WHEN TRUST MATTERS

Analyzing the Impact of Terrain Undulations on Yield for Different Motor Block Sizes

Umay Akkoseoglu, William Hayes, Mark Mikofski

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Is there a limit to optimizing for undulated terrain?

- More need for solar means more use of land with complex terrain conditions
- Common perception is that single row motor-blocks can bring better optimization against terrain impacts, assuming single-row will always have the highest yield
- Goal to provide an outline the workflow of what goes into modeling optimized backtracking and how the gains are estimated

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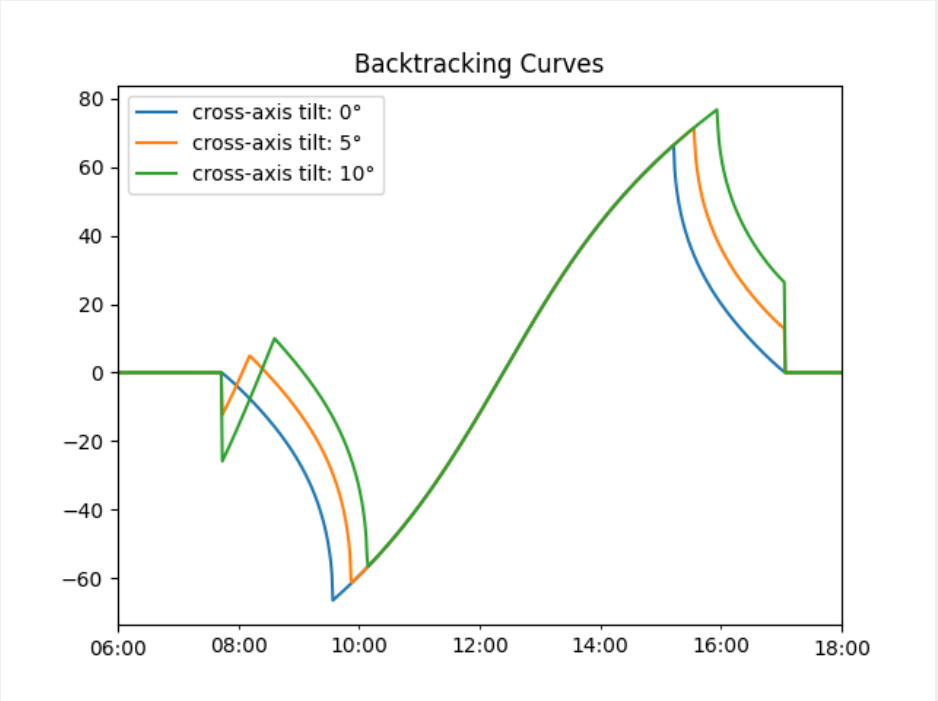
What is backtracking and why avoid row-to-row shade?

- Backtracking is employed by moving away from the sun (towards zero-tracker angle) to avoid row-to-row shade
- Row-to-row shade causes electrical mismatch loss which is non-linear for cSi systems
- On sloping terrain that is perfectly monoslope, the solution to avoid r2r shade for zero electrical losses is well known [1][2]
- However uneven terrain has possible losses that can be recaptured to a limit by this optimization: electrical mismatch, near shade losses



https://pvlib-python.readthedocs.io/en/stable/gallery/solar-tracking/plot_single_axis_tracking_on_sloped_terrain.html

[1] https://www.osti.gov/servlets/purl/1089596/

[2] https://www.nrel.gov/docs/fy20osti/76626.pdf

A workflow to assess the optimization limits with a case study

1	2	3	4	5	6
Simulate model for various motor-block size scenarios	**Compare terrain vs energy results**	**Analyze Results**	**Size Motor-Blocks**	**Finalize standard workflow**	**Site-Based Assessment**
Employ optimized complete shade avoidance rotations*	Project, Block & Inverter levels	Identify yield drivers & limits	Select size(s) for highest yield	Define a workflow with defined parameters to assess optimized tracking gain and assess motor-block sizing	Use site conditions + tracking gain

