Evaluation of Snow Losses in a Vertical Agrivoltaic and Ground-Mounted Fixed-Tilt Bifacial PV Systems



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Background

- Bifacial PV modules have gained attention due to their **additional energy gain** (vs. monofacial) especially in high-latitude regions [1].
- The reflectivity of the ground, particularly in sites that experience snowfall (high albedo), influences the performance of bifacial systems.
- Accurately estimating **snow losses** caused by snow coverage on the PV modules is a challenging issue.
  - Models have been developed [2]
  - Higher in monofacial, lower in bifacial modules [3]
  - Climate, yearly conditions and system design dependent [4]

Goals

- ✓ Show the **performance of two types of bifacial systems** in a high-latitude region during **snowy winter days**: a vertical agrivoltaic (VPAV) system and a ground-mounted (GM) with a fixed 30° tilt angle.
- ✓ Enhance our **comprehension of snow-related losses** in these two system types to facilitate the development of more accurate models for estimating snow losses.

[1] L. Burnham, D. Riley, and J. Braid, "Design Considerations for Photovoltaic Systems Deployed in Snowy Climates," 37th Eur. Photovolt. Sol. Energy Conf. Exhib. 1626-1631
[2] R. E. Pawluk, Y. Chen, and Y. She, "Photovoltaic electricity generation loss due to snow – A literature review on influence factors, estimation, and mitigation," Renew. Sustain. Energy Rev., vol. 107, pp. 171–182, Jun. 2019
[3] K. S. Hayibo, A. Petsiuk, P. Mayville, L. Brown, and J. M. Pearce, "Monofacial vs bifacial solar photovoltaic systems in snowy environments," Renew. Energy, vol. 193, pp. 657–668, Jun. 2022
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Methodology: Snow Loss Calculation

System 1: 22.8 kW_p vertical configuration with an east-west orientation with Jolywood frameless mono-Si modules (JW-D72N-380).

System 2: 11.8 kWp GM configuration with a 30° tilt and south orientation, with Longi framed mono-Si modules (LR4-60HBD-370M).

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Production data (AC power) is collected every 5-min for two bifacial PV systems.

Measured / real power

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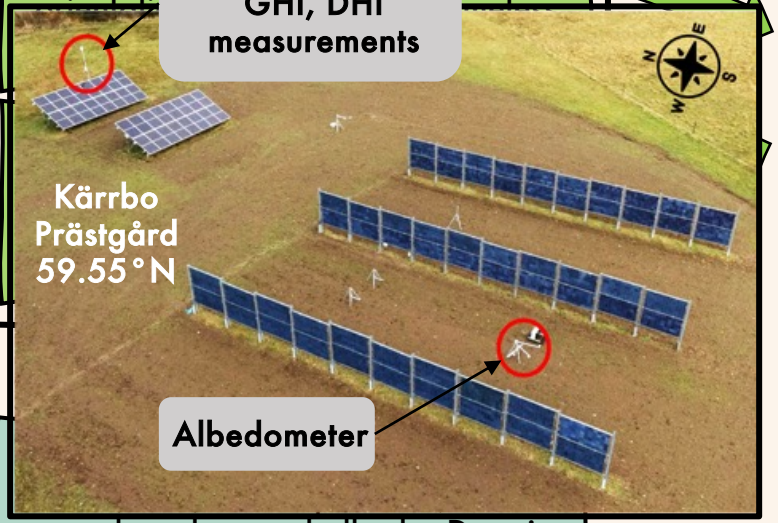
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Monitored parameters (1-min) of GHI, DHI, air temperature, wind speed, and ground albedo. Data is quality-controlled and resampled to align with the production data.

