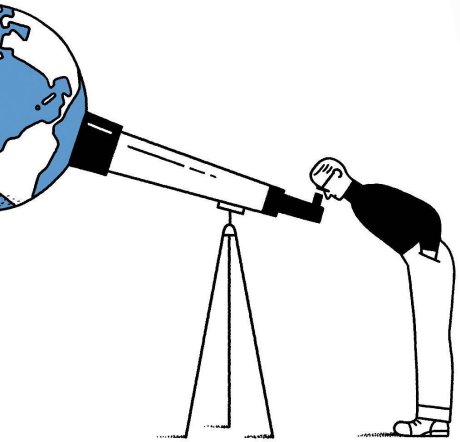
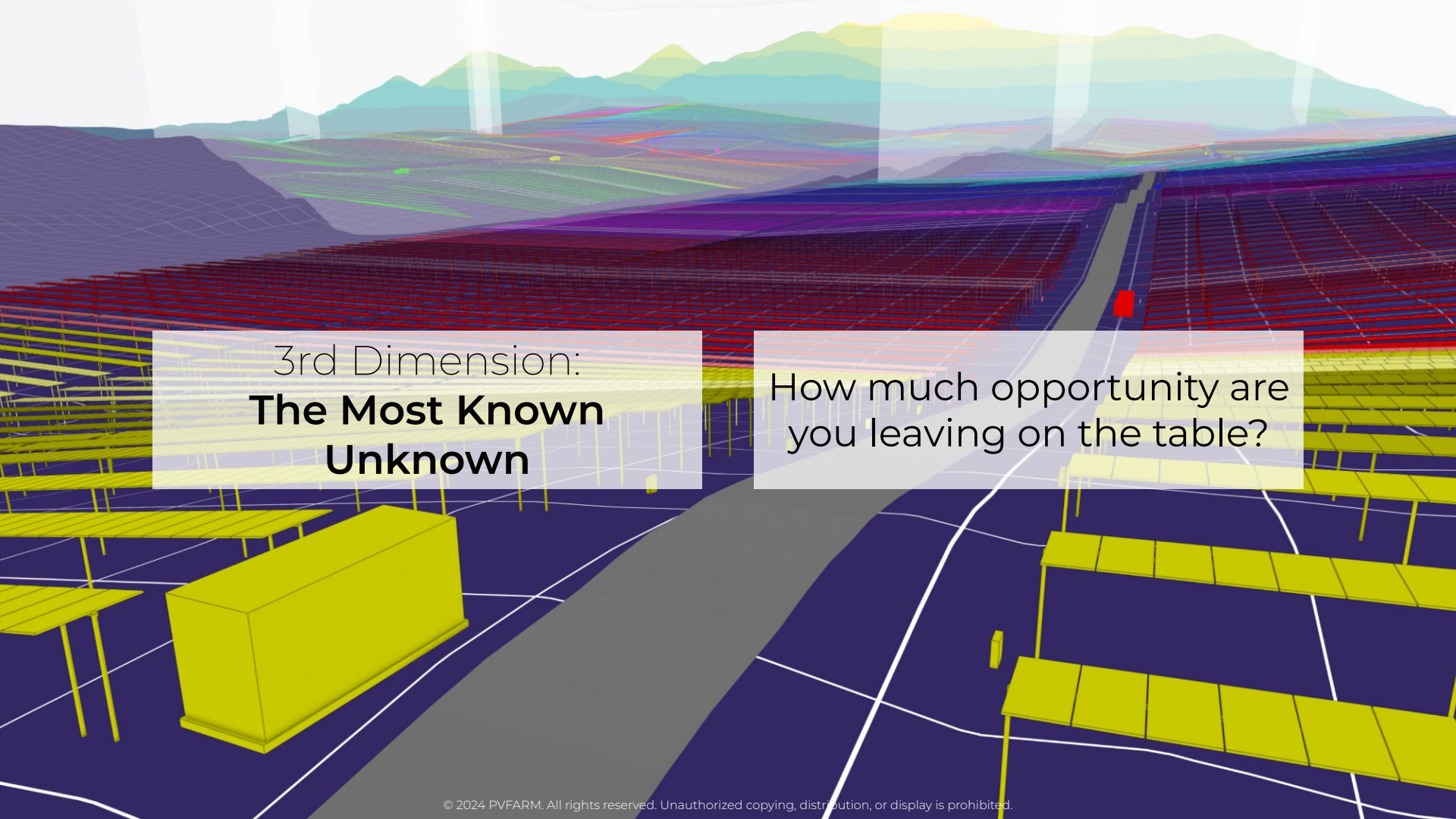
Solar Design in the 3rd Dimension

Terrain-Following Trackers, Cut/Fill, Piles and Shading Optimization.

Solar is NOT a Two-Dimensional Industry.

Don’t be a Flat-Siter.





Financial Impact

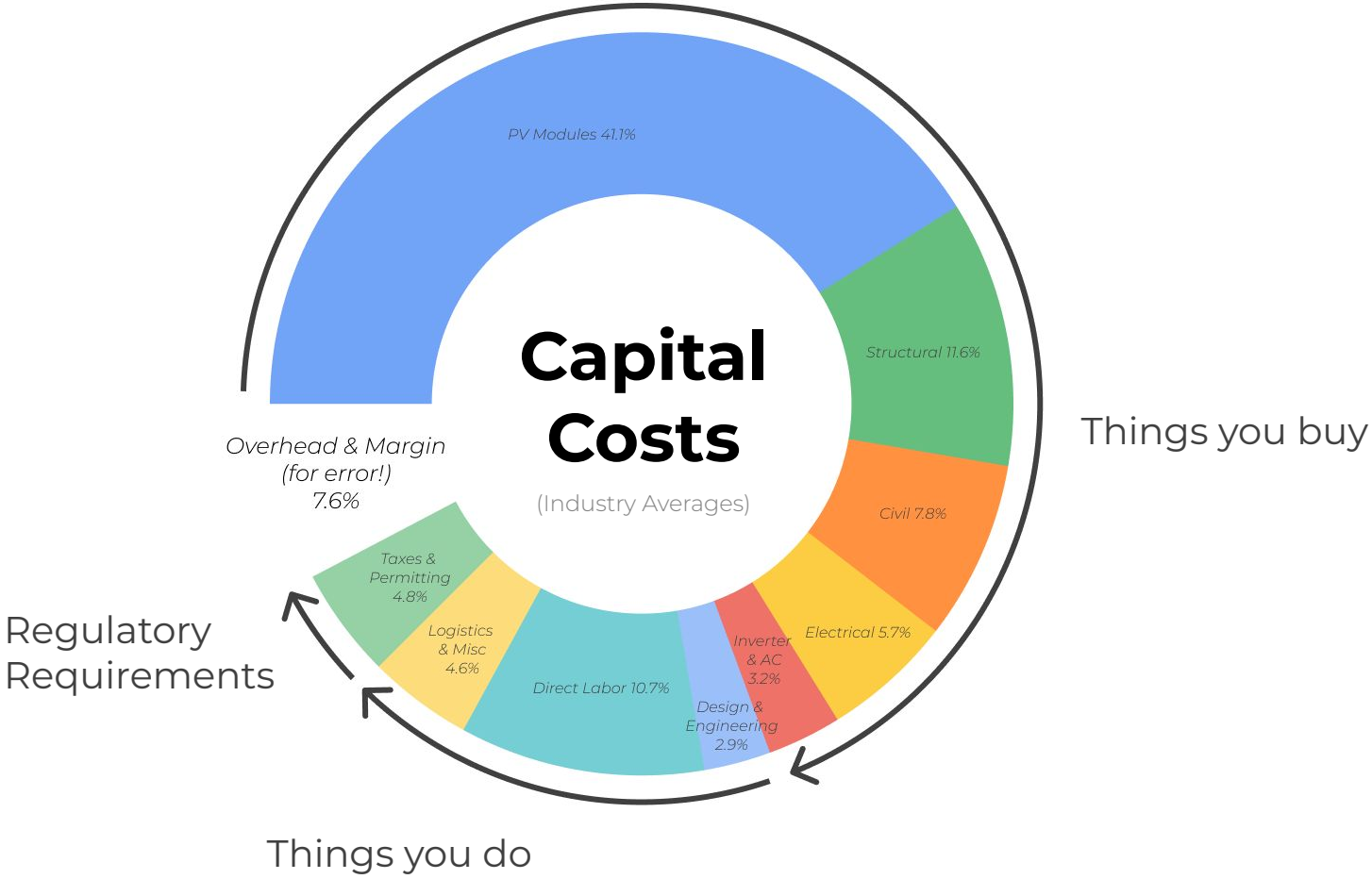
Which components of a utility-scale pro forma are affected by 3D considerations? (direct and indirect)

“Don’t step over dollars to pick up dimes!”

- Jedi Solar Engineer

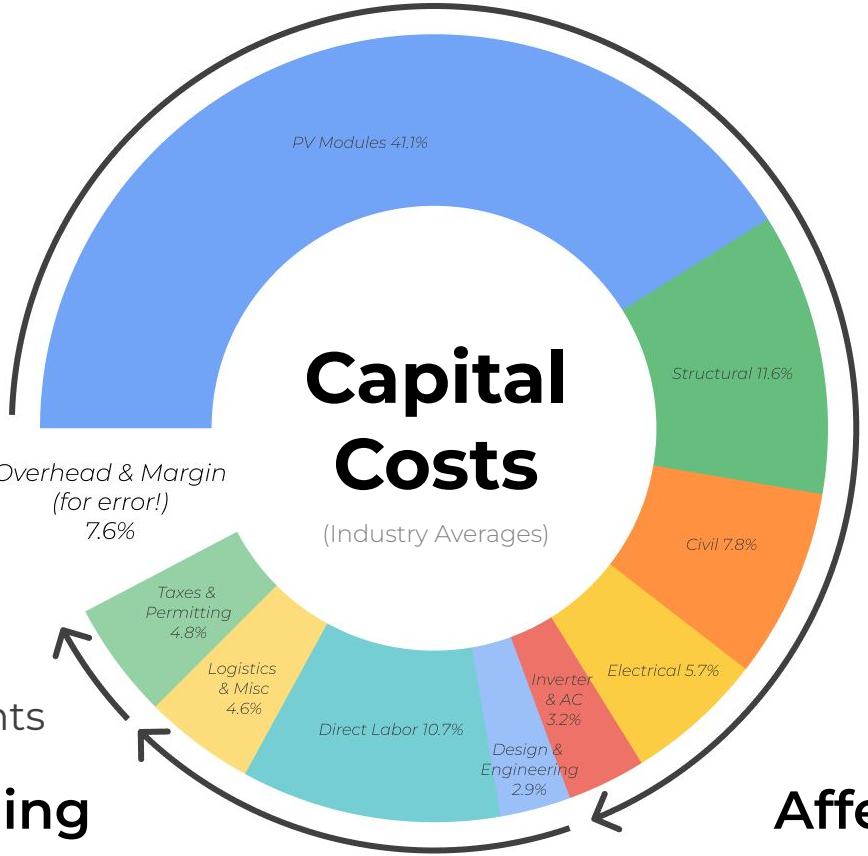
PROFIT = **INCOME** - **CAPEX** - **O&M COST** - **DEBT & TAXES**

PROFIT	INCOME	CAPEX	O&M COST	DEBT & TAXES
Totals net gain, over lifetime of the asset.	Gross earnings from power production, adjusted for depreciation and incentives.	Including land and construction.	Ongoing costs to operate and maintain the project	Financing costs and tax obligations.



