PVTECH TECHTalk Product Series

SUN&STEEL solar

Single Axis Tracking

# *Simplistic Tracker Design for Significant Cost Benefits*

**Robert Dally**

**November 10, 2021**

# Important Web Links

**Sun and Steel Solar Website**

www.sunandsteelsolar.com

**Promotion YouTube Video (7.5 minutes)**

**https://youtu.be/l_JwIZ58Txs**

**https://youtu.be/l_JwZ58Txs**

*(or Google "YouTube Sun and Steel Solar")*

# Vision Statement

*To offer the simplest, most reliable and lowest risk cost-competitive Single-Axis Tracker mounting system for photovoltaic solar farms*

# Technology Statement

***"The Better Mousetrap"***

*Sun and Steel Solar has an exciting, disruptive and leapfrogging technology which can save $30 million per gigawatt (GW) up-front and* ***$50mm/GW*** *over a project's lifetime*

# Management & the Team

## Robert Dally – Engineer, Inventor, Director

- BS Electrical Engineering,  BA Spanish,  MBA
- ***42 years*** in solar PV
- ***13 years*** project engineering PV solar panels for satellites
- ***28+ years*** terrestrial PV internationally as engineer, PM, Manager, Director, CTO, consultant, and entrepreneur
- Two previous tracker developments (2004 & 2007)

- Extensive network of *engineers, consultants, contractors, universities, test facilities, suppliers, sales & marketing professionals, PMs, stakeholders & potential customers*

# Management Experience

- **13 yrs.** project engineering satellite solar panels (Scientific, Commercial, Military)
- **17 yrs.** of tracker development
  - 2004, Shell Solar, **1 MW**, 48 rows, 3.3 meter chord
  - 2007, Conergy, **24 MW** and more, becoming FTC Solar's **AP-90 for 600MW** of tracker deployment

# Seeking Round A

***Sun and Steel Solar*** is a ***pre-sales start-up***

- We designed, prototyped, tested and proved our vision of a *superior* ***Single-Axis Tracker*** for C&I and grid PV solar farms
- *2* ***patents*** *issued, 6 pending,* all eight *strategically* ***reduce cost*** and ***enhance reliability*** via *simplicity*
- We seek ***Round A*** funding of ***$2.5mm*** for ***25% ownership***

# Seeking Round A

## ***Target Investors***

- ***Angels, Private Equity, VCs***
- Fixed-tilt racking &/or single-axis tracker companies
- PV module manufacturers
- Steel companies
- EPCs
- Project Developers
- Utilities

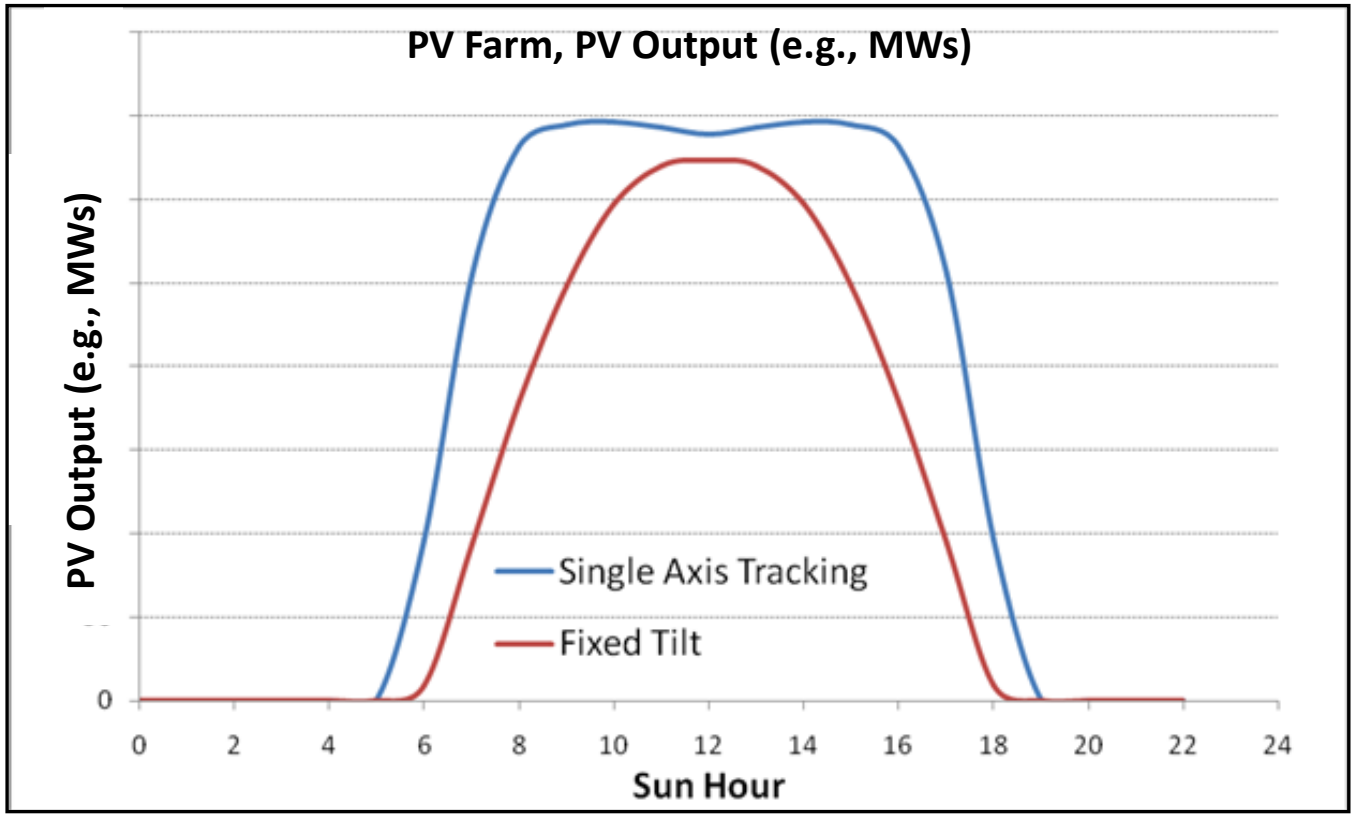
## ***Others Potential Investors***

- Bankers & Financiers?
- Suppliers of plastics, Elect. Boxes, Const. &/or Farming Equipment?
- Suppliers and their VCs of last century's energy supply?
- Insurers, Ag industry, NGOs, DOE?
- Foundations?  Entrepreneurs?
- Masdar, DEWA, ACWA Power?

# Single Axis Tracking Basics

## Typical Sunny Day (Single-Axis Tracker *vs.* Fixed Tilt)

- Tracker tilts from ***east to west*** once a day, every day
- ***Full sun on tracking rows (PV) & aisles*** from late morning to early afternoon
- ***Back-tracks*** in early morning and late afternoon to maximize sun capture while avoiding self-shading

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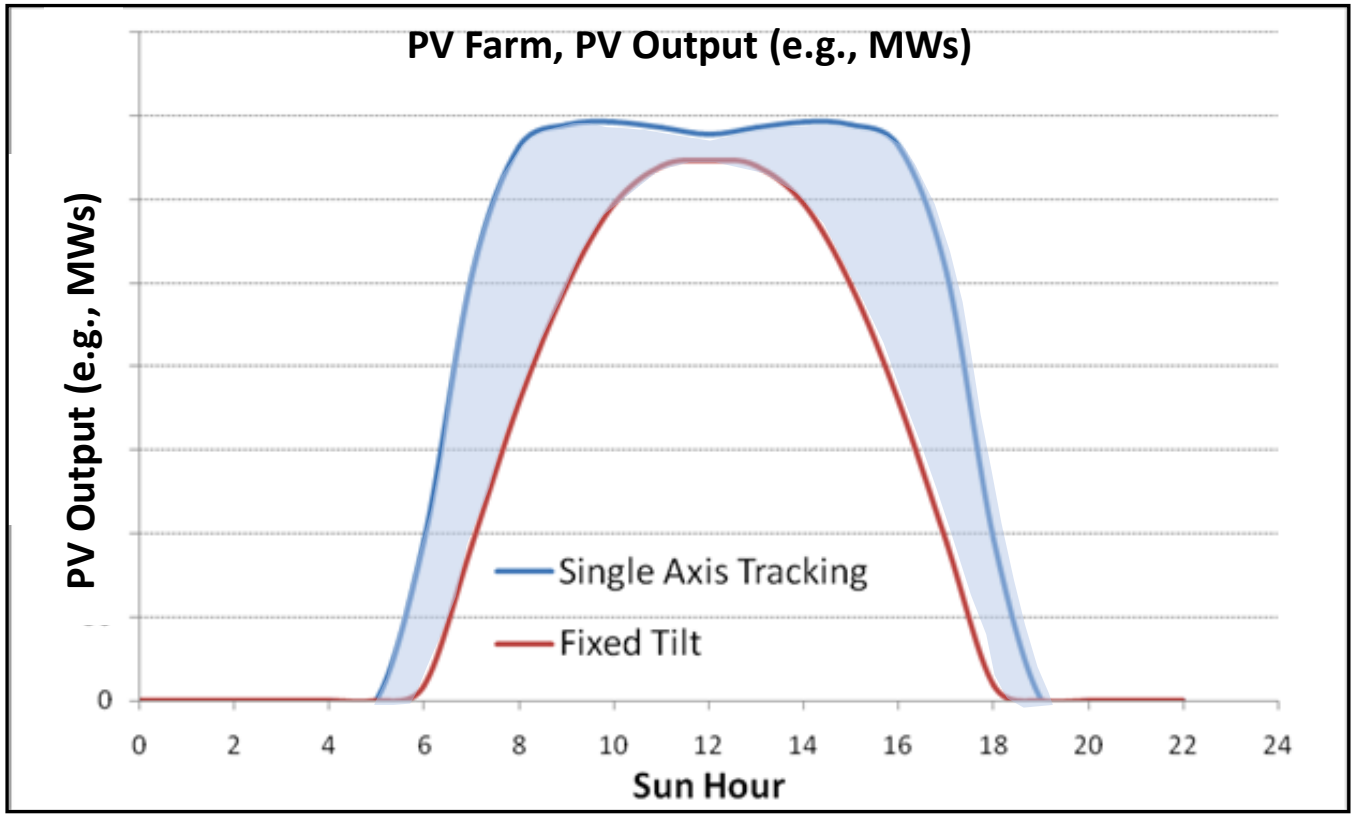
# Single Axis Tracking Basics

## Typical Sunny Day (Single-Axis Tracker *vs.* Fixed Tilt)

***Typical energy gain*** on a sunny day

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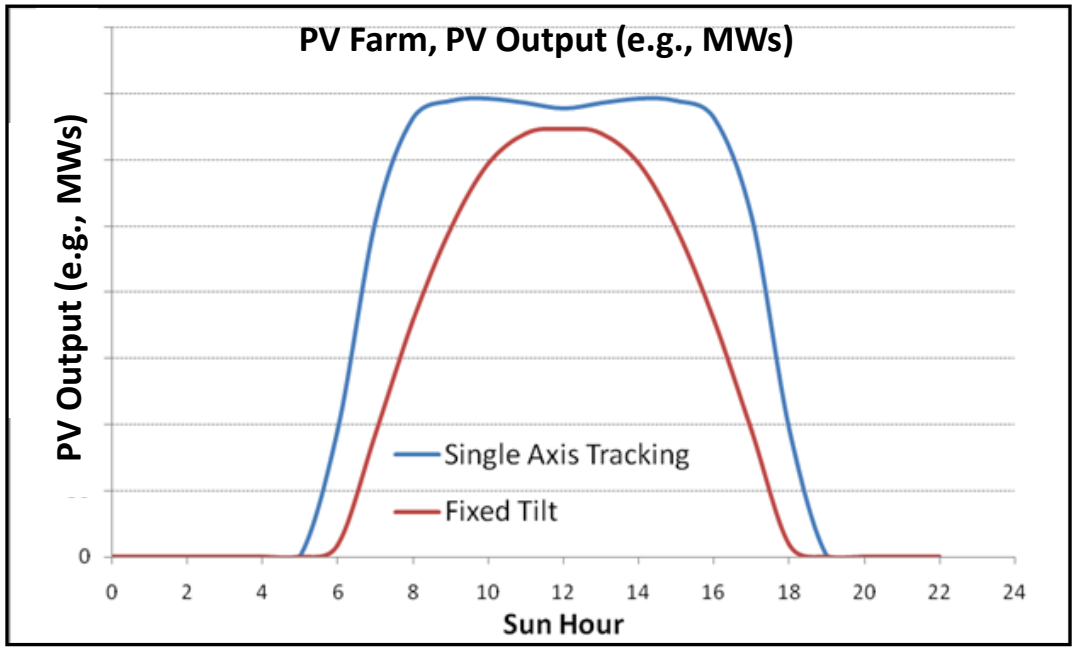
# Single Axis Tracking Basics

## Typical Sunny Day (Single-Axis Tracker *vs.* Fixed Tilt)

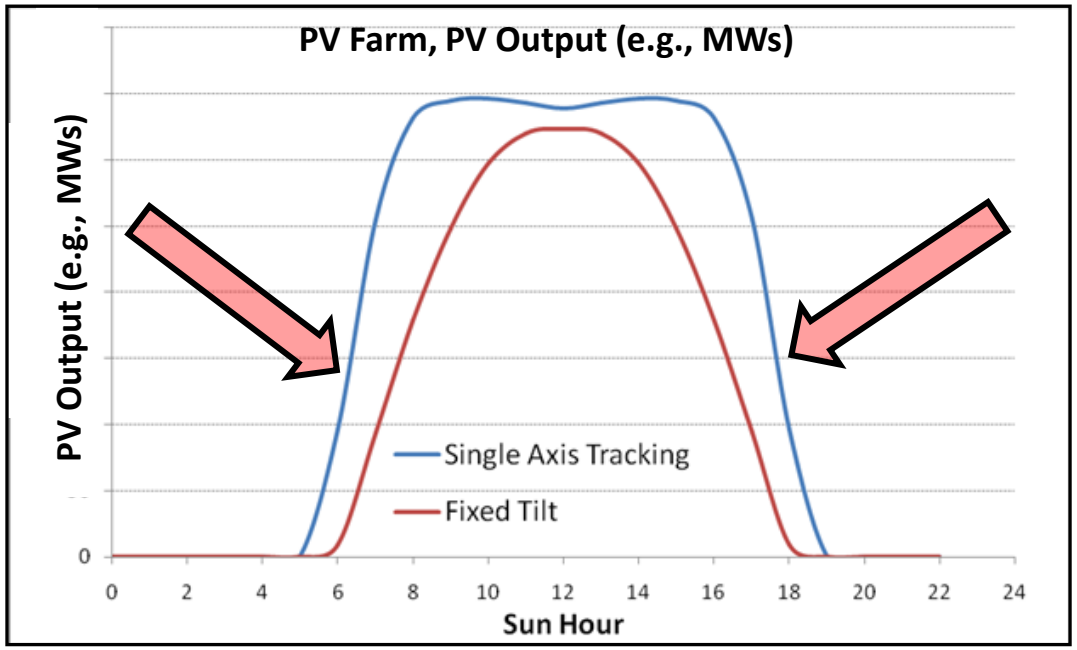
- ***Full sun*** on rows of PV and on the ***aisles in between*** for ***agriculture***
- 365 days/year (except when cloudy)




# Single Axis Tracking Basics

## Typical Sunny Day (Single-Axis Tracker *vs.* Fixed Tilt)

- Back-tracking is maybe 10% of total tracker energy delivery?
- 99% ground shadow = 1% lost sun x 10% energy = a meaningless 0.1% loss!




