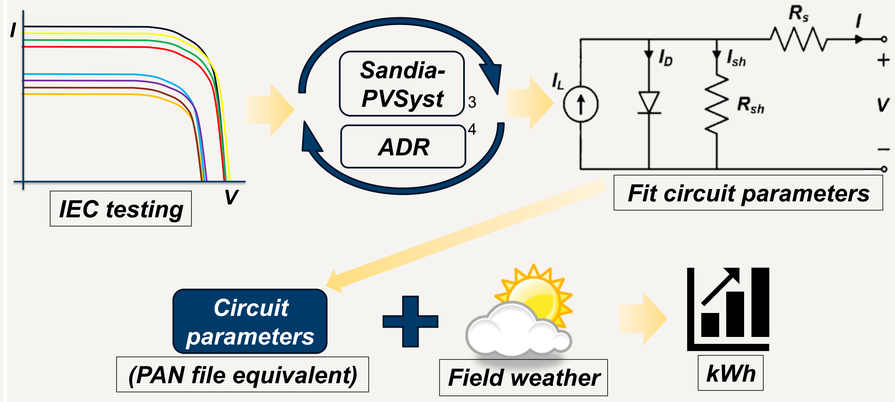
National Laboratory of the Rockies

Introduction

- Growth in tandem photovoltaic (PV) manufacturing has opened a **new era of tandem performance modeling**[1]
- Double-junction **equivalent circuit models**, e.g., PVcircuit[2], are **accurate** but require **high fidelity device data**
- **IEC 61853-1** testing for 1J devices involves device characterization that can be used for energy yield calculations
  - Testing is under various **temperature and irradiance** conditions, and the **AM1.5G** spectrum
- Standard 1J modeling: post-characterization I_{sc} **spectral correction**, accounting for non-AM1.5 field conditions
- 2T tandem output is heavily dependent on the **spectrum** due to **subcell coupling** and **current matching**
- Given the importance of spectral variation for tandems, **is IEC 61853-1 useful for tandem energy yield modeling?**

Workflow



Data

Meteorological data:

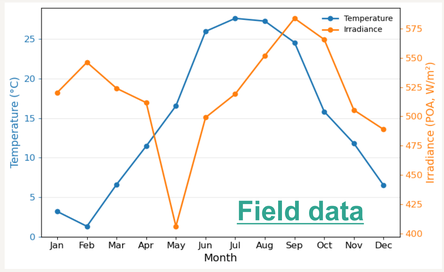
- **IEC:** Temperature/irradiance
- **Field:** Golden, Colorado. AOI-corrected NSRDB
- **Structured:** artificial 3D parameter space to enable single-parameter sweeps for analysis

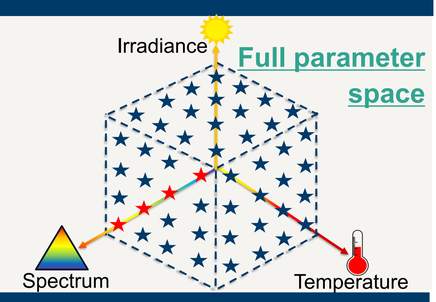
Device and model:

- GaInP/GaAs 2J/2T Tandem (1.74eV, 1.42eV)
- Uses measured EQE(T)[5]
- ADR+Sandia-PVsyst 1J model

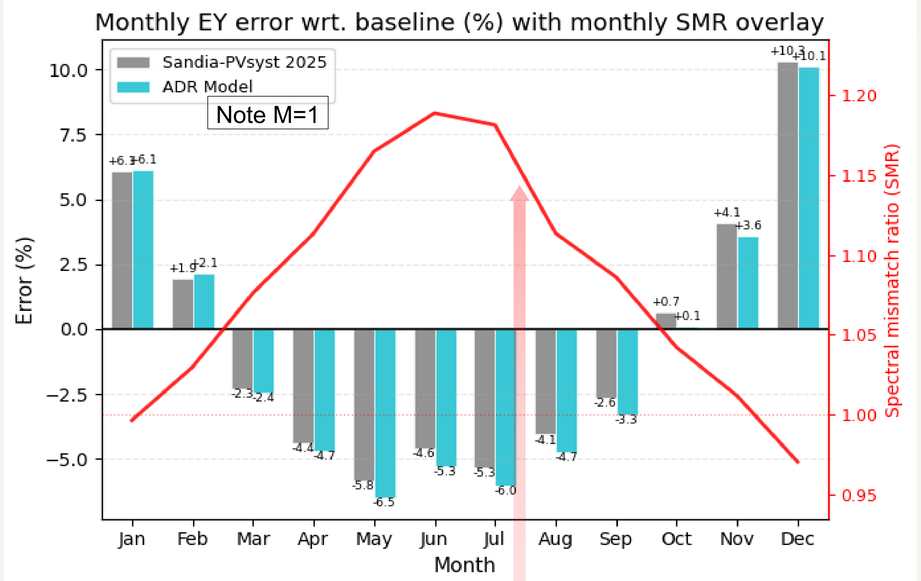
Irradiance (W/m^2)	Module Temperature (°C) 15	25	50	75
1100		X	X	X
1000	X	X	X	X
800	X	X	X	X
600	X	X	X	X
400	X	X	X	
200	X	X		
100	X	X		