Capital Costs

(Industry Averages)



And eat into your

The
Things you buy

Regulatory Requirements

Including

Affect the

Things you do

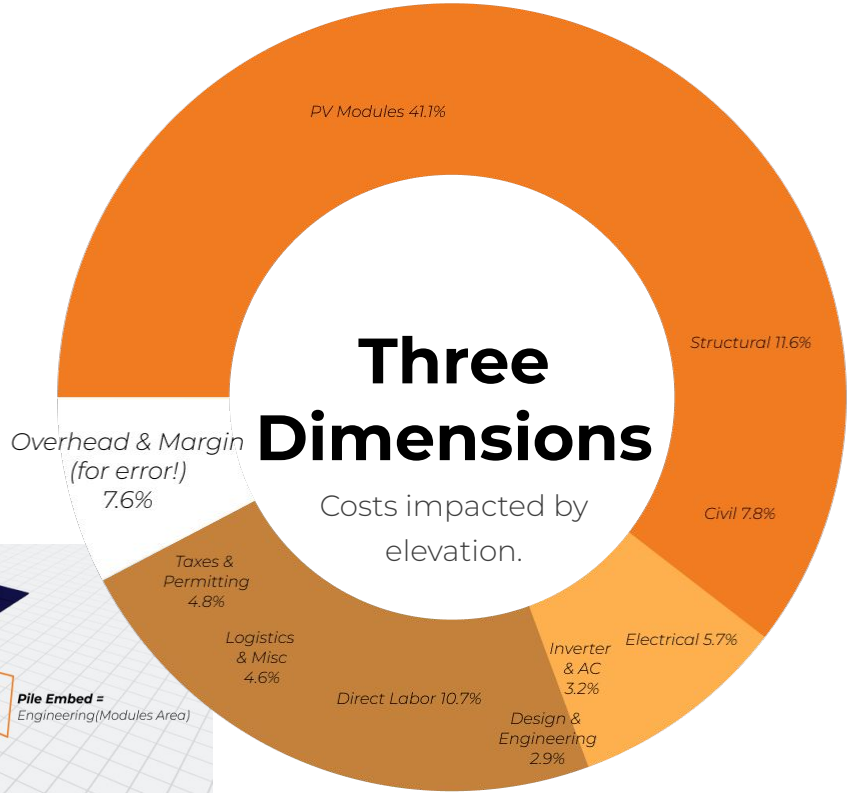
Primary

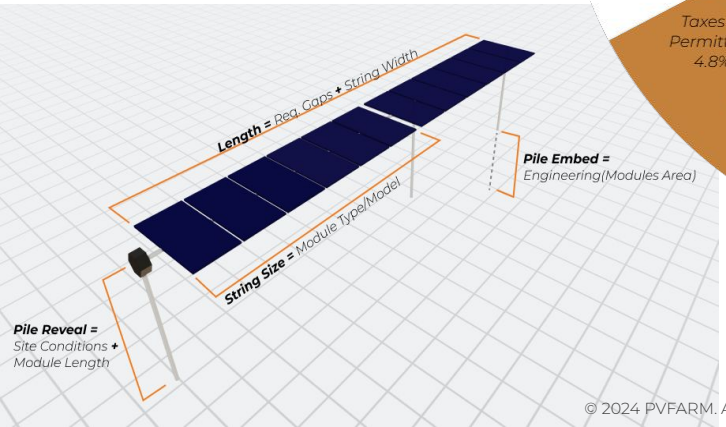
Secondary

Tertiary

Three Dimensions

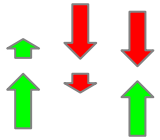
Costs impacted by elevation.



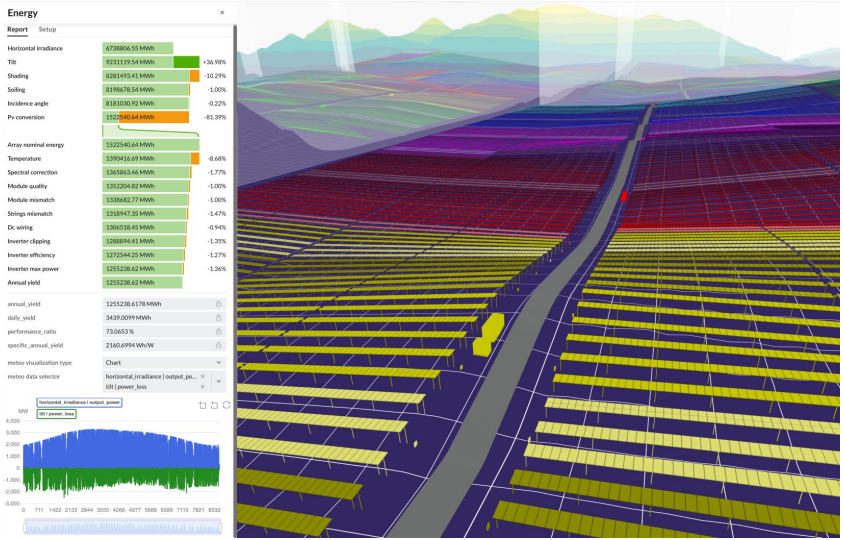


Let’s not forget the denominator…

$$LCOE = \frac{\text{Cost}}{\text{Production}}$$



(As in the case of a PPA, for example)



Which OEMs are the best fit relative to site geometry and project requirements?

Do generalized wiring strategies work well or will further engineering be required?

What power density is required to meet my generation requirements and avoid subprime land?

Where do I need grading or specialized approaches to install equipment?

What is the cost trade-off of piles versus civil work?

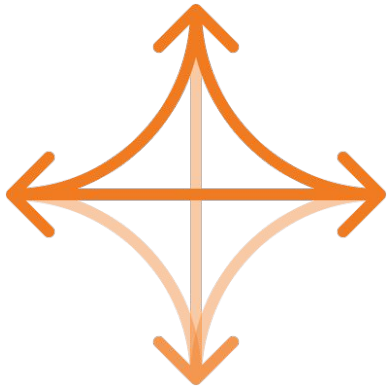
Are terrain-following trackers “worth it” on my site?

With PVFARM Optimization

Know your Unknowns.

Energy

Module Selection
Land Strategy
Shading



Array System

Fixed Tilt
Single-Axis:
Length
Terrain Adaptability
Drive Technology

Civil

Allowable Slopes
Pile Length
Grading Window
Road Layout
Trenching

Electrical

Wiring Topology
Equipment Sizing
Cable Selection

What is the optimal size inverter for this site? Will multiple sizes improve capacity?

Is it possible to avoid all subprime land and still meet energy targets?

Is it more advantageous to expand GCR on specific areas of the site due to topography?

Can fixed-tilt and single-axis arrays be mixed to maximize production value for specific times of year?

Is the site geometry more conducive to drive-line or independent tracking systems?

Which OEMs are the best fit relative to site geometry and project requirements?

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With PVFARM Optimization

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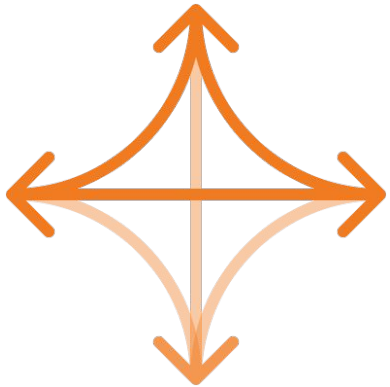
Energy

Module Selection
Losses Assumptions
Shading



Layout

Layout Topology
Racking Selection
Blocking Settings
Roads

Civil

Allowable Slopes
Pile Length
Grading Window
Road Layout
Trenching

Electrical

Wiring Topology
Equipment Sizing
Cable Selection

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Time to Level-Up.

Organization cannot mature or achieve strategic optimization without fully incorporating 3D detail into your processes and analysis.

1

“No Idea”

Unpredictable results, poorly controlled approach, reactive.

2

“Some Idea”

Early understanding of implications but approach is reactive.

3

“Educated Guess”

Quantitative estimates and risk identification inform some decisions.

4

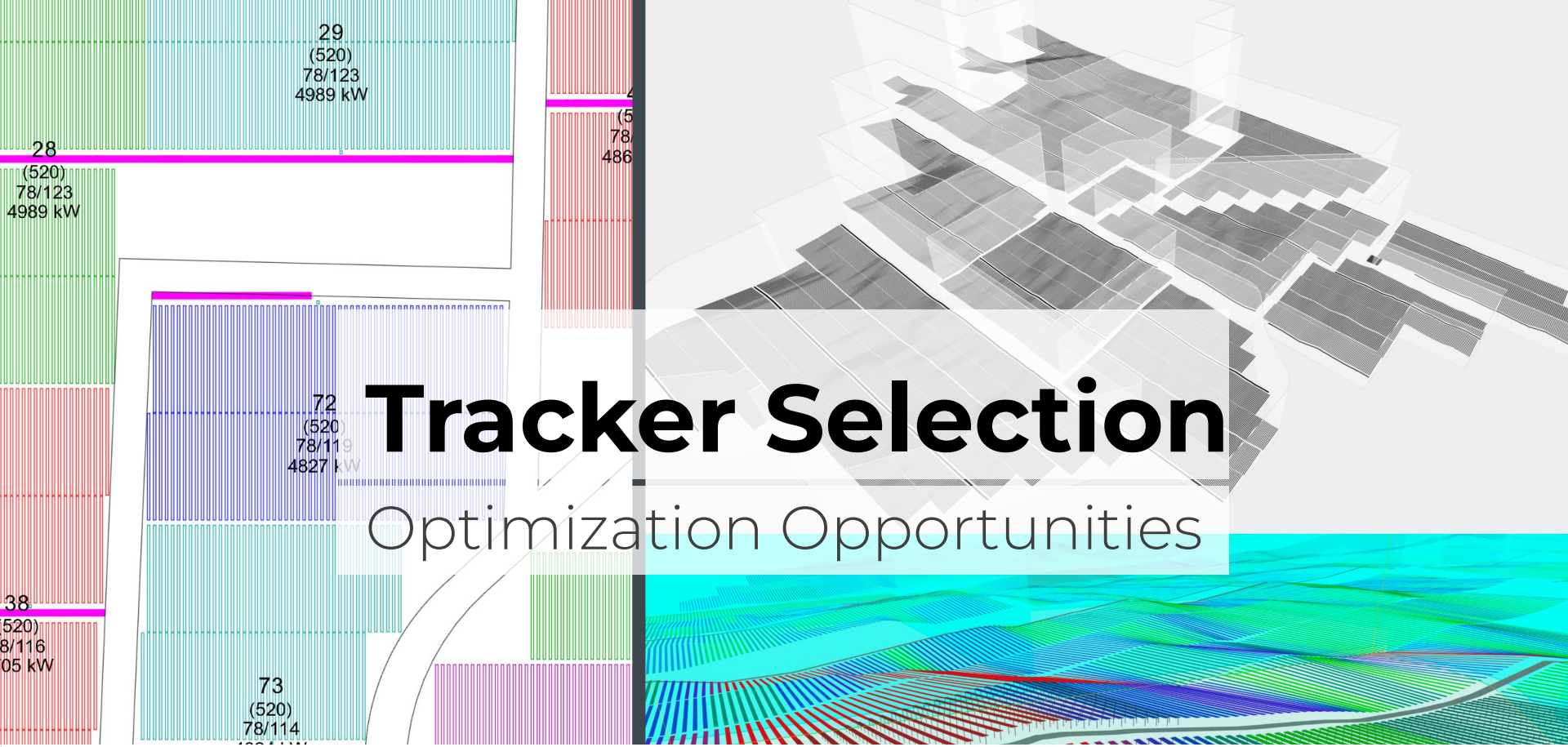
“Actionable”

Detailed planning based on robust data, accounts for lifecycle implementation.

5

“Strategic”

Macro-level insights, surgical approach to customization and refinement toward portfolio-driven KPIs.



Tracker Selection

Optimization Opportunities

1 — "No Idea"

2 (2D) — "Some Idea"

3 — "Educated Guess"

4 (3D) — "Actionable"

5 — "Strategic"