# Single Axis Tracking Basics

## Single-Axis Tracker Gain over Fixed Tilt

- ~20% annual energy gain
  - ~24% Chile = great economics
  - ~12% N. Europe = poor economics, but good weed access (O&M)
- >30% gain in summer months
- Additional "gain" from Ag revenue in the aisles in between the rows

| 1 MW system in Abu Dhabi, UAE | | | |
|---|---|---|---|
| **Month** | **Fixed Tilt** (kWh) | **Tracking** (kWh) | **Gain** (SAT/FT) |
| Jan | 122.4 | 130.4 | 7% |
| Feb | 127.0 | 142.9 | 13% |
| Mar | 134.0 | 157.6 | 18% |
| *Apr* | 142.1 | 181.1 | ***27%*** |
| *May* | 153.6 | 210.0 | ***37%*** |
| *Jun* | 143.1 | 199.6 | ***39%*** |
| *Jul* | 133.7 | 175.1 | ***31%*** |
| *Aug* | 136.7 | 175.7 | ***29%*** |
| Sep | 137.8 | 170.2 | 24% |
| Oct | 141.5 | 163.2 | 15% |
| Nov | 125.9 | 136.7 | 9% |
| Dec | 114.2 | 119.0 | 4% |
| **Year** | **1612** | **1962** | **22%** |

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# Problem Statement

The main ***issue*** with single-axis tracking is…

1. Material ***(Cost)***
2. Logistics ***(Cost)***
3. EPC ***(Cost)***
4. O&M ***(Cost)***
5. Wind ***(Cost)***

# Solution Statement

## Achieving ***True Cost Reduction*** for Single Axis Tracking

1. Material *Make it **simple***
2. Logistics *The simpler, the **easier***
3. EPC *The simpler & easier, the **lower the cost***
4. O&M ***Simplicity throughout** for ease of OPEX and a robust reliability*
5. Wind ***Strategic simplicity & strength** for a **truly bankable ROI***

# Problem Statement

## Costs

1. Piers (Posts)
2. Bearings
3. Torque Tube or Table
4. Drive System
5. PV Attach (Purlins)
6. Control (Comm.)
7. Wind
8. EPC
9. OPEX

# Problem Statement

## Costs; *We* avoid these ***costly complications***

1. Piers (Posts)
   *Complicated, One Choice, HDG*
2. Bearings
   *Tight Alignment, Complex, Slippery*
3. Torque Tube or Table
   *Faceted Tubes, Flimsy Tables*
4. Drive System
   *Elaborate, Strict Alignments, Risky*
5. PV Attach (Purlins)
   *Pre-attach 2P purlins, 1 mod attach*
6. Control
   *1/Row, BSS, Wi-Fi Net, Vulnerable*
7. Wind
   *Add Dampers, Drives/Row, Shafts*
8. EPC
   *Congested Access, Tight Tolerances*
9. OPEX
   *Weeds, Congested Access, Complex, Multiple Drives/Row, Spinning Drive Shafts, vulnerable wireless*

# Solution Statement

## Cost Savings *(Simplify Everything)*

1. Piers
   *$0.002/W*
2. Bearings
   *$0.002/W*
3. Torque Tube
   *$0.004/W*
4. Drive System
   *$0.004/W*
5. PV Attach
   *$0.003/W*
6. Control
   *$0.003/W*
7. Wind
   *$0.004/W*
8. EPC
   *$0.01/W*
9. OPEX
   *$0.02/W*

***Sub: $0.032/W***

***Total: > $0.05/W***

***> $50M/GW***

# Solution Statement

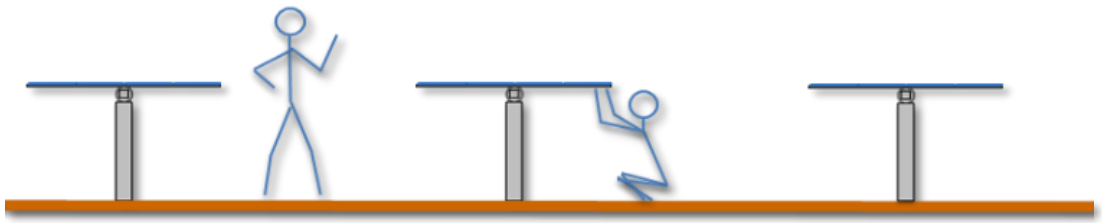
## Cost Savings *(Simplify Everything)*

1. Piers
   *Simple; non-HDG, opt. Mtlrs.*
2. Bearings
   *Steel/Steel, Loose Fit, non-HDG, IP*
3. Torque Tube
   *Simple Round, Strong, non-HDG, IP*
4. Drive System
   *Cable/Pulley, Leveraged, Durable, IP*
5. PV Attach
   *Balanced, Utility Scale, "Panels", IP*
6. Control
   *Simple; 1 PLC, hardened, IP*
7. Wind
   *Simple; Unique, Self-Locking, IP*
8. EPC
   *Simple; Utility Scale, accessable*
9. OPEX
   *Simple; Robust, Reliably unfailing, Wind-Worthy, Ample accessibility, No Moving Wires, AgriVoltaics*

# Problem Statement

## Key Cost Issues

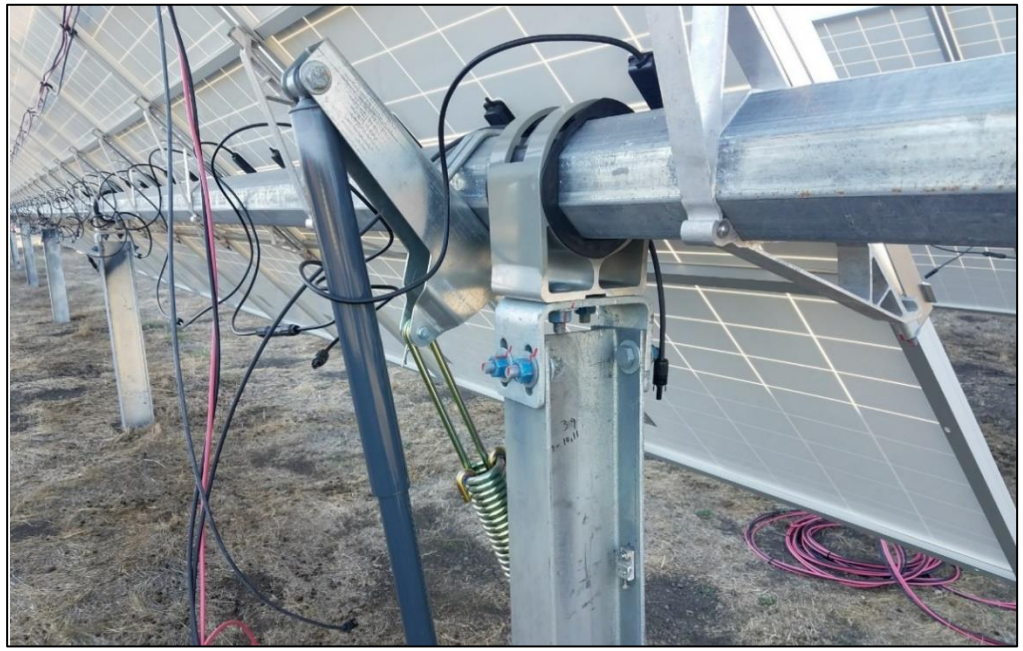
- Complex designs
- Difficult assembly
- Congested access
- Inconsistent quality
- Difficult PV attachment
- Unpredictable durability and reliability
- Costly O&M for mech, elect and weeds
- Underestimated 30+ years of ownership



# Problem Statement

**Hidden Costs** *(complication, add-ons, congestion for EPC & O&M, other)*

- Spinning drive shafts, plastic bushings, shock absorbers, springs, special torque tubes …
- Wireless net, 1,000's of batteries & controllers in the field, unnecessary software …

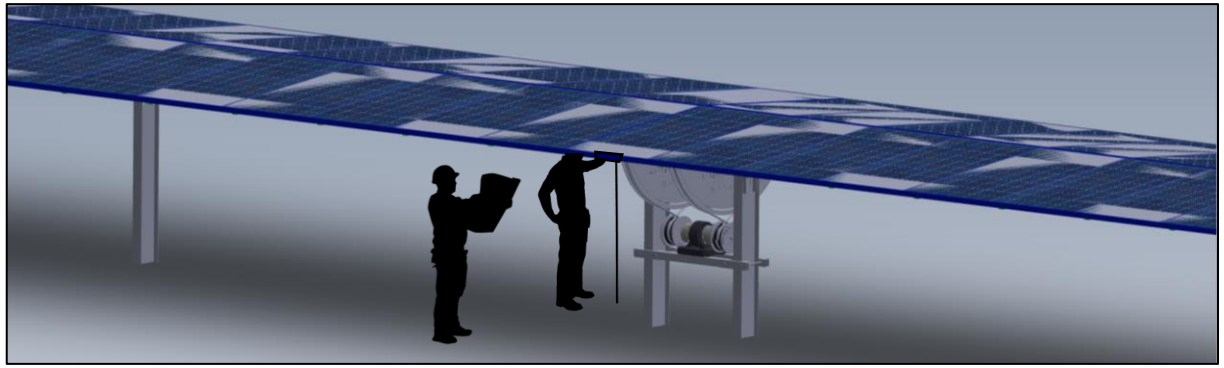


# Solution Statement

## Truest “Lowest Cost”

- Address the Triple Cost of ***CAPEX, EPC, & OPEX***
- Ensure ***Fool-Proof Simplicity*** for reliability and truly lowest ***LCOE***

# Our Solution



# Solution #1 (Piers)

## Cost Savings *(Simplify Everything)*

1. **Piers**
   ***$0.002/W***
2. Bearings
   *$0.002/W*
3. Torque Tube
   *$0.004/W*
4. Drive System
   *$0.004/W*
5. PV Attach
   *$0.003/W*
6. Control
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7. Wind
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8. EPC
   *$0.01/W*
9. OPEX
   *$0.02/W*

***Sub: $0.032/W***

***Total: > $0.05/W***

***> $50M/GW***

# Solution #1 (Piers)

## Cost Savings #1

1. **Piers (Posts):** *Options of **Steel** (I-Beam or Cold Form, HDG or non-HDG), **Wood** (Telephone Poles), **Reinforced Concrete**, other?*

*(L) 1MW Wood, (C) 40MW RI Concrete, (R) 7MW Non-HDG I-Beam*

# Solution #1 (Piers)

## Non-HDG Steel Posts

***Non-HDG option*** for cost savings

**Heritage:** 7 MW project in Folsom, CA, 2009, tracker by OSolar (formerly Conergy Korea)

✓ *Note: The two S&SS prototype rows tested at Cal Poly SLO utilized and **proved non-HDG** on the steel torque tubes and on 50% of the steel/steel bearings (races & journal-couplers)*

# Solution #1 (Piers)

## Wood Posts after 17 years

Top photo from March 2021

***Still operational*** with simple thru-bolt attach of the steel structure to ***480 wooden telephone poles***

Enhanced renewable energy value as replacement Douglas Fir trees grow in Oregon

Bottom Photos: 2004 when the 1 MW (48 row) system went on-line

# Solution #2 (Bearings)

## Cost Savings *(Simplify Everything)*

1. Piers
   *$0.002/W*
2. **Bearings**
   ***$0.002/W***
3. Torque Tube
   *$0.004/W*
4. Drive System
   *$0.004/W*
5. PV Attach
   *$0.003/W*
6. Control
   *$0.003/W*
7. Wind
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   *$0.01/W*
9. OPEX
   *$0.02/W*

***Sub: $0.032/W***

***Total: > $0.05/W***

***> $50M/GW***

# Solution #2 (Bearings)

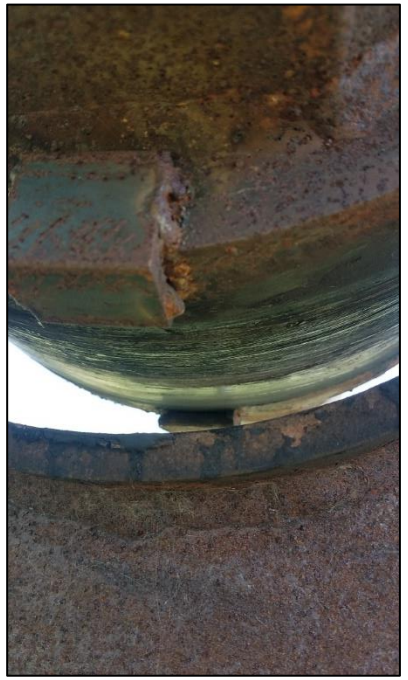
## Cost Savings #2

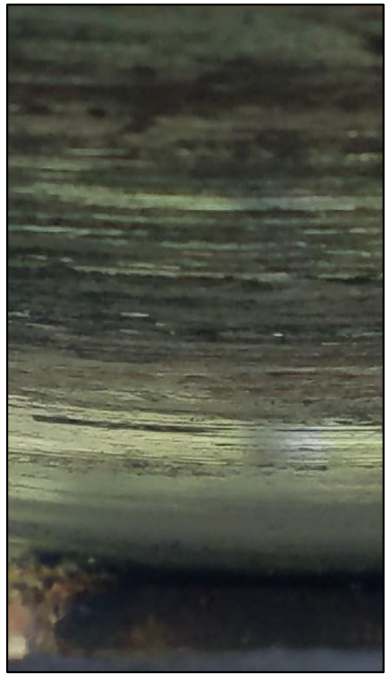
2. **Bearings:** *Simple steel on steel, loose fit = ease of alignment, optional HDG, friction damping, integral elect. gnd. path, integral N-S thrust stops and E-W tilt stops with wind-proportional holding, opt. field weld or field bolt.* ***Patented.***

# Solution #2 (Bearings)

## Cost Savings #2

**”Simple Bearing”:** ***100% steel;*** round ***Journal-Coupler*** in round ***Race,*** *opt. HDG*





# Solution #2 (Bearings)

## Uniquely Simple of Exceptional Value

***A Bearing with Self-Regulating Damping!***

Our extremely ***simple bearing*** of a steel journal (Journal-Coupler) turns ±45°, slowly (8 sec/deg) in a steel race that has a unique combined thrust-stop & tilt-stop that employs the ***wind itself to regulate the bearing's damping power***!

