# Impacts on Backtracking Energy Generation from Underlying Terrain Undulations and Varying Motor Block Size

Billy Hayes, Kendra Conrad, Kyumin Lee | ARRAY Technologies

## Motivation

Single-axis tracker (SAT) solar power systems are being installed across undulating terrain at scale, creating a need to accurately model the impact of terrain-aware backtracking on energy production.

The impact of specific terrain undulations on backtracking energy performance is often modeled as a black box which limits the due-diligence independent engineers can perform.

ARRAY collaborated with DNV - Energy Services (U. Akkoseoglu and M. Mikofski) to develop a PV modeling process that enables users of commercial software to model backtracking energy gains.

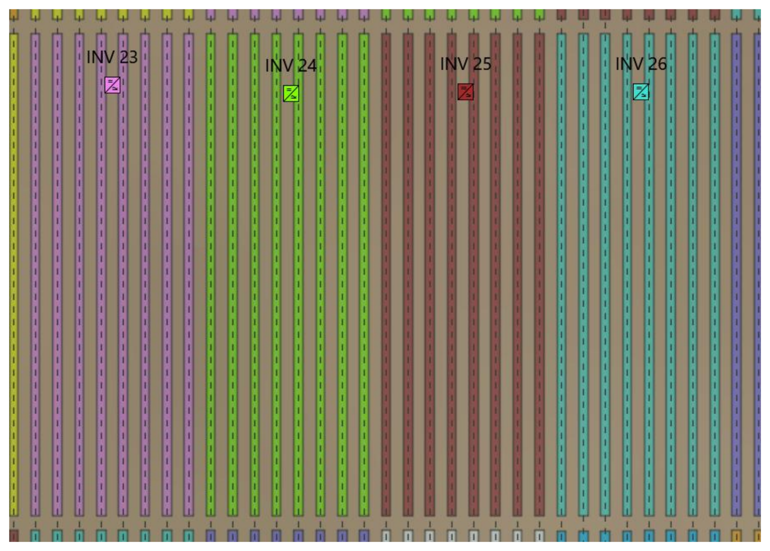
This process is applied to a set of PV projects to understand and quantify the impact of undulating terrain on project and combiner-box-level annual energy for different motor driveline lengths (where all tracker tables connected to a driveline are referred to as a motor block).

## Methodology

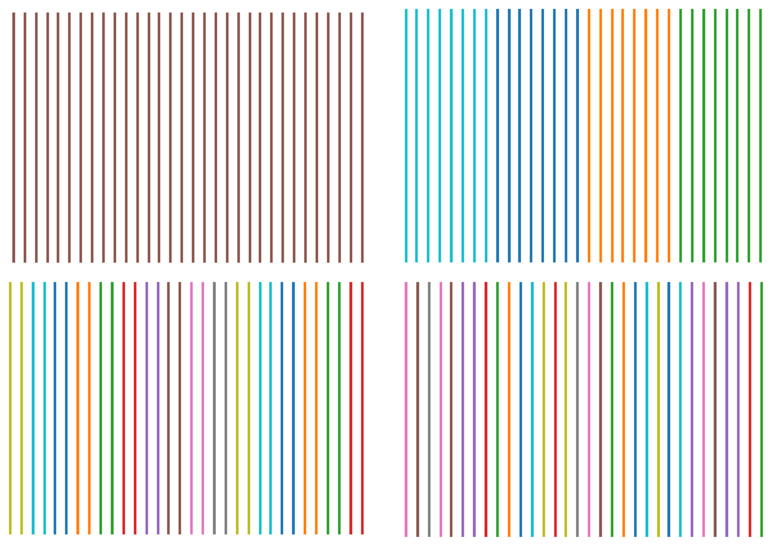
This study follows the method described in "A Workflow to Analyze The Impact of Terrain Undulations on Energy Yield for Different Motor Block Sizes" (U. Akkoseoglu, M. Mikofski, W. Hayes) which relies on commercially available PV modeling software and time series tracking angles provided by the tracker vendor to model the energy performance of SAT power systems.

