Faculty of Engineering
School of Photovoltaic and Renewable Energy Engineering

Thermal-Aware Single-Axis Tracking: Reducing PV Module Temperature and UV Exposure Without Sacrificing Yield

PVPMC, Albuquerque, USA 12-14 May 2026

Z. Haydous[1], R. Cavieres[1,2], P. Hamer[1], N. Chang[1], B. Hoex[1]

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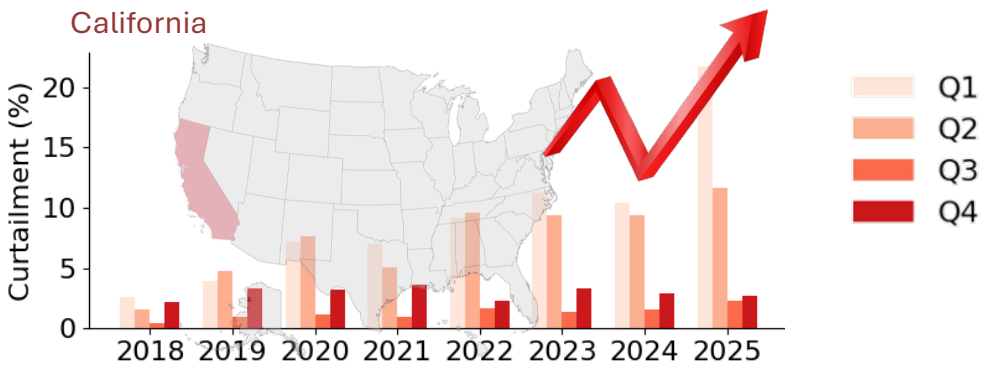
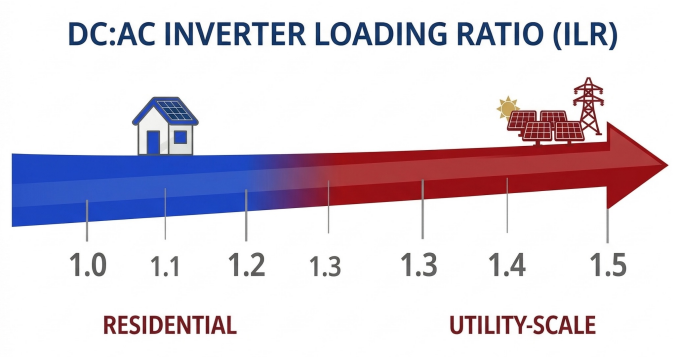
Motivation

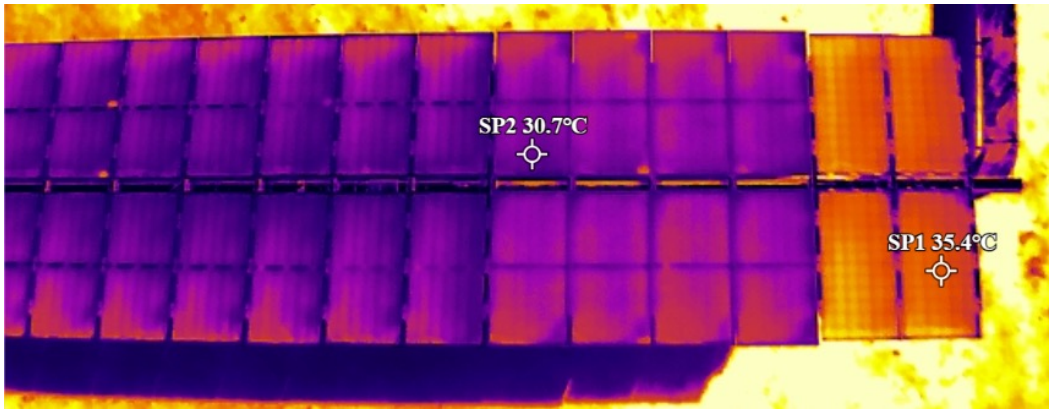


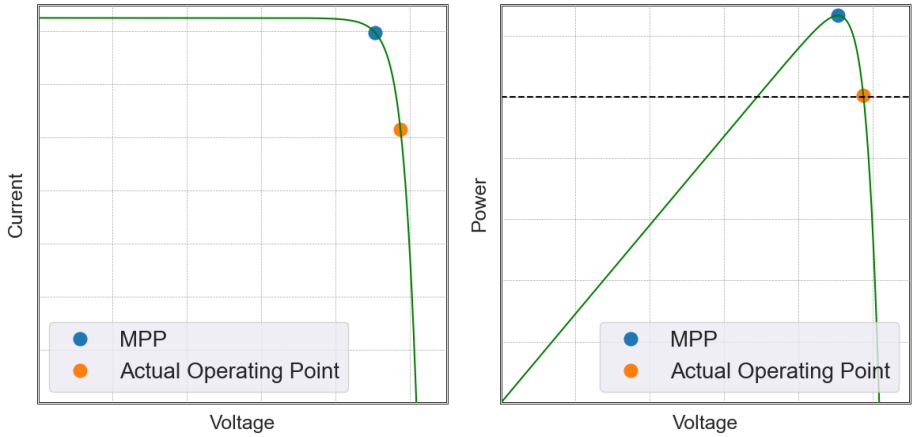


- Curtailment: Grid Management level
- Clipping: System Design Level

- California Independent System Operator. (n.d.). *Production and curtailments data*. Retrieved March 20, 2026, from https://www.caiso.com/library/production-curtailments-data

Clipping and Curtailment in Amplifies PV Stress and Limits

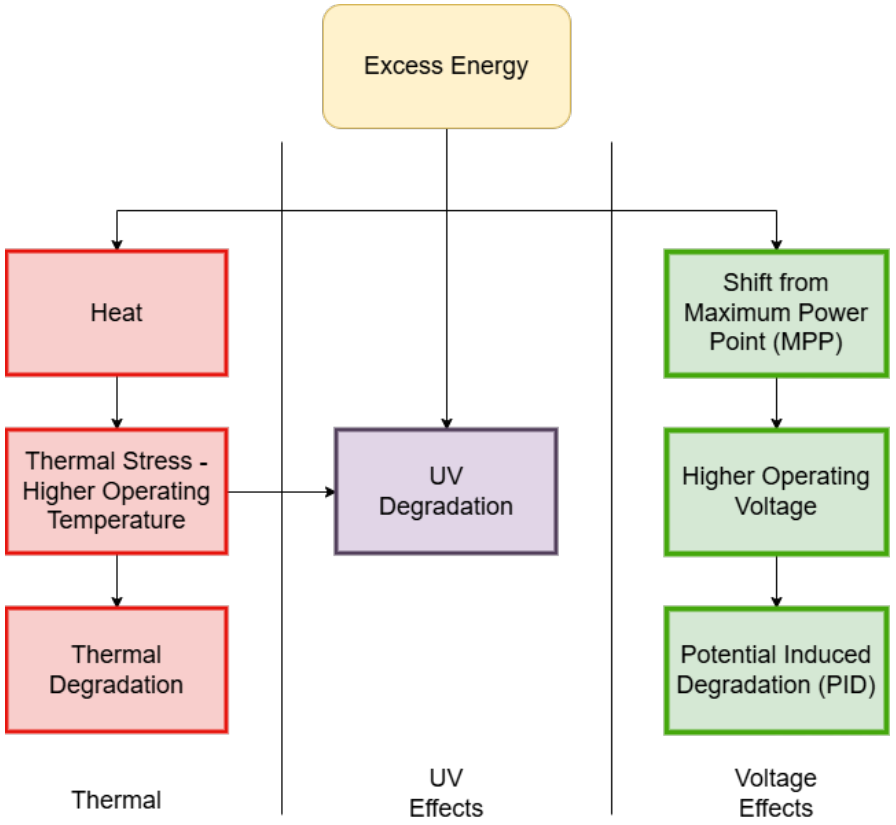


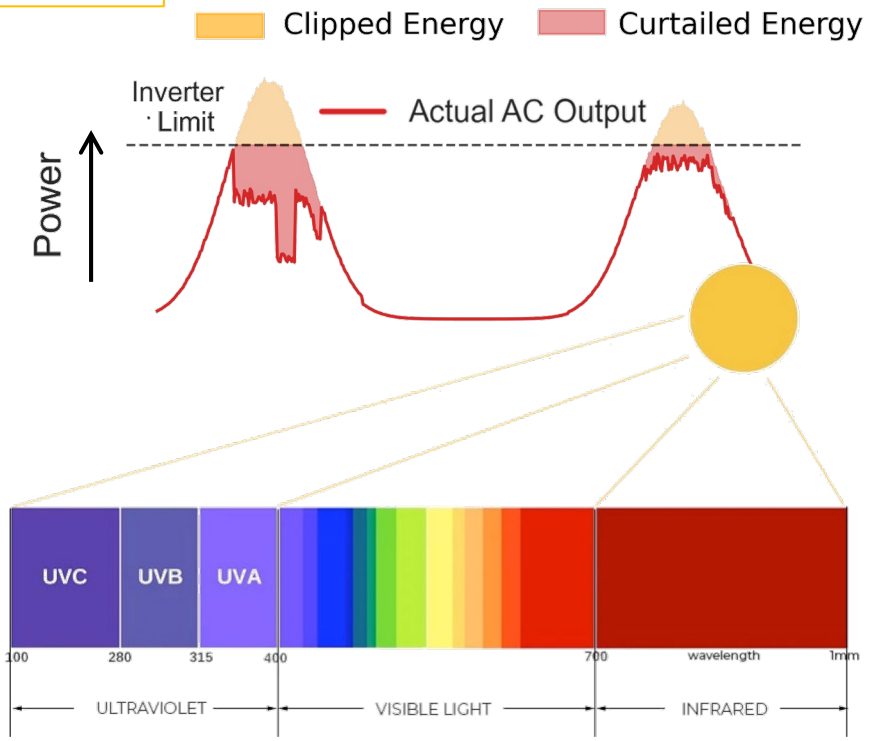


- Extra power dissipates as Heat
- **This temperature increase can significantly accelerate system degradation**

- Best Case scenario: BESS
- Worst Case scenario: ???