***Imagine that;***

***The wind dampening itself!***

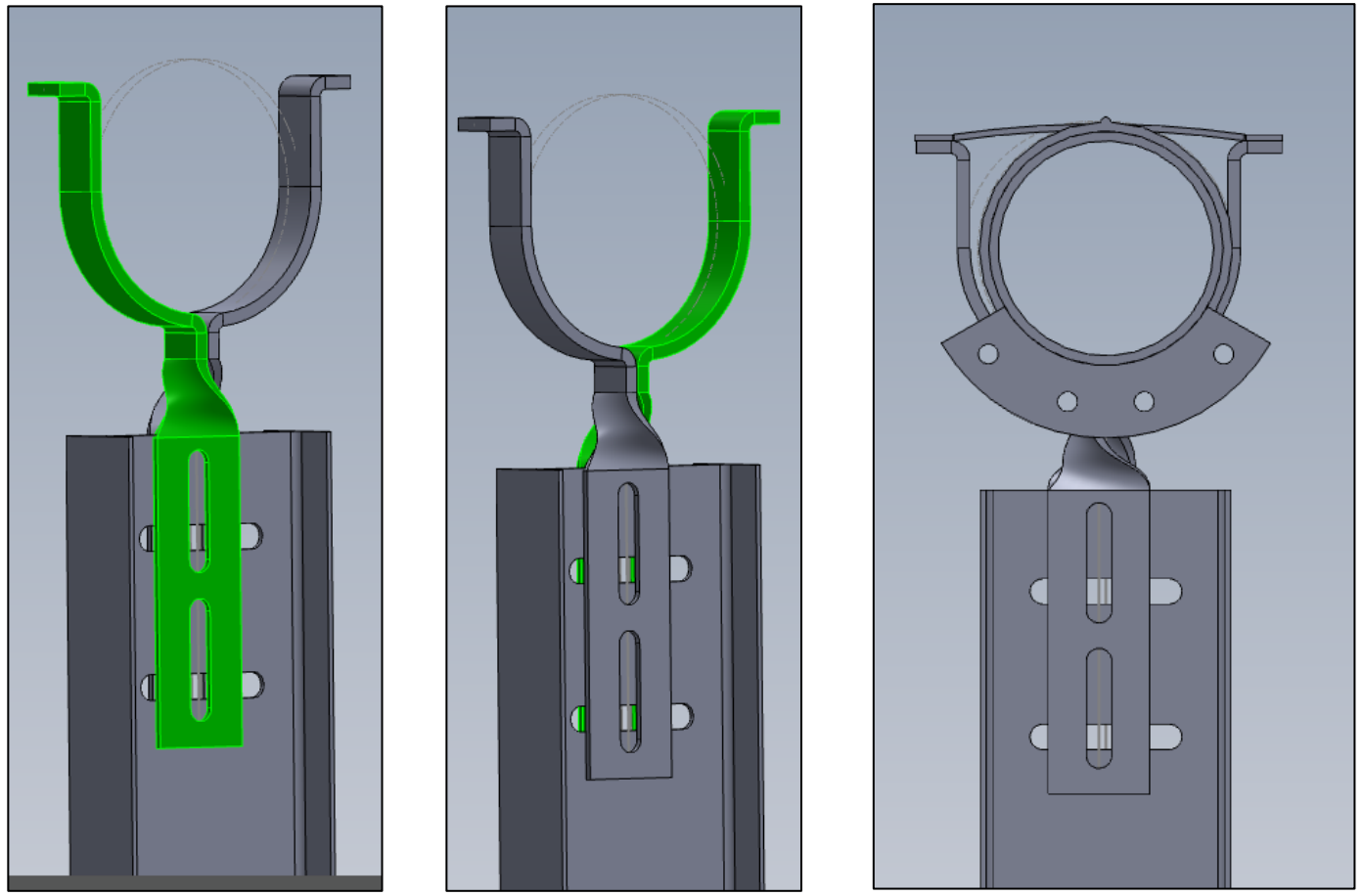
# Solution #2 (Bearings)

## Cost Savings #2

**Bearings:**

- Bottom race holds 80% of torque tube's Journal-Coupler
- ***Single flat stock forms 1/2 of bottom race*** via cold formed radii, twist, flatten, holes & slots
- Two ***identical bottom halves interleave*** to create a full bottom race & attachment post

***Patent Pending***



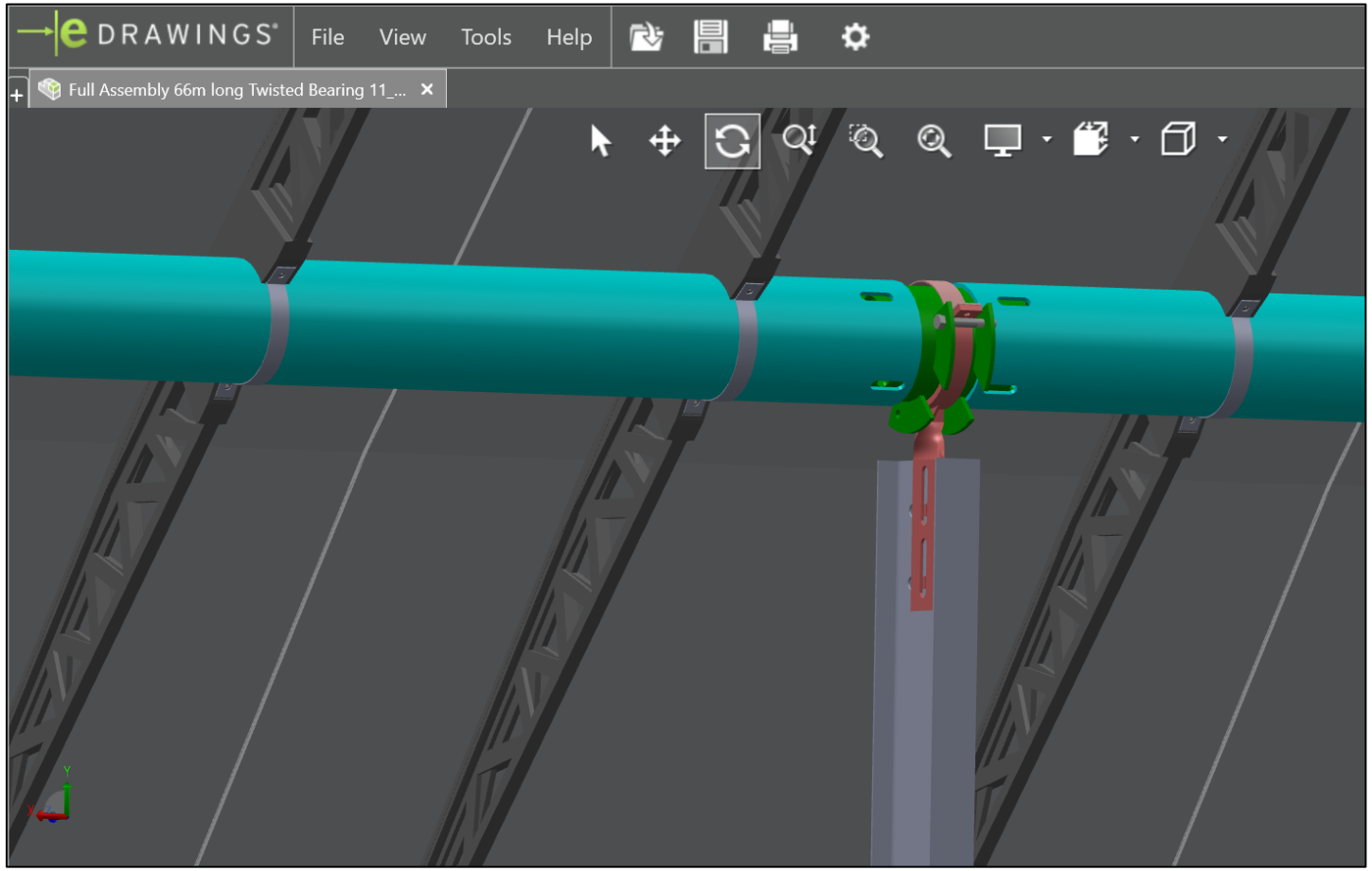
# Solution #2 (Bearings)

## Cost Savings #2

**Bearings:**

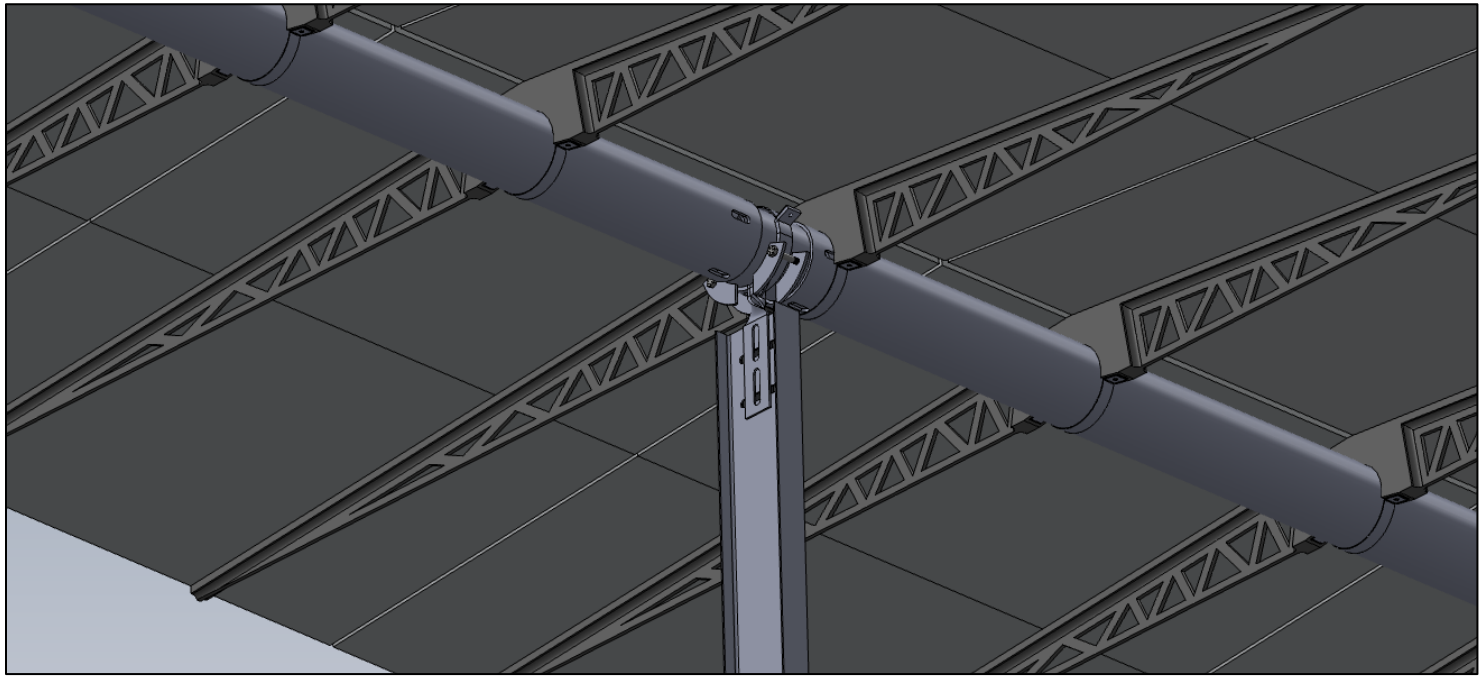
- A simple bearing when needed (100% of the time)
- A friction damper when needed (< 50% of the time?)
- A pinching clamp when needed (< 1% of the time?)

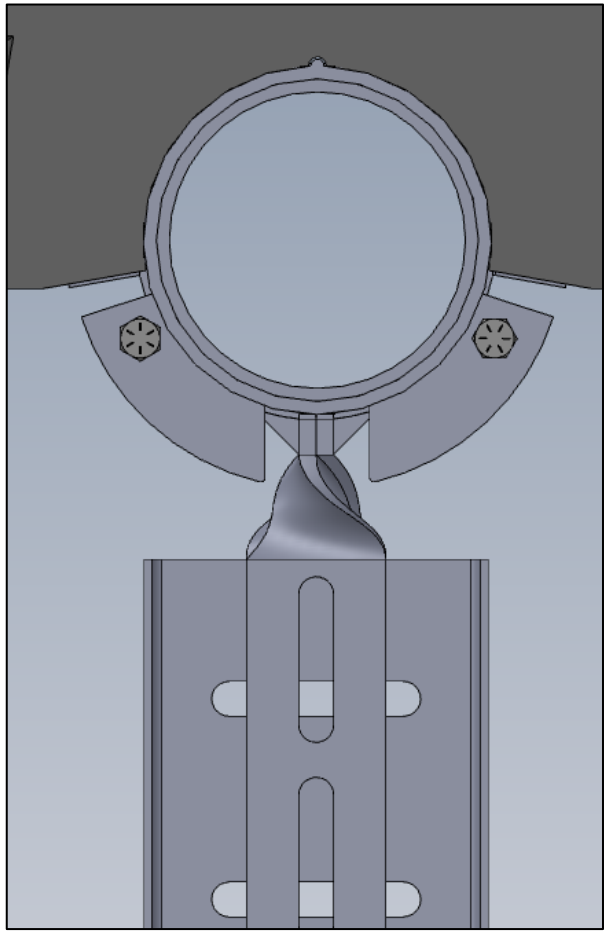
***Patent Pending***



# Solution #2 (Bearings)

Two tilt-stop bolts ***prevent lift-off***, and also squeeze or pinch the bottom race against the Journal-Couple, the tightness, friction and ***locking power increases with increasing wind speed*** and uplift force