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Syste… …ical
config… …west



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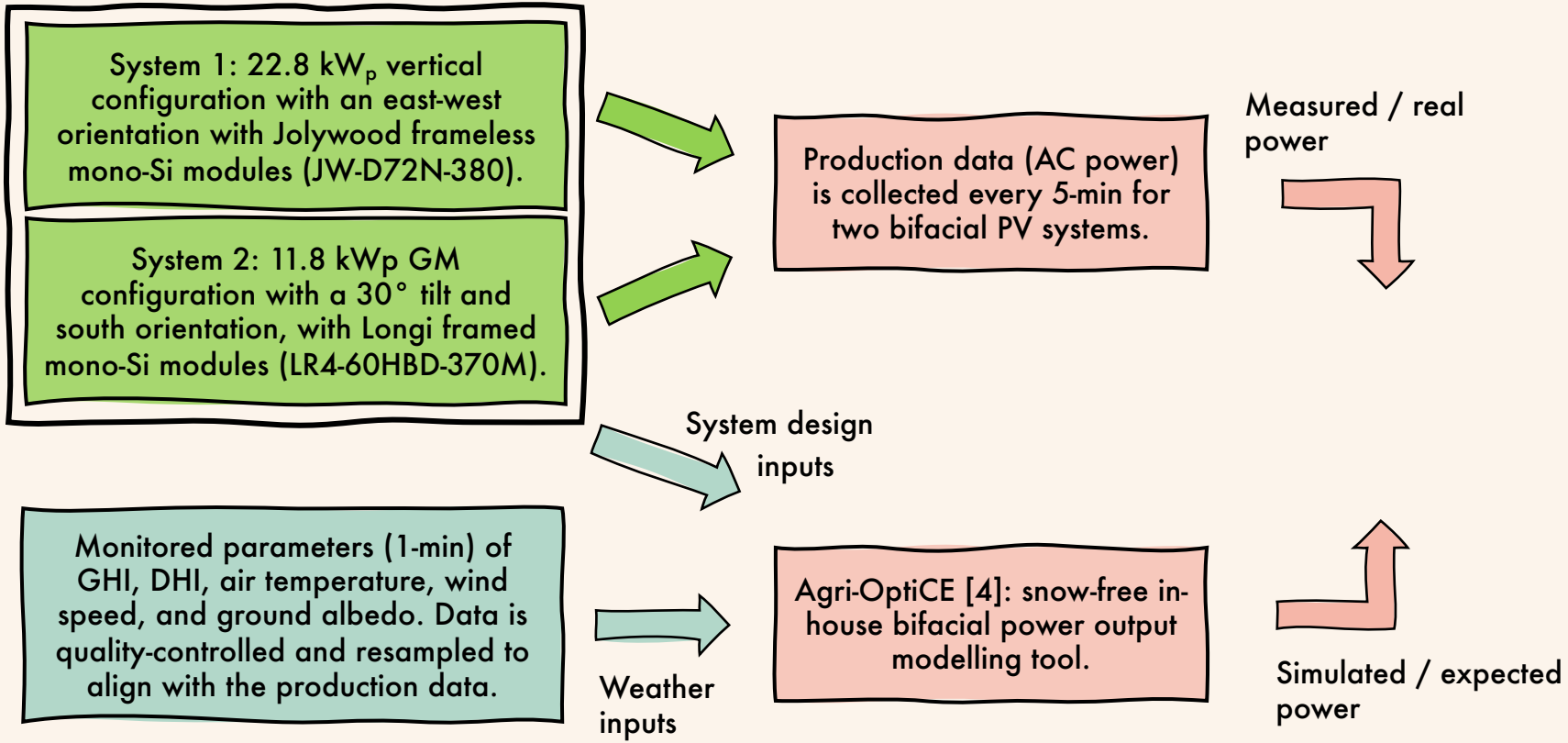
System design inputs

Monitored parameters (1-min) of GHI, DHI, air temperature, wind speed, and ground albedo. Data is quality-controlled and resampled to align with the production data.

Weather inputs

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Weather inputs

Agri-OptiCE [4]: snow-free in-house bifacial power output modelling tool.