** Diffuse boost or half-module tracking are outside the scope of this work*

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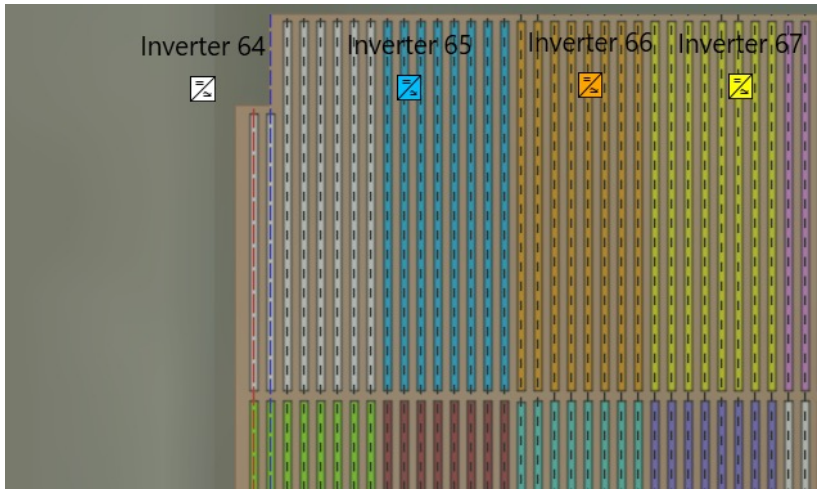
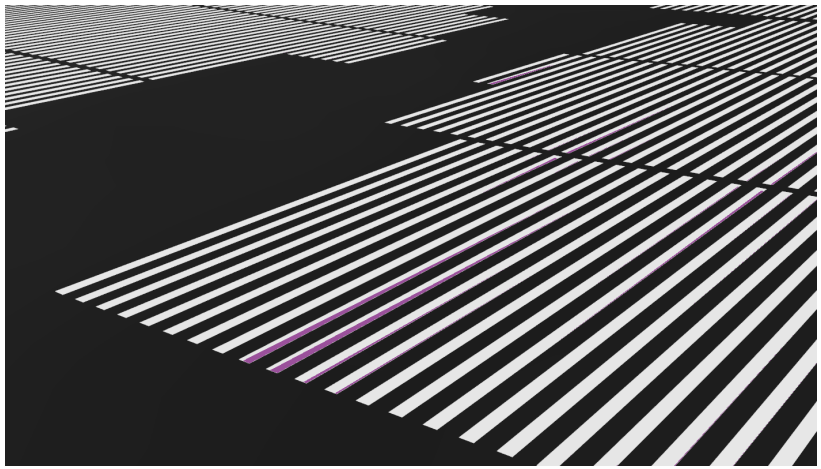
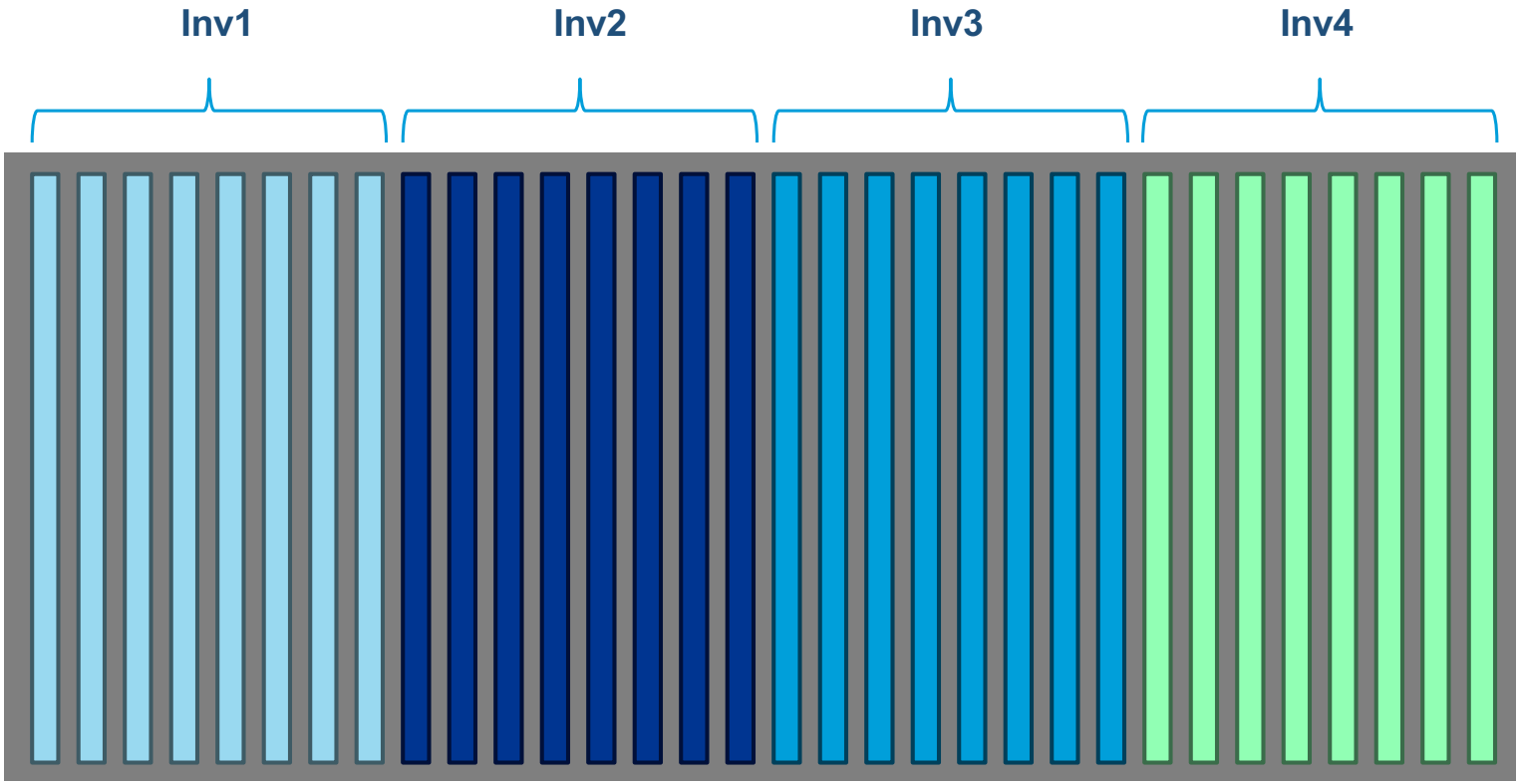
Case Study & Methods