Elevated Thermal and UV Stress Under Operational Constraints



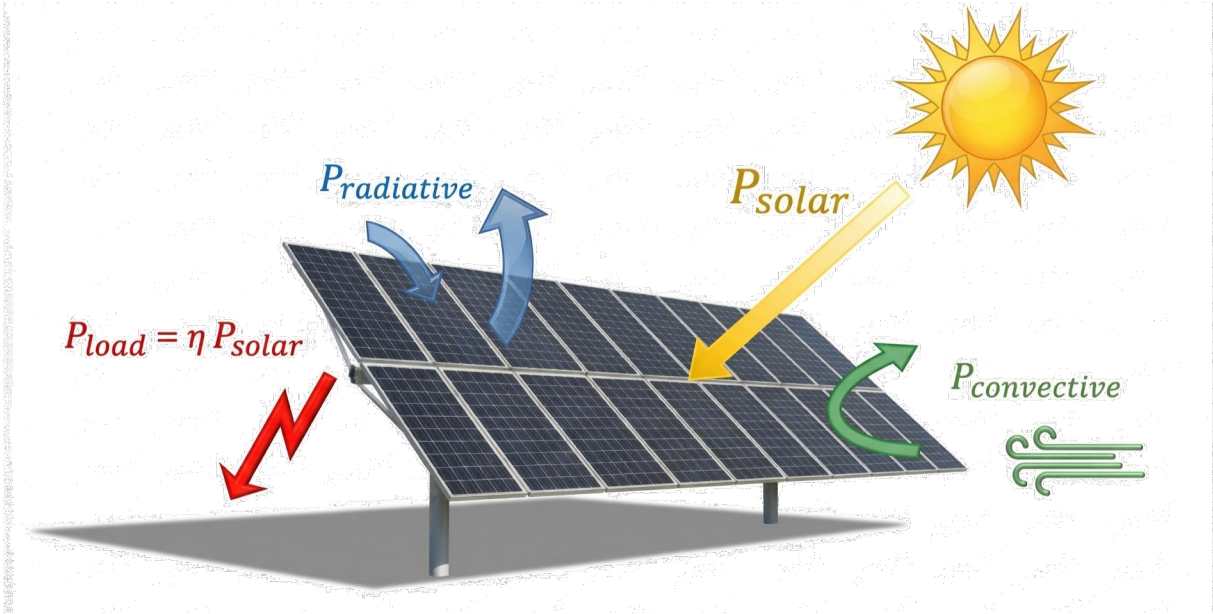


Better response in new technologies

Maximum Conversion to Electricity

Good Conversion & Part Not Absorbed

Heat Balance and Tilt: Controlling Module Temperature



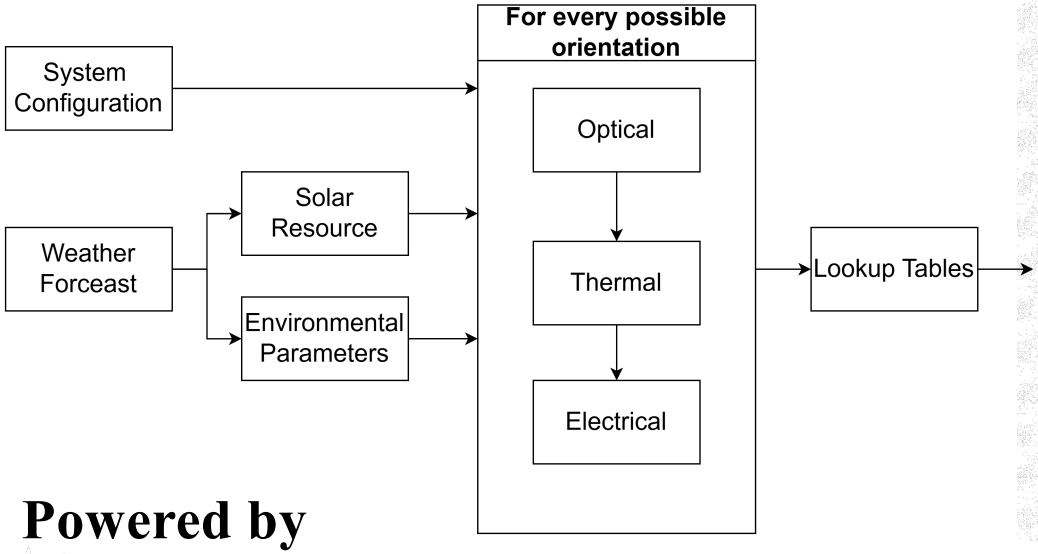
- $P_{solar} = f(Irradiance, \boldsymbol{\theta})$
- $P_{load} = f(T_{mod}, P_{solar}, \boldsymbol{Operation})$
- $P_{radiative} = f(T_{mod}, Q_{dr}, \boldsymbol{\theta})$
- $P_{convective} = f(T_{mod}, Environment, \boldsymbol{\theta})$

$$m_{mod} Cp_{mod} \frac{dT_{mod}}{dt} = P_{solar} - P_{load} - P_{radiative} - P_{convective}$$

$$T_{mod} = f\left(P_{load}, P_{solar}, P_{radiative}, P_{convective}\right)$$

$$T_{mod} = f(\theta)$$

UNSW Tracking Algorithm

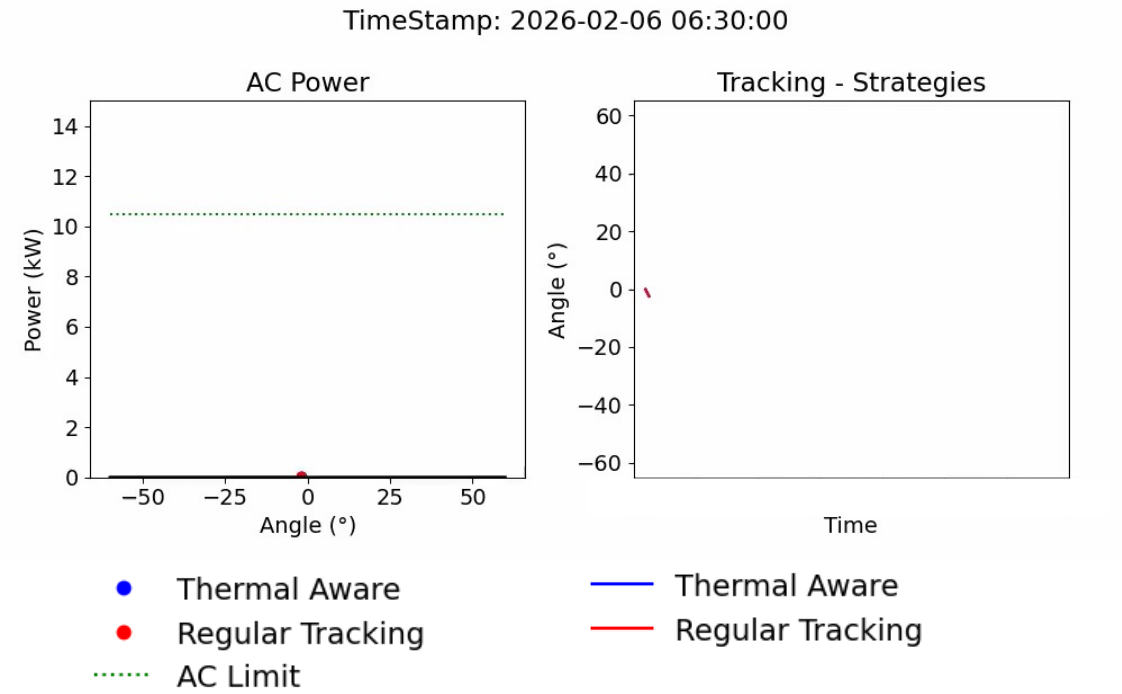


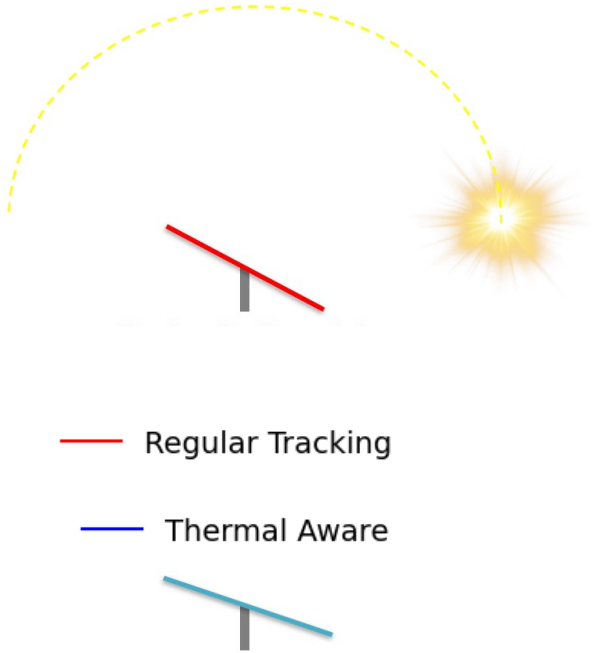
Powered by

pvlib

Manage the sun, don't chase it!

UNSW Tracking Algorithm





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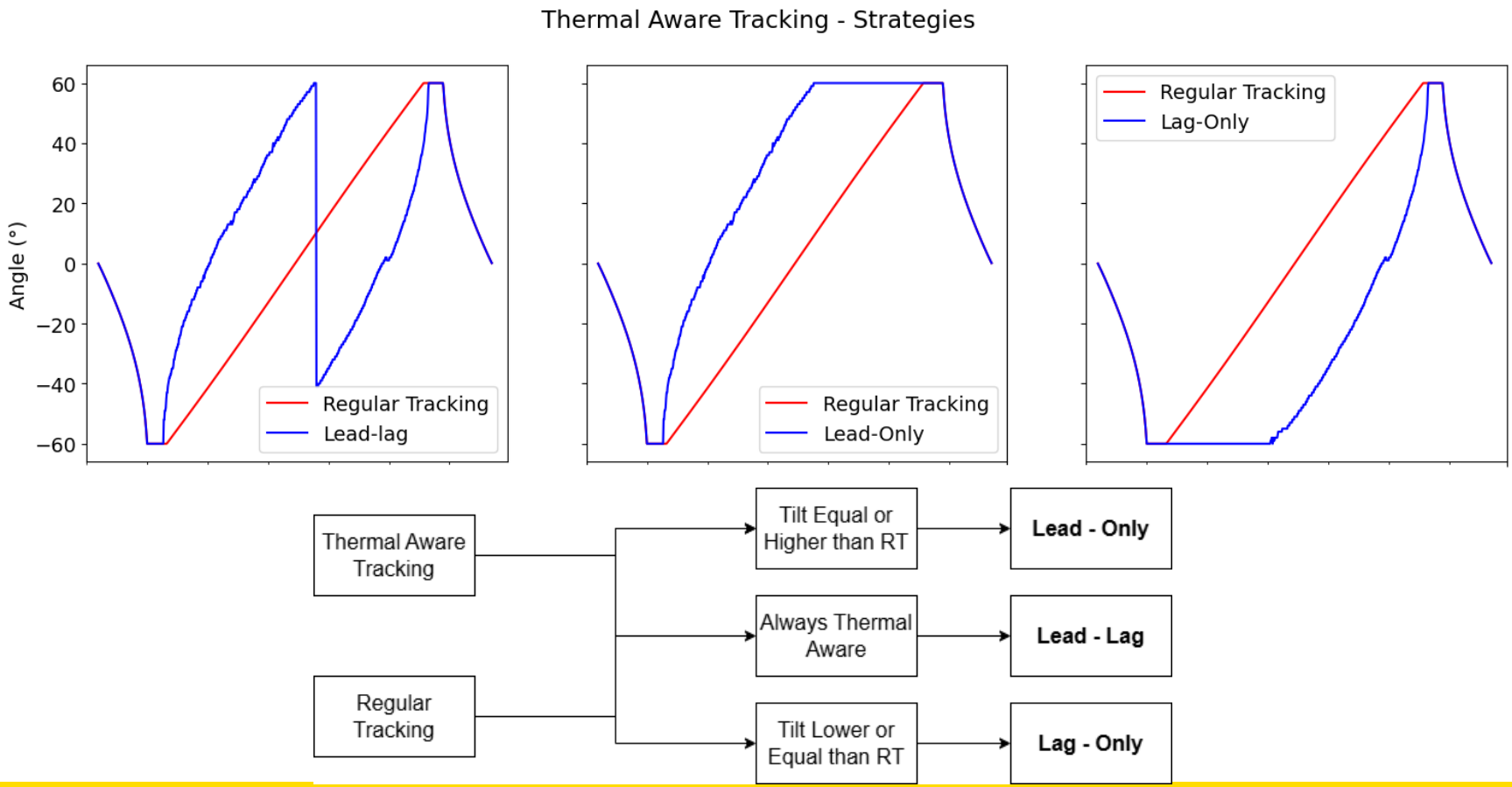