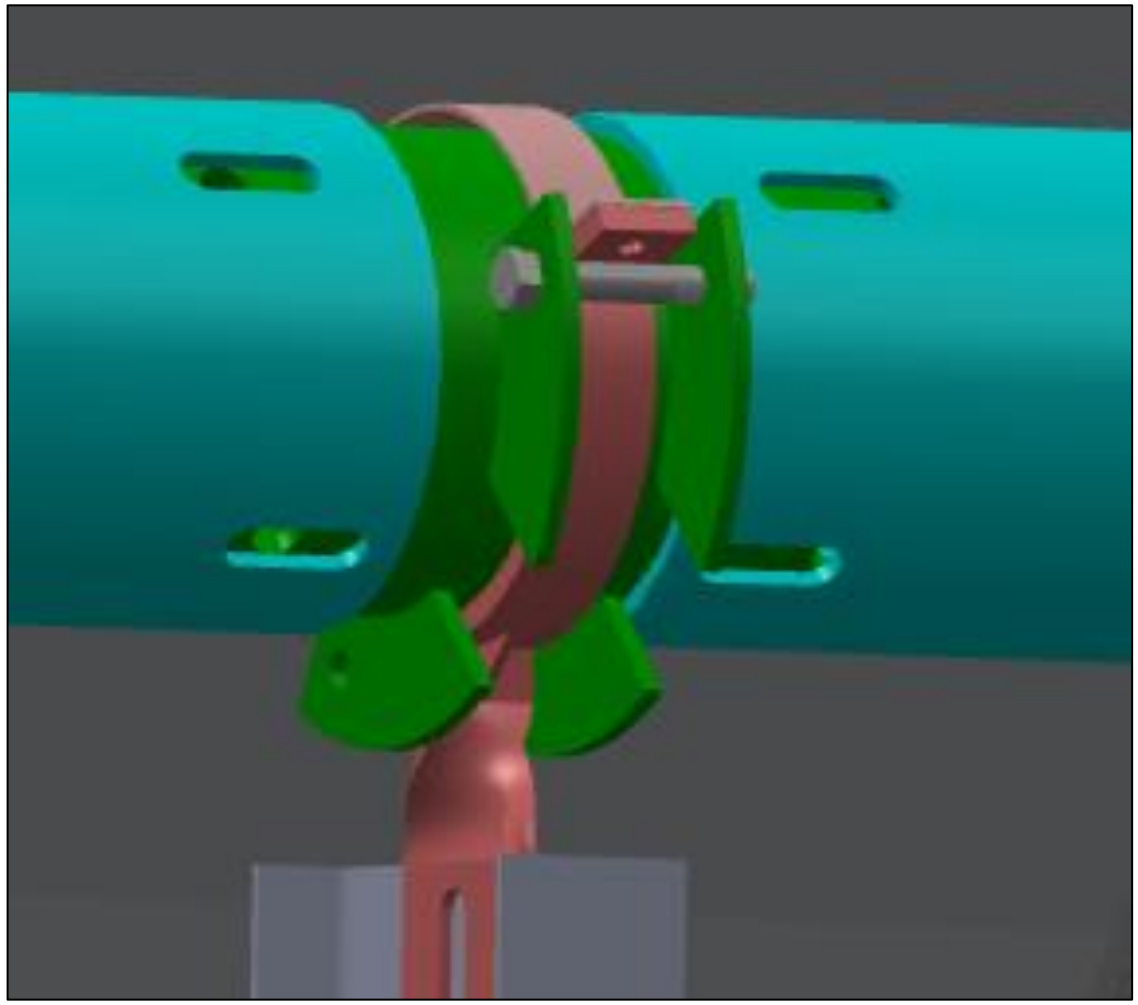


# Solution #2 (Bearings)

## Cost Savings #2

***A Closer Look:***

- A simple bearing
- A friction damper
- A passive pinching & holding clamp activated by the wind itself



***Patent Pending***

# Solution #3 (Torque Tube)

## Cost Savings *(Simplify Everything)*

1. Piers
   *$0.002/W*
2. Bearings
   *$0.002/W*
3. **Torque Tube**
   ***$0.004/W***
4. Drive System
   *$0.004/W*
5. PV Attach
   *$0.003/W*
6. Control
   *$0.003/W*
7. Wind
   *$0.004/W*
8. EPC
   *$0.01/W*
9. OPEX
   *$0.02/W*

***Sub: $0.032/W***

***Total: > $0.05/W***

***> $50M/GW***

# Solution #3 (Torque Tube)

## Cost Savings #3

### 3. Recap:

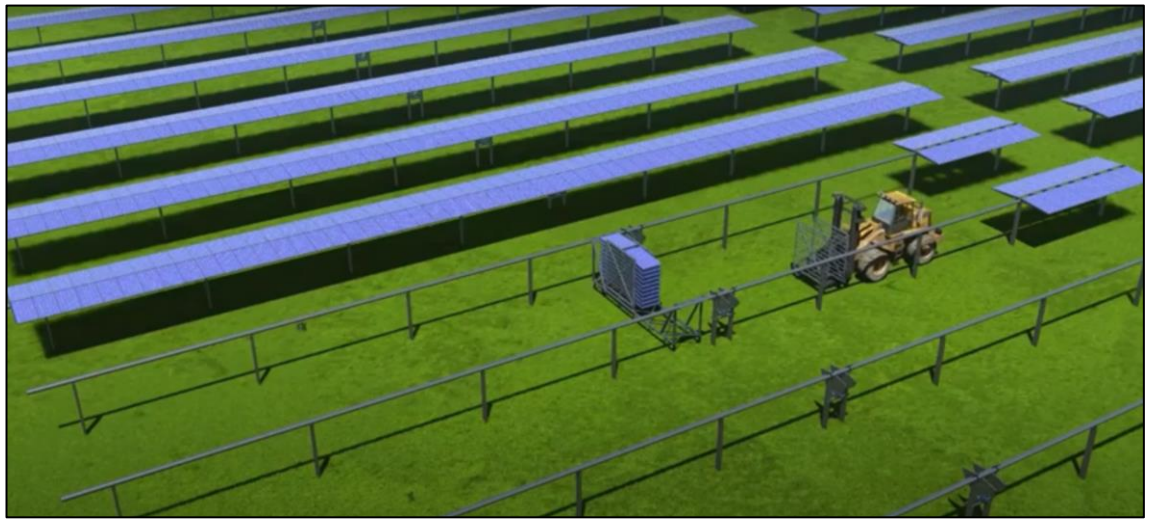
- ✓ ***Posts*** *(10/Row)*
- ✓ ***Bottom Bearing Races***
- ✓ ***Journal-Couplers***
- ➢ ***Torque Tubes*** *(9 Sections)*
  - ➢ *1 Drive (center)*
  - ➢ *4 Inner*
  - ➢ *4 Outer*

# Solution #3 (Torque Tube)

## Cost Savings #3

3. **Torque Tubes:** *Round, 2 wall thicknesses for three lengths & locations, opt. non-HDG, opt. field weld or bolt/pin to Journal-Couplers.* ***Patented.***

***EPC:*** *use top of round torque tube as* ***trolley rails***



# Solution #3 (Torque Tube)

## Cost Savings #3

**Torque Tubes:** ***Round***

Use ***torque tubes*** as ***trolley rails***

***Shuttle*** crates of modules or stacks of 2P or 3L-5L panels

- ***EPC:*** *Faster-Better-Cheaper, environmentally sensitive land, muddy or wet aisles, other*
- ***Ag:*** *Harvesting platform*

# Solution #3 (Torque Tube)

## Cost Savings *(Simplify Everything)*

1. Piers
   *$0.002/W*
2. Bearings
   *$0.002/W*
3. Torque Tube
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***Sub: $0.032/W***

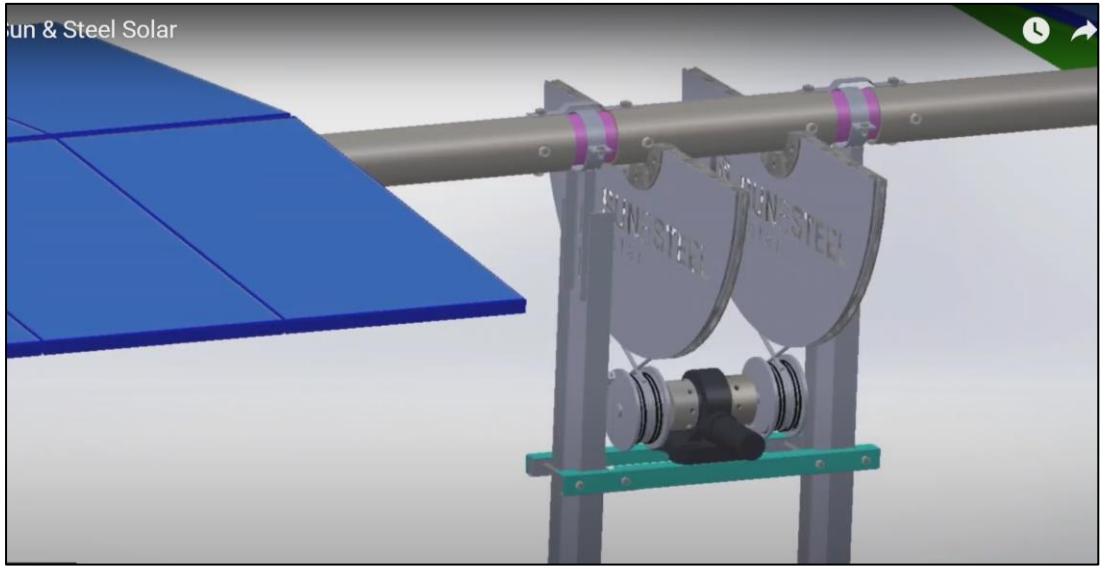
***Total: > $0.05/W***

***> $50M/GW***

# Solution #4 (Drive)

## Cost Savings #4

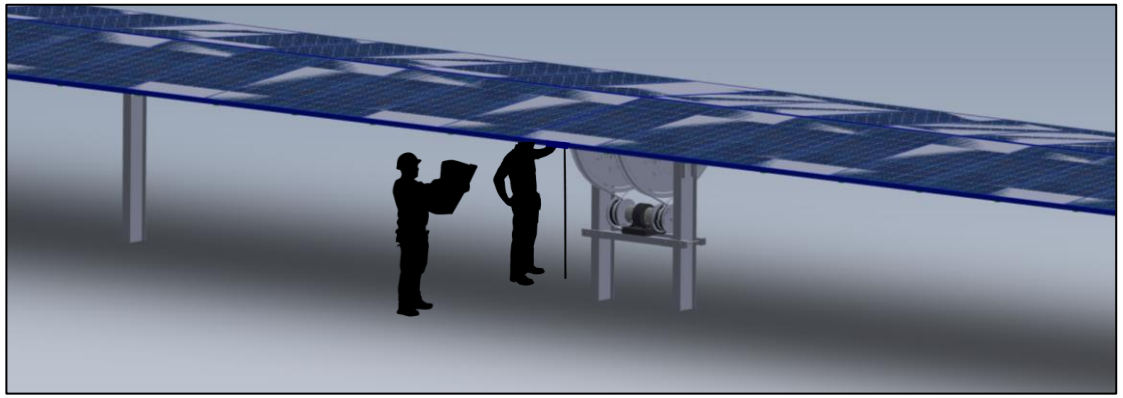
4. **Drive System:** *Simple, slew drive as a winch with 8X leverage via redundant wire rope to two large half-pulleys, natural cable alignment & tautness at setup, durable, easy to operate, 100% no moving wires.* ***Patent Pending.***



# Solution #4 (Drive)

## Cost Savings #4

### Wire Cable & Pulley Drive



***Small slew drive***, two drums, ***8:1 leverage***

***Two large half-pulleys*** attach to Drive Torque Tube


***Two wire ropes,*** steel (bare, HDG, SS), reliably tolerant

***Self-aligning & self-tautness*** at install; slew drive hangs by wire ropes and is then clamped to the two drive posts)

***No gears;*** cable/pulley system tolerant of mis-alignments

***No moving electrical wires***; 100% on stationary side

***Full PV coverage*** (top) or optional gap (bottom)

# Solution #3 (Torque Tube)

## Cost Savings *(Simplify Everything)*

1. Piers
   *$0.002/W*
2. Bearings
   *$0.002/W*
3. Torque Tube
   *$0.004/W*
4. Drive System
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5. **PV Attach**
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   *$0.02/W*

***Sub: $0.032/W***

***Total: > $0.05/W***

***> $50M/GW***

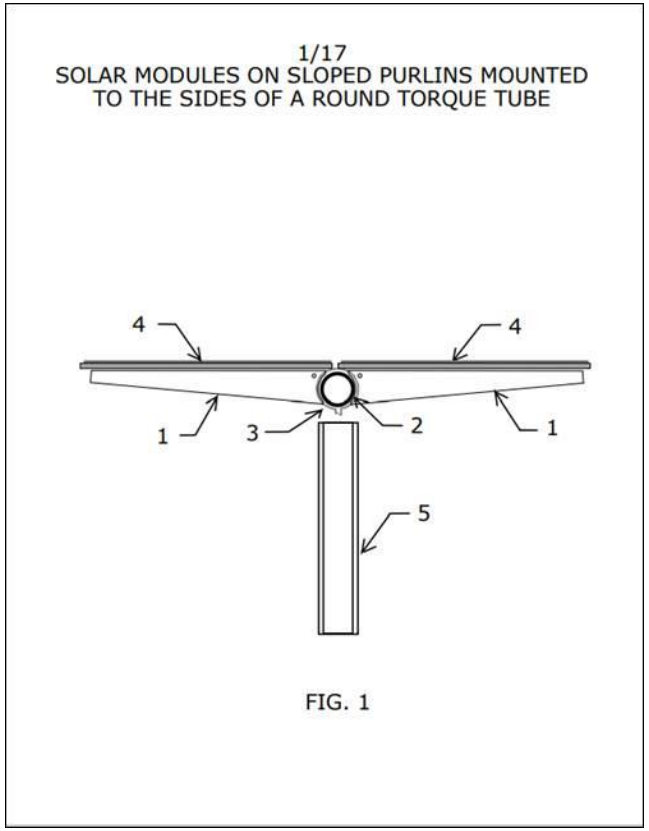
# Solution #5 (PV Attach)

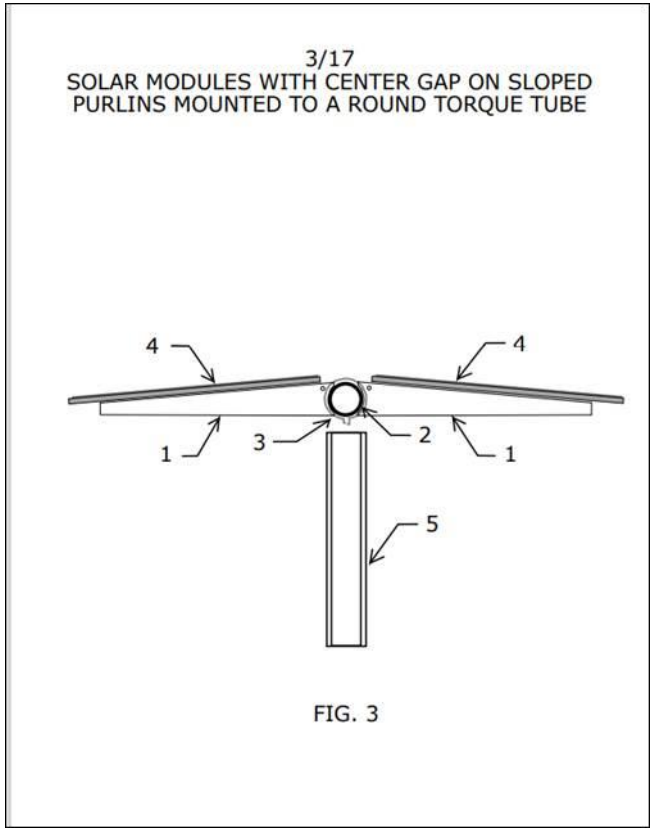
## Cost Savings #5

5. **PV Attach:** *Options of pre-assembled panels (2P, 3L, 4L, 5L) or attach one module at a time. Can use round torque tubes as trolley rails to deliver stacks of pre-assembled panels or crates of modules.* ***Patent Pending.***