- Site in Central Texas
- SolarFarmer 3D energy models for four different motor-block scenarios based on 5-minute rotations
  - Baseline (standard non-slope aware backtracking)
  - 32, 8, 2, 1-row motor-block
- 5-min tracker angles calculated employing ARRAY SmarTrack algorithm using tracker pile coordinates
- Combiner Box were used to represent inverters to facilitate the analysis at the inverter level
  - Each “32-row block” group correspond to the same inverters for 32, 8, 2 and 1-row motor block scenarios
  - One row is typically four 1500V strings



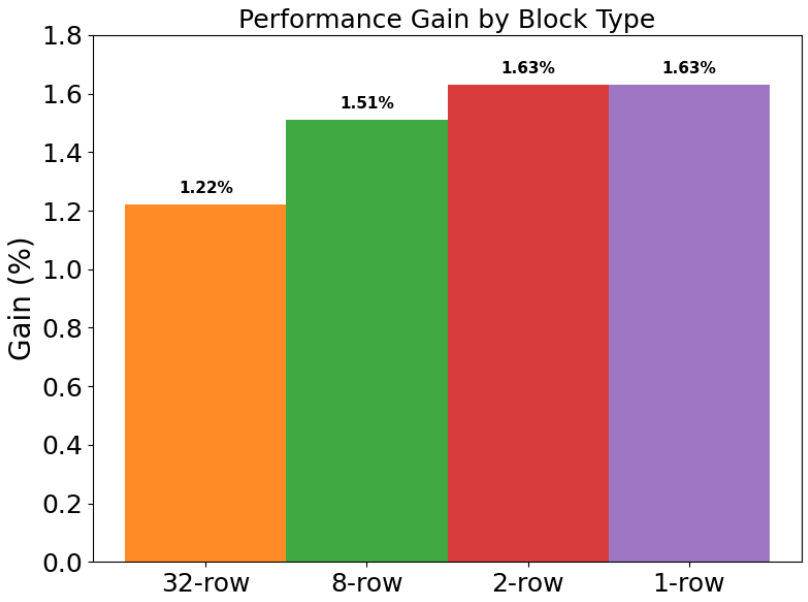


Combiner box inverters



Results & Analyses – Project Level

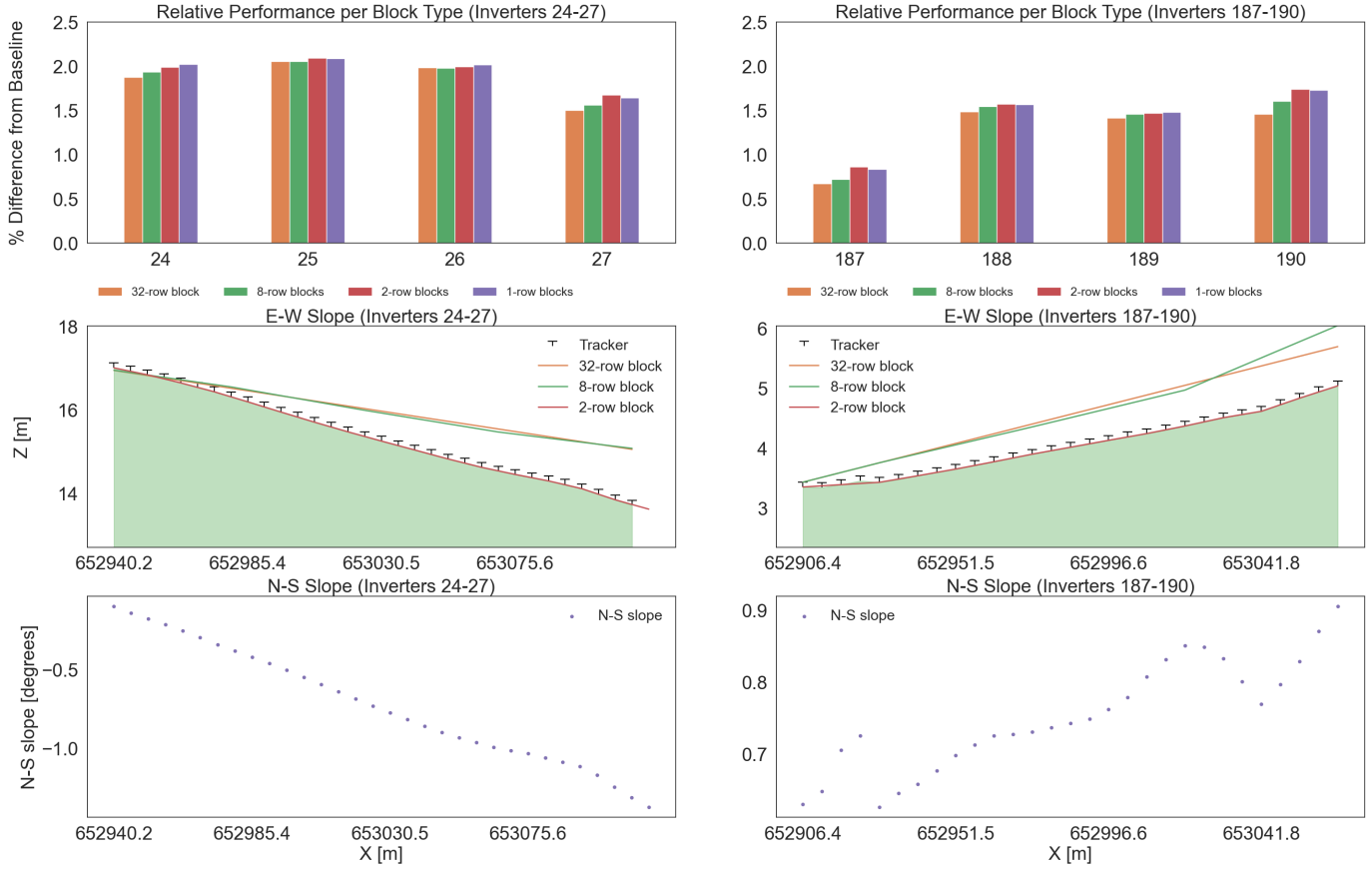
- The optimized tracker angles offered a maximum site level gain of 1.6% over the Baseline



Case	Baseline	32-row Block	8-row Block	2-row Block	1-row Block
Platform	SolarFarmer 3D Desktop 1.6				
Backtracking	ARRAY Baseline	ARRAY Custom Rotations	ARRAY Custom Rotations	ARRAY Custom Rotations	ARRAY Custom Rotations
Terrain	Array	Array	Array	Array	Array
Shade objects	No				
Bifacial	No				
SolarFarmer	**Loss %**	**Loss %**	**Loss %**	**Loss %**	**Loss %**
POA	-29.3	-28.8	-29.0	-29.1	-29.1
Horizon	0.0	0.0	0.0	0.0	0.0
Near shading	1.8	1.5	1.5	1.5	1.5
			...		
Electrical effect	1.8	0.3	0.2	0.1	0.1
Year 1 – Generation [GWh/yr]	**172.2**	**174.3**	**174.8**	**175.0**	**175.0**