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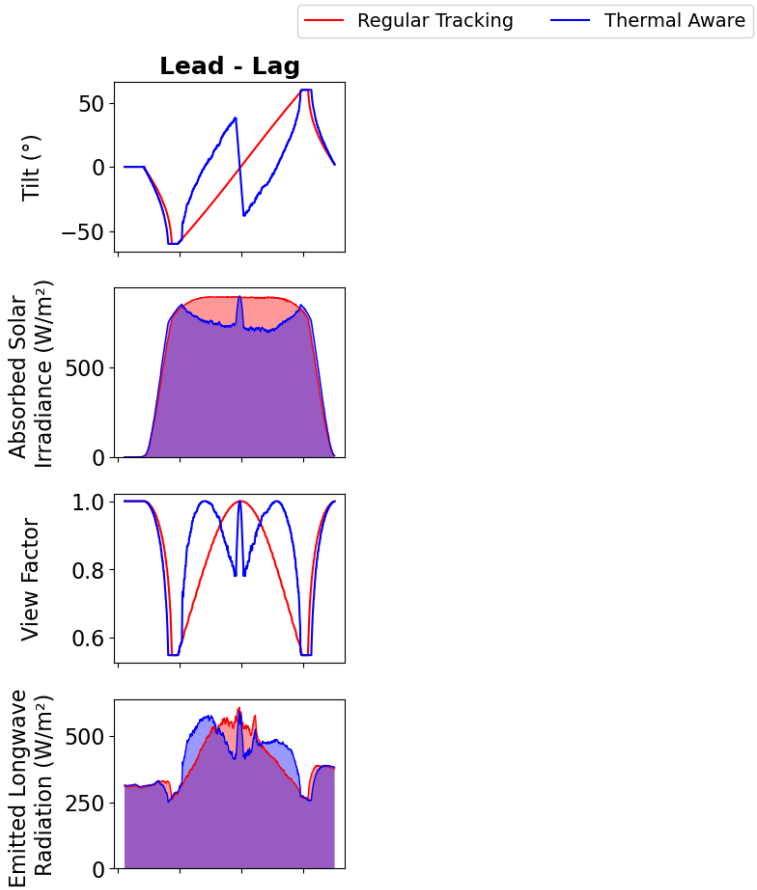

- Lead – Lag: Follows the alternative tracking during the entire day

  + Better Heat Exchange with the sky
  + Less absorbed Irradiance
  - Higher stress on the trackers

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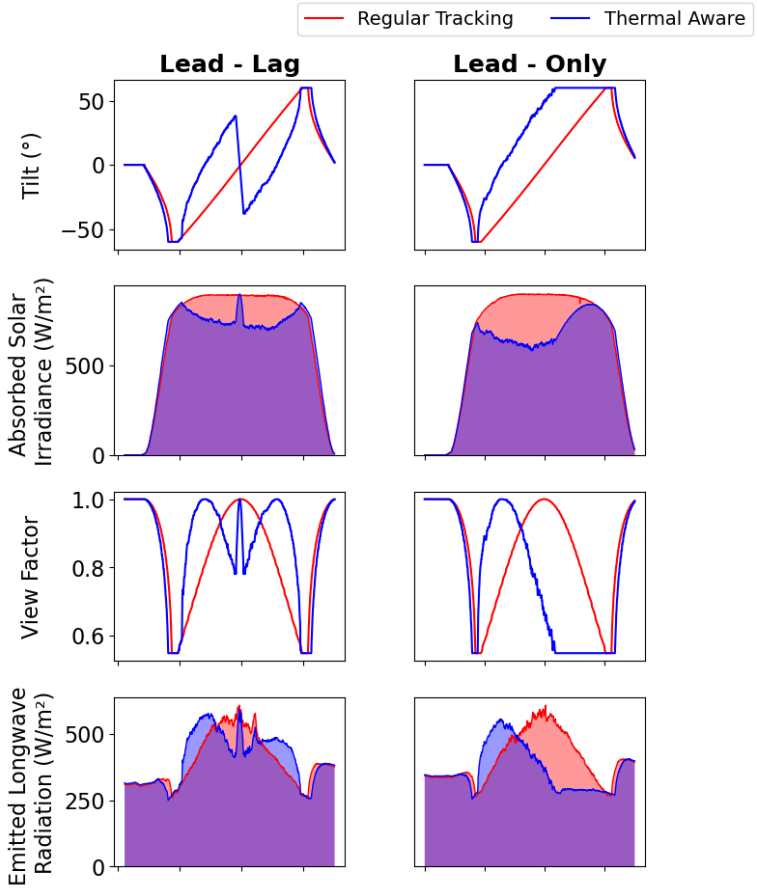
UNSW Tracking Algorithm



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- Lead – Only: Keeps tilt equal or higher than regular tracking

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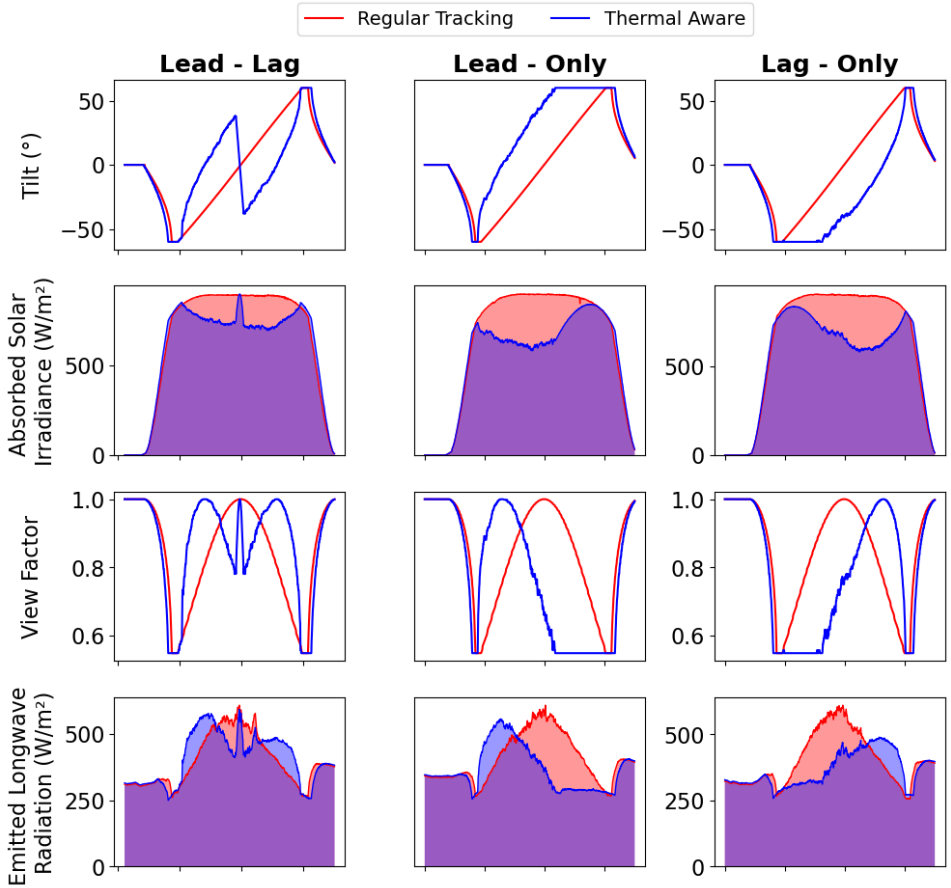

- Lead – Lag: Follows the alternative tracking during the entire day

  + Better Heat Exchange with the sky
  + Less absorbed Irradiance
  - Higher stress on the trackers

- Lead – Only: Keeps tilt equal or higher than regular tracking
- Lag – Only: Keeps tilt equal or lower than regular tracking

  + No extra stress on the trackers
  - Shorter Beneficial Window

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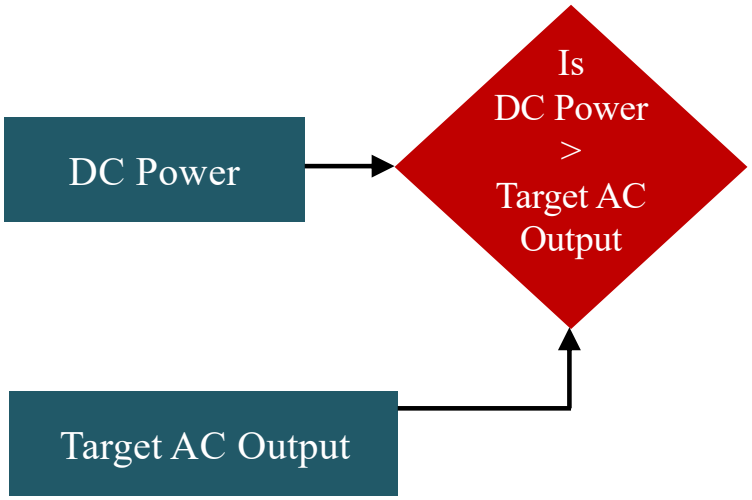