The features required of commercial PV modeling software to support this workflow are (1) a 3D layout, (2) custom tracker angles for the 3D layout, (3) 3D irradiance transposition across all trackers, (4) 3D row-to-row shading, (5) 3D diffuse shading, (6) associated electrical mismatch calculations due to 3D shading, and (7) sub-hourly time step modeling. DNV's SolarFarmer meets these requirements and was used in this study. PlantPredict was evaluated and meets these requirements with version 12.

The size of motor blocks studied are 32-row (DuraTrack/OmniTrack), 8-row (SkyLink), 2-row (H250), and 1-row.




Electrical hierarchy of 8 rows per inverter used for all scenarios

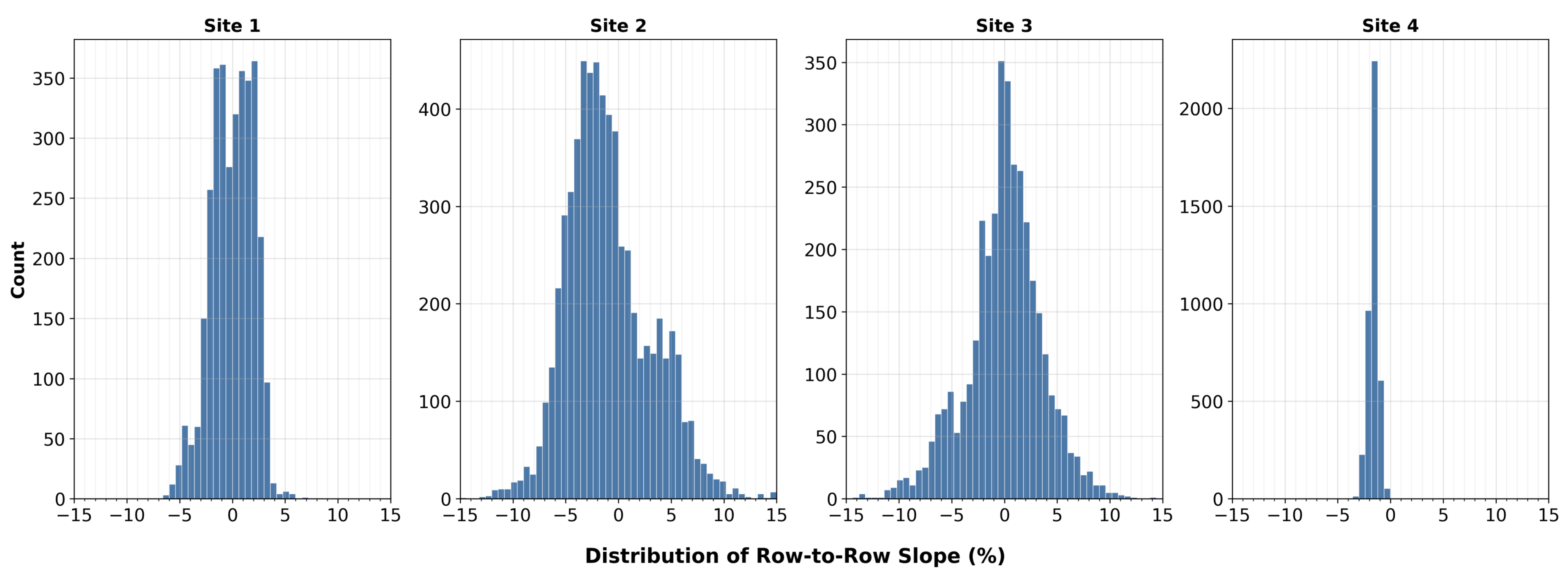


Mechanical hierarchies modeled include 32-row, 8-row, 2-row, and 1-row motor blocks.

The inverters defined in SolarFarmer are scaled down to be equivalent of a typical size of a combiner-box to generate modeled electrical system data at a granular level. The overlay of the electrical and mechanical systems is mapped such that each inverter maps to a single, 8-row motor block. Aggregating neighboring inverters allows for analysis and direct comparisons of the impact of different motor block size on energy generation as a function of the underlying terrain with specific spans of the project.