Simulated / expected power

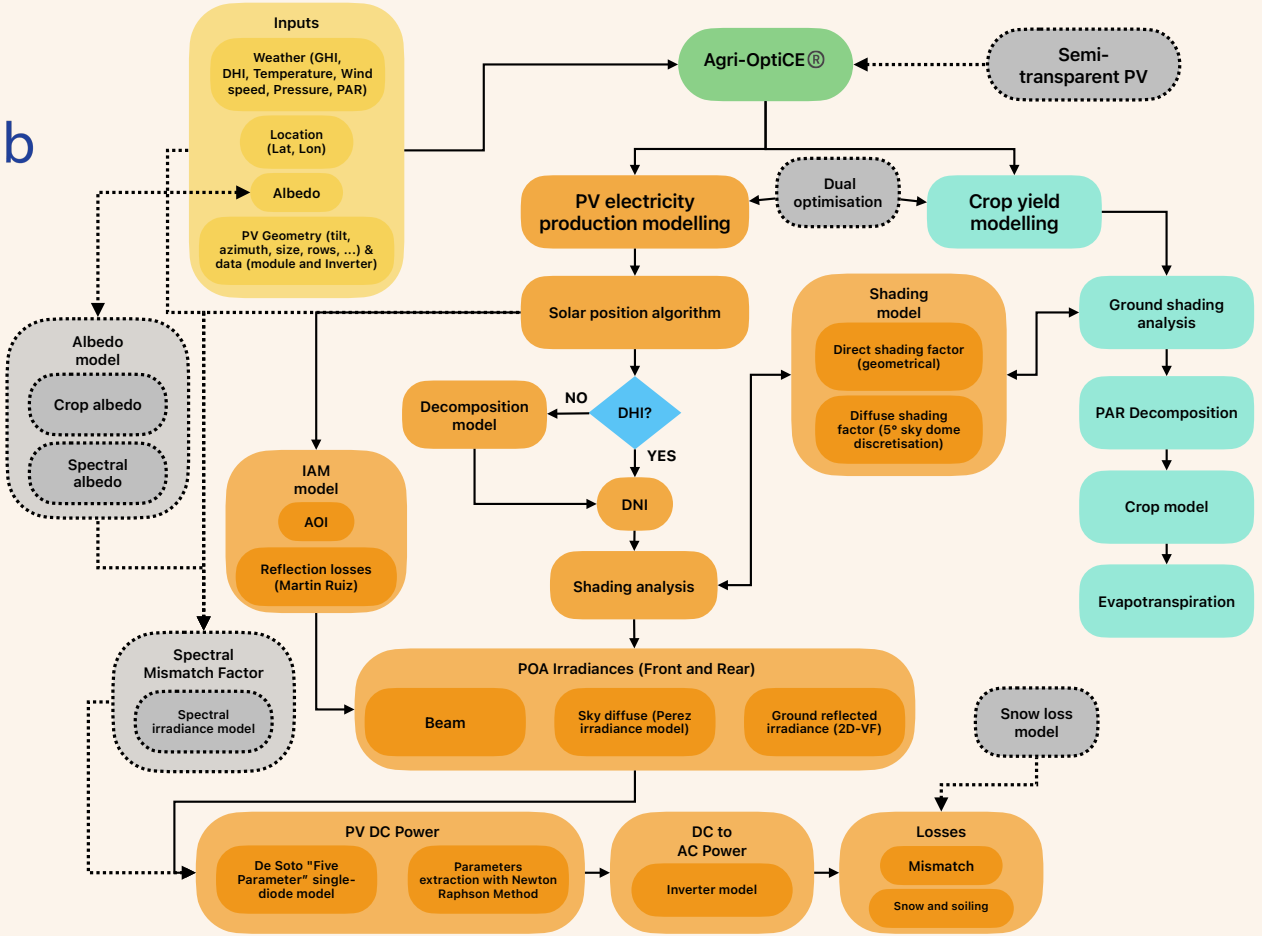
Snow losses calculated similarly as in [1], [2] and [3]:

$$Snow\ loss\ (\%) = \frac{Expected\ power - Real\ power}{Expected\ power}$$

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Agri-OptiCE

MATLAB® pvlib

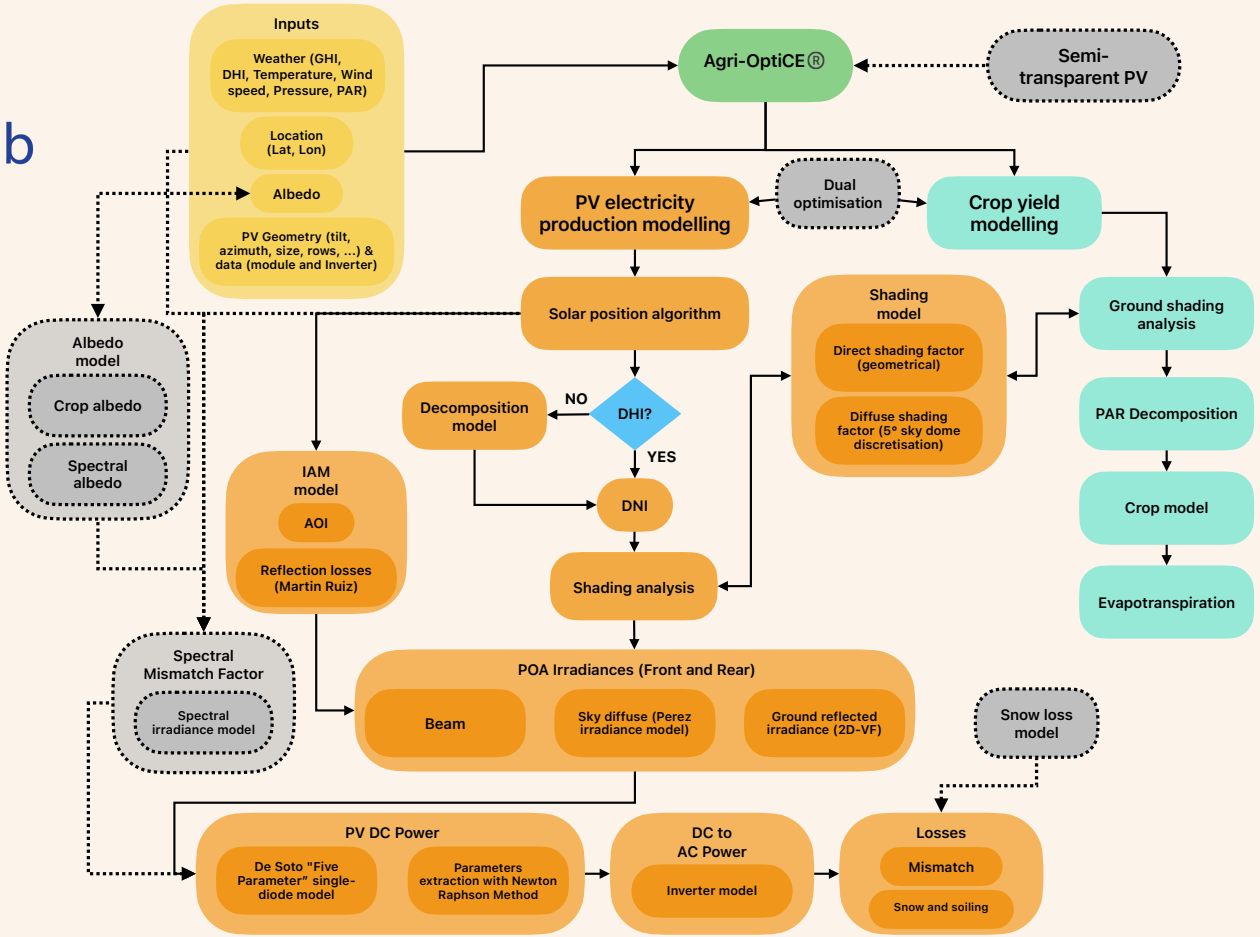


[1] S. Ma Lu et al., "Validation of Vertical Bifacial Agrivoltaic and Other Systems Modelling - Effect of Dynamic Albedo on Irradiance and Power Output Estimations," AgriVoltaics Conf Proc, vol. 2, May 2024