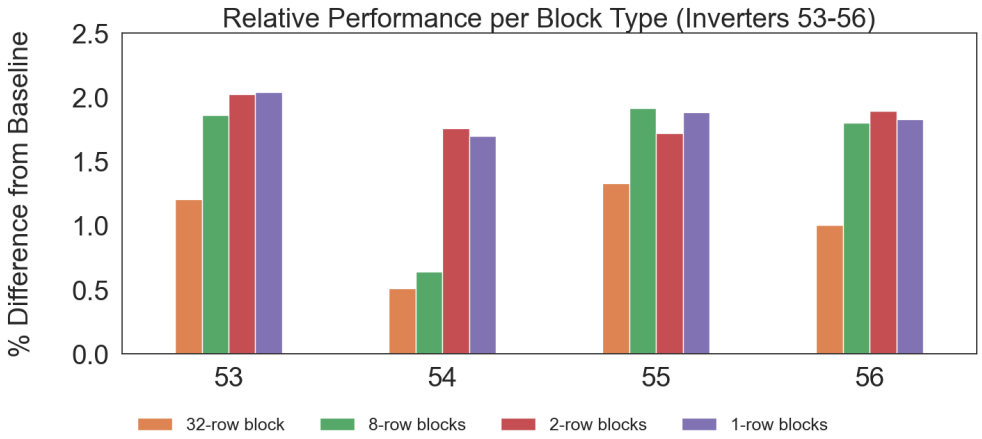
Results & Analyses – Inverter Level

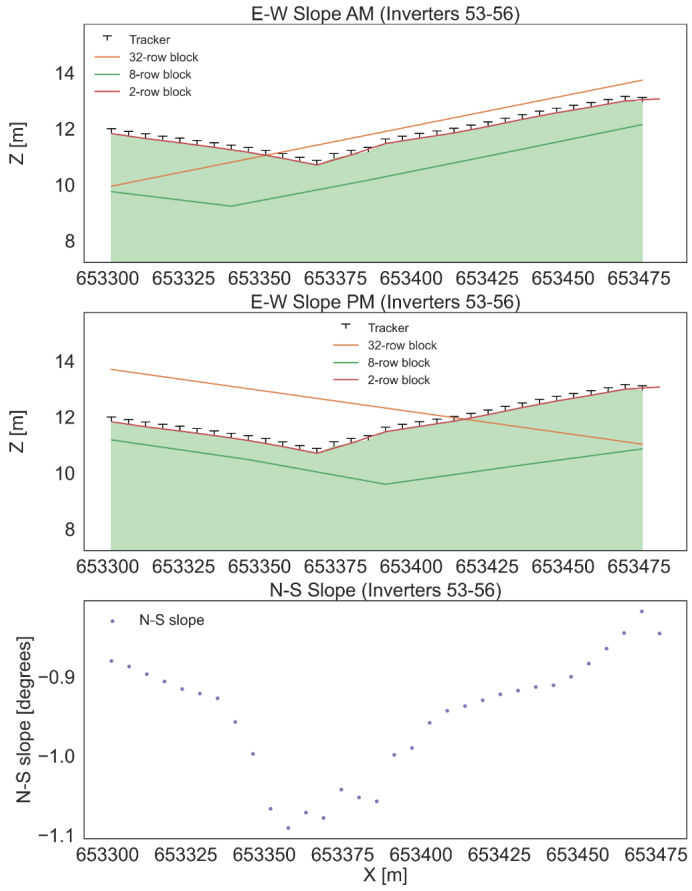
- In areas with monoslope, the impact of the motor-block size is negligible