# Solution #5 (PV Attach)

Our PV attaches flat (***coplanar***) or sloped (***up-down***, airplane wing)



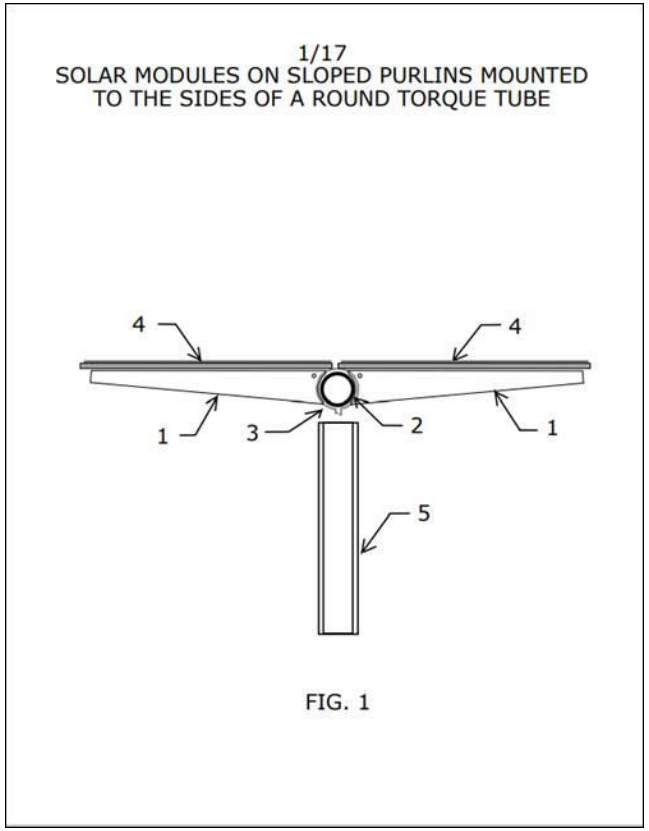




## ***Up-down benefits***

- *Low center of gravity (Balanced)*
- *Improved wind tolerance*
- *No sediment ponding*
- *Cooler operating temp*
- *Unique aesthetics*

# Solution #5 (PV Attach)

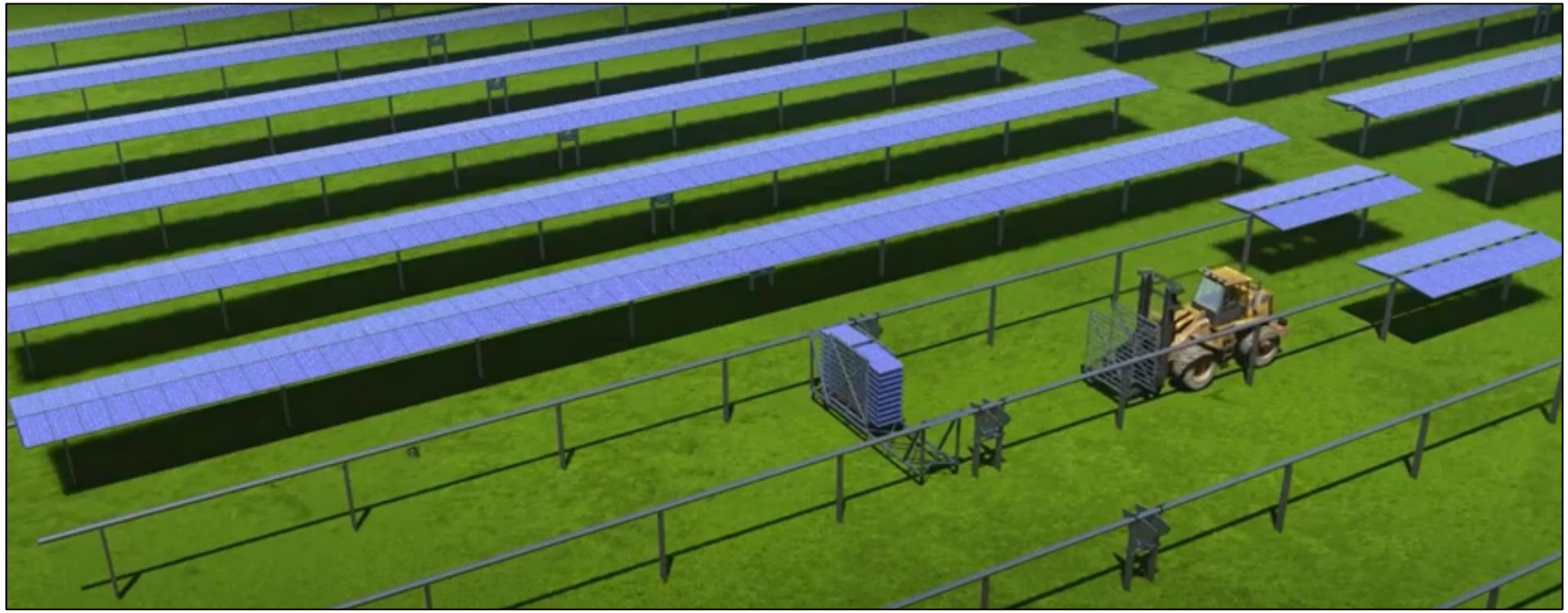
## *Co-planar* (Cal Poly Test Site)




# Solution #5 (PV Attach)

## Trolley for PV-Attach

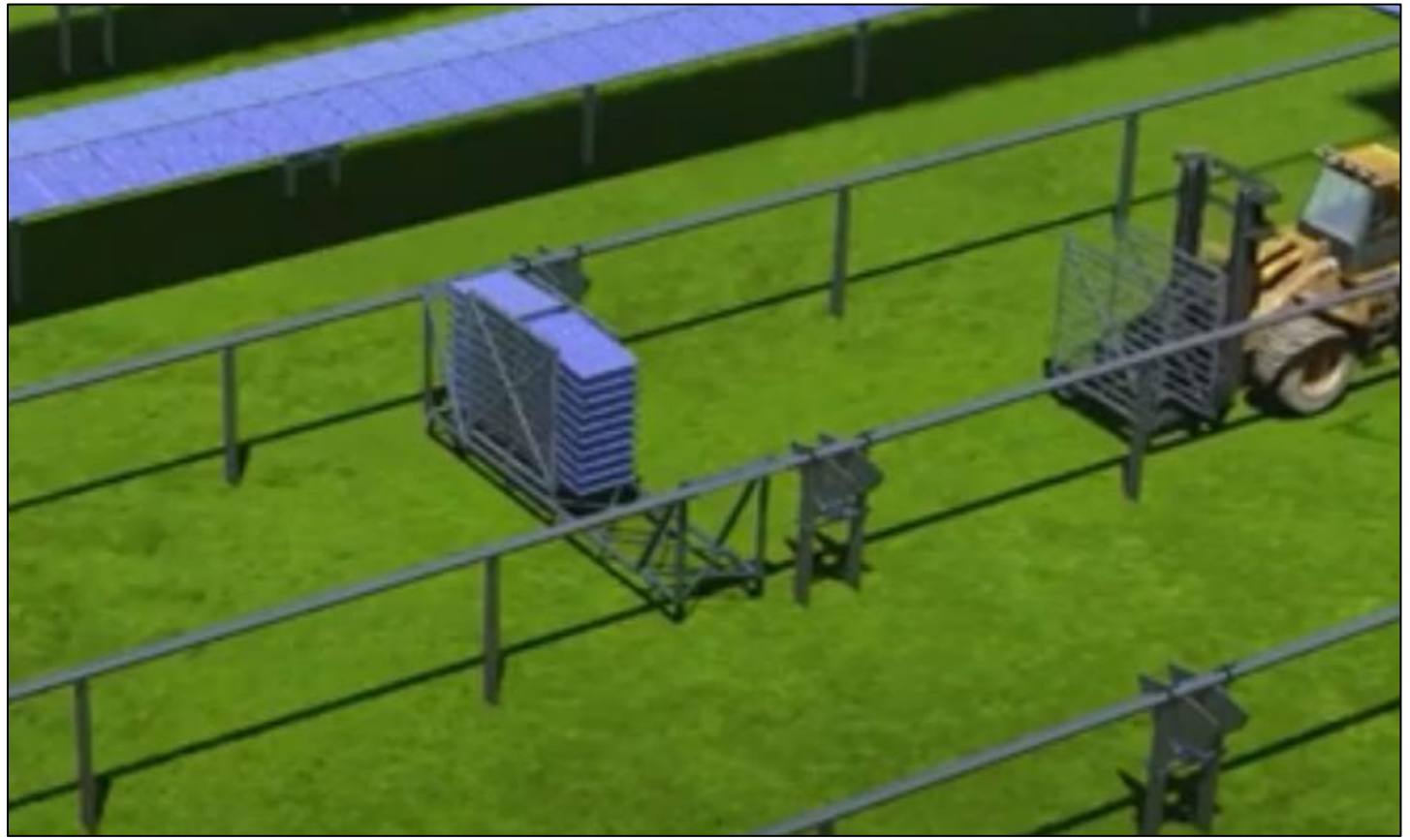
Productivity improvement, or necessary when the aisles are muddy, environmentally sensitive, restrictive, other



# Solution #5 (PV Attach)

## PV-Attach Trolley

Trolley system to deliver either ***pre-assembled panels (2 purlins + # of modules),*** or ***crates of single modules*** for ease of manual attachment one module at a time



# Solution #5 (PV Attach)

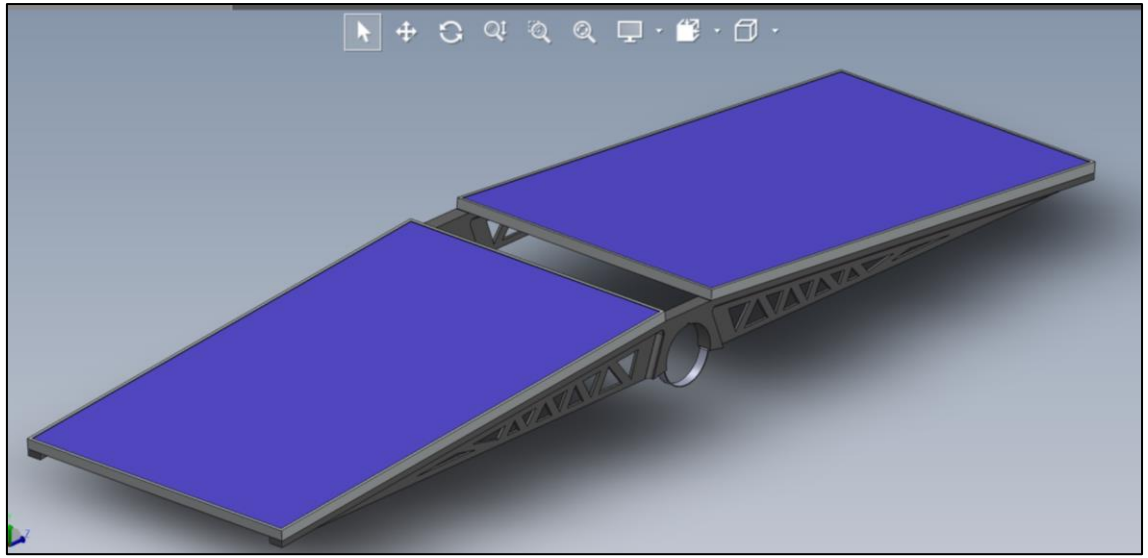
***2P, 3L, 4L, & 5L, mono or bifacial*** PV, ***small or large format*** module

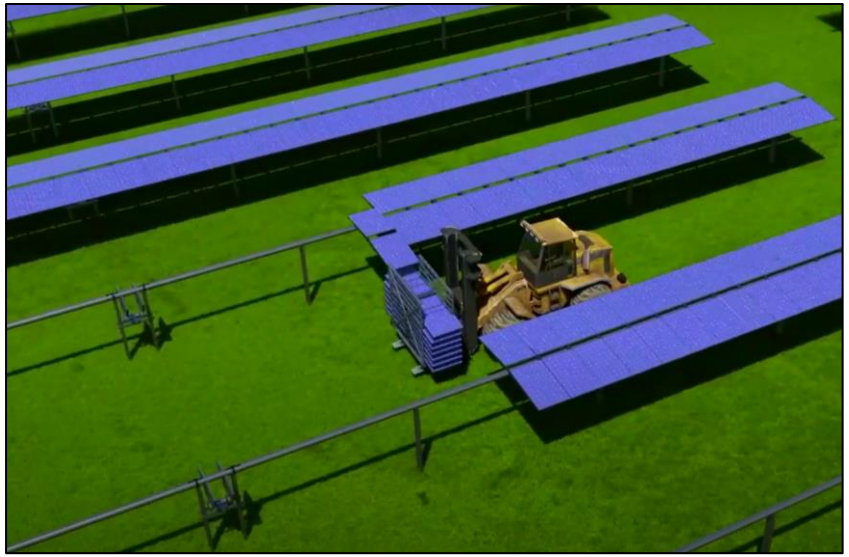
- Can attach ***one module at a time*** (purlins pre-set on the torque tube), or…
- Attach pre-assembled ***"PV Panels" (2 purlins + # of modules)*** to the torque tube, in truly industrial size application, as shown on the next slide…

# Solution #5 (PV Attach)

## Pre-assembled PV panels; e.g. 2P

- ***2 purlins + 2 modules in 2P*** as shown, or multiple modules in landscape
- Stack panels, bring stack to aisles
- Transfer panels to torque tube like an ***industrial PEZ dispenser***