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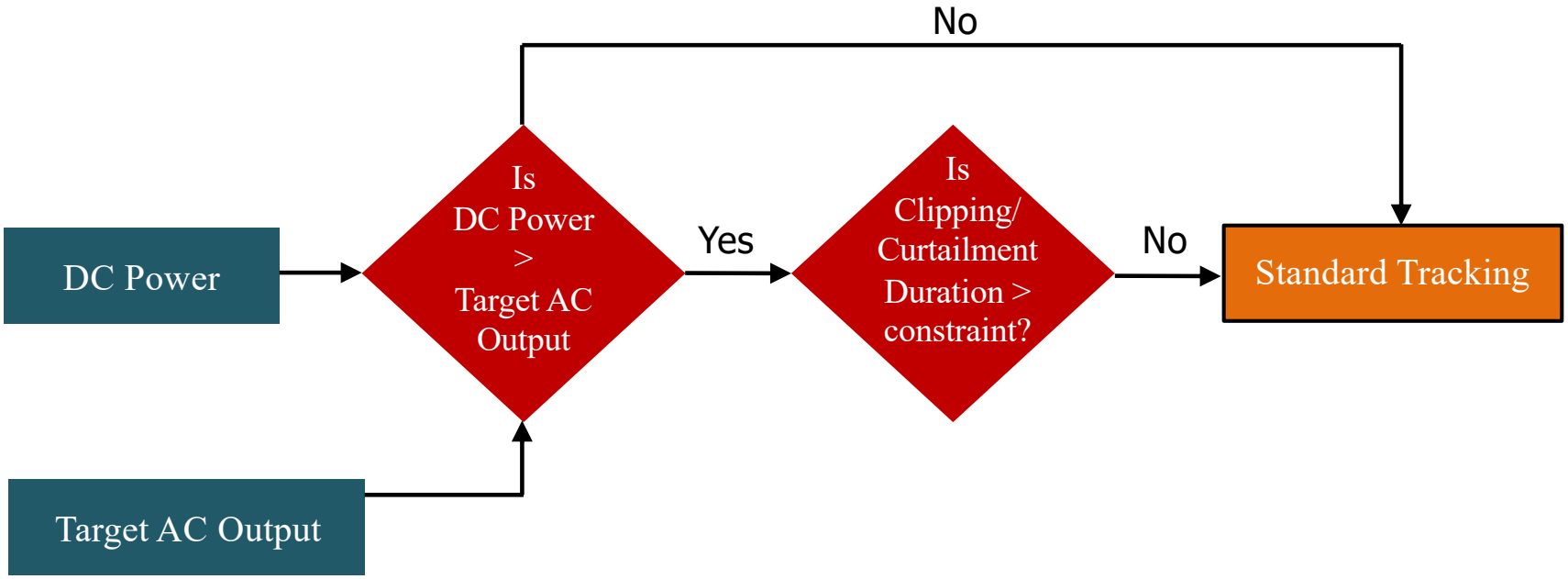

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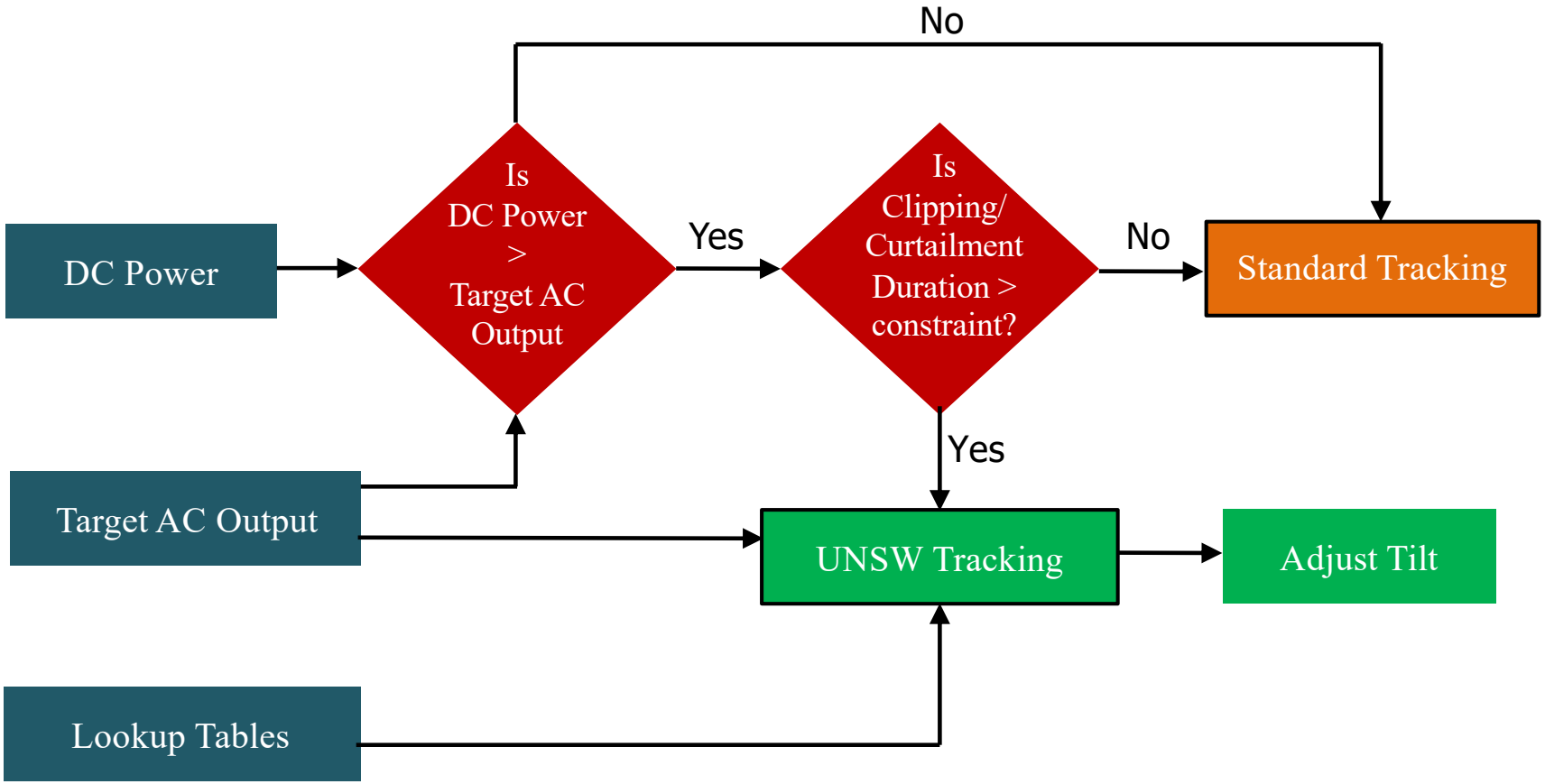

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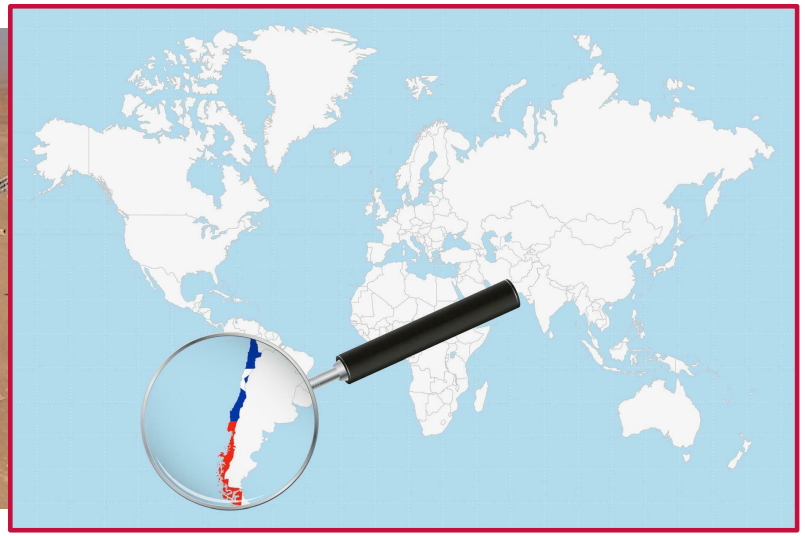
Case Study – Chile: Experimental Setup

- Conducted at Atacama Desert, Chile
- ATAMOSTEC Test Site at PSDA (Plataforma Solar del Desierto de Atacama)
- Winter 2025 – Summer 2026



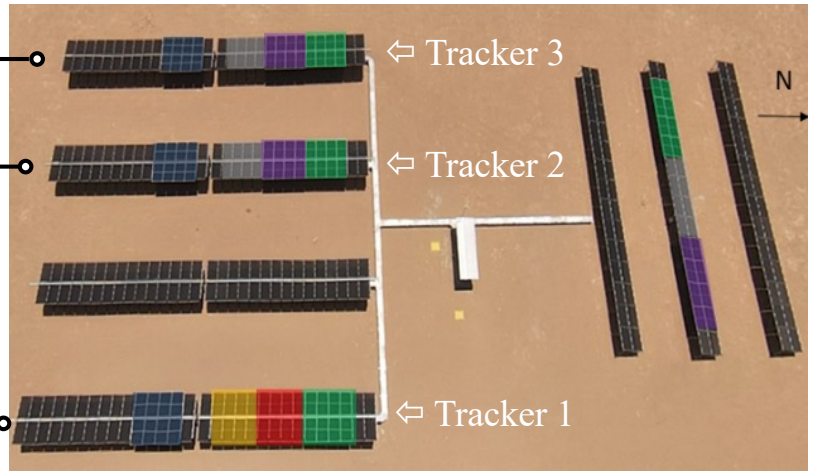
[Atacama Desert: 3SUN panels outperform PERC | INES - Institut National de l'Énergie Solaire]

Case Study – Chile: Experimental Setup

- Each tracker: 4 strings × 8 modules + 28 dummy modules
- Individual 60 kW inverter per tracker, 6 MPPTs (4 active → 12 kW total)

- Each MPPT monitors **DC output**
- Reference cells recorded **front and rear POAI**
- Weather station monitors **ambient temperature, wind speed and direction**
- PT100 sensors record **module Temperature**

3	**UNSW** Tracking	**DC clipping**
2	**Conventional** Tracking	**DC clipping**
1	**Conventional** Tracking	**No Clipping**



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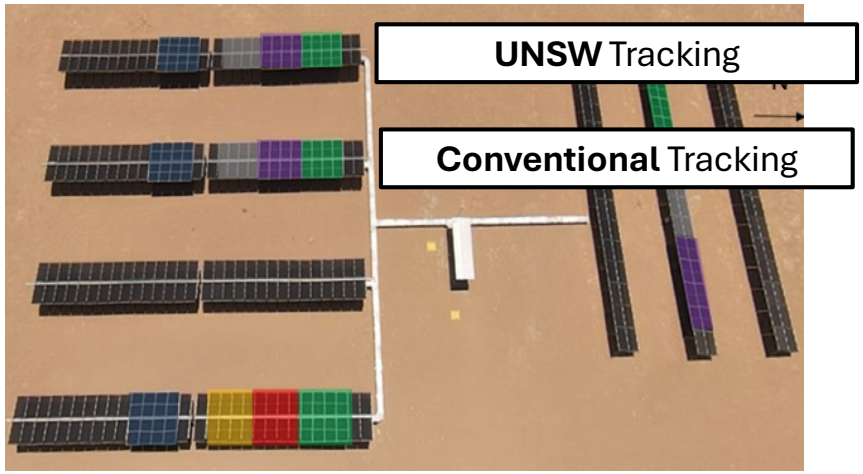
Case Study – Chile: Experimental Setup

Apply strategies to tilt off panel on Tracker 3

Lead-only: Panel tilt is **ahead** of the normal tracking position.
Lag-only: Panel tilt is **behind** of the normal tracking position.
Lead-Lag: Panel **leads** in the morning and **tilts off** (lags) in the afternoon.