Finding the optimal tracker size

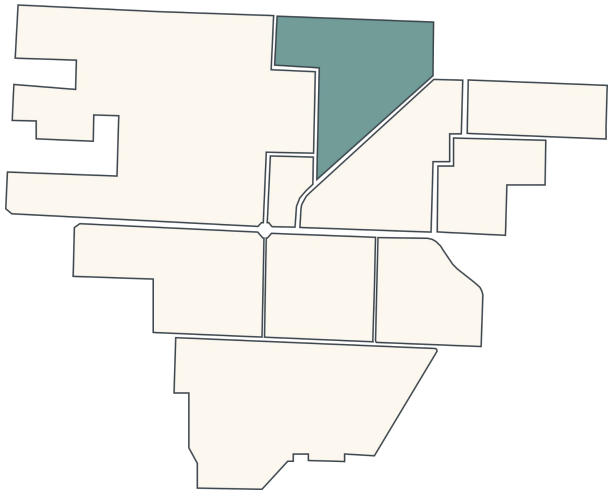
3rd dimension perspective

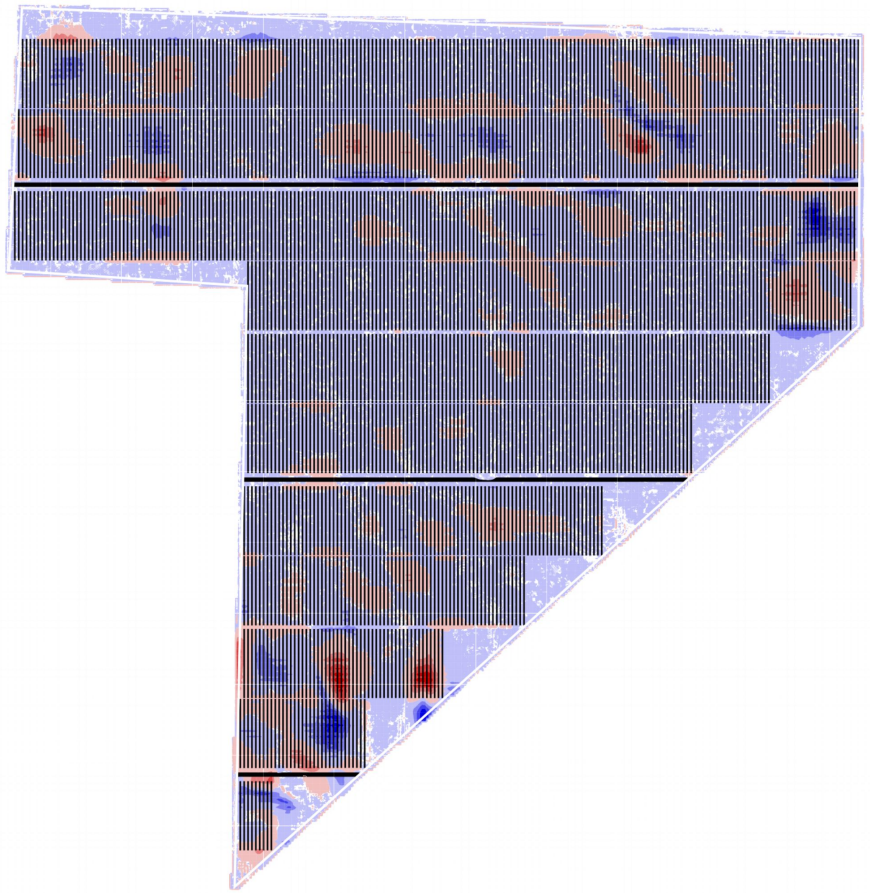
Base case: **78 mod trackers**

76,600 Y3 CUT

68,500 Y3 FILL

Total grading cost: **$508,200**

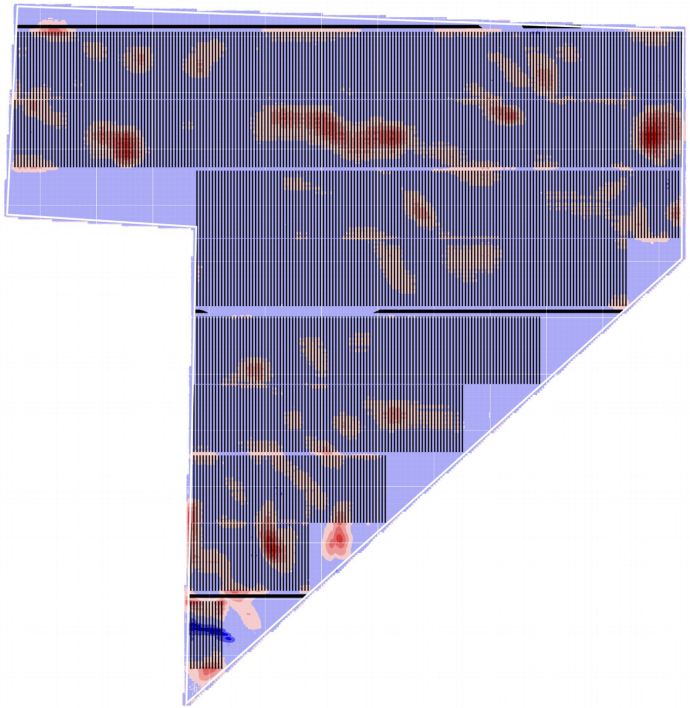




96 mod trackers

103,000 Y3 CUT
113,000 Y3 FILL

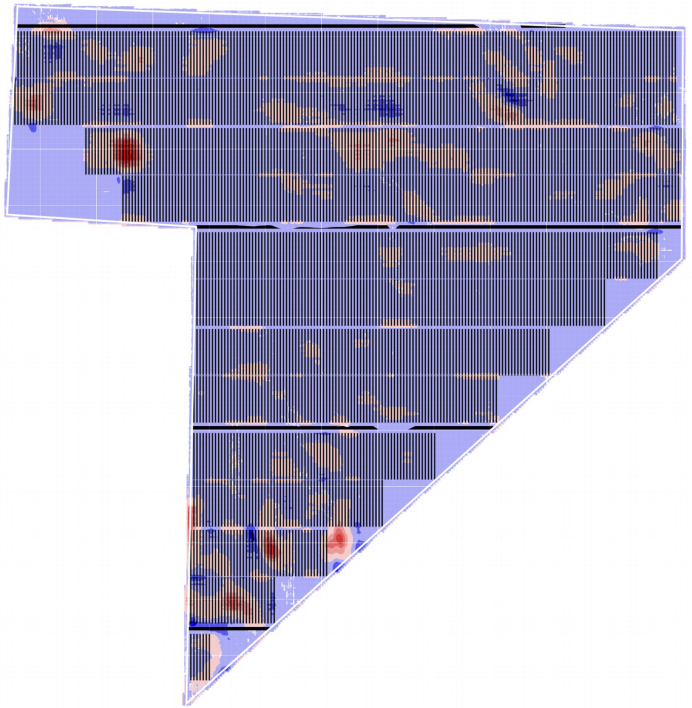
Total cost: **$782,800 (35%⬆️)**



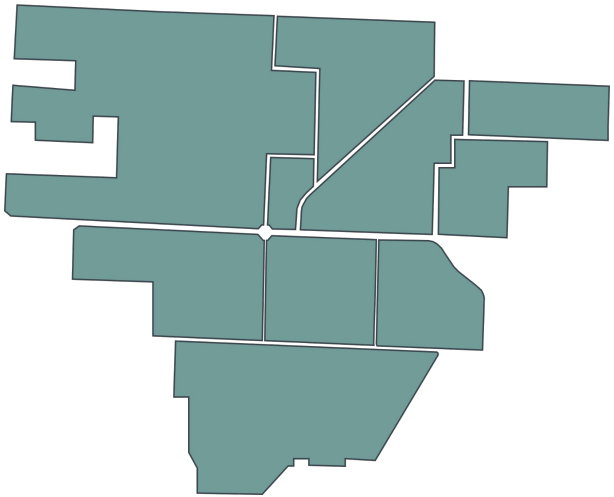
66 mod trackers

66,240 Y3 CUT
64,000 Y3 FILL

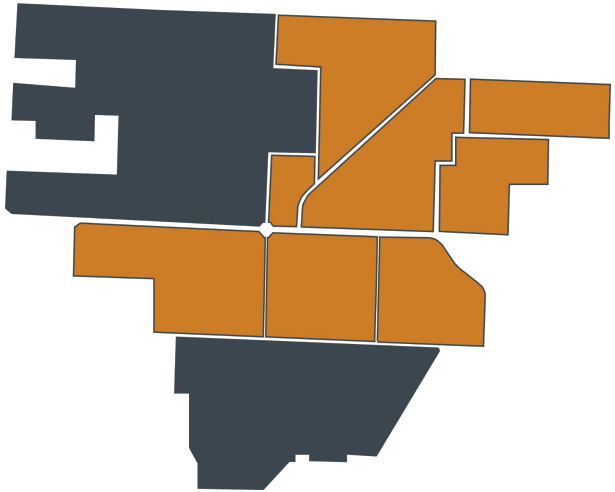
Total cost: **$455,800 (11.5%⬇️)**



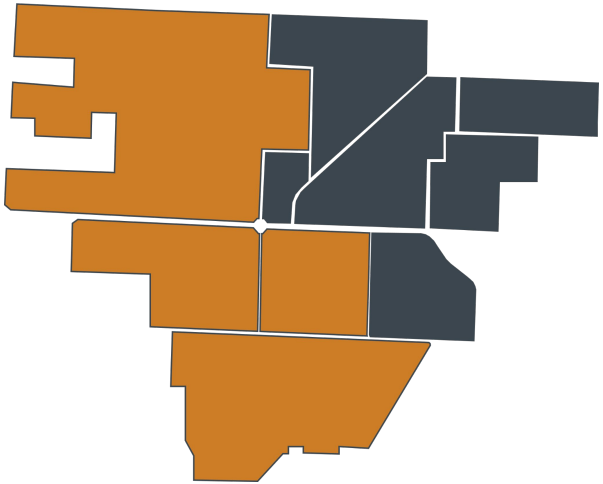
Finding the optimal tracker mix for the whole site