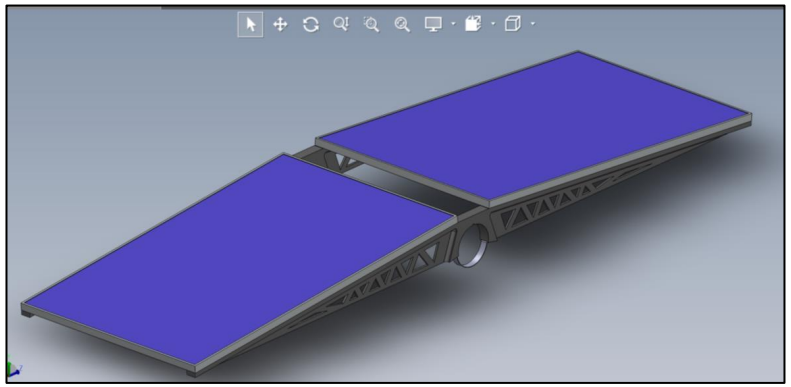


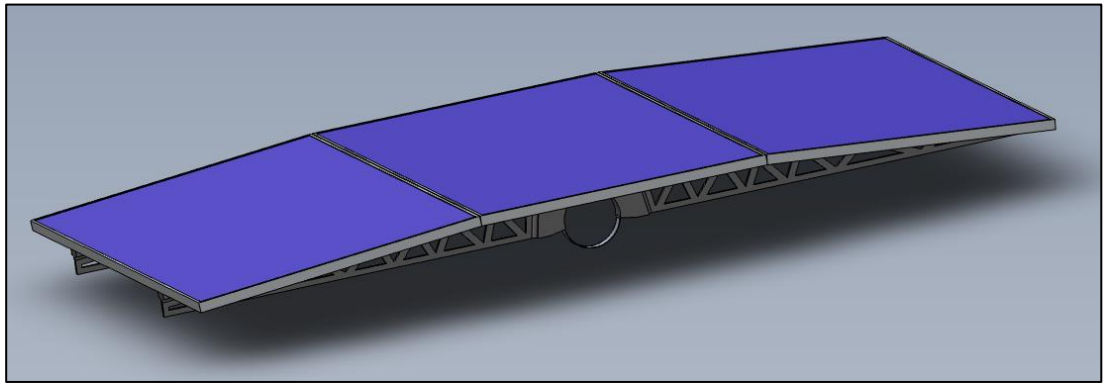


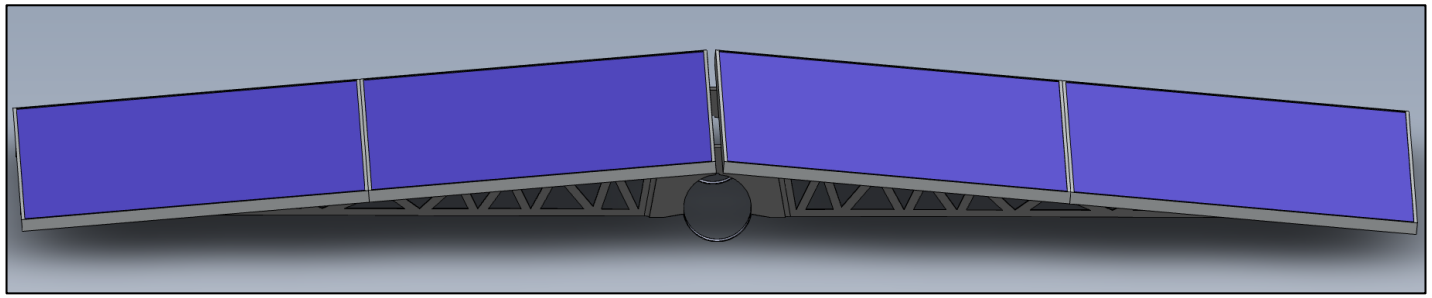
# Solution #5 (PV Attach)

## Pre-assembled PV panels

- 2P, 3L, 4L; options for 2L (2.6m chord) and 5L (5m chord)
- Fully flexible for many manufacturers' PV module sizes







# Solution #6 (Tracking Control)

## Cost Savings *(Simplify Everything)*

1. Piers
   *$0.002/W*
2. Bearings
   *$0.002/W*
3. Torque Tube
   *$0.004/W*
4. Drive System
   *$0.004/W*
5. PV Attach
   *$0.003/W*
6. **Control**
   ***$0.003/W***
7. Wind
   *$0.004/W*
8. EPC
   *$0.01/W*
9. OPEX
   *$0.02/W*

***Sub: $0.032/W***

***Total: > $0.05/W***

***> $50M/GW***

SUN&STEEL solar

# Solution #6 (Tracking Control)

## Cost Savings #6

### 6. Tracking Control:

a. *Use OEM controller (more expensive)*

b. ***S&SS:*** *One off-the-shelf PLC in the control room (or out in a box) for 100's or 1,000's of rows, all rows tracking and back-tracking in unison, no special software, addressing or complication for undulating land, no wireless net, no battery + PV + controller + inclinometer at each row in the field, no dangling moving wires, optional powerline communication, hardened one-way communication (absolute lowest cost & highest reliability)* ***Patent Pending.***

# Solution #6 (Tracking Control)

## Cost Savings #6

- *One off-the-shelf PLC with simple astronomical timing*
- *One motor drive box per row*
- *No wireless net*
- *No special software*
- *No special feedback to know the tilt of each and every row; simply use the solar farm's PV monitoring to detect failure*
- *No battery + special PV charger + controller + inclinometer at each row with dangling, moving wires violating NEC*
- *No moving wires*
- *Optional powerline communication on existing powerline distribution*
- *Hardened one-way communication* ***Patent Pending.***

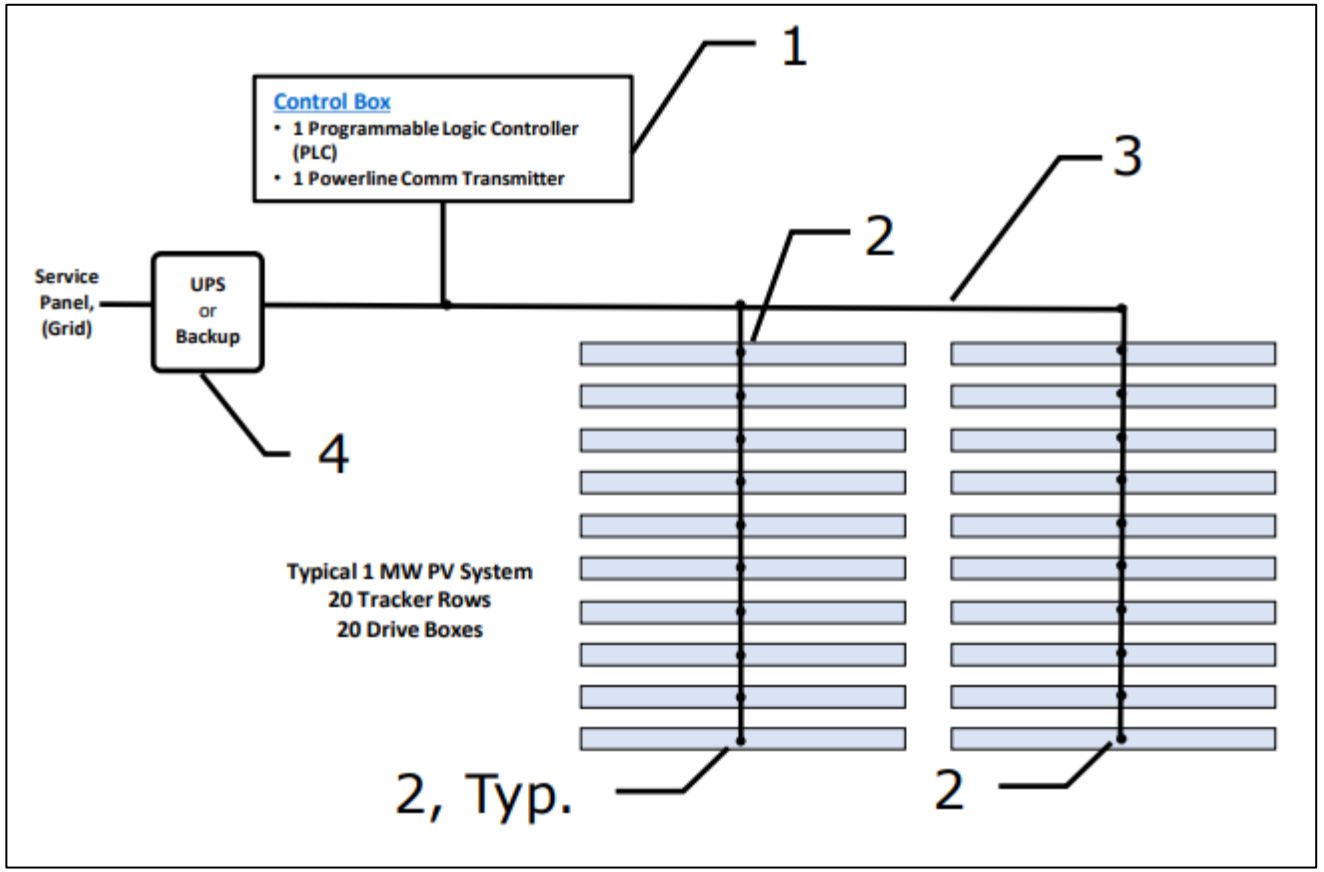
# Solution #6 (Tracking Control)

## Cost Savings #6

**Tracking Control:**

***One PLC for entire PV farm!***

- No controller/row in field
- No batteries (BSS)/row in field
- No wireless & 2-way comm
- No addressing ***(but optional)***
- Optional ***powerline carrier*** for lowest cost & high security



# Solution #6 (Tracking Control)

**Tracking Control *(Sun and Steel Solar)***

***E-W Elevation Changes***

**Complicated Method:**

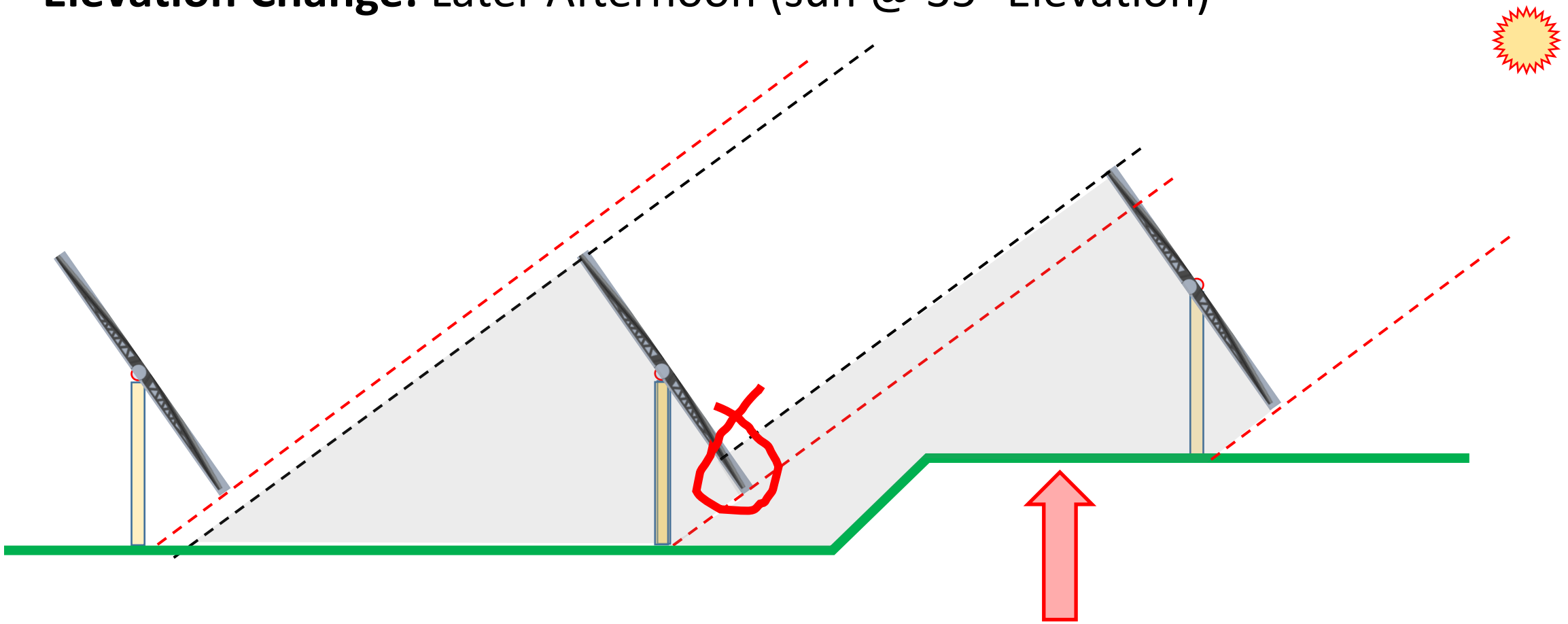
Unique backtracking algorithm for each row, with inclinometers (tilt angle sensors), 2-way wireless communication, photocell array to sense adjacent rows' shadows, learning software for unique backtracking of affected row(s)

***Simple Method:***

*Compensate via. additional spacing between those few rows at elevation changes (same process used to layout fixed tilt solar farms)*

# Solution #6 (Tracking Control)

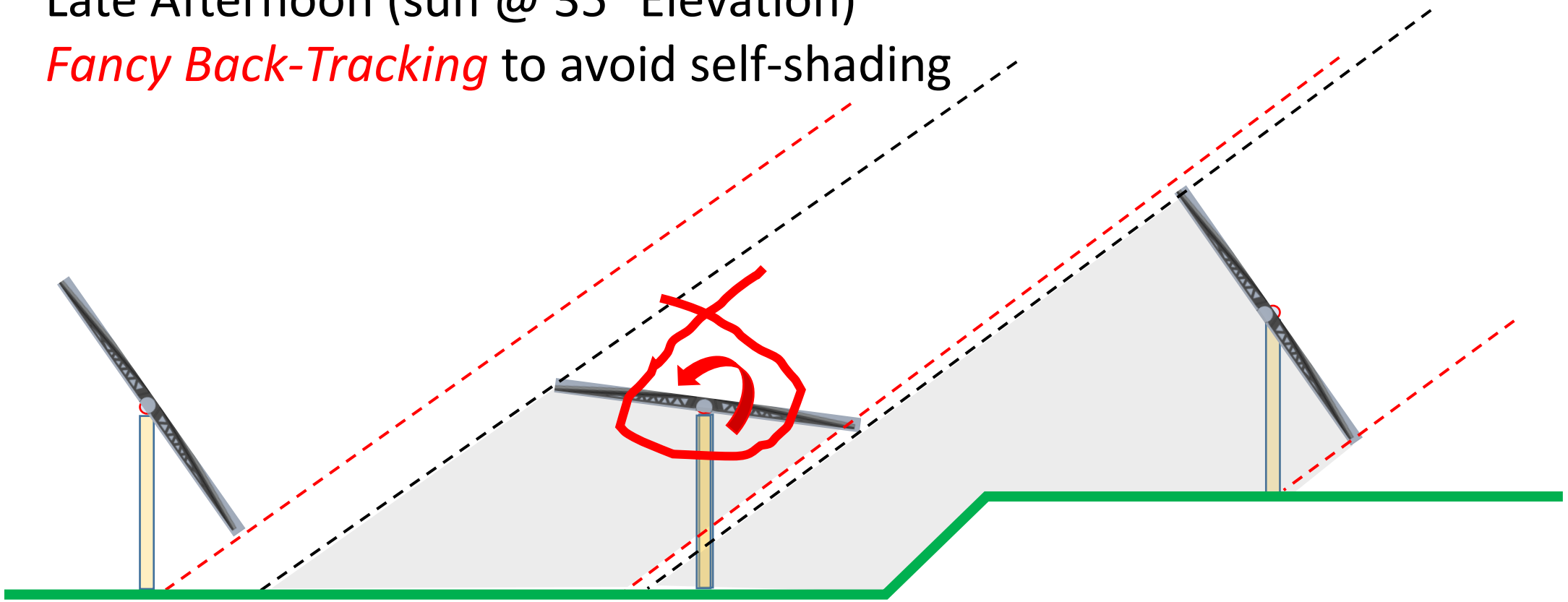
**Elevation Change:** Later Afternoon (sun @ 35° Elevation)