Sites were selected with a varying range of terrain undulations as well as location, ground coverage ratio (GCR), and diffuse fraction.

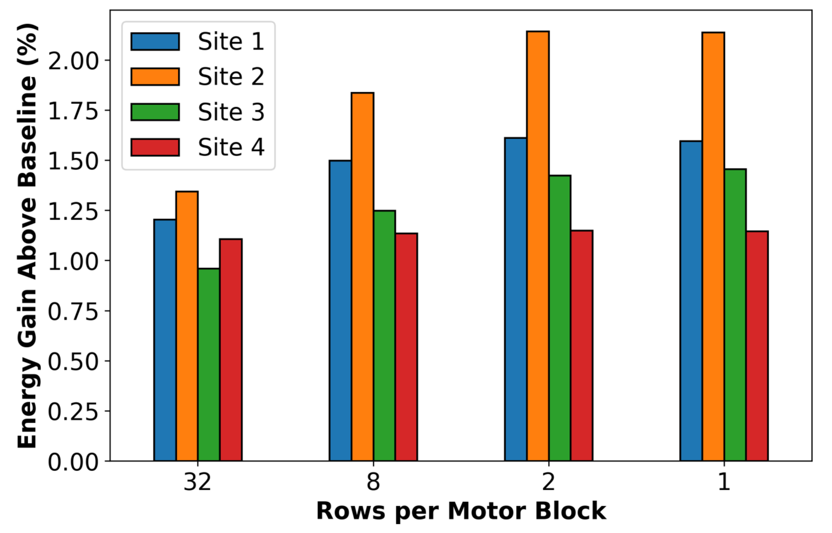
| Site | #1 | #2 | #3 | #4 |
|---|---|---|---|---|
| Location | TX, USA | NSW, AUS | IN, USA | NM, USA |
| Size (DC) | 100 MW | 160 MW | 90 MW | 122 MW |
| GCR | 40.2% | 42.5% | 42.0% | 28.7% |
| Diffuse Fraction | 34.9% | 30.1% | 40.3% | 27.5% |




## Project-Level Results

Terrain-aware backtracking provides significant performance uplift for all motor block scenarios analyzed across all sites, ranging from 1.1% of annually energy generation to upwards of 2% compared to non-terrain-aware backtracking.

The practical limit for how much energy backtracking can generate will be tied to the tradeoff between a reduced POA transposition gain, the reduction in the amount of beam shading loss, and the reduction in electrical shading loss (which is non-linear for c-Si modules).



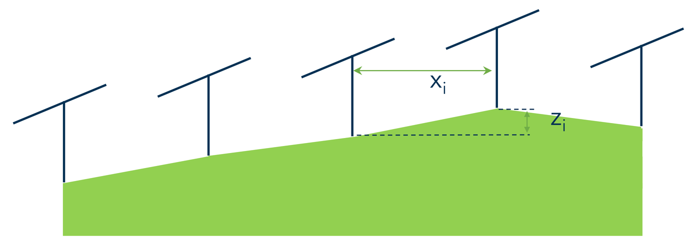

| Site #1 Key Parameters | POA Transposition Gain (%) | Near Shading Loss (%) | Electrical Shading Loss (%) |
|---|---|---|---|
| Baseline | 32.1 | 2.23 | 2.62 |
| 32-row | 30.7 | 1.57 | 0.61 |
| 8-row | 31.2 | 1.55 | 0.60 |
| 2-row | 31.3 | 1.5 | 0.42 |
| 1-row | 31.1 | 1.46 | 0.33 |

Relative performance gains reduce as motor block sizes decrease, with the largest difference demonstrated between 32-row and 8-row systems. Moving from 8-row to 2-row shows less relative gain in comparison, and the 2-row and 1-row motor block systems have backtracking gains that are virtually identical.