	Winter - 2025	Summer - 2026
Lead-only	02-Jun to 10-Jun	19-Feb to 24-Feb 14-Mar to 15-Mar
Lag-only	-	25-Feb to 04-Mar
Lead-Lag:	11-Jun to 22-Jun	05-Mar to 12-Mar



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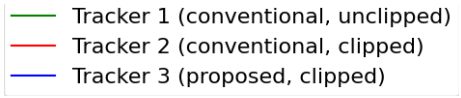
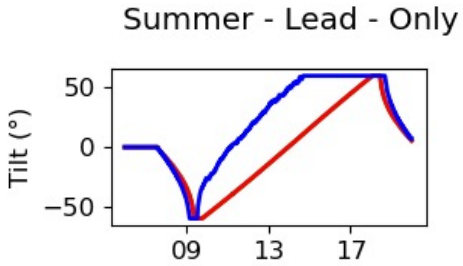
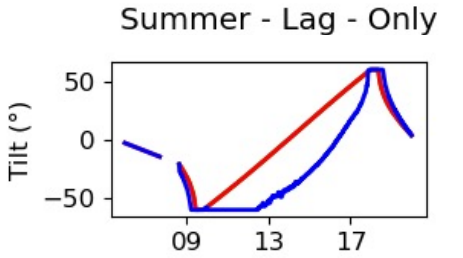
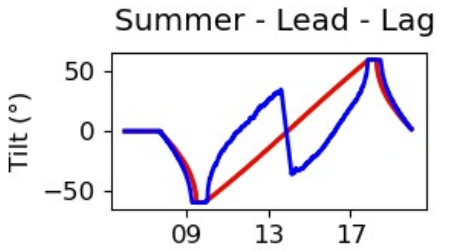
Case Study – Chile: Results and Insights

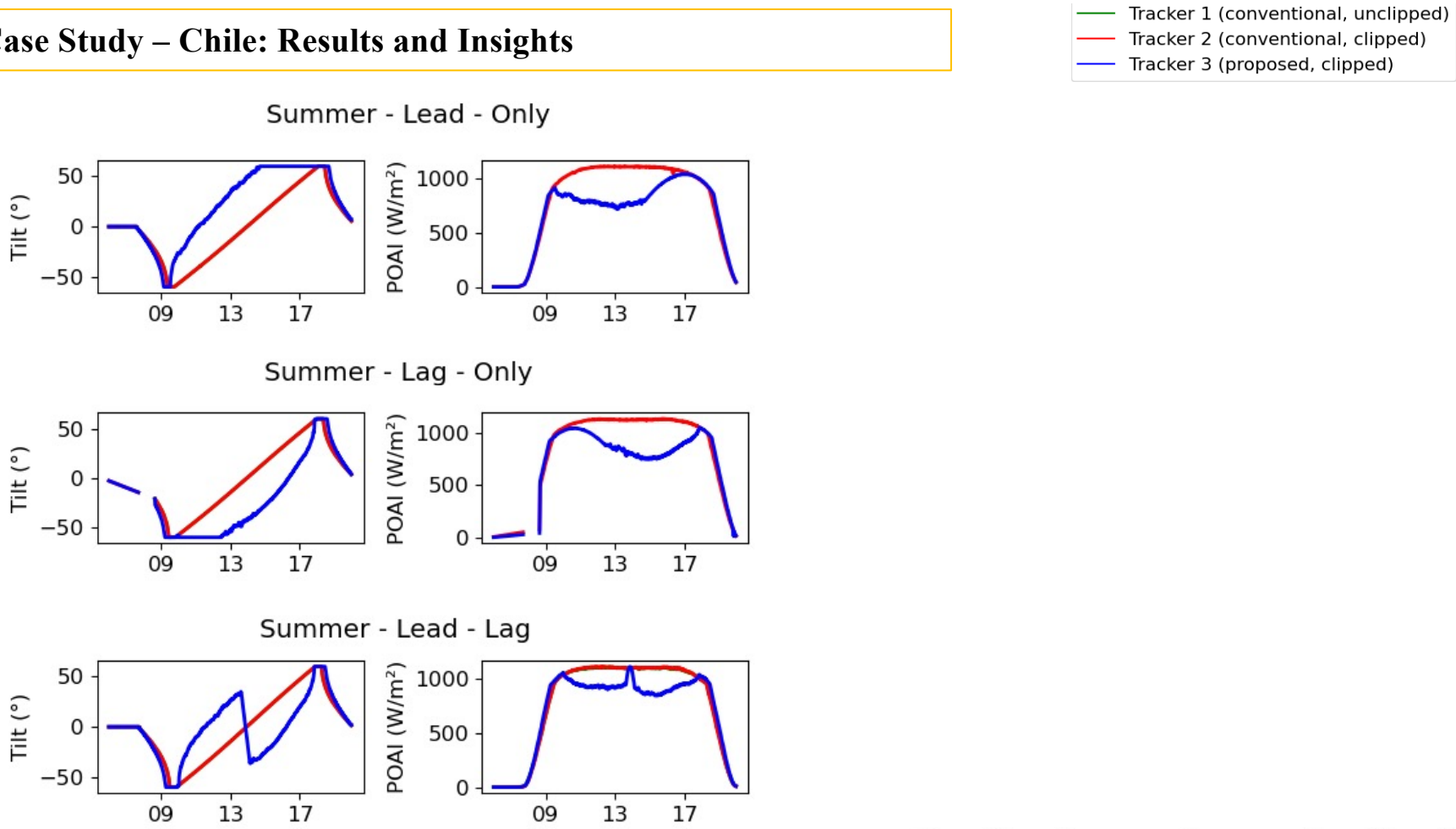








Case Study – Chile: Results and Insights



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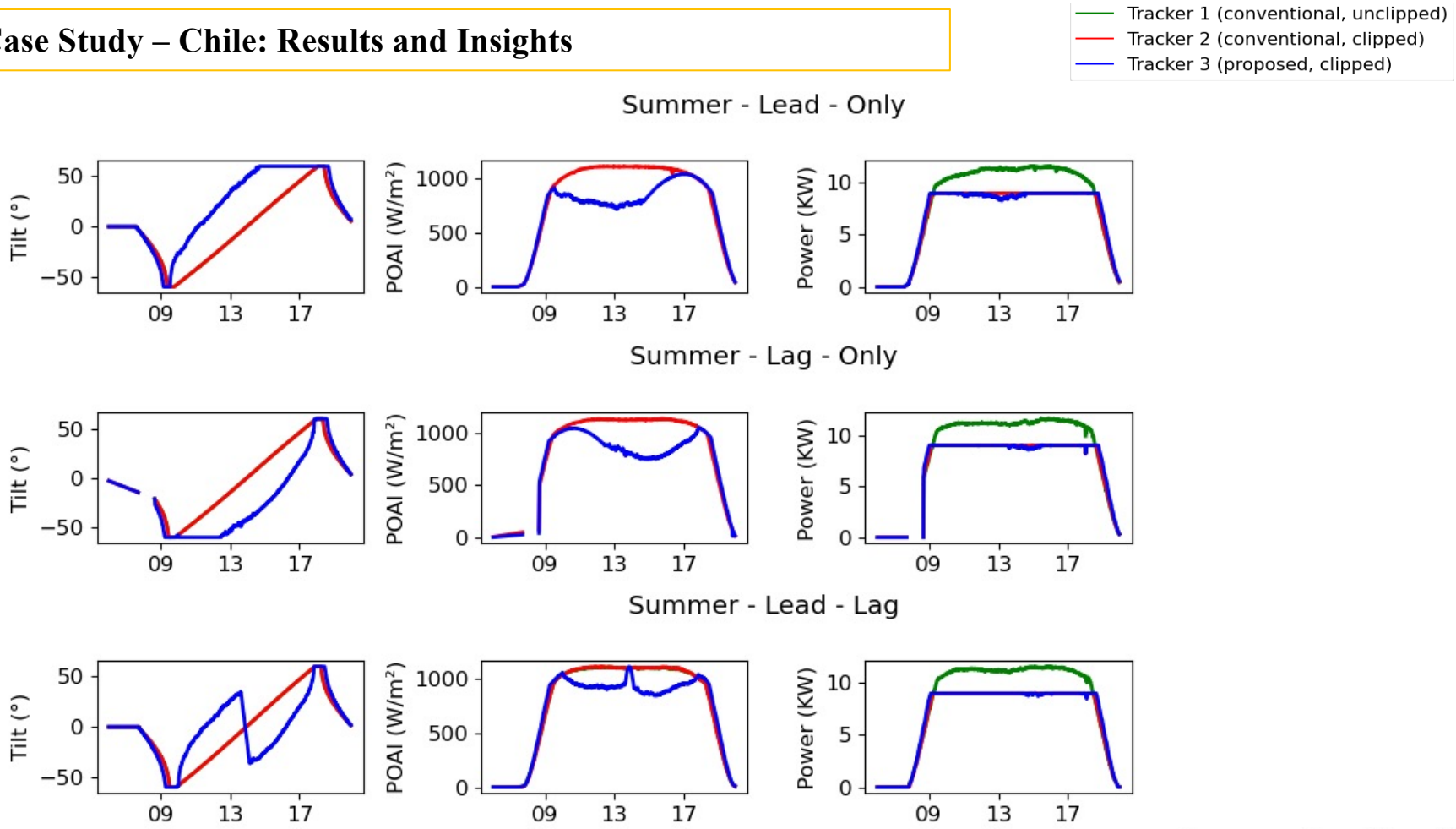