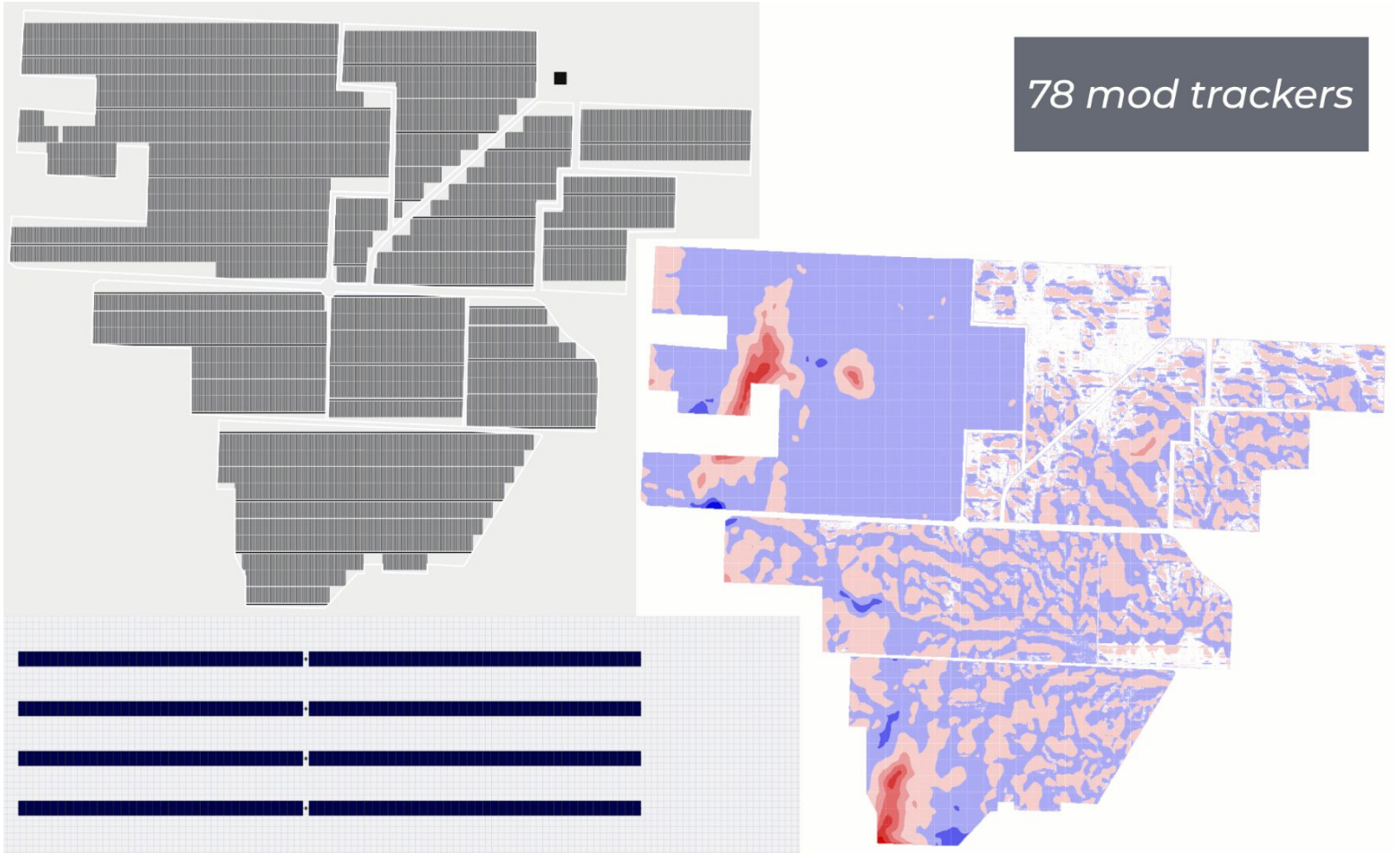
78 or 96 mod trackers only



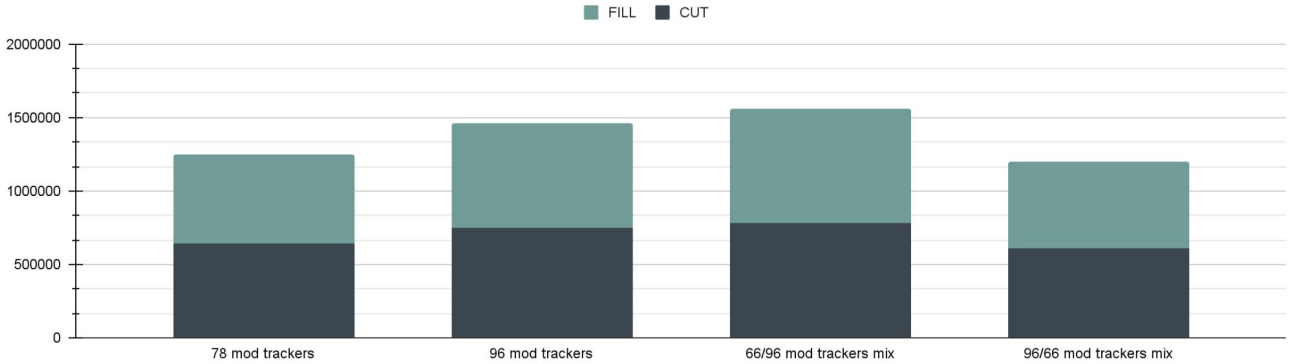
66 / 96 mod trackers mix

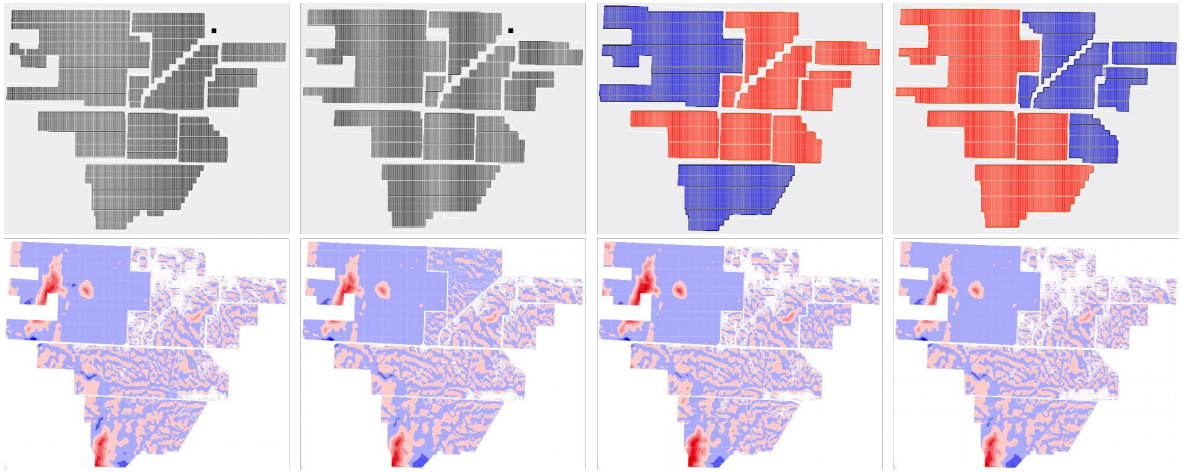


66 / 96 mod trackers mix



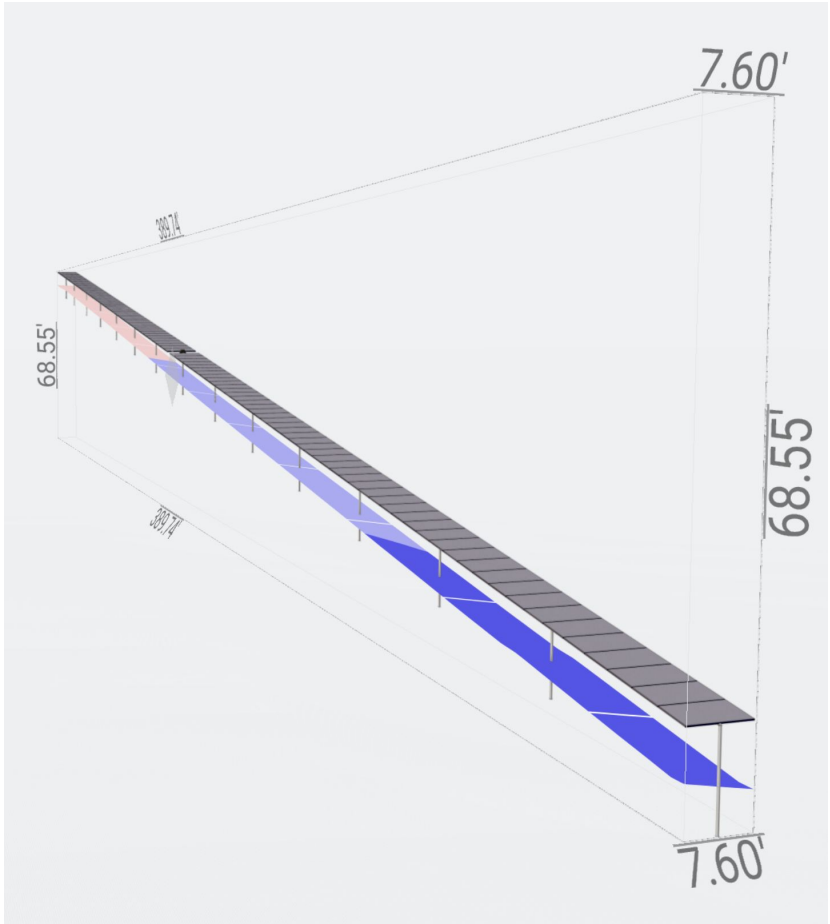
CUT and FILL, Y3

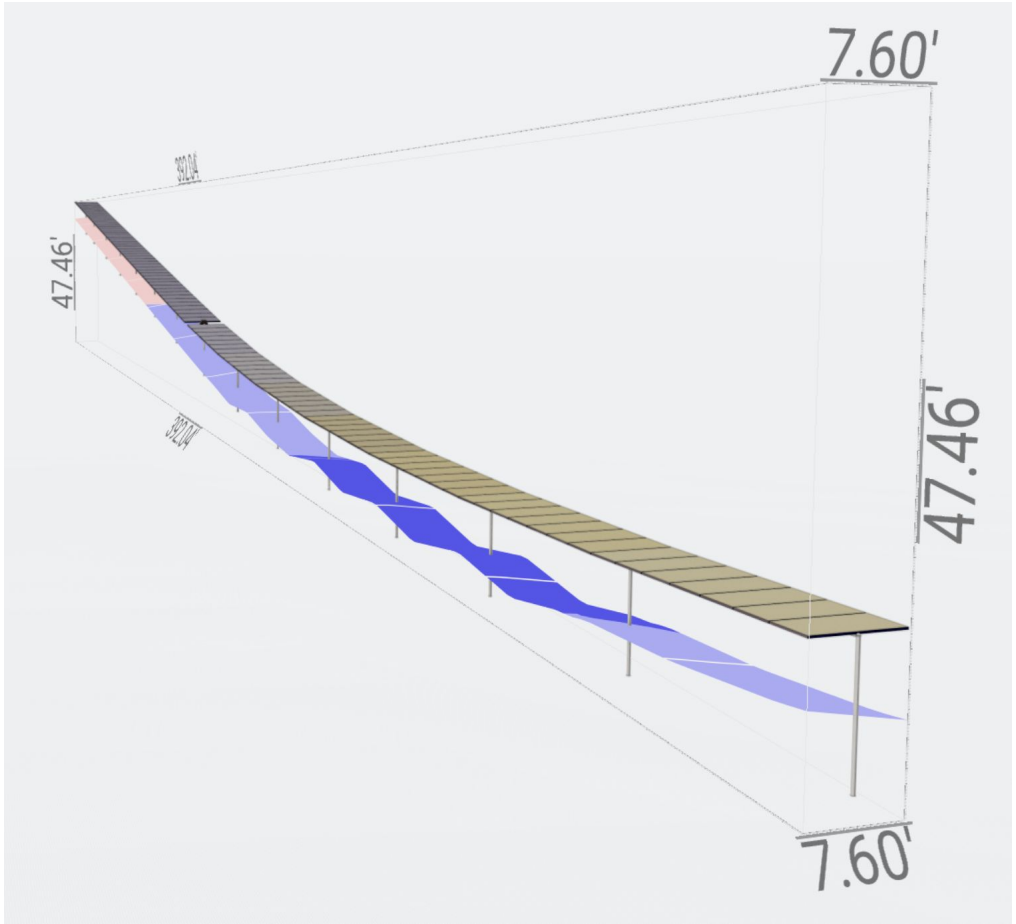




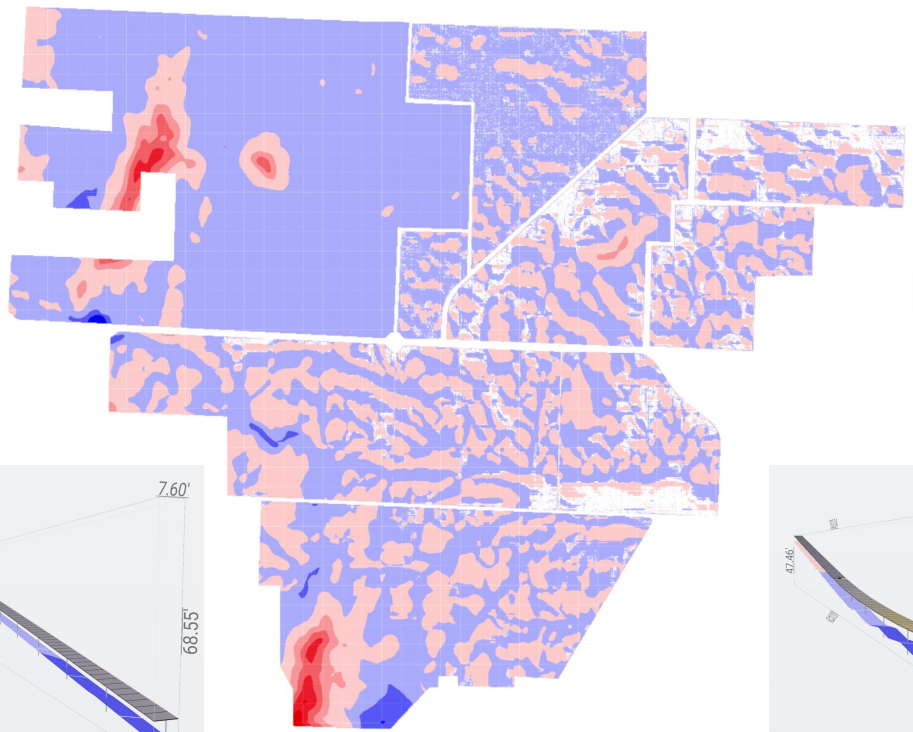
Rigid vs Terrain Following Trackers

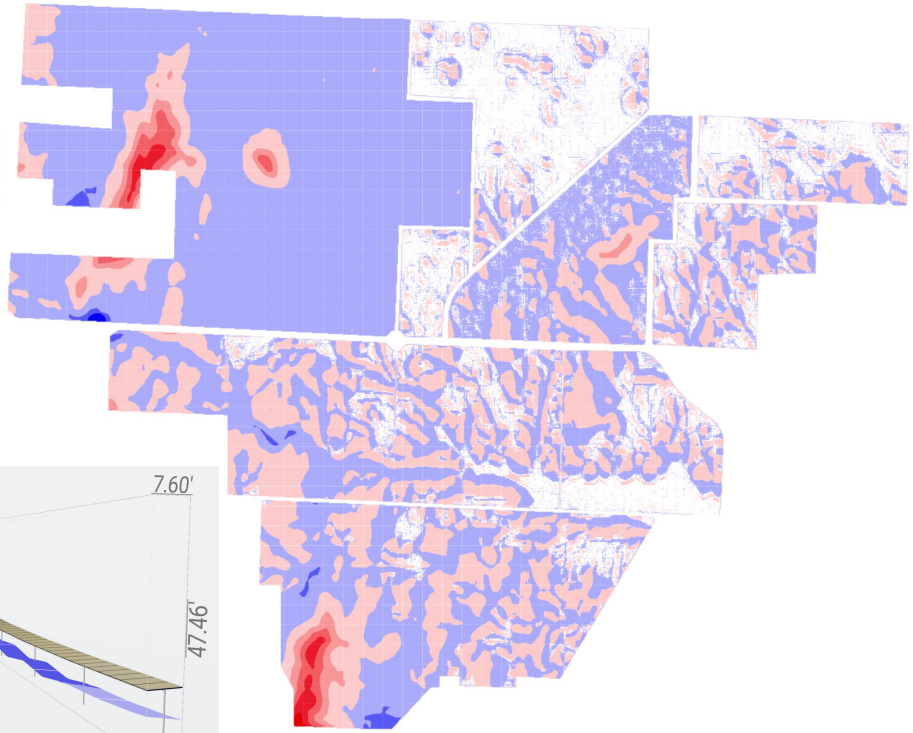
The battle rages on...