IEC conditions





Example Result

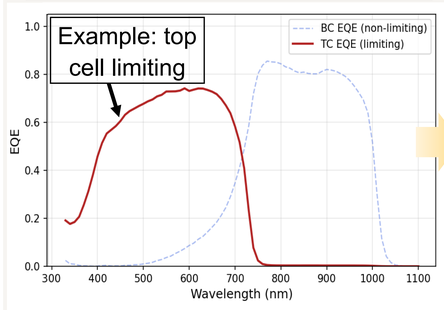


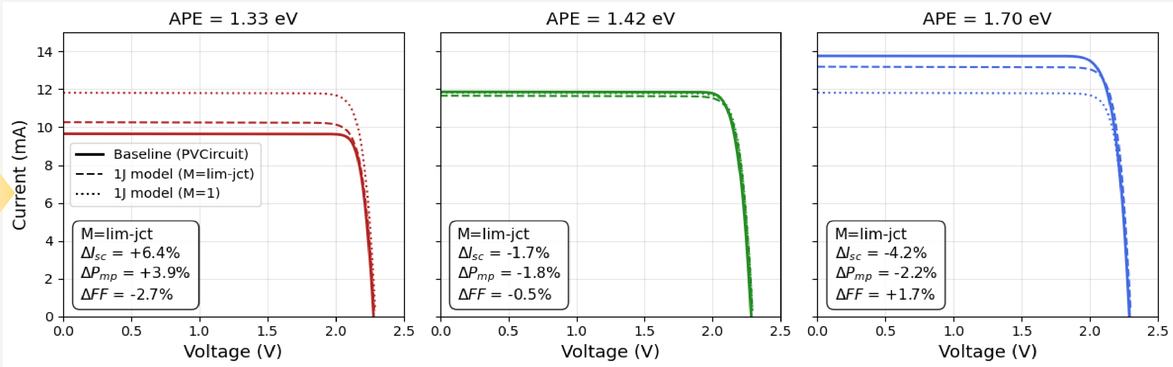
- Large magnitude **error** relative to baseline, high **seasonality**
- Error correlated to **current mismatch** due to spectral variation