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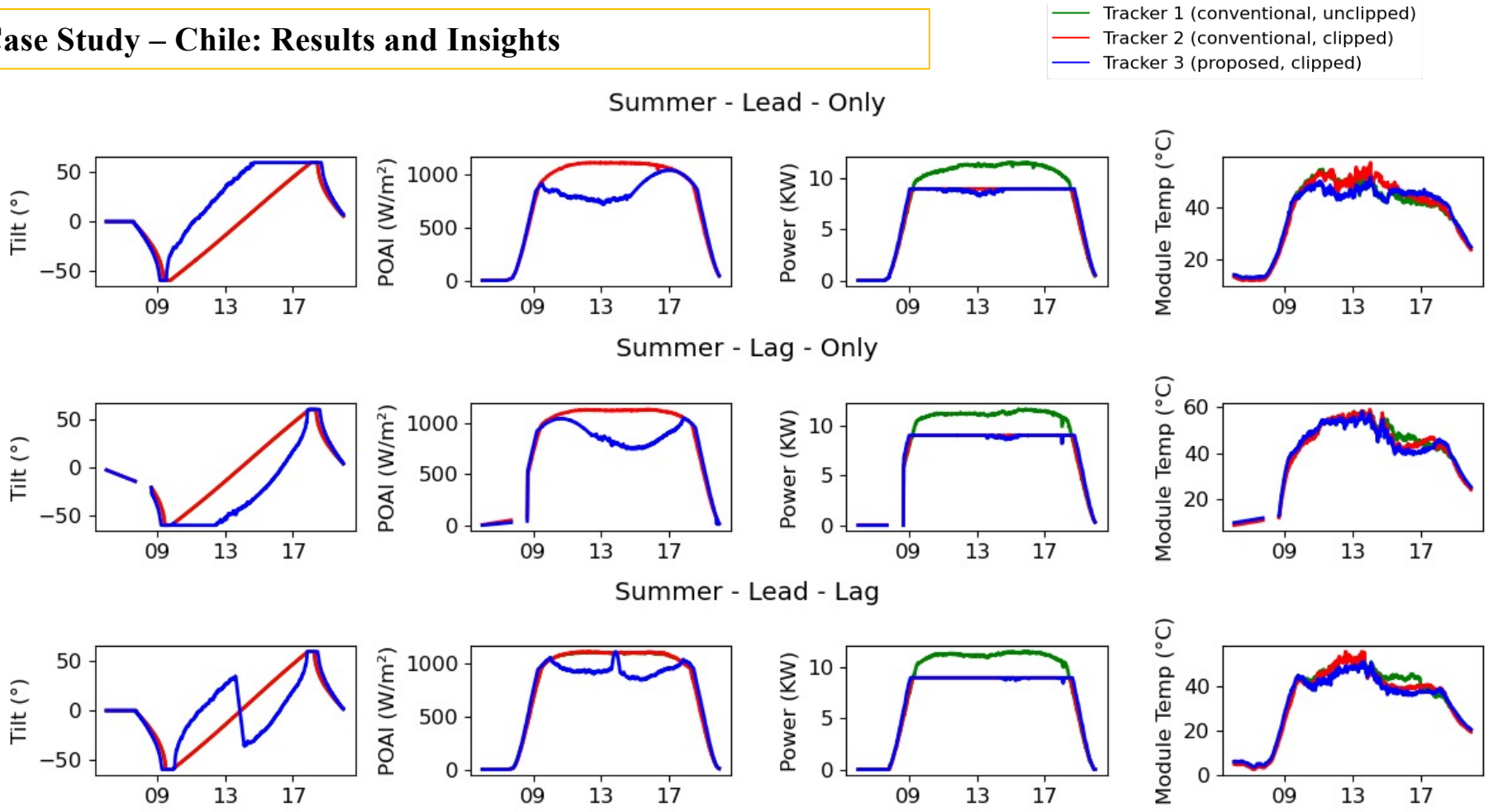

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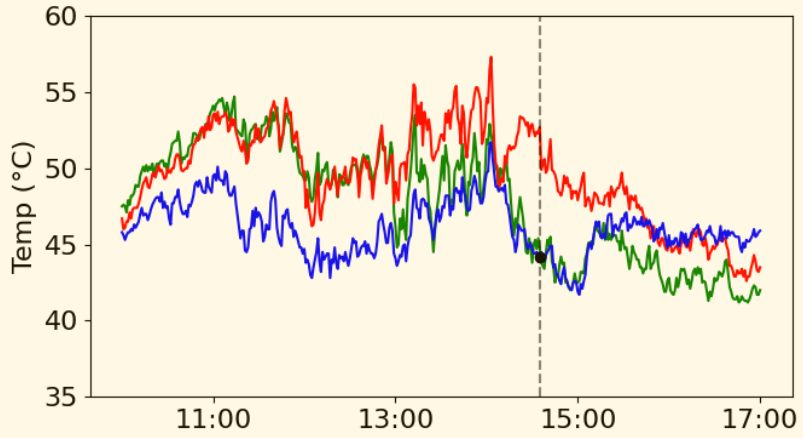
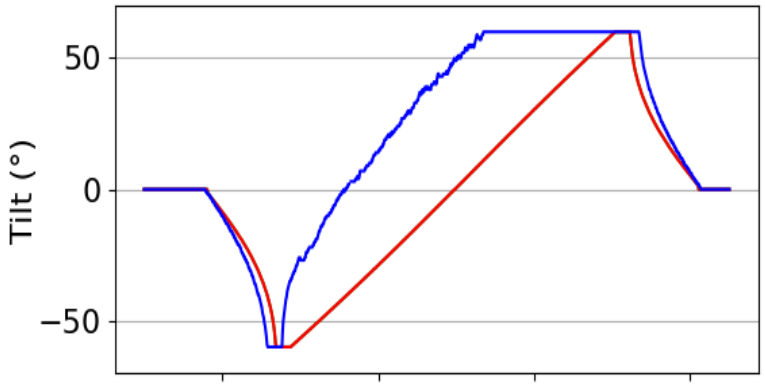
Case Study – Chile: Results and Insights (summer)

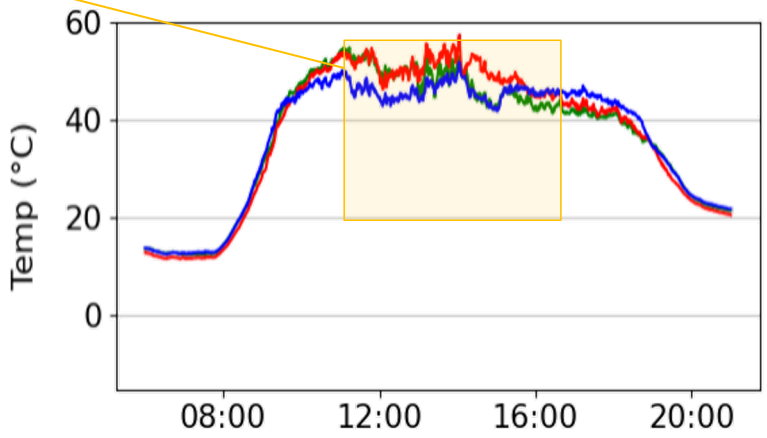
Temperature reduction up to 8.5 °C

Max T (Tracker 2) = 57.3 °C

Tracker 1 = 54.7 °C, Tracker 3 = 51.7 °C







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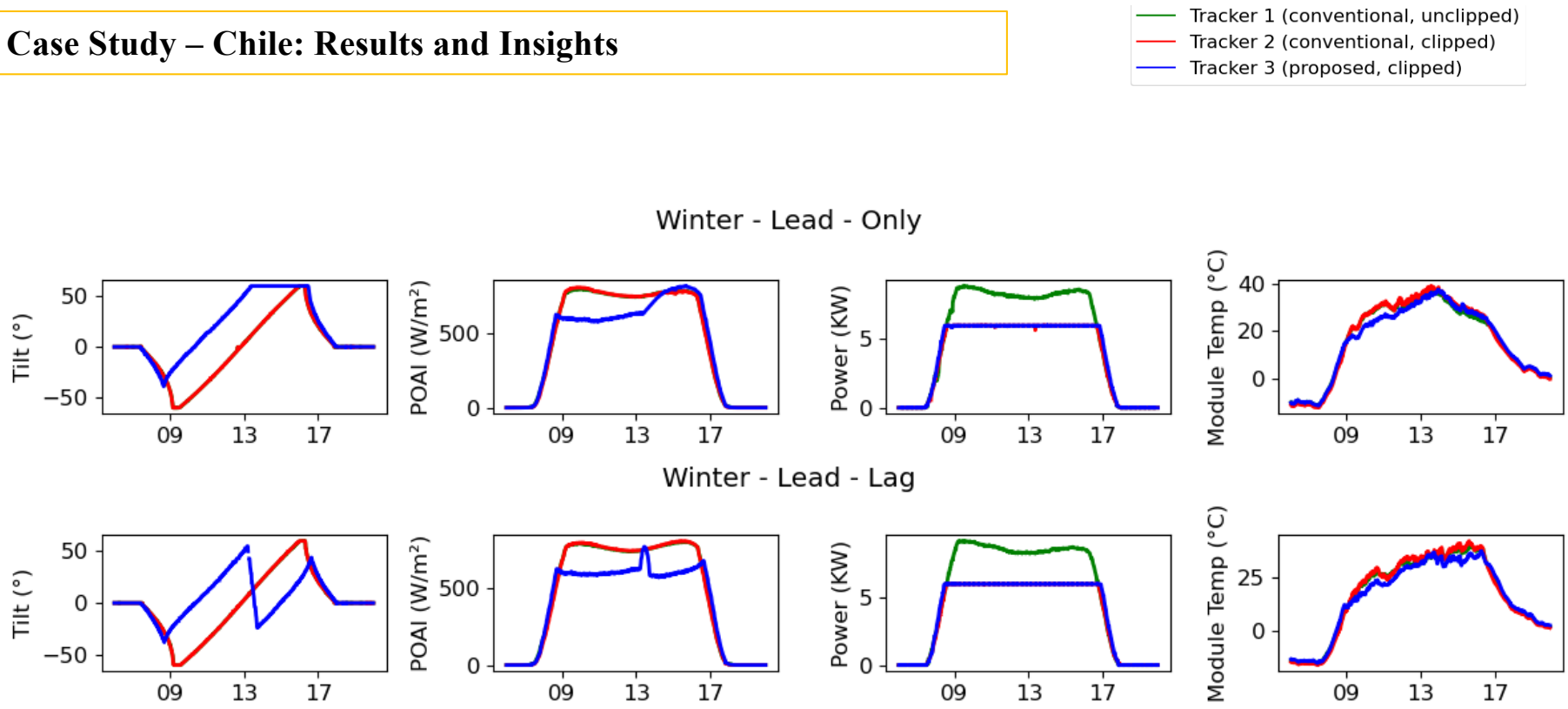
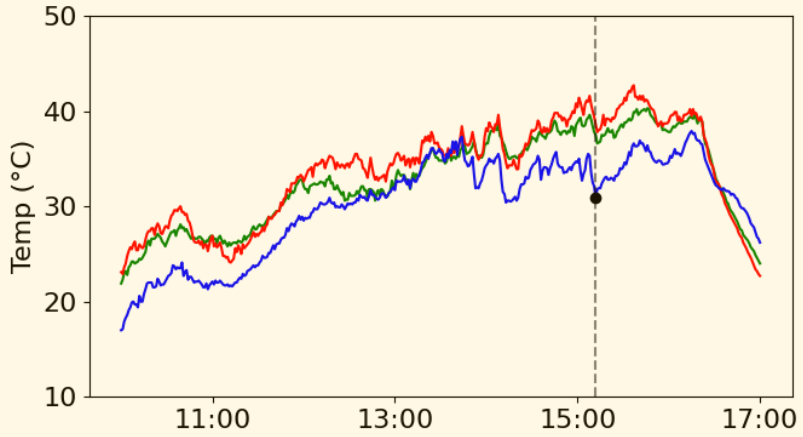