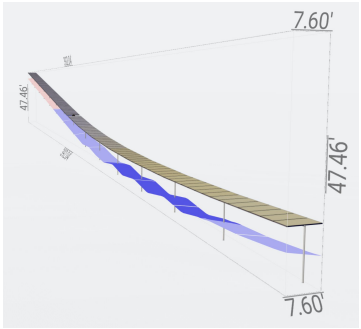




587 MW site: **35% reduction** in cut and fill **[2,200,000 Y3 avoided]**







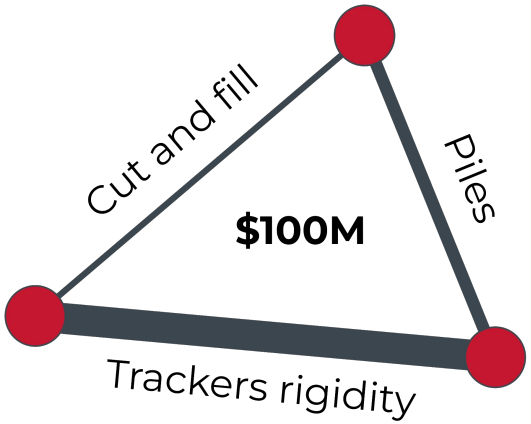
Civil & Pile

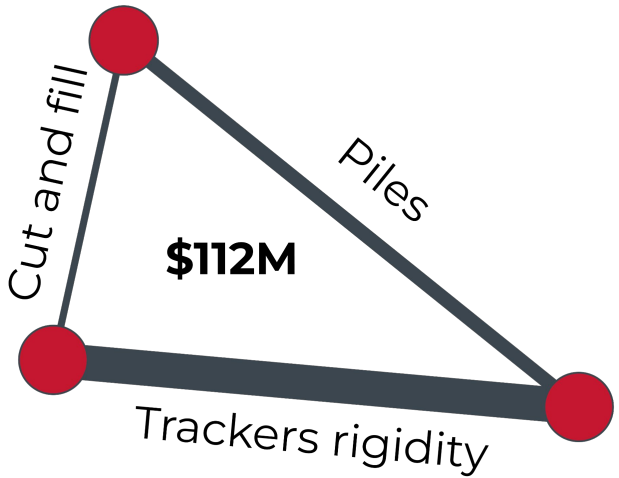
Optimization Opportunities

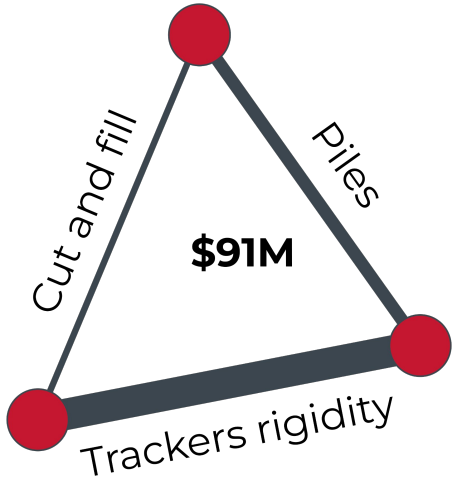
1 "No Idea" → 2 (2D) "Some Idea" → 3 "Educated Guess" - - - → 4 (3D) "Actionable" → 5 "Strategic"

A BALANCING ACT

Cut & Fill vs Piles vs Trackers



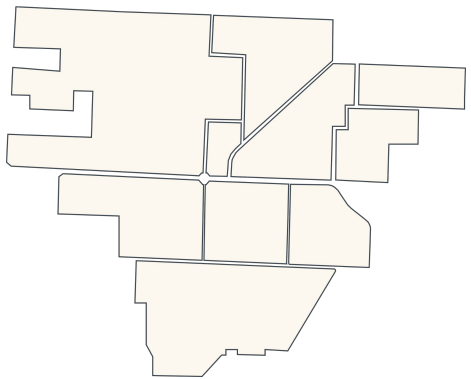


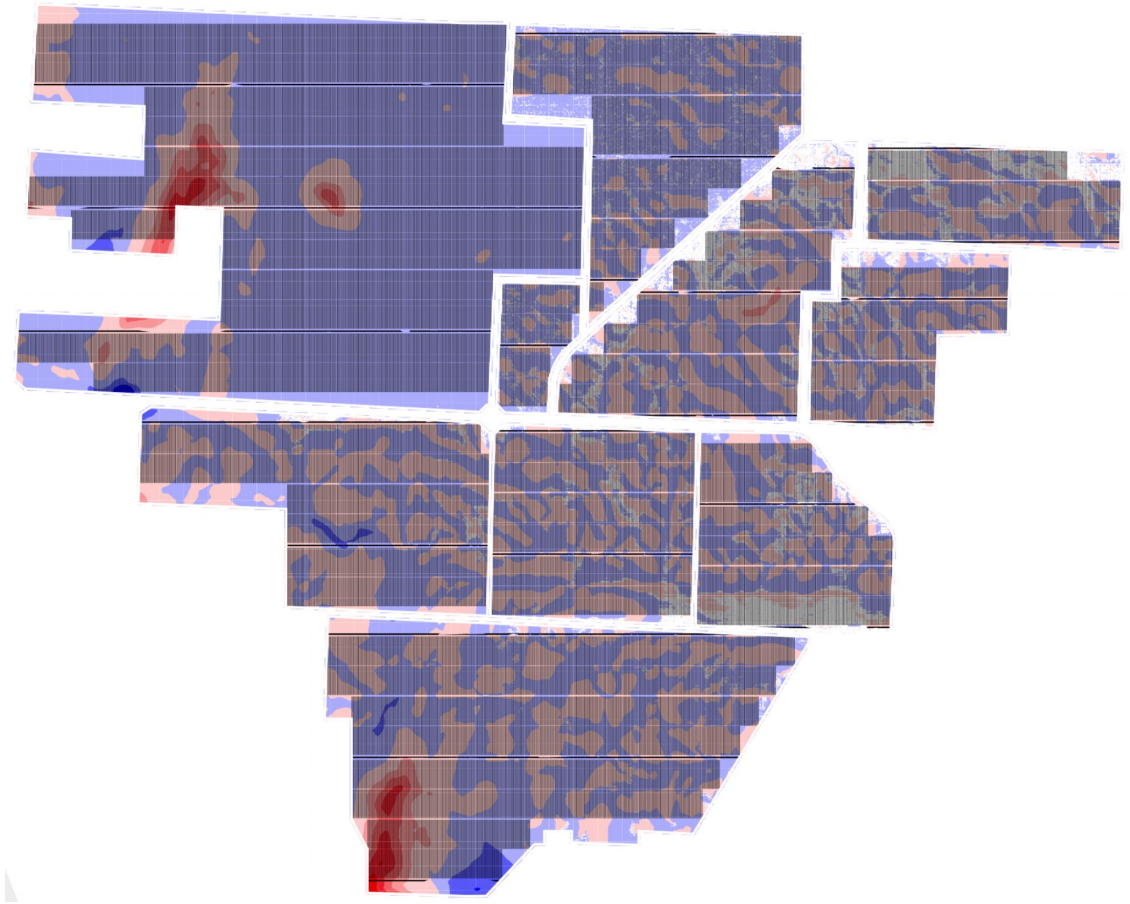


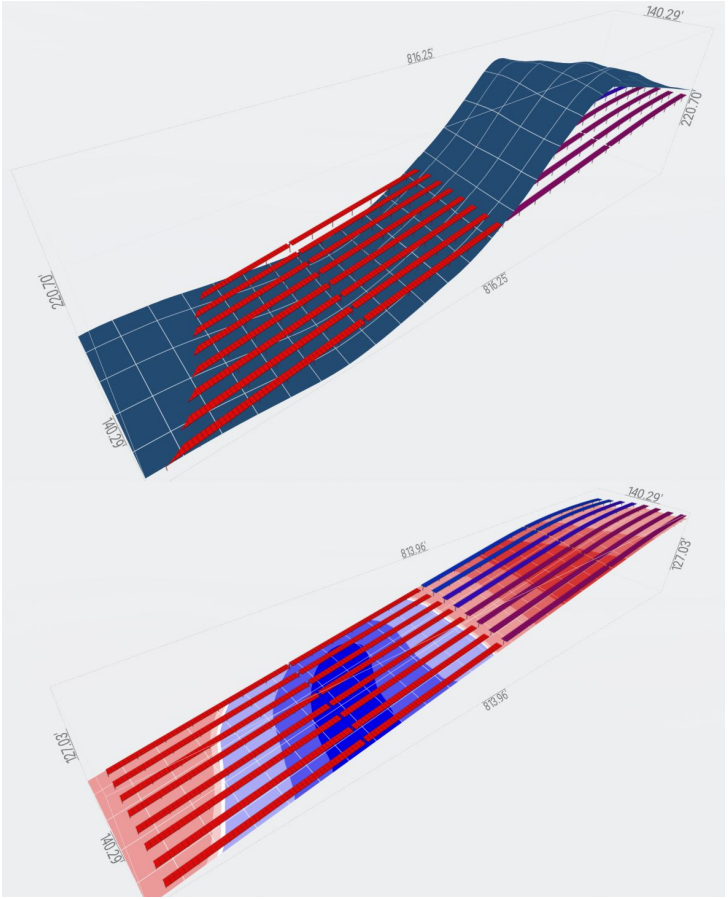
Base case

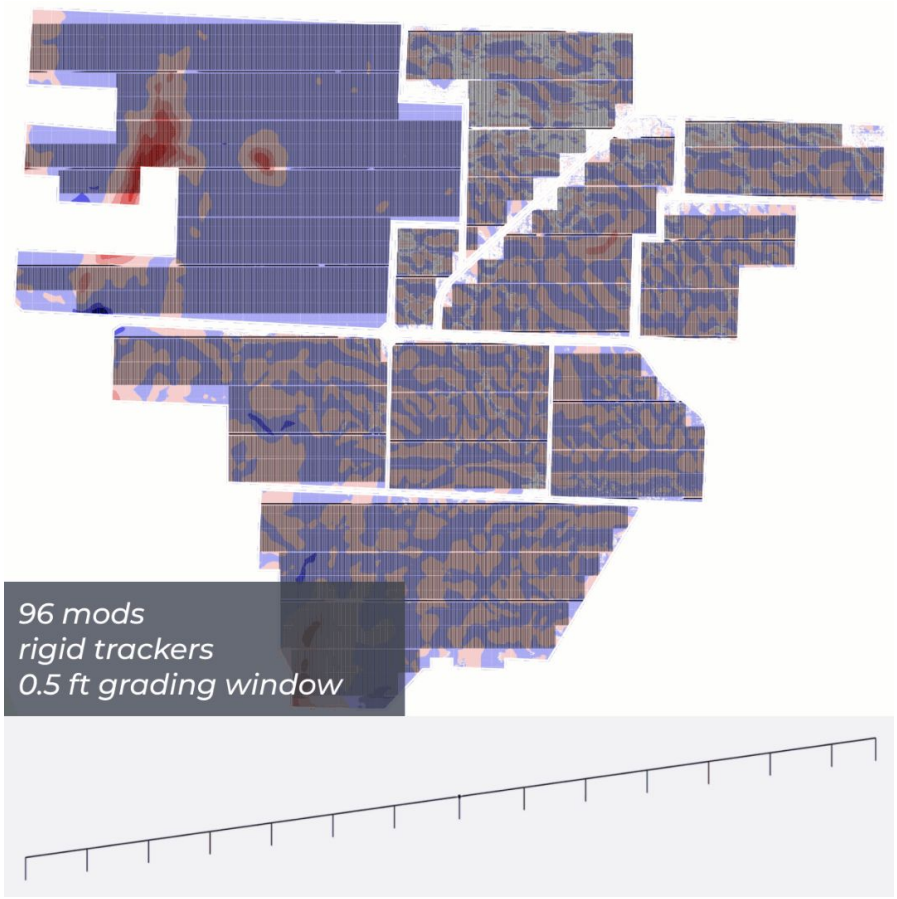
Rigid Trackers
0.5 ft grading window
0 net balance grading strategy