Results & Analyses – Inverter Level

- In areas with high slope variance, smaller block sizes show higher performance





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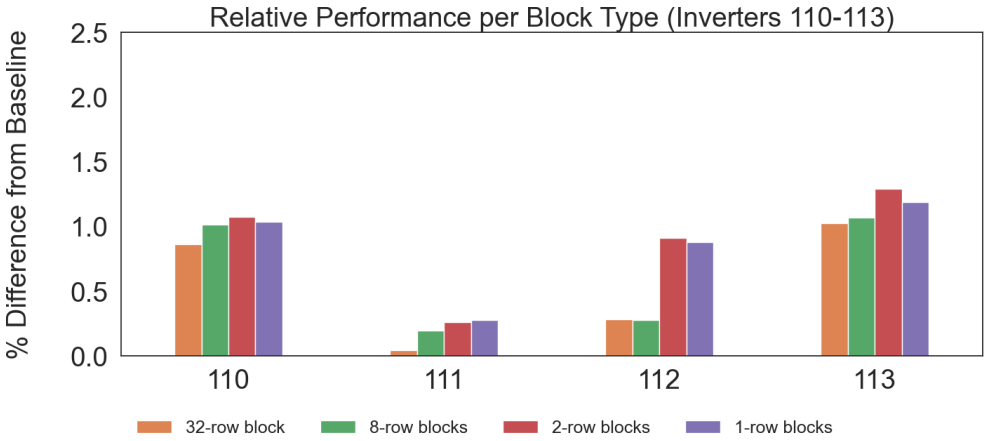
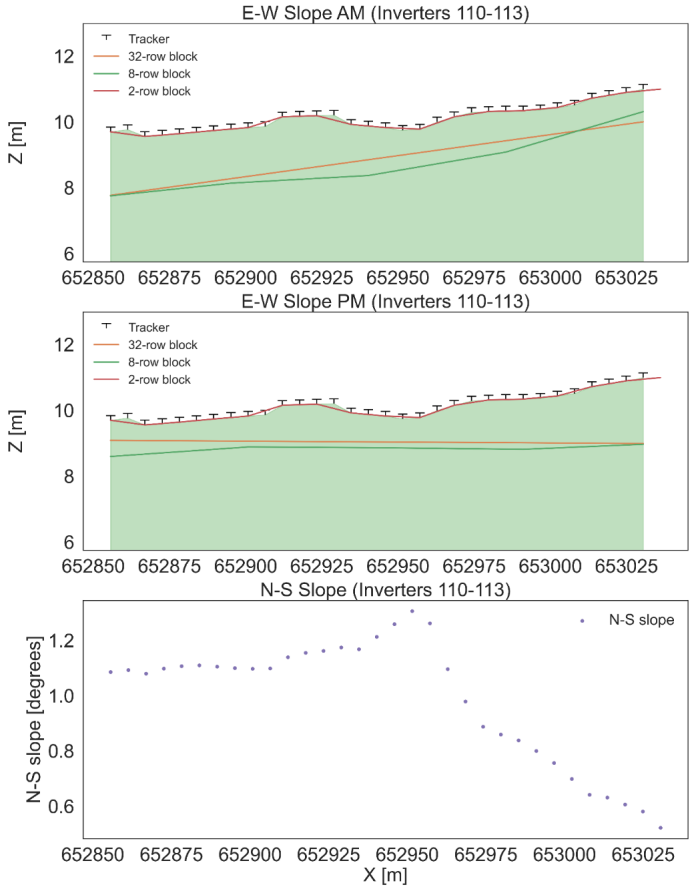
Results & Analyses – Inverter Level

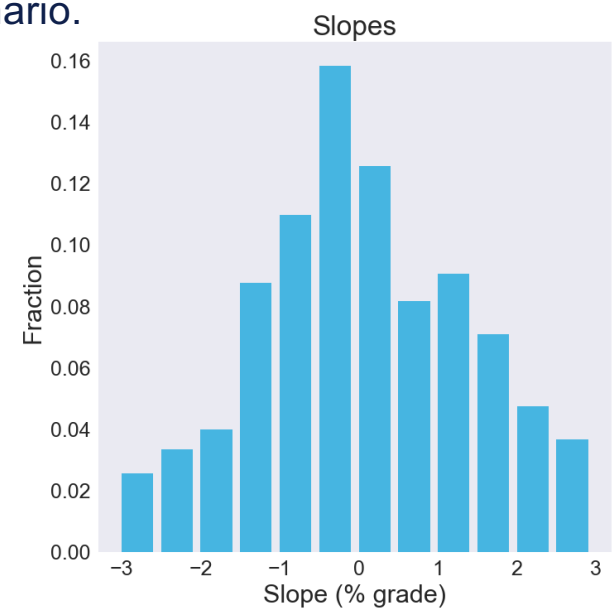
- The relative energy gain can only be captured by the smaller motor-block size scenario to the extent of the terrain undulations occurring beneath the tracker group.