# Solution #6 (Tracking Control)

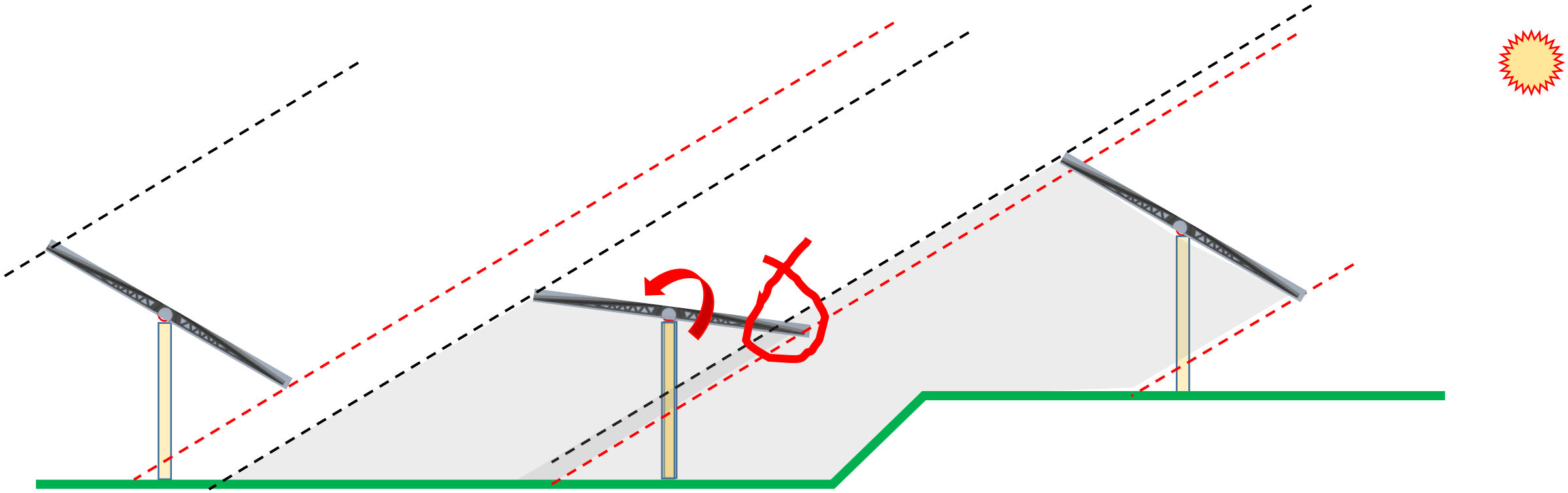
Late Afternoon (sun @ 35° Elevation)

*Fancy Back-Tracking* to avoid self-shading



# Solution #6 (Tracking Control)

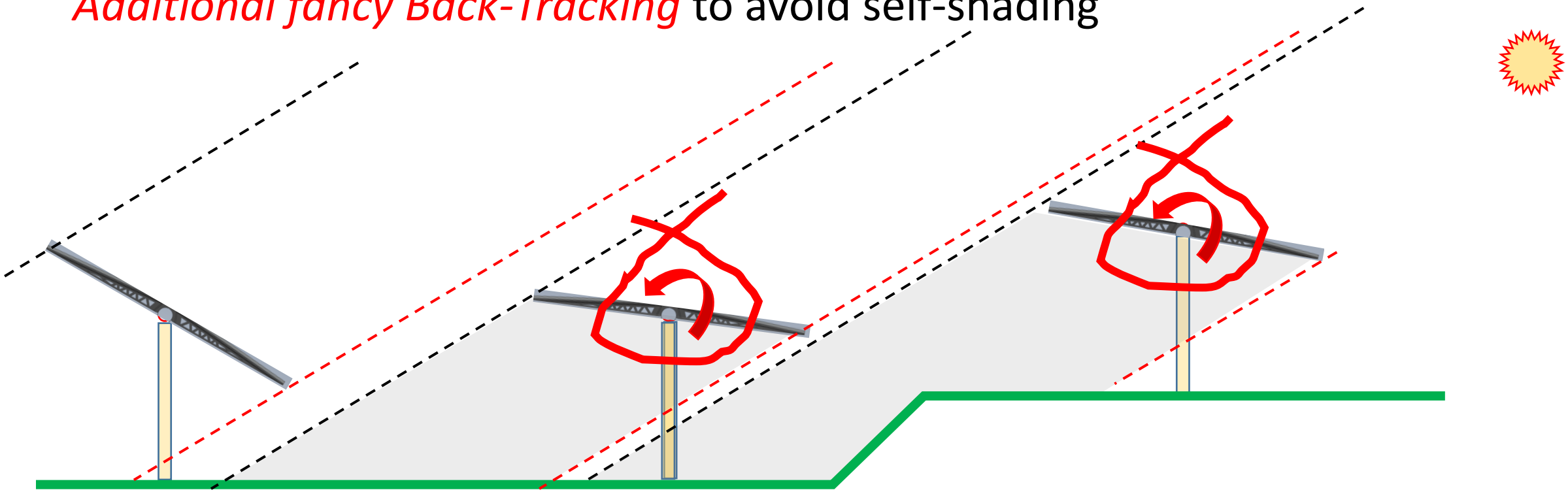
Later Afternoon (sun <35° Elevation)



# Solution #6 (Tracking Control)

Later Afternoon (sun <35° Elevation)

*Additional fancy Back-Tracking* to avoid self-shading



# Solution #6 (Tracking Control)

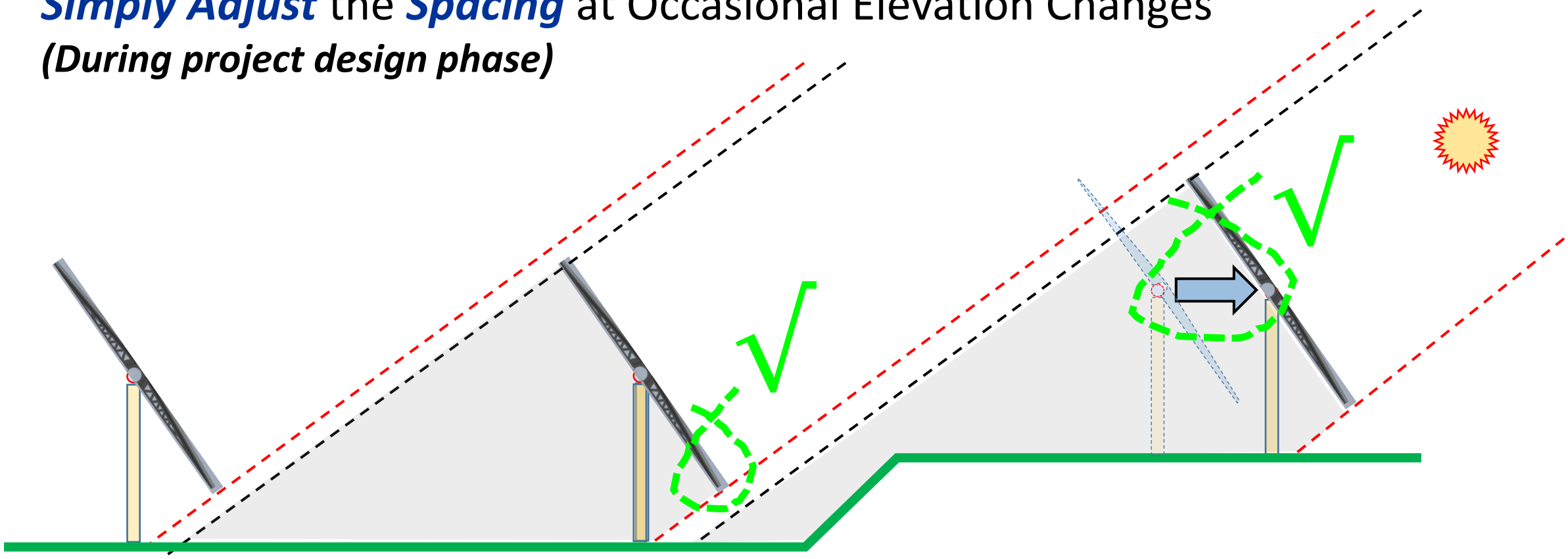
***Complicated Method***

- Elaborate Software
- Shadow detectors (1/row)
- Tilt sensors (1/row)
- Many local controllers (1/row)
- Wireless Net (1/row)
- Central controller (monitor, fiddle, refine software)

# Solution #6 (Tracking Control)

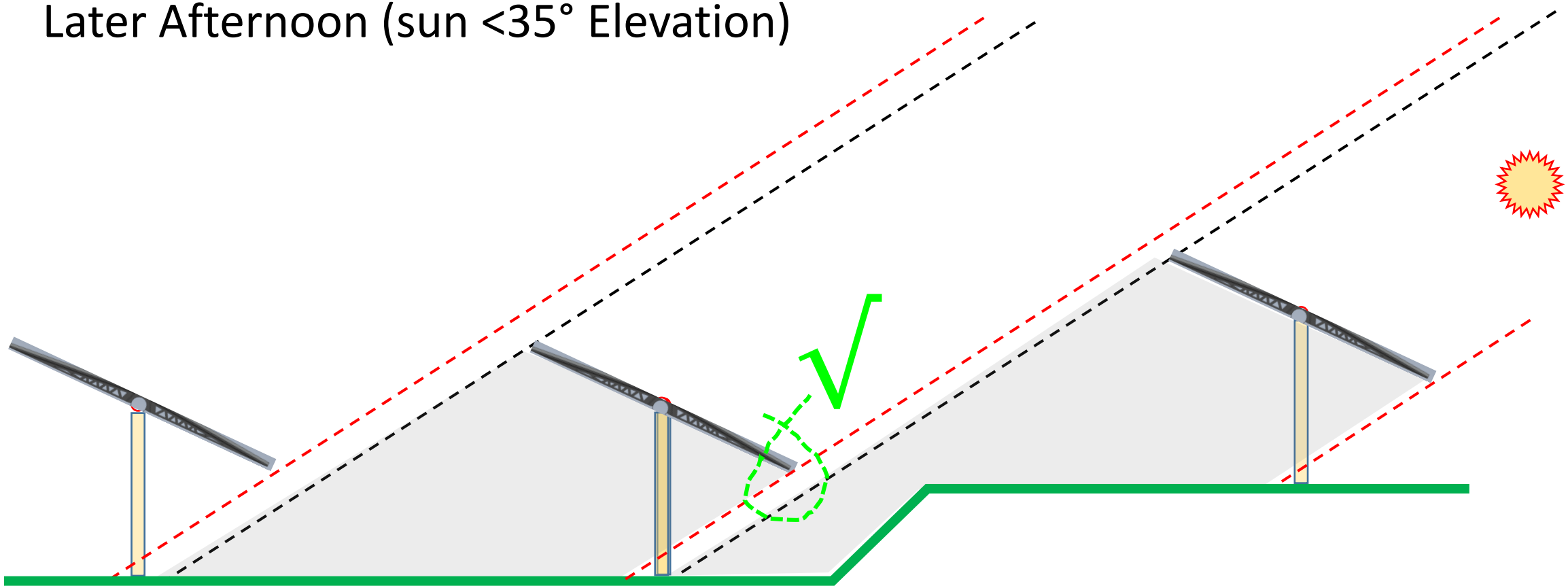
***Simply Adjust*** the ***Spacing*** at Occasional Elevation Changes

***(During project design phase)***



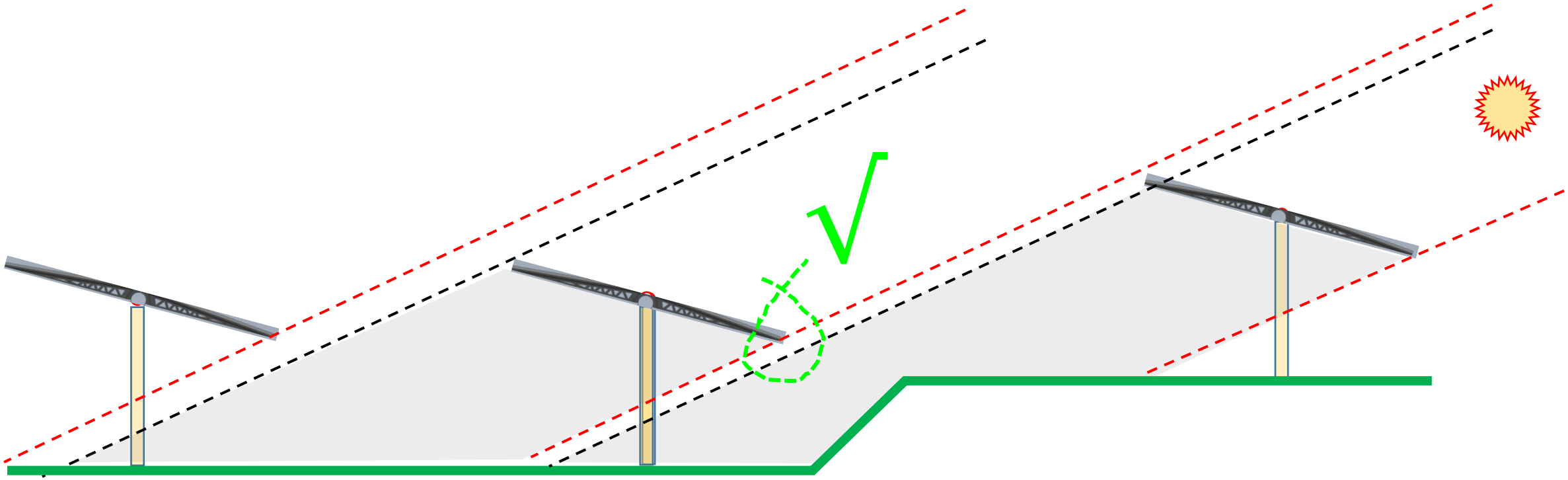
# Solution #6 (Tracking Control)

Later Afternoon (sun <35° Elevation)