Civil cost: $38,600,000
Piles cost: $24,800,000
Trackers cost: $52,200,000

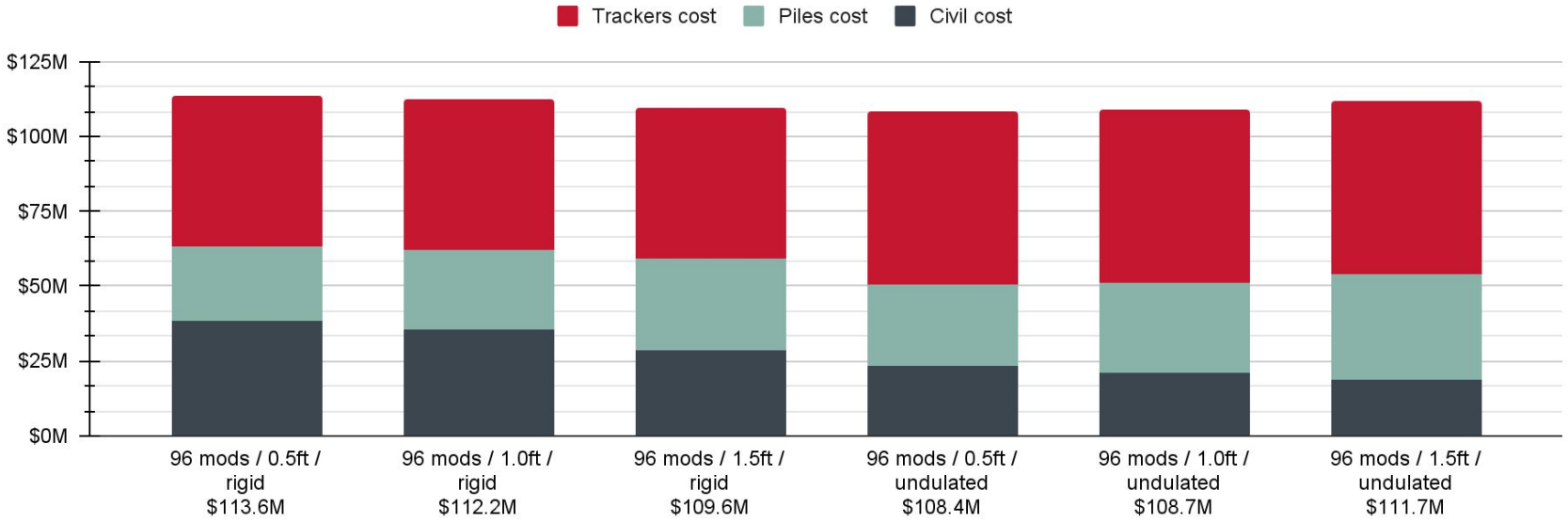


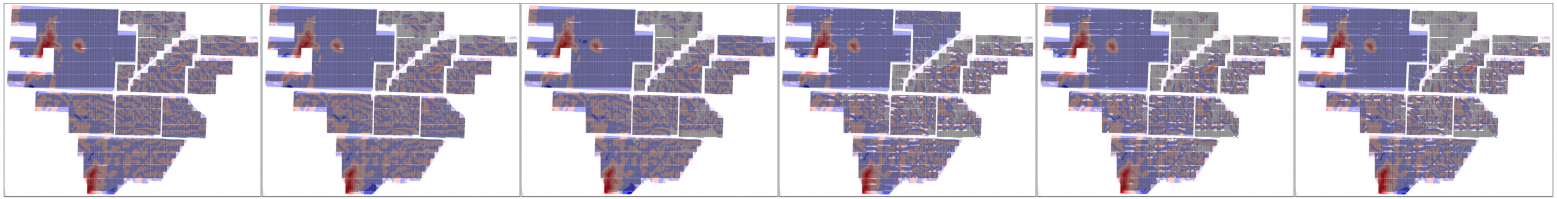




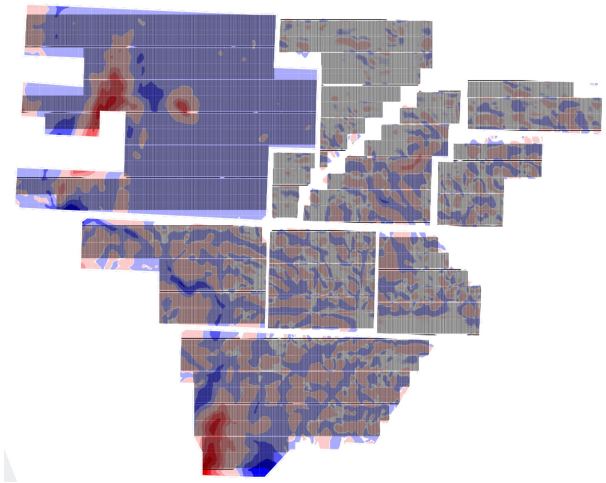


Civil cost, Piles cost and Trackers cost

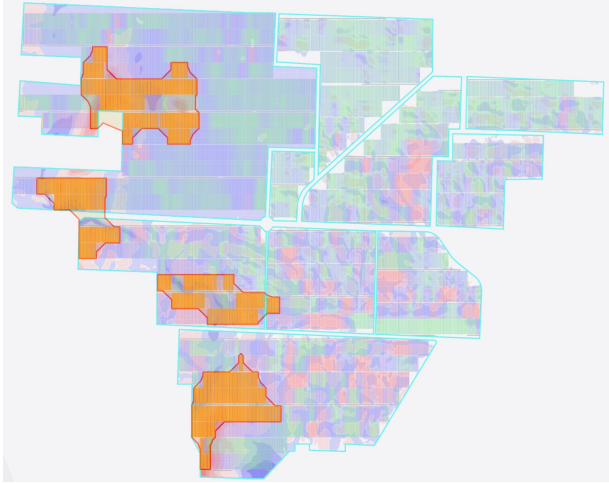




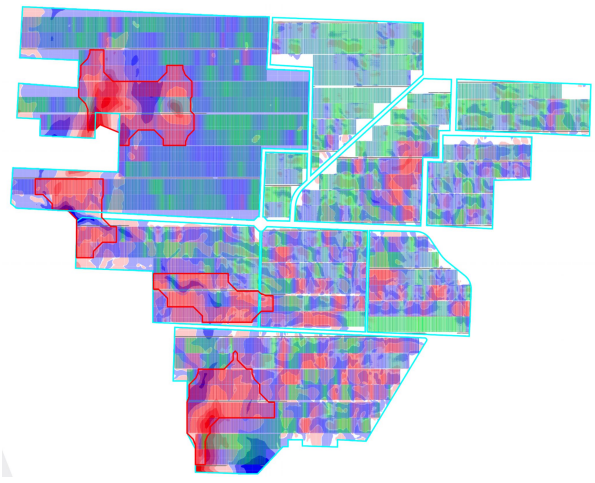
Drill down optimisation



Running initial analysis
(0.5 ft grading window)

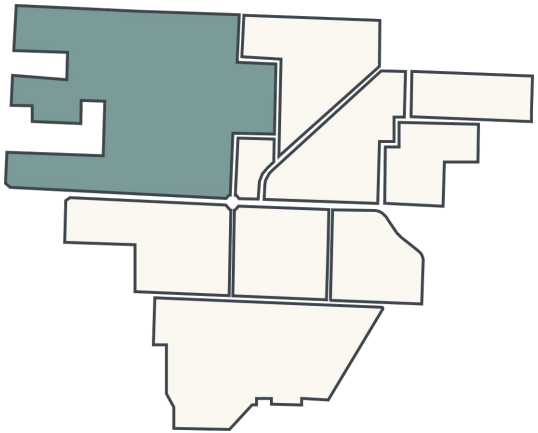


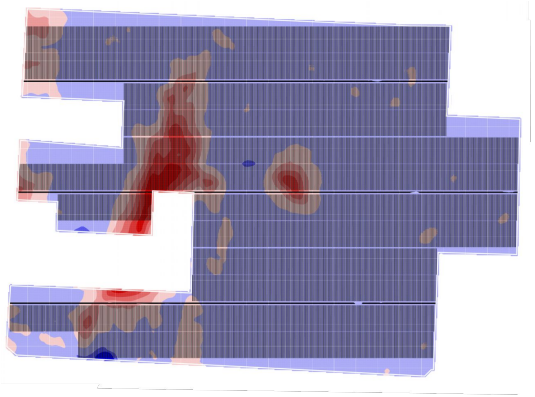
Defining areas with the
biggest amount cut and fill



Rerunning analysis with
increased grading window

Constraints polishing

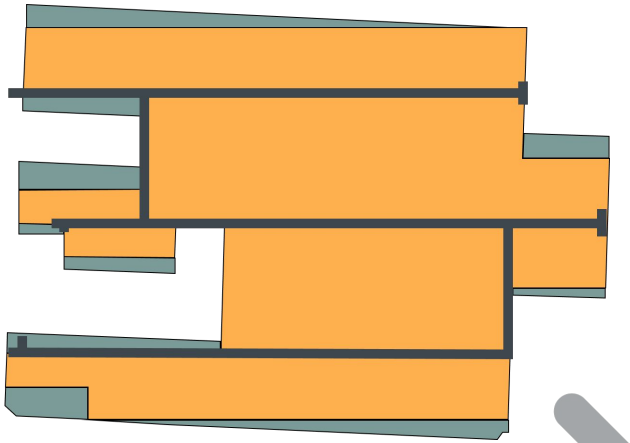




Array grading

Catch grading

Roads grading



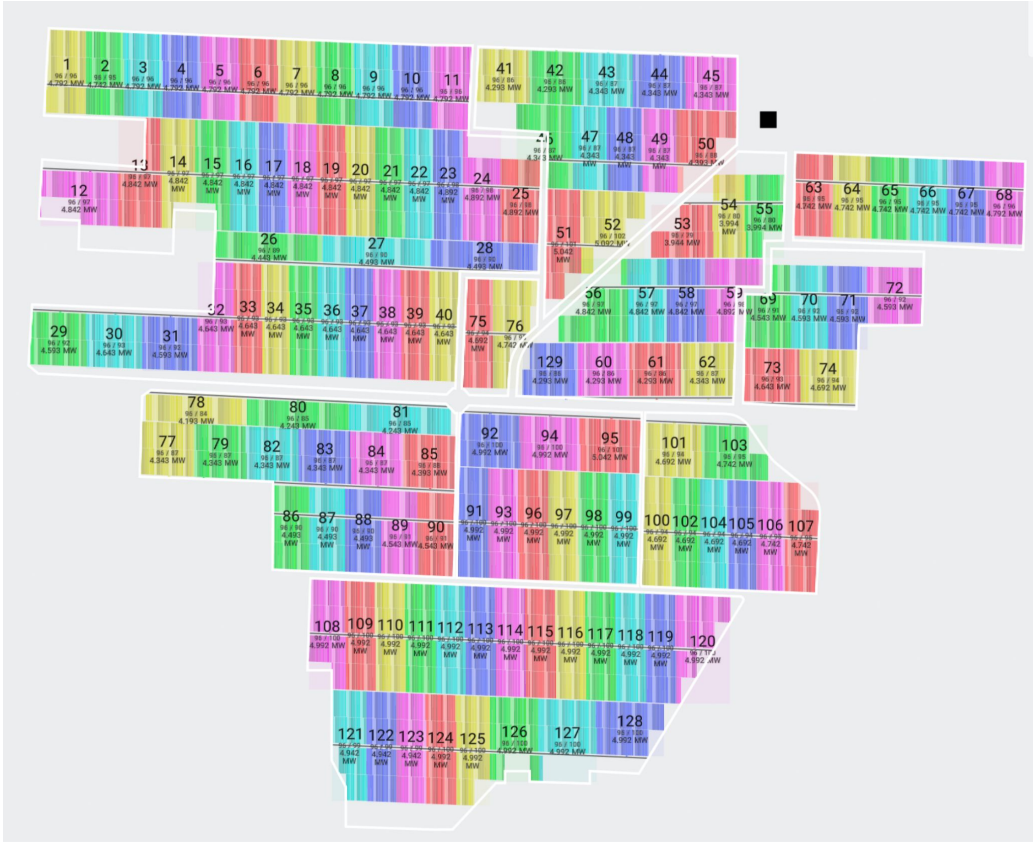
Energy Production

Everything affects everything else, and you have to understand that whole web of connections ©

FLAT LAYOUT

851,017 MWh

Horizontal irradiance	4631364.44 MWh	
Tilt	5733233.06 MWh	+23.79%
Shading	5733233.06 MWh	–
Bifaciality	5733233.06 MWh	–
Soiling	5675900.63 MWh	-1.00%
Incidence angle	5661617.60 MWh	-0.25%
Pv conversion	1053662.20 MWh	-81.39%
Array nominal energy	1053662.20 MWh	
Temperature	979660.37 MWh	-7.02%
Spectral correction	973313.22 MWh	-0.65%
Module quality	963580.08 MWh	-1.00%
Module mismatch	953944.29 MWh	-1.00%
Strings mismatch	944404.85 MWh	-1.00%
Dc wiring	934056.24 MWh	-1.10%
Inverter clipping	923636.36 MWh	-1.12%
Inverter efficiency	907214.44 MWh	-1.78%
Inverter max power	851016.75 MWh	-6.19%
Annual yield	851016.75 MWh	