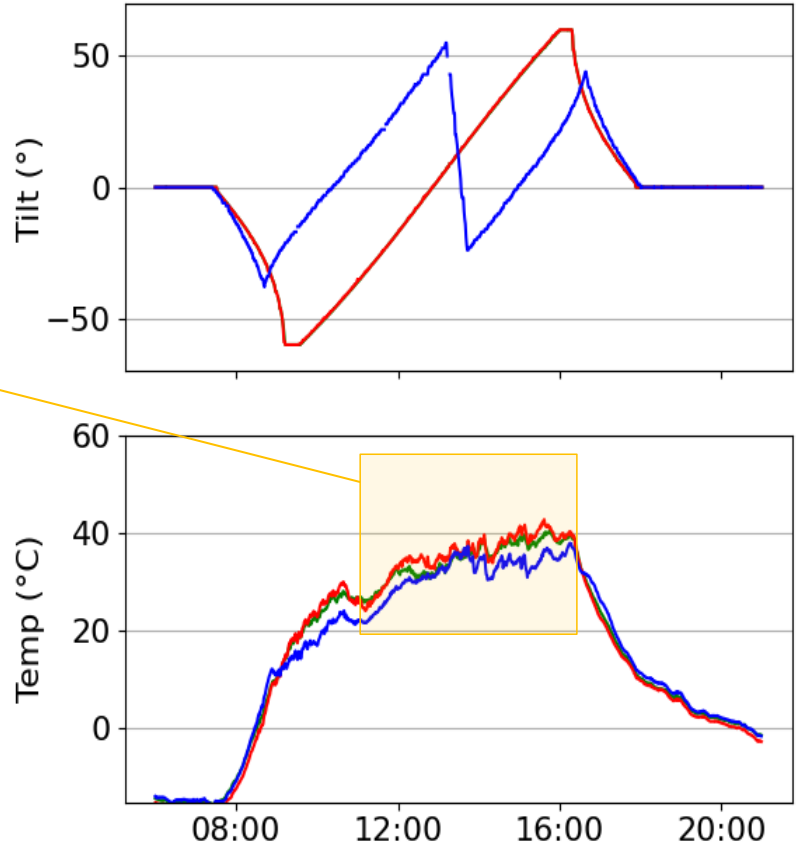
Case Study – Chile: Results and Insights (winter)

Temperature reduction up to 7.7 °C

Max T (Tracker 2) = 42.7 °C

Tracker 1 = 40.3 °C, Tracker 3 = 40.9 °C





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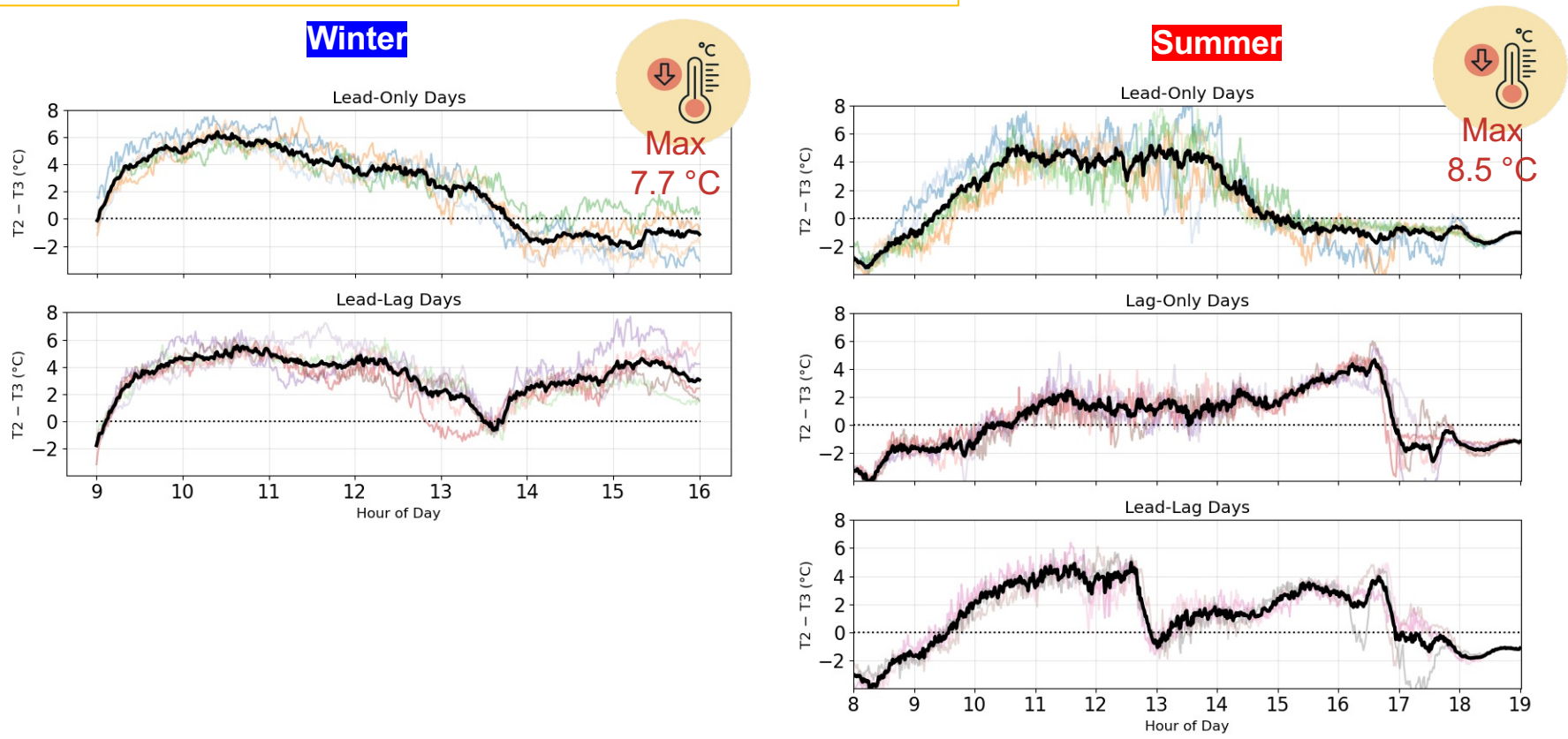

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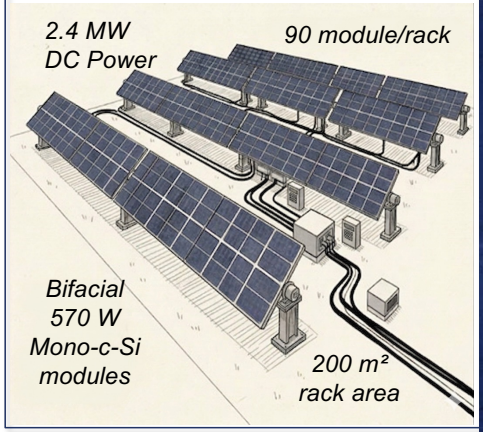
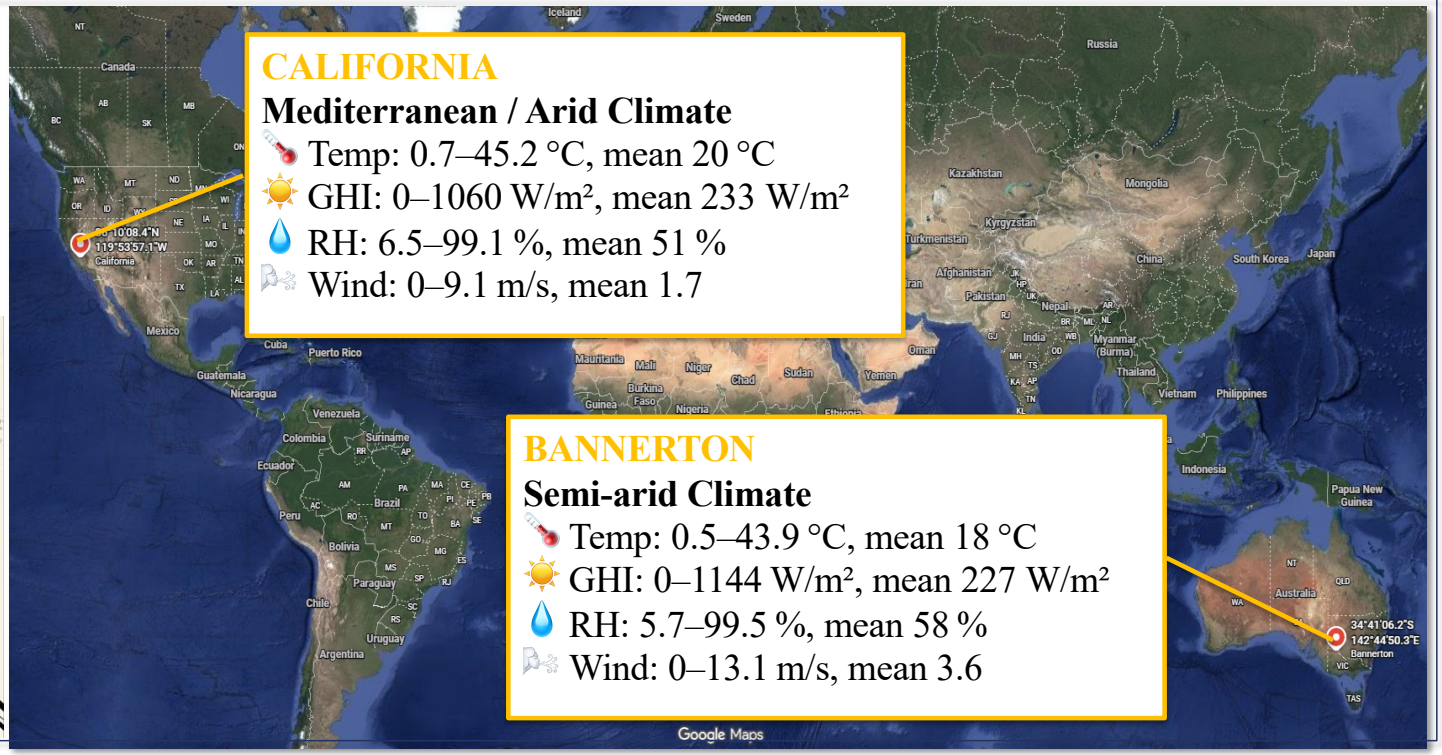
Generic Solar Farm Performance Simulation

Simulate a **generic system** at each location in **2024** under both clipping and curtailment scenarios





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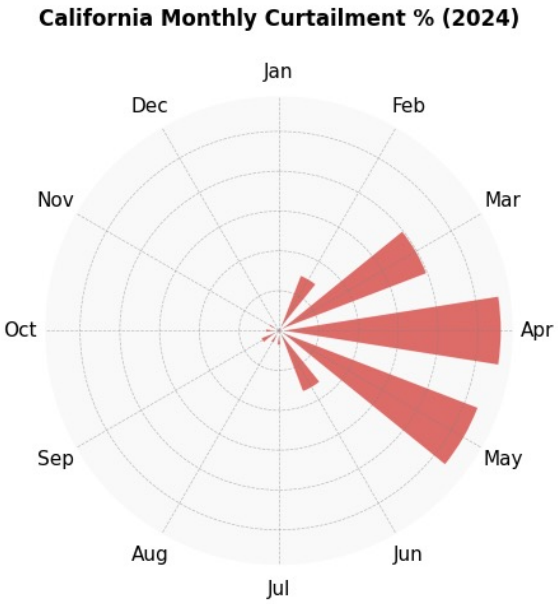