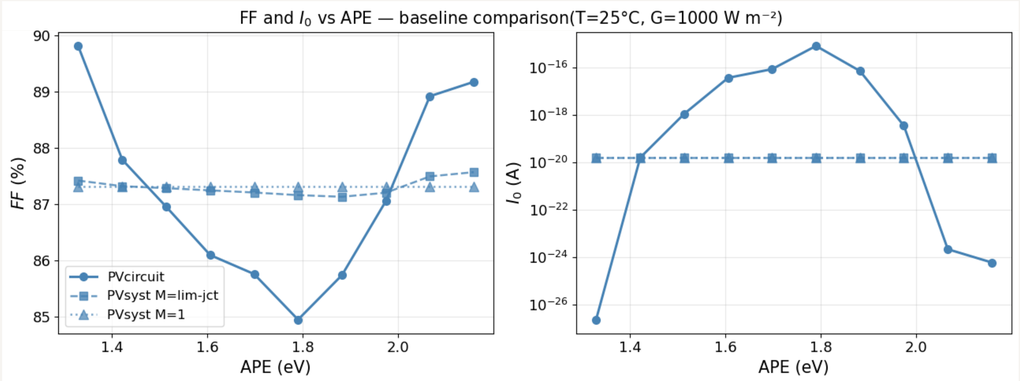
Analysis

- Apply a spectral mismatch factor (M) using the **limiting subcell EQE** (drawback: requires subcell data)
- $M = \frac{J_{sc,l}^{\text{field}}/G_{\text{field}}}{J_{sc,l}^{\text{ref}}/G_{\text{ref}}} \times \left(\frac{J_{sc,l}^{\text{ref}}}{J_{sc,\text{dev}}^{\text{STC}}}\right)$, l = limiting subcell (modified from IEC 61853-2; there is no single "tandem device EQE")
- IV at ~AM1.5 is predicted well, but blue/red spectral shifts reduce prediction accuracy significantly
- Spectral correction mitigates $\boldsymbol{\Delta I_{sc}}$ but errors in the **shape** of the IV curve (**fill factor**) are left unaddressed
- Sandia-PVsyst physics does not apply to tandems, for example the assumption $I_0 = \text{constant}$ with variable spectra

M from the limiting subcell EQE







These results use the *structured dataset* of spectra, irradiance, and temperature triplets to assess systematically their correlation with individual SDM parameters.

Note: each APE has a uniquely assigned spectrum, computed by binning field spectra[7]

Ongoing Work

- We propose modifying the **measurement** and **fitting** stage:
  - Add spectral variation to IEC 61853-1 characterization
  - Add spectral fitting term(s) to the parameter equation(s)
  - Targeting I_0 first for the proposed spectrally-adjusted SDM
- We will publish our tandem energy yield model fully open source in **SAM** and (will propose for) **pvlib-python**

Conclusion

- Conventional spectral consideration in IEC testing is inadequate for energy yield modeling tandem photovoltaic devices
- Resultant EY errors are **seasonal** and strongly correlated with **spectral variation** and subsequent **current matching** behavior
- EQE **spectral corrections improve $\boldsymbol{I_{sc}}$** estimates but require **subcell data** and do not address the full spectral impact on power
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REFERENCES

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Photovoltaic Performance Modeling Workshop
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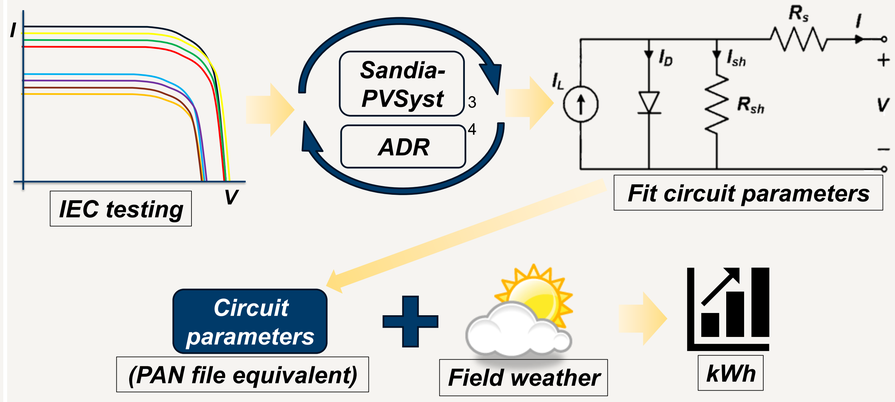

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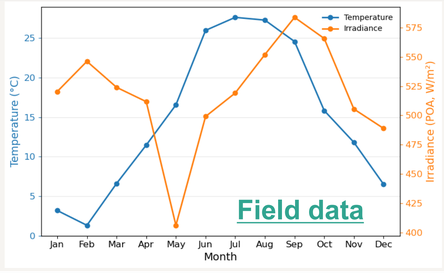