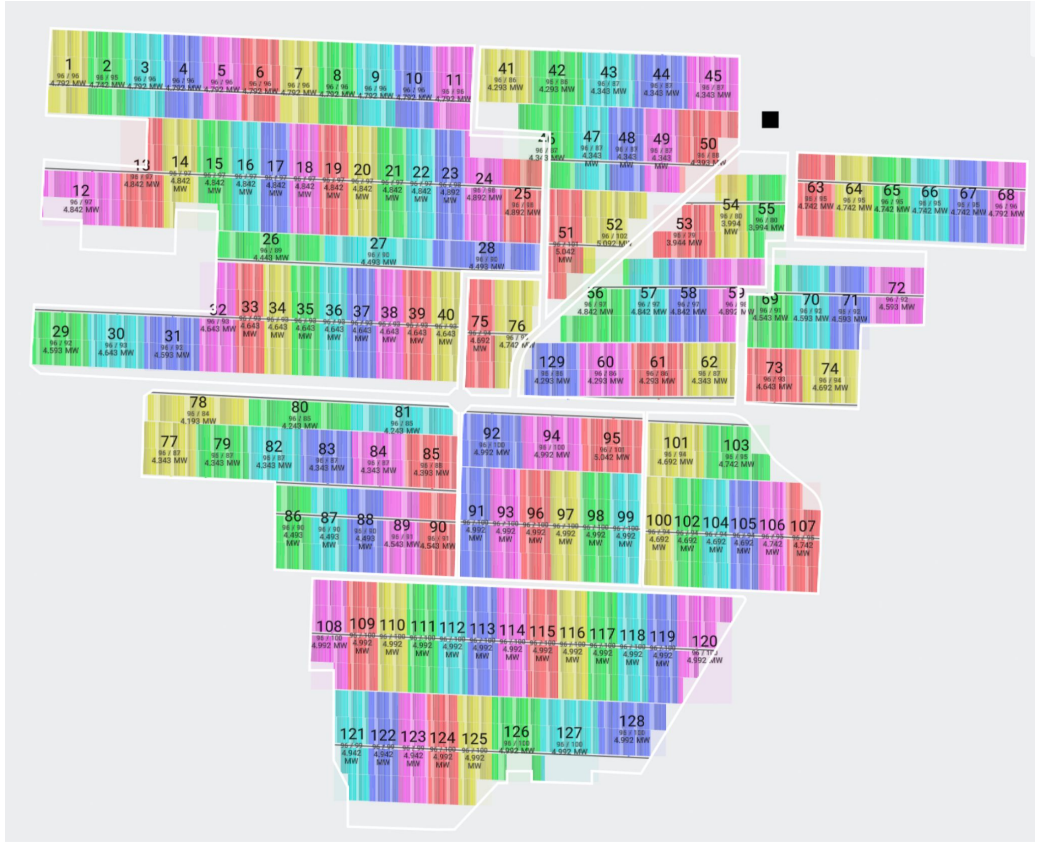


FLAT LAYOUT **SHADING**

784,220 MWh **[8.5%⬇️]**

25Y Energy Δ $35M⬇️

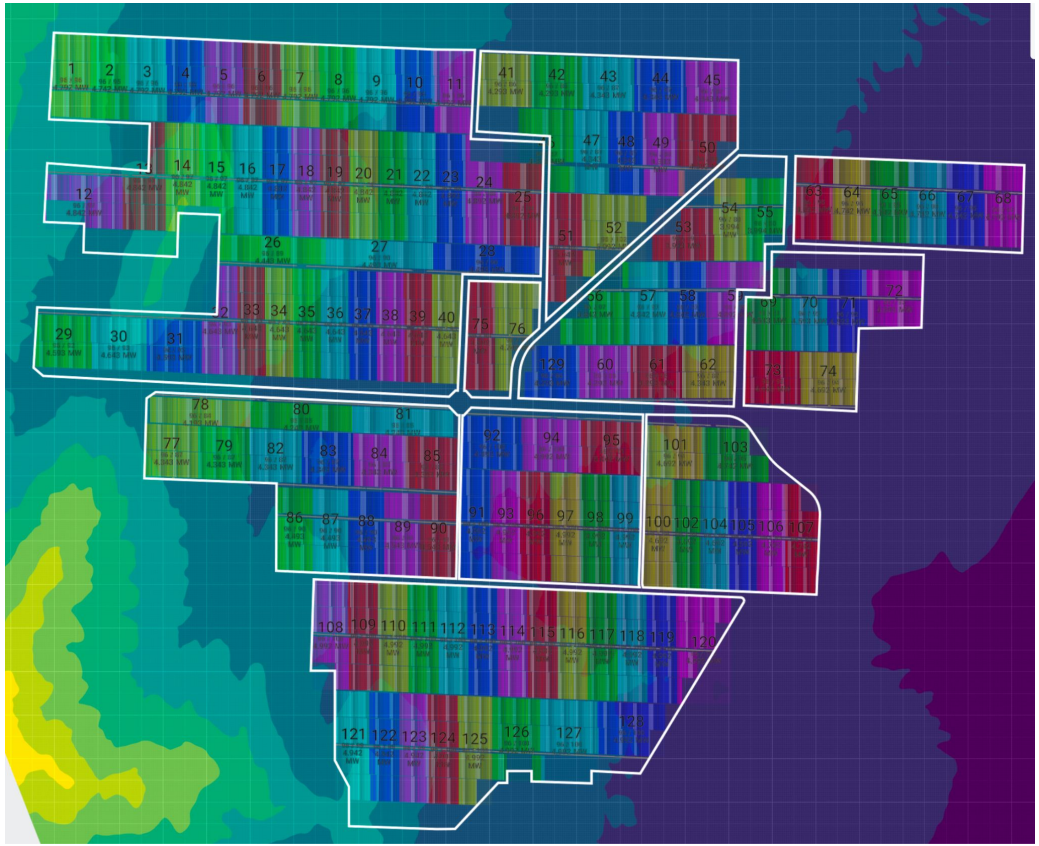
Horizontal irradiance	4631364.45 MWh	
Tilt	5733233.05 MWh	+23.79%
Shading	5248074.96 MWh	-8.46%
Bifaciality	5248074.96 MWh	–
Soiling	5195594.21 MWh	-1.00%
Incidence angle	5182809.34 MWh	-0.25%
Pv conversion	964553.00 MWh	-81.39%
Array nominal energy	964553.00 MWh	
Temperature	899062.40 MWh	-6.79%
Spectral correction	896947.45 MWh	-0.24%
Module quality	887977.97 MWh	-1.00%
Module mismatch	879098.19 MWh	-1.00%
Strings mismatch	869306.56 MWh	-1.11%
Dc wiring	860175.79 MWh	-1.05%
Inverter clipping	851322.03 MWh	-1.03%
Inverter efficiency	835508.89 MWh	-1.86%
Inverter max power	784219.94 MWh	-6.14%
Annual yield	784219.94 MWh	



3D LAYOUT **SHADING**

791,553 MWh [0.9%⬆️]
25Y Energy Δ $3.8M⬆️

Horizontal irradiance	4631364.43 MWh	
Tilt	5733232.95 MWh	+23.79%
Shading	5294059.94 MWh	-7.66%
Bifaciality	5294059.94 MWh	–
Soiling	5241119.39 MWh	-1.00%
Incidence angle	5228222.65 MWh	-0.25%
Pv conversion	973004.69 MWh	-81.39%
Array nominal energy	973004.69 MWh	
Temperature	907077.01 MWh	-6.78%
Spectral correction	904118.89 MWh	-0.33%
Module quality	895077.69 MWh	-1.00%
Module mismatch	886126.92 MWh	-1.00%
Strings mismatch	874042.26 MWh	-1.36%
Dc wiring	864968.14 MWh	-1.04%
Inverter clipping	855750.76 MWh	-1.07%
Inverter efficiency	839941.85 MWh	-1.85%
Inverter max power	791552.98 MWh	-5.76%
Annual yield	791552.98 MWh	

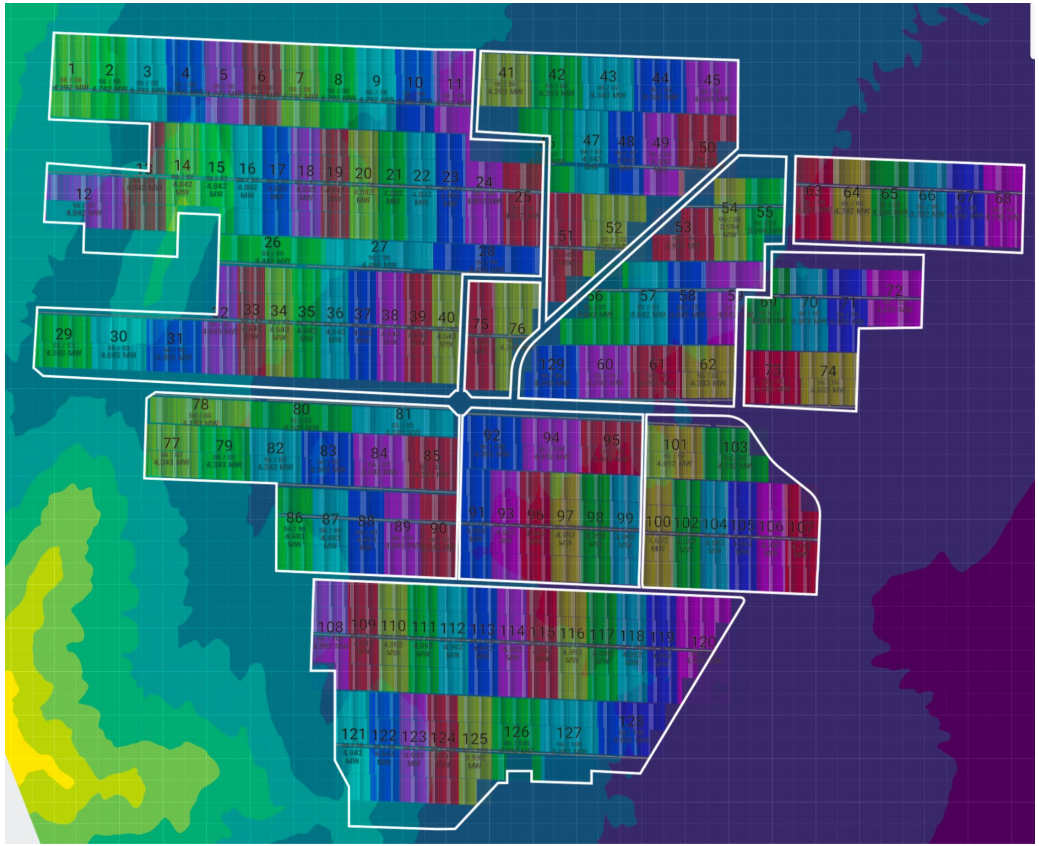


INCLUDING TERRAIN

784,220 MWh **[2.4%⬇️]**

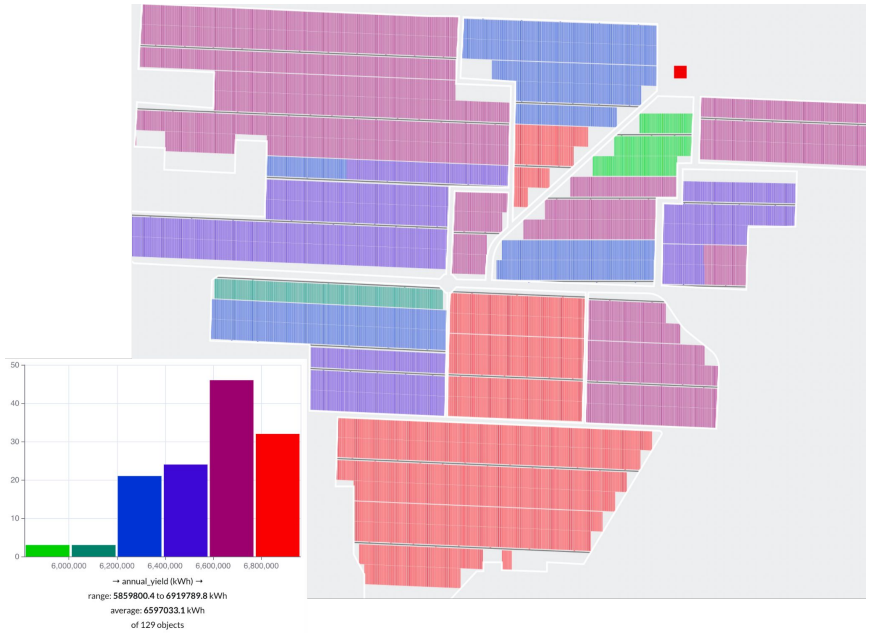
25Y Energy Δ $9.7M⬇️

Horizontal irradiance	4631364.43 MWh	
Tilt	5733232.95 MWh	+23.79%
Shading	5151727.91 MWh	-10.14%
Bifaciality	5151727.91 MWh	–
Soiling	5100210.63 MWh	-1.00%
Incidence angle	5088099.30 MWh	-0.24%
Pv conversion	946926.87 MWh	-81.39%
Array nominal energy	946926.87 MWh	
Temperature	883372.47 MWh	-6.71%
Spectral correction	881460.78 MWh	-0.22%
Module quality	872646.16 MWh	-1.00%
Module mismatch	863919.70 MWh	-1.00%
Strings mismatch	851789.41 MWh	-1.40%
Dc wiring	843108.88 MWh	-1.02%
Inverter clipping	834711.68 MWh	-1.00%
Inverter efficiency	819082.54 MWh	-1.87%
Inverter max power	773168.45 MWh	-5.61%
Annual yield	773168.45 MWh	