## Terrain Undulations v. Energy Performance Analysis

Modeled combiner-box-level AC energy generation was analyzed, providing a distribution of energy performance based on the 32-row spans of trackers grouped together for analysis. Comparisons were made for these 32-row spans relative to baseline backtracking for tracker angles of each motor-block size scenario.

Terrain was parameterized using two parameters: the absolute value of the mean slope and the variation of that slope defined as the root-mean square deviation. Using tracker height data from the PVC files, these parameters were defined for each 32-row span.

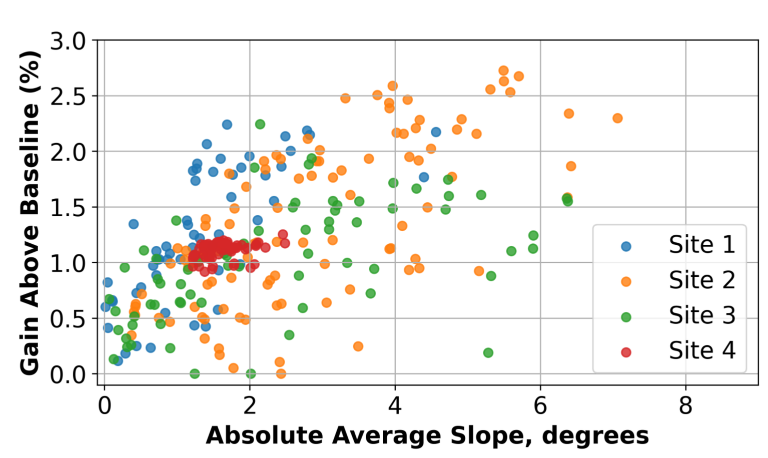


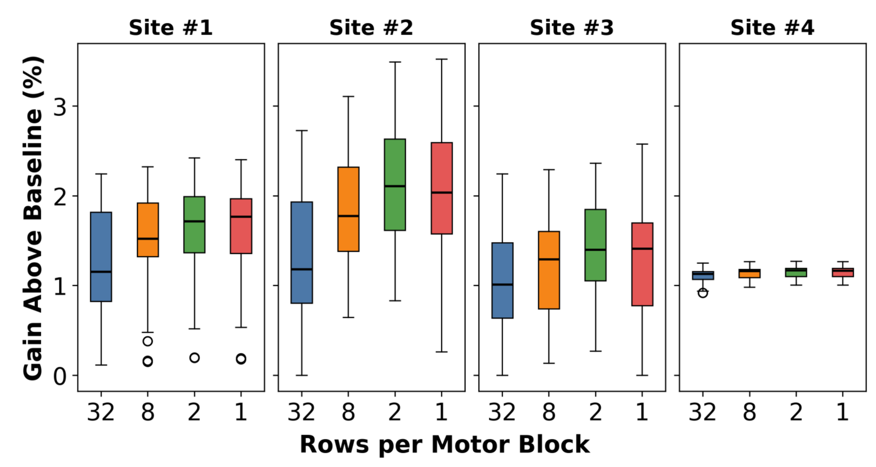

$$\alpha_i = 100 * \frac{z_i}{x_i}$$ Row-to-row slope

$$\hat{\alpha} = \frac{\sum_{i=1}^{N} \alpha_i}{N}$$ Mean slope

$$RMSD = \sqrt{\frac{\left(\sum_{i=1}^{N} (\alpha_i - \hat{\alpha})\right)^2}{N}}$$ Root mean square deviation of slope

Of the sites analyzed, the increase in total energy at the site level for the 8-row motor block over a 32-row motor block ranged from 0.02% to 0.4% . The increase from 8-row to 2-row ranged from 0.02% to 0.3%. And the increase from 2-row to 1-row was negligible at < 0.02%.




At very low RMSD, the terrain is virtually a monoslope and all trackers would have the same optimal backtracking angles, resulting in no advantage to smaller motor block sizes. The benefits of smaller motor blocks sizing increases as RMSD increases.

For specific locations that have significant terrain undulations, the relative gains can exceed 1.5%. These instances occur infrequently with most terrain across the sites having a RMSD < 2deg which dominates the site-level energy gain.