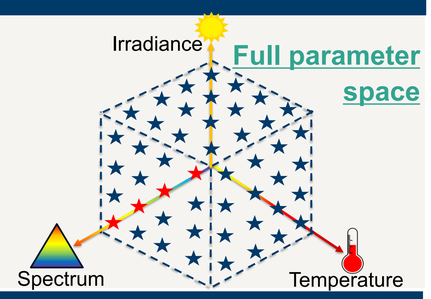

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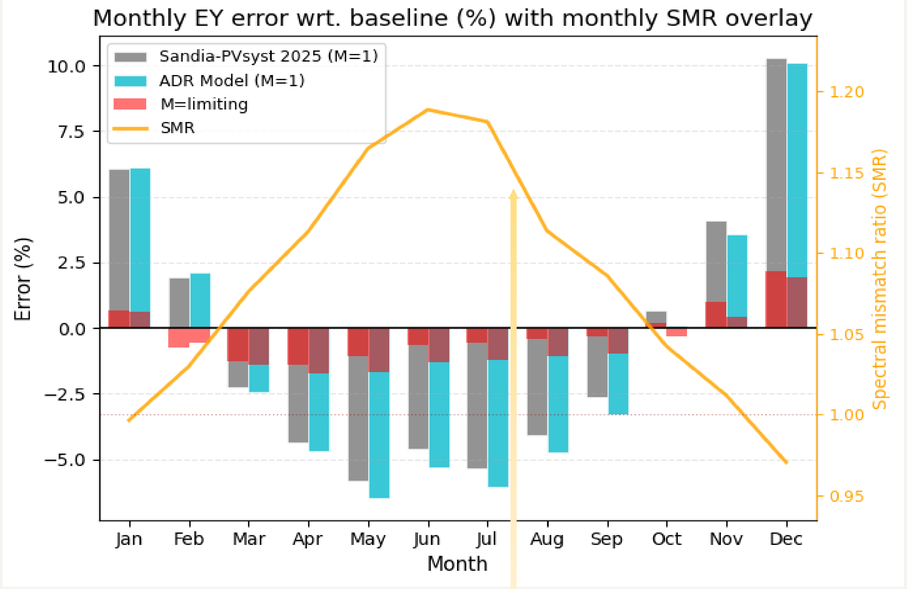

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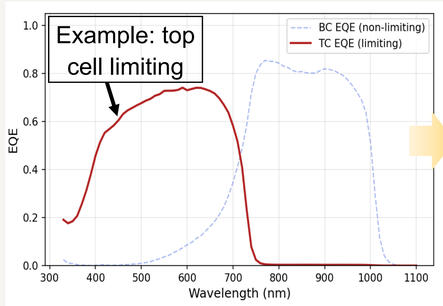

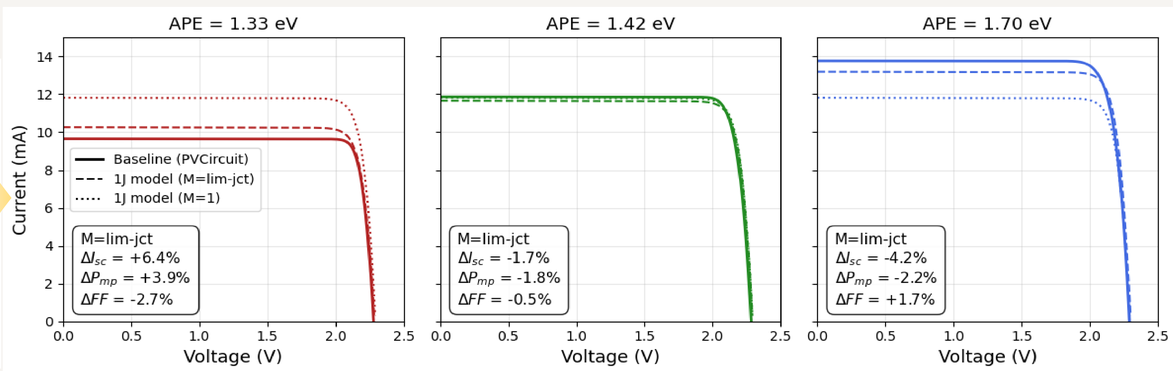

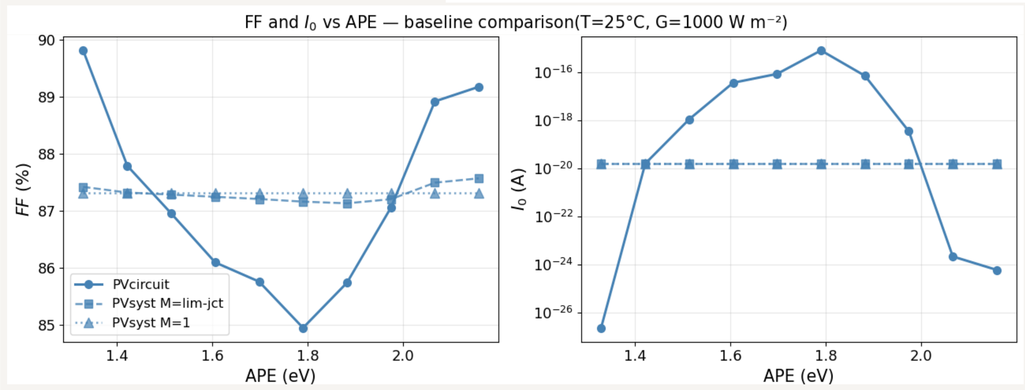

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