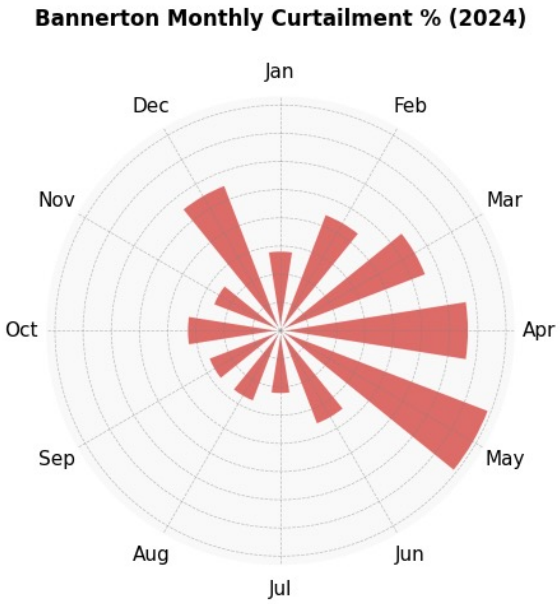

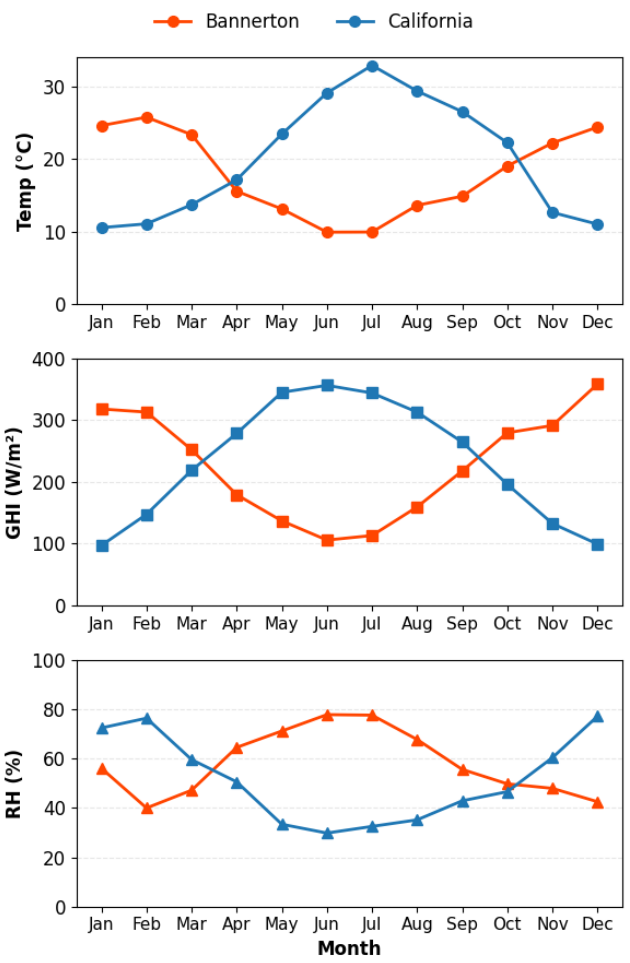

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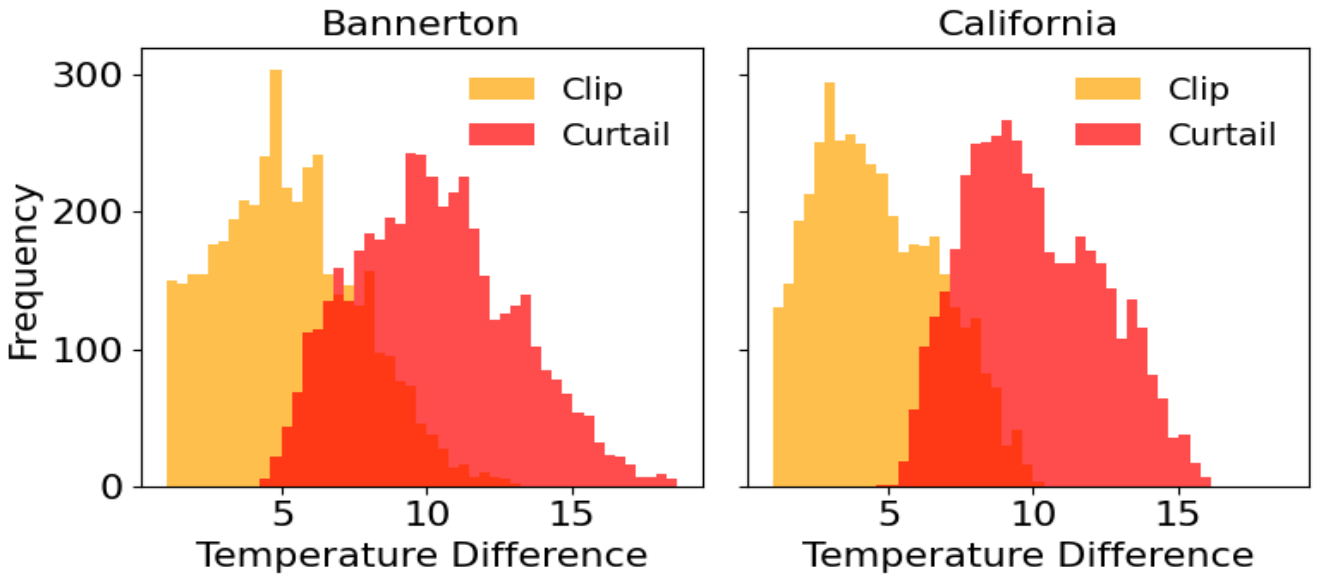
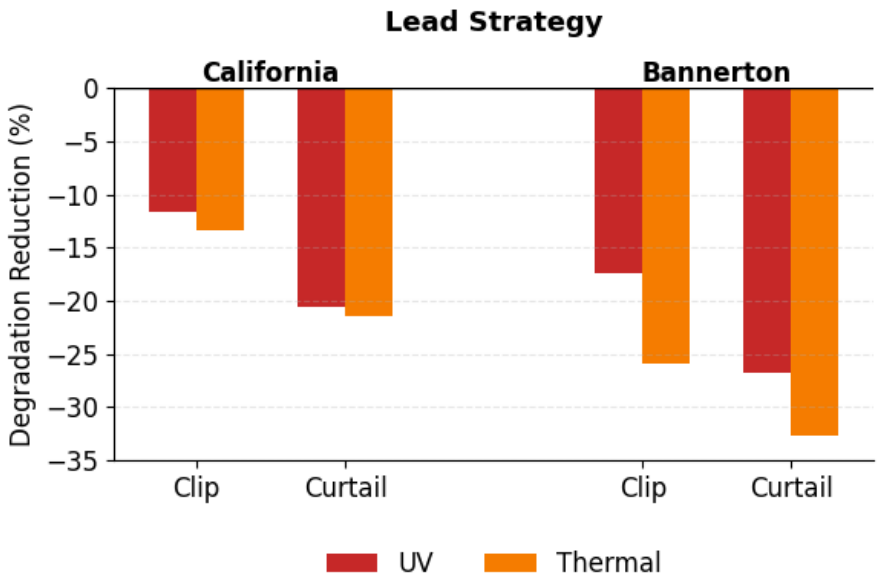


Generic Solar Farm Performance Simulation

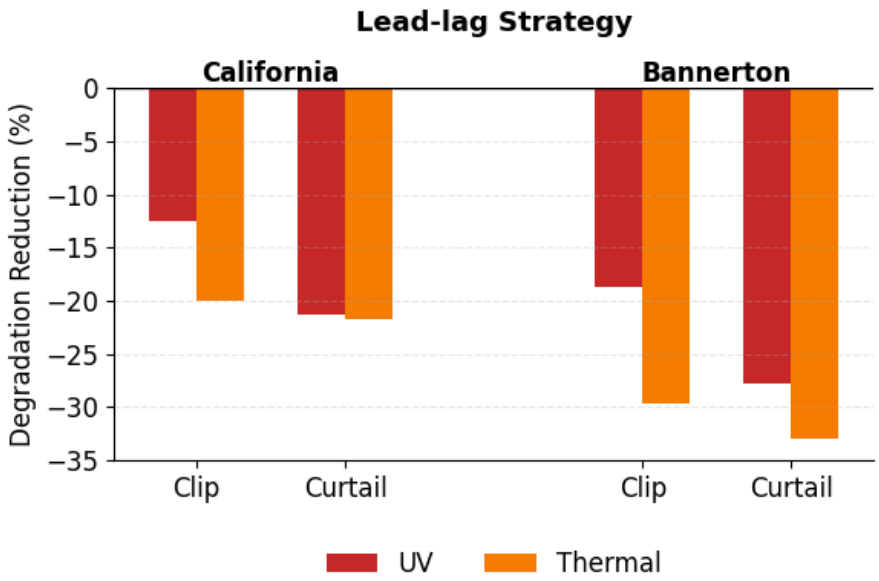
Thermal Degradation

$$R_{deg,thermal} = Ae^{-\frac{E_A}{kT}}$$



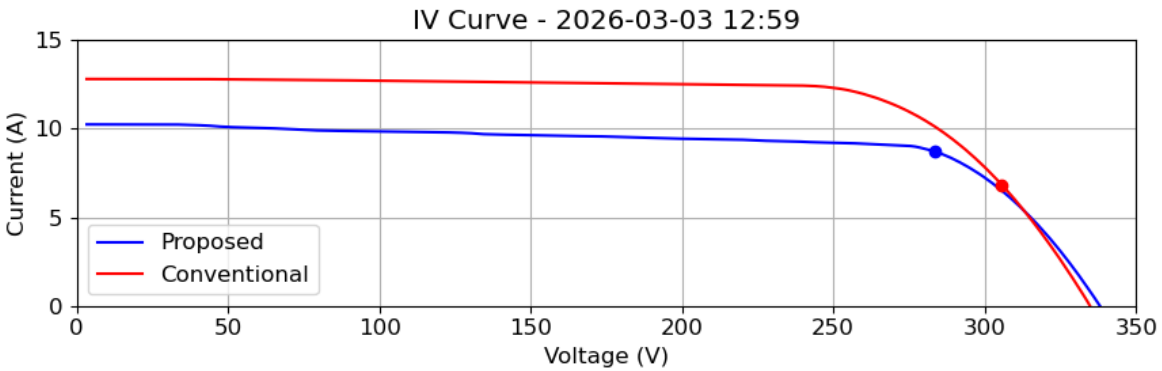
UV Degradation

$$R_{deg,UV} = A \cdot UV^{0,63} \cdot (1 + RH_{eff}^{1,8})e^{-\frac{E_A}{kT}}$$



Conclusion

- Our UNSW Tracking Algorithm **reduces module temperature** and **reduces UV dose** during clipping and curtailment **while sustaining maximum energy output**.
- Validated through real-world testing in Chile.
  - Lead–lag control with shallower tilt **improved cooling**.
  - Reduction up to **8.5 °C**.
- **Future Work:**
  - Explore impact on inverters.
  - Explore integration with **battery storage** for combined thermal and energy optimization.



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