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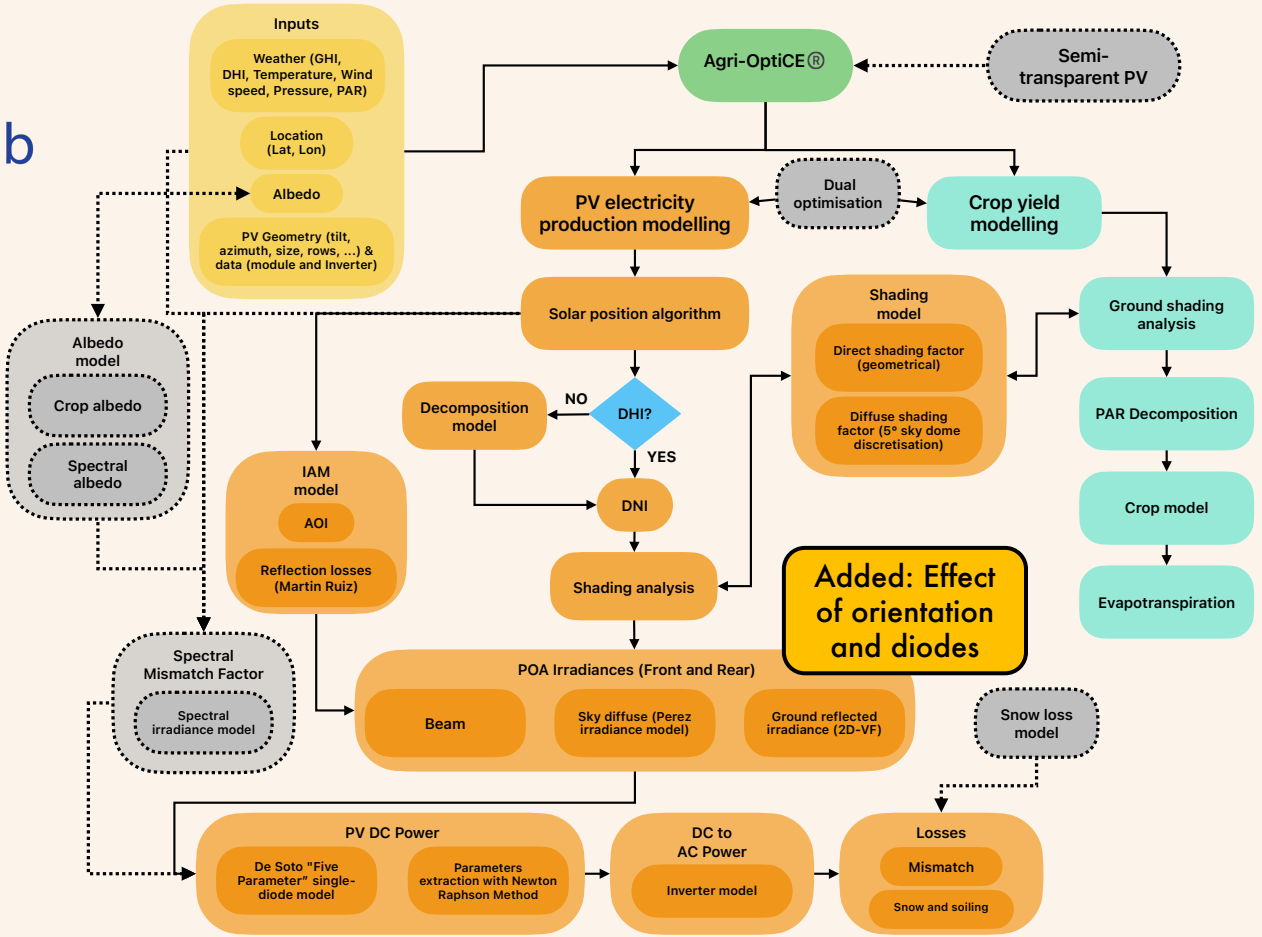
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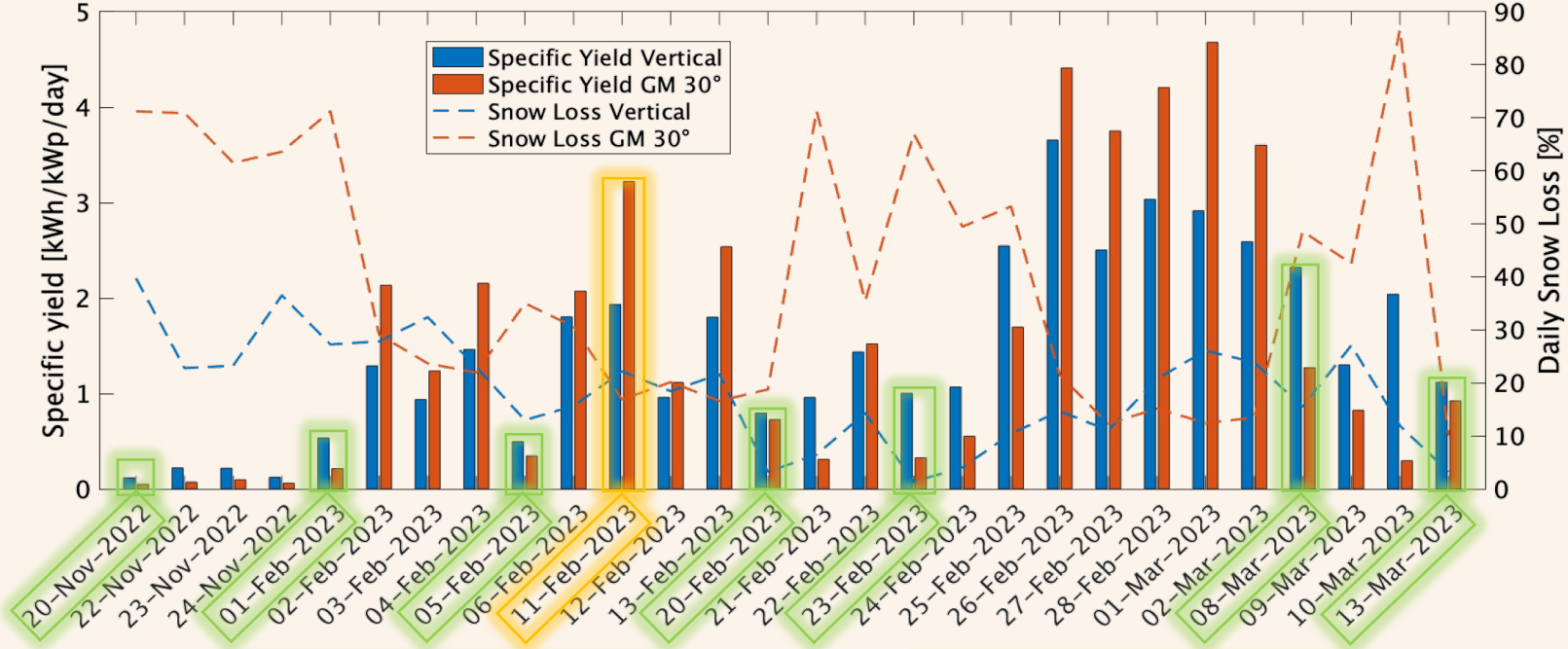