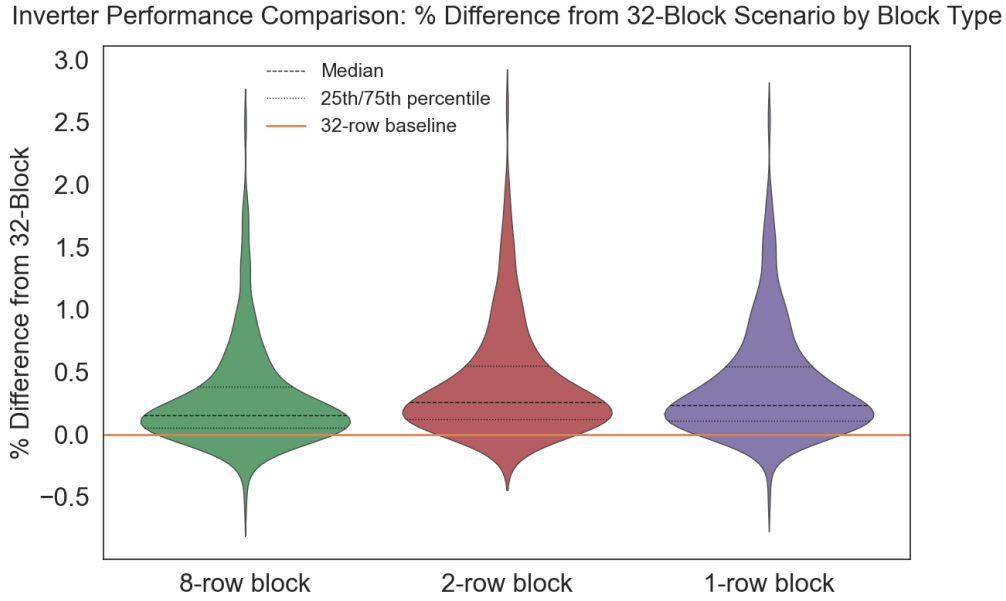




The impact at the inverter vs at the project level

- Looking at the site conditions, it is ~50-50 split to be upsloping and downsloping west to east
- At the site level, the overall gain is 0.4% for the 1-row block scenario against the 32-row block for annual energy.
- For a single combiner inverter, however, the gain can be as high as 2.5% against 32-row block scenario.





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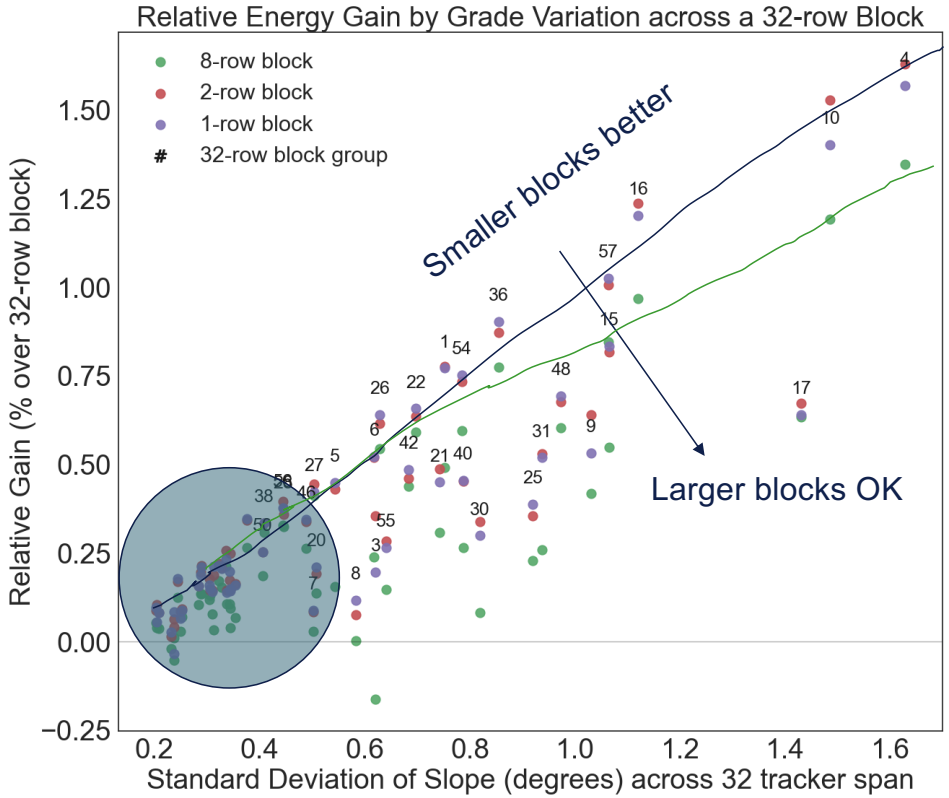
Assessing the limit to the optimization