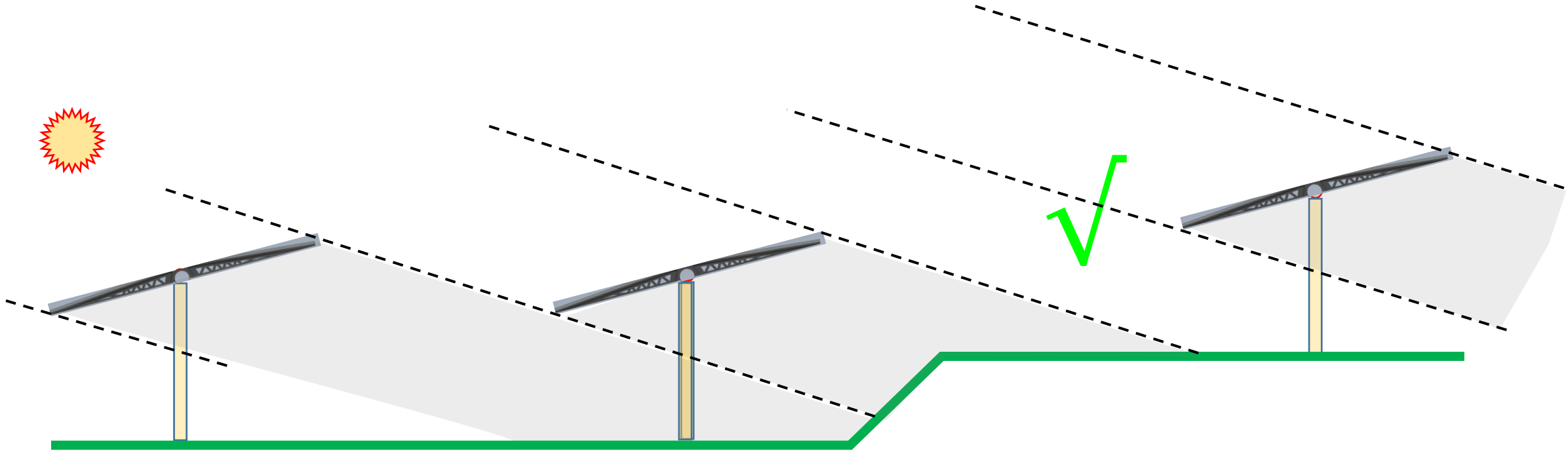
# Solution #6 (Tracking Control)

Very Late Afternoon



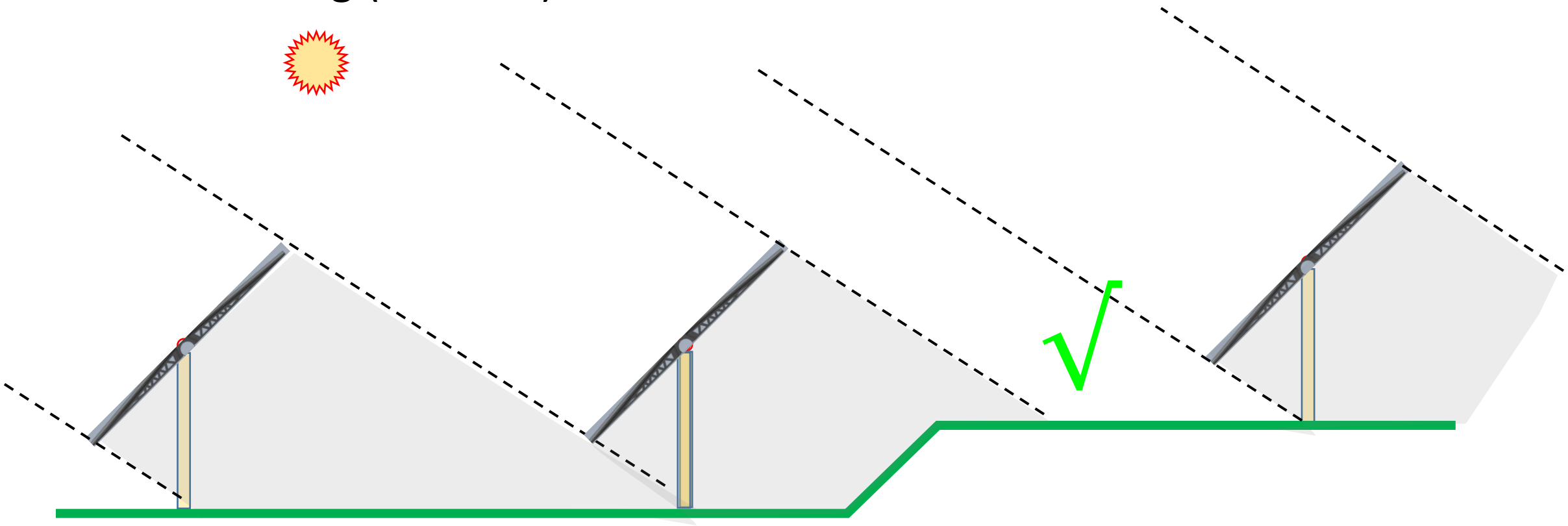
# Solution #6 (Tracking Control)

Early Morning (no issue)



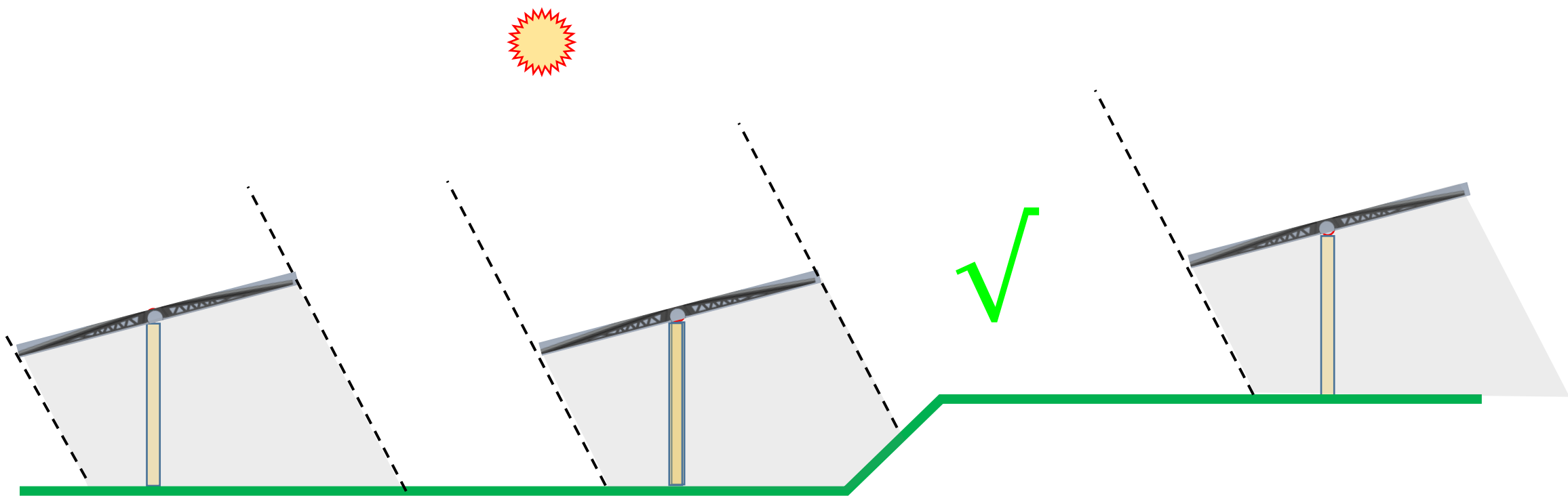
# Solution #6 (Tracking Control)

Mid-Morning (no issue)



# Solution #6 (Tracking Control)

Remainder of the Day (no issue)



# Solution #7 (Wind)

## Cost Savings *(Simplify Everything)*

1. Piers
   *$0.002/W*
2. Bearings
   *$0.002/W*
3. Torque Tube
   *$0.004/W*
4. Drive System
   *$0.004/W*
5. PV Attach
   *$0.003/W*
6. Control
   *$0.003/W*
7. **Wind**
   ***$0.004/W***
8. EPC
   *$0.01/W*
9. OPEX
   *$0.02/W*

***Sub: $0.032/W***

***Total: > $0.05/W***

***> $50M/GW***

SUN&STEEL solar

# Solution #7 (Wind)

## Cost Savings #7

7. **Wind:** *Strong, leveraged drive with strong round torque tube, friction damping at each bearing* ***with increased friction and holding at bearings via pinching action when wind speed/force increases,*** *sloped purlins (airplane wind PV), ±45° mechanical stops at each bearing, simple stow signal from control room instruction to single PLC*

   ***Option for purlin slip*** *on round torque tube interface for* ***worst case wind gust*** *(prevents destruction, requires manual realignment afterward)*

   ***Option for actuated locking system*** *(1 actuator per row) for all 10 posts/row*

   ***Two Patents issued & several pending.***

# Solution #7 (Wind)

## Cost Savings #7

7. **Wind:** ***We don't need AWD!*** ***We only need brakes!***

# Solution #8 (EPC)

## Cost Savings *(Simplify Everything)*

1. Piers
   *$0.002/W*
2. Bearings
   *$0.002/W*
3. Torque Tube
   *$0.004/W*
4. Drive System
   *$0.004/W*
5. PV Attach
   *$0.003/W*
6. Control
   *$0.003/W*
7. Wind
   *$0.004/W*
8. **EPC**
   ***$0.01/W***
9. OPEX
   *$0.02/W*

***Sub: $0.032/W***

***Total: > $0.05/W***

***> $50M/GW***

SUN&STEEL solar

# Solution #8 (EPC)

## Cost Savings #8

8. **EPC:** *Simple & fool-proof assembly, no obstructions (ample access), optional field weld or field bolt, loose bearings, self-aligning drive, optional pre-assembly of PV panels (2P, 3L, 4L, 5L) for enhanced consistency and speed of attachment, optional powerline communications, optional trolley on torque tubes for delivery of PV (pre-assembled panels or crates of modules) and as a productivity & safety improving standing platform (especially when aisles are muddy).*

***Faster-Better-Cheaper.***

# Solution #8 (EPC)

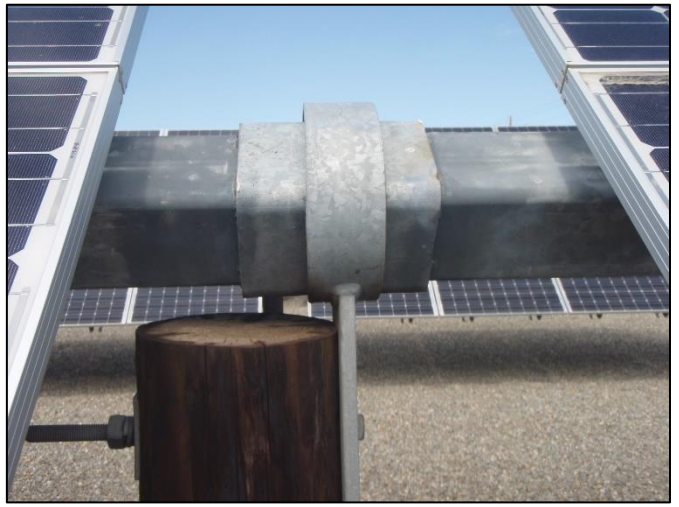
## Cost Savings #8

- *Simple & fool-proof assembly*
- *No obstructions (ample access)*
- *Opt. field weld or field bolt*
- *Loose bearings are simply guides*
- *Self-aligning and self-tautening drive*
- *No add-on (field weld) gnd. lugs or fab & attach gnd. wires at each post*
- *No add-on dampers, springs, other*
- *Opt. pre-assembly of PV panels (2P, 3L, 4L, 5L) for reliable consistency and improved speed of PV attachment*
- *Opt. powerline communication*
- *Opt. trolley on torque tubes for delivery of PV (pre-assembled panels or crates of modules) and as a productivity & safety improving standing platform (especially when aisles are muddy)*

# Solution #8 (EPC)

## Field Weld Option

- (R) Shell Solar 1 MW project, HDG square torque tubes field welded to the HDG square coupler, then sprayed with zinc-rich paint
- The two bottom corners of the square coupler (acting also as a journal) had too much pressure in the round bearing race and were wearing out too quickly
- A round journal in a round bearing race (S&SS design) has much more surface area and hence less pressure and less wear over 30 years (~22,000 ±45° turns)
- ***Field welding option supports local content*** (e.g., employable welders in Vietnam, MENA, & even Union Labor situations)



# Solution #8 (EPC)

## Field Weld after 17 years

- Top photo from March 2021
- I visited my first tracker (1 MW Shell Solar project) 17 years after it was built
- Still operational, no rust at the field welds of the galvanized corners of the square journal-coupler
- Note: Retrofit of HDPE plastic inserts were installed ~2007 to reduce the wear on the two lower corners of the square Journal-Coupler

# Solution #9 (OPEX)

## Cost Savings *(Simplify Everything)*

1. Piers
   *$0.002/W*
2. Bearings
   *$0.002/W*
3. Torque Tube
   *$0.004/W*
4. Drive System
   *$0.004/W*
5. PV Attach
   *$0.003/W*
6. Control
   *$0.003/W*
7. Wind
   *$0.004/W*
8. EPC
   *$0.01/W*

***Sub: $0.032/W***

9. **OPEX**
   ***$0.02/W***

***Total: > $0.05/W***

***> $50M/GW***

# Solution #9 (OPEX)

## Cost Savings #9

**9. OPEX (O&M):**

- *Simple system*
- *No obstructions (ample access)*
- *Robust & reliable drive*
- *One PLC (in control room)*
- *No wireless net*
- *No moving wires*
- *No 1,000's of controllers & batteries in the field*
- *Optional agriculture farming in aisles*
- *Optional panel spin-allowance for worst case wind-yield with ease of repair (re-adjust) afterward*

# Our Cost Savings Summary

## Cost Savings *(Recap)*

1. Piers
   *$0.002/W*
2. Bearings
   *$0.002/W*
3. Torque Tube
   *$0.004/W*
4. Drive System
   *$0.004/W*
5. PV Attach
   *$0.003/W*
6. Control
   *$0.003/W*
7. Wind
   *$0.004/W*
8. EPC
   *$0.01/W*
9. OPEX
   *$0.02/W*

***Sub: $0.032/W***

***Total: > $0.05/W***

***> $50M/GW***

# Our IP Solution (1 of 3)

## Patents

1. Round Torque Tube (Issued)
2. Bolt-on Bearing (Issued)
3. Weld-on Bearing (Pending)
4. Sloped Purlins (Pending)
5. Winch-Cable-Pulley Driven System (Pending)
6. Bearing Race (Pending)
7. Control System (Pending)
8. Self-Damping & Clamping Bearing (in Process)

# Our IP Solution (2 of 3)

| # | USPTO Application | File Date | Description and Value to Solar Farms |
|---|---|---|---|
| 1 | 16/363,294 **(Awarded)** | 05/29/2018 | **ROUND TORQUE TUBE WITH PROTRUDING WELD SEAM**<br>1. Round torque tube is the strongest tube shape for torsion (wind strength).<br>2. Protruding weld seam performs as additional mechanical hold (or stop) for purlin attachment.<br>3. Includes the addition of material along the weld seam for enhanced hold/stop.<br>4. Relies on existing round tube manufacturing tooling. |
| 2 | 16/363,288 **(Awarded)** | 03/25/2019 | **JOURNAL-COUPLER FOR BEARING (Field