To be implemented



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Results: daily snow losses and specific yield



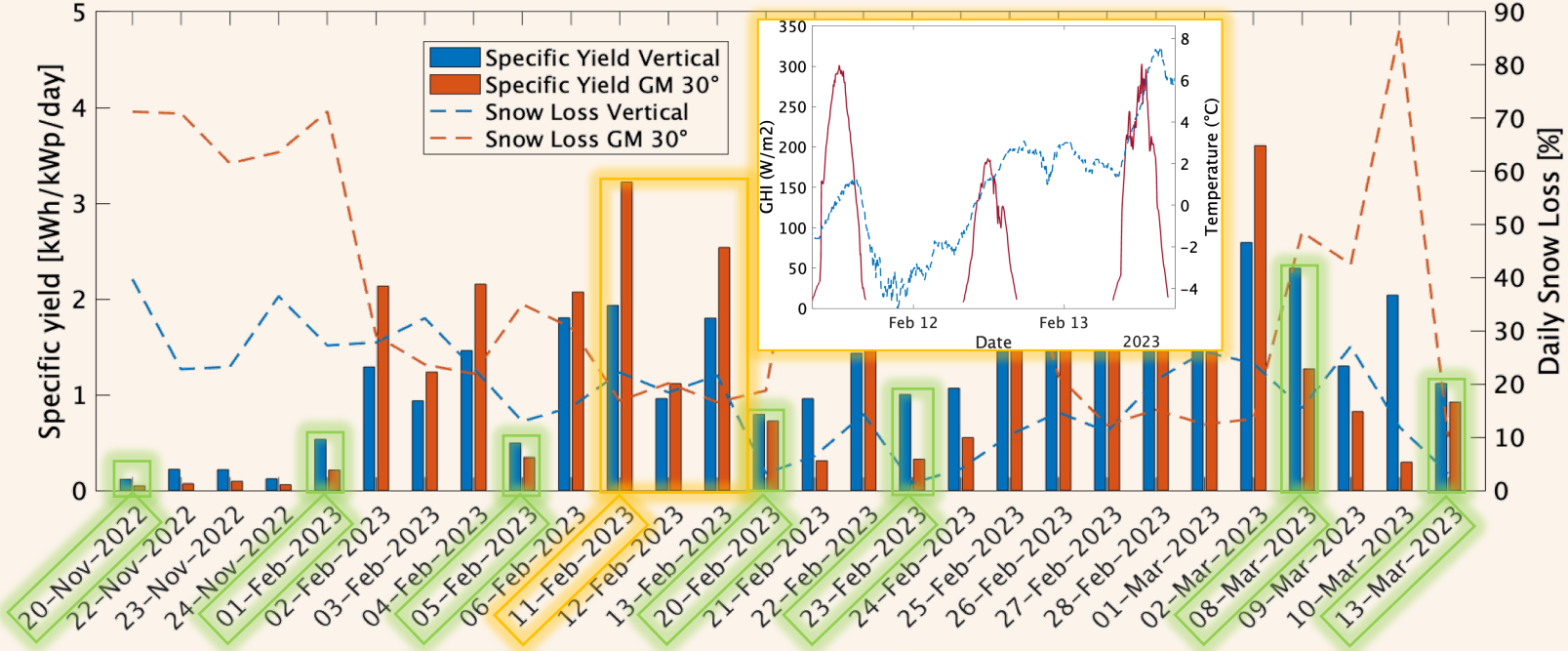
"Heavy"snowfall event

Yield: Vertical > GM
Radiation levels: low
Temperature: mostly below zero
Prolonged snow coverage

"Light"snowfall event

Yield: GM > Vertical
Radiation levels: high
Temperature: mostly above zero
Short snow coverage