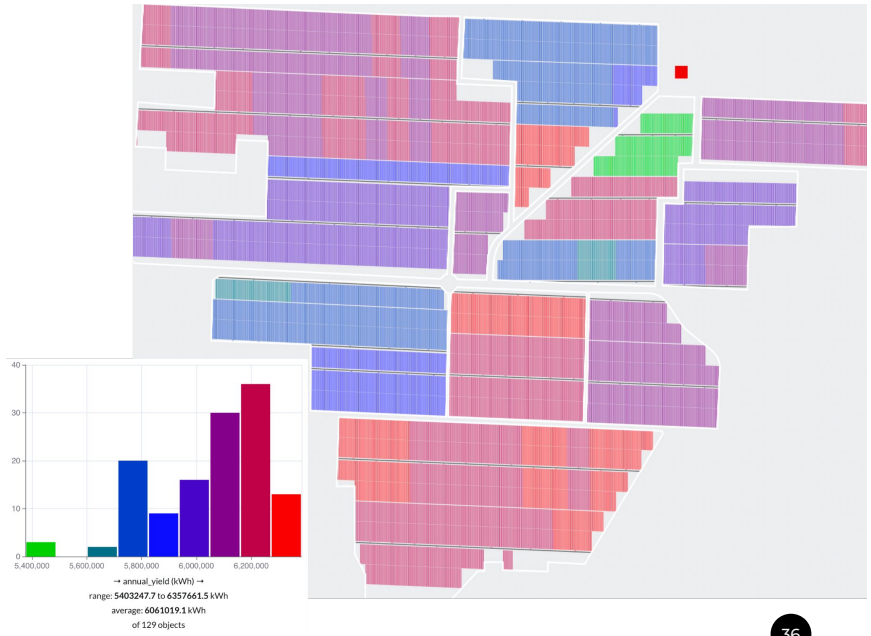


Annual Yield by blocks

FLAT LAYOUT

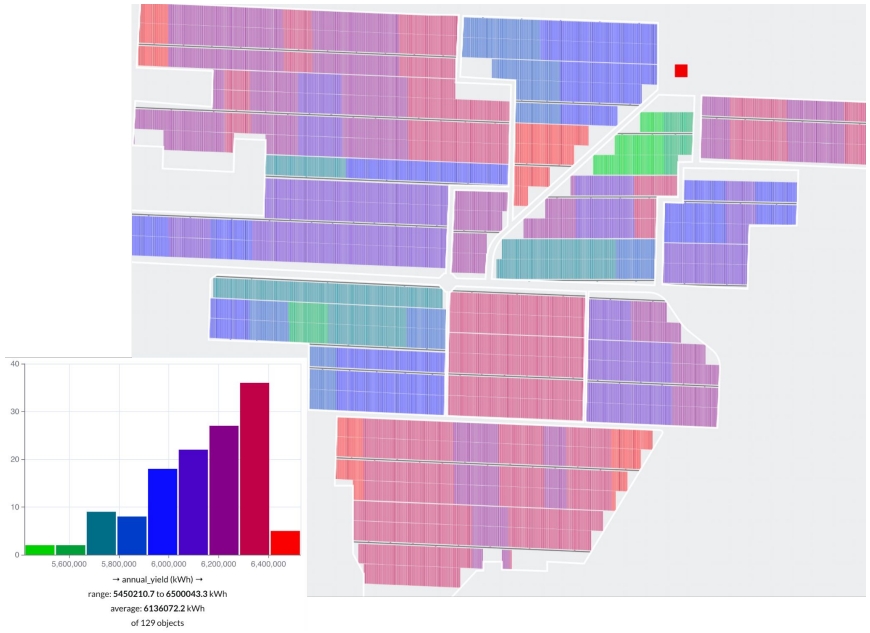


FLAT LAYOUT **SHADING**

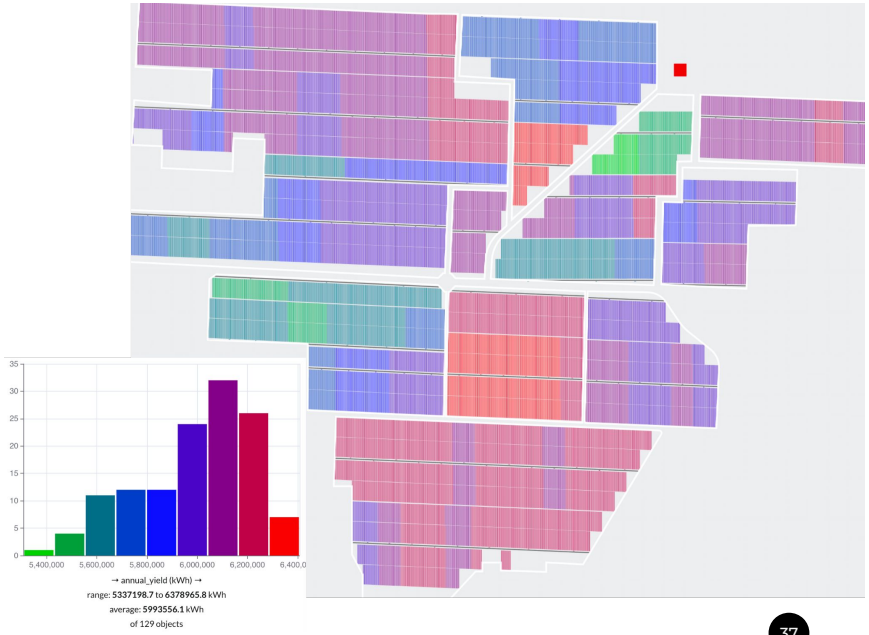


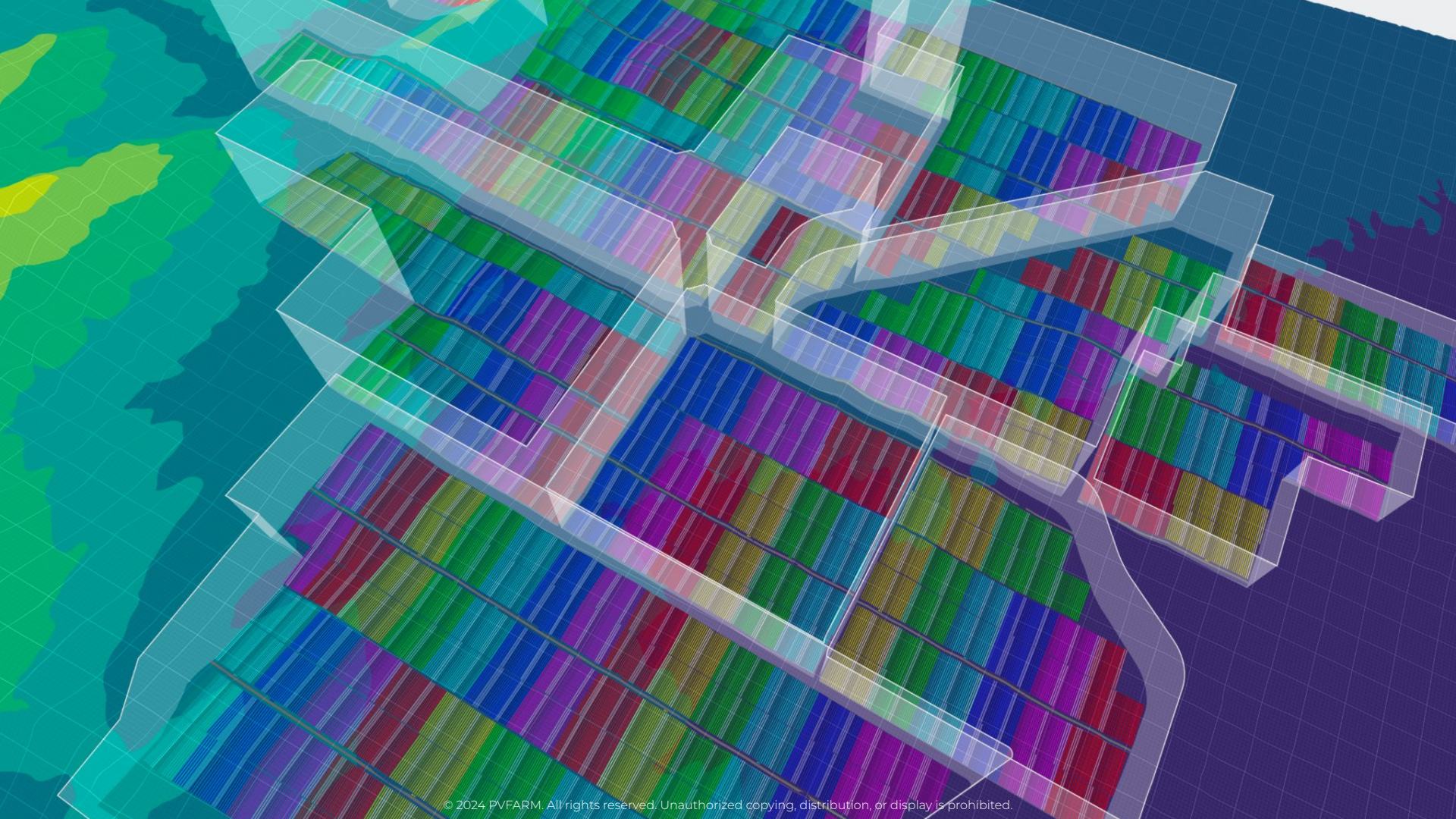
Annual Yield by blocks

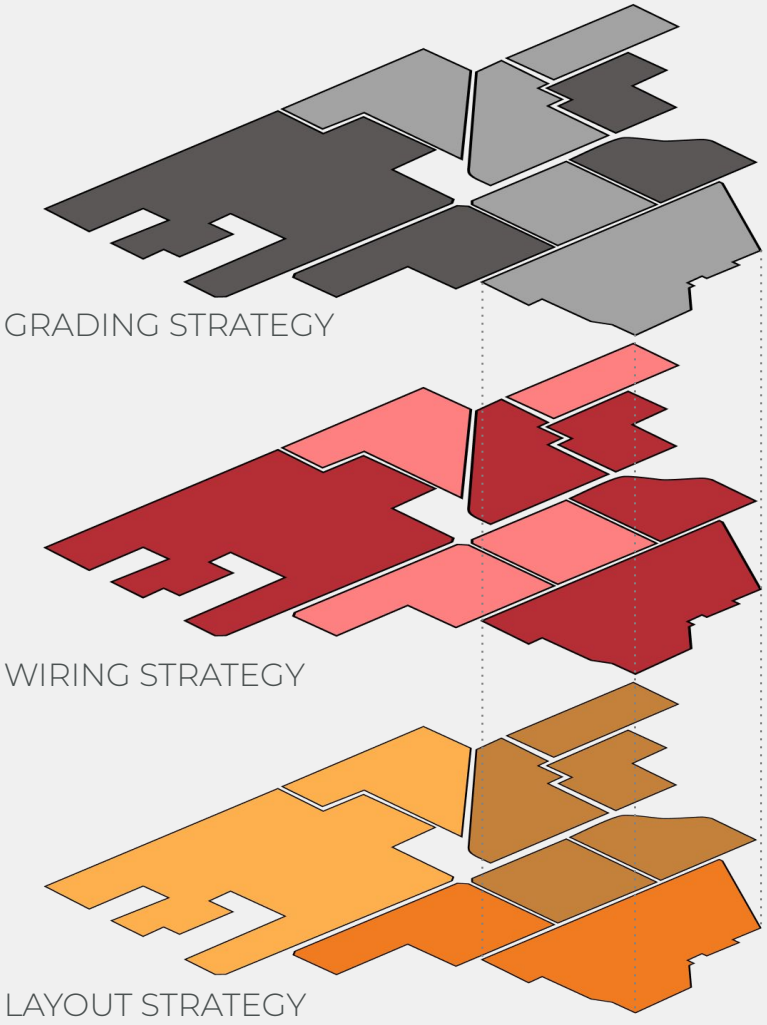
3D LAYOUT **SHADING**



INCLUDING TERRAIN







Jedi-Level

Field-by-Field Optimization

Leveraging both multidisciplinary nature and multiplicity of parcels to achieve truly optimized layouts:

- apply distinct configurations to different subareas
- analyse layout as the whole

Energy
Module Selection
Losses Assumptions
Shading

Layout
Layout Topology
Racking Selection
Blocking Settings
Roads

Civil
Allowable Slopes
Pile Length
Grading Window
Road Layout
Trenching

Electrical
Wiring Topology
Equipment Sizing
Cable Selection

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THANK YOU

QUESTIONS?