- E-W grade variation in degrees
  - Calculated the slope between trackers: Row-to-row elevation difference in terms of degrees
  - Root mean square of the deviations represents the parameter defined as “E-W grade variation”

$$grade\ variation = \sqrt{\frac{\sum(\mu - \mu)^2}{N}} = STDEV(\mu)$$

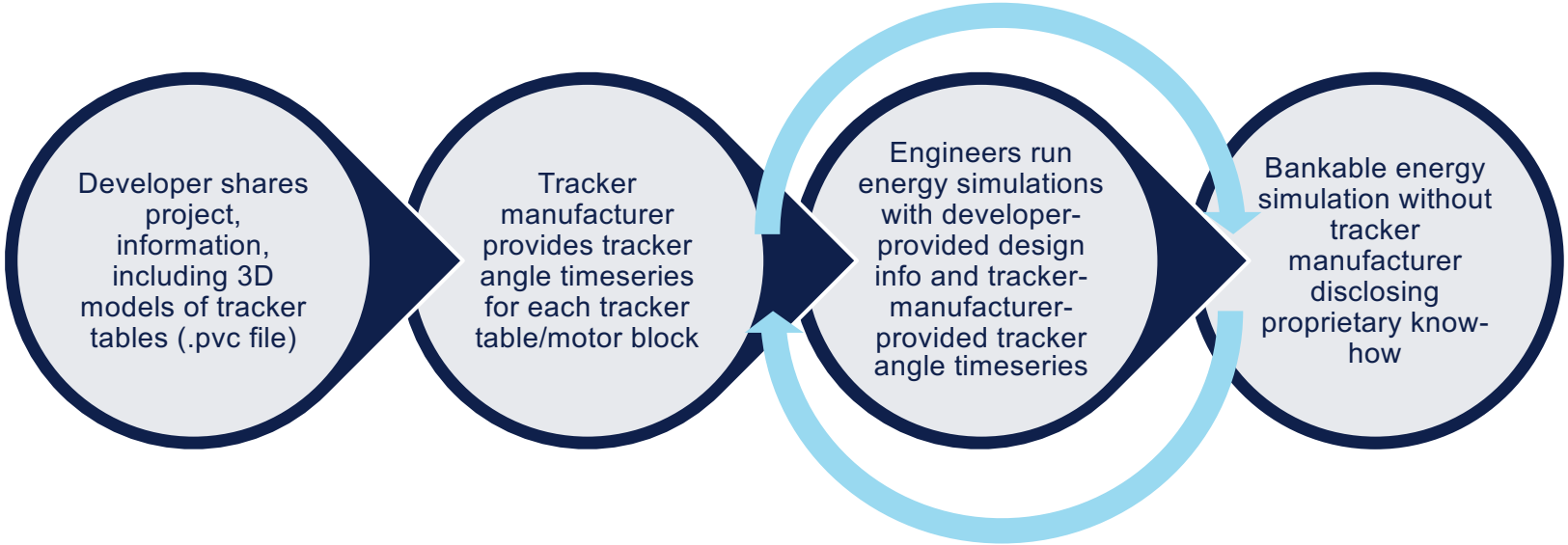
$$where\ \mu = slope$$

- For small grade variations, all block scenarios perform similarly.
- The relative gain amongst the smaller motor-block sizes stay negligible until much higher deviations in slope



A Workflow to assess the optimization gains and limits

- A transparent repeatable and independent process to estimate optimized backtracking gains



- Smaller motor-block sizes can yield higher energy gains in areas with pronounced terrain variation, but the incremental benefit diminishes after a certain grade variation threshold

Thank you!

Umay Akkoseoglu
Umay.Akkoseoglu@dnv.com

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