Results: daily snow losses and specific yield



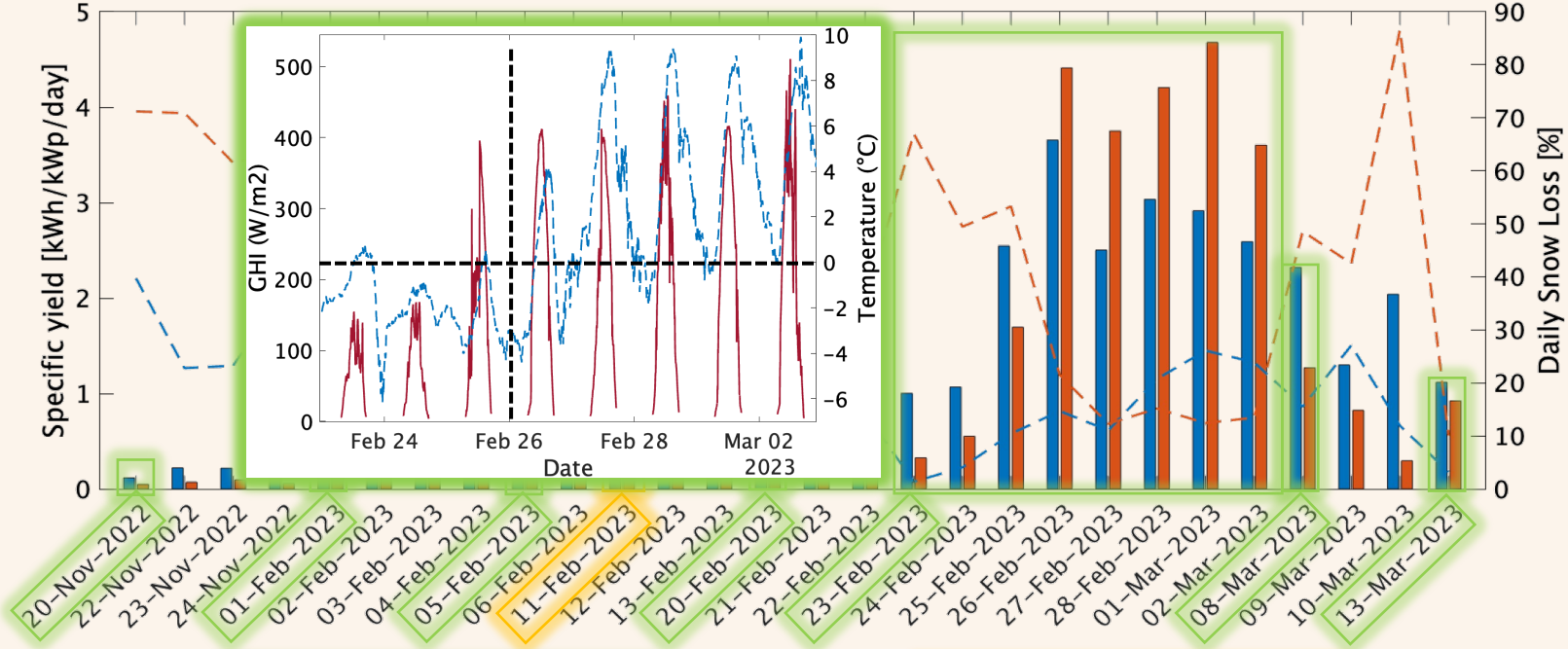
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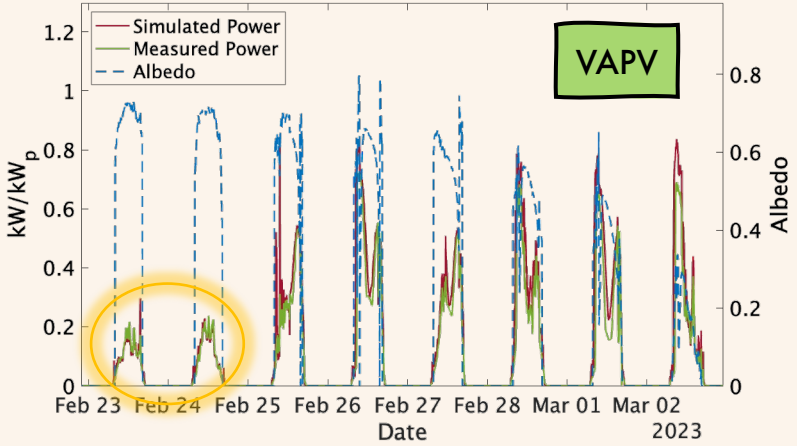
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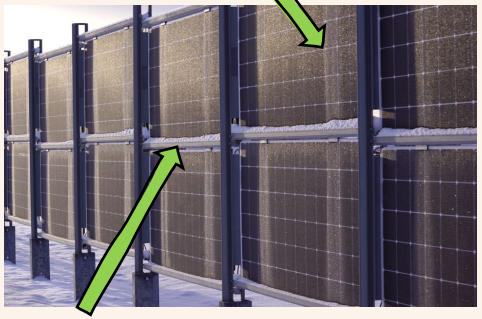
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Results: 23 Feb – 2 Mar 2023

Good alignment between simulated and measured → Lower snow losses

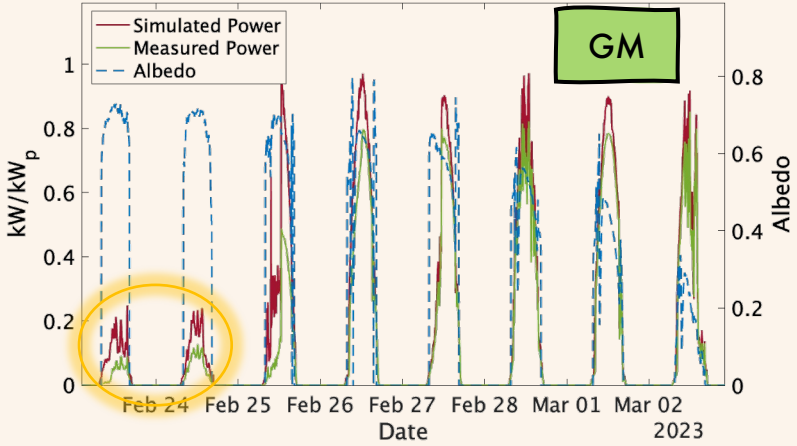


Frost and ice



Snow captured

Higher discrepancy between simulated and measured → Full or partial snow coverage





Take-away

- GM system experienced higher impact of snow losses due to:
  1. Tilt angle of 30° (vs. 90° in the VAPV).
  2. Portrait orientation (vs. landscape in the VAPV), more susceptible to bypass diode effects [1].
  3. Module frames (vs. frameless in the VAPV), obstructing the sliding of the snow off the panels [2].
- **Aggregated snow losses** over the studied period yielded **29% for the GM** and **18% for the VAPV**.
- Despite greater snow coverage, the **GM system** (1.59 kWh/kWp/day) **had higher mean daily specific yield than the VAPV** (1.47 kWh/kWp/day) for the studied period.
- **Vertical bifacial PV modules** in high-latitude regions, besides capturing sunlight at lower sun elevations and better aligning energy conversion patterns with load profiles [3], have demonstrated **less vulnerability to snow losses** than GM bifacial PV systems. But these are not negligible!

Limitations

- ✗ Issues with data collection: both with the inverter and sensors
- ✗ Modelling and simulation tool uncertainties
- ✗ Snow events identified by albedo values rather than precipitation and snow depth monitoring

Next Steps

- ✓ Test and refine existing snow loss models in vertical systems (most of them primarily designed for monofacial PV modules)
- ✓ Video camera on-site to record snow accumulation and melting
- ✓ Evaluate bifacial gain
- ✓ Improve modelling tool to reduce uncertainty

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[3] M. R. Khan, A. Hanna, X. Sun, and M. A. Alam, "Vertical bifacial solar farms: Physics, design, and global optimization," Appl. Energy, vol. 206, pp. 240–248, Nov. 2017

Mälardalen University Agrivoltaic Team



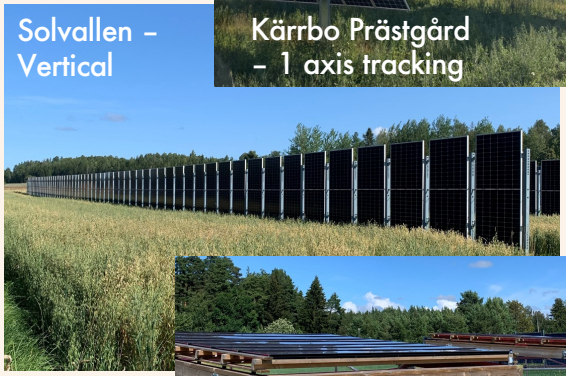
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Dr. Anders Avelin
Dr. Mohammed Guezgouz

Post-docs:
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Follow us to see our latest research activities. We are also open to collaborations!

Thank you for your attention!





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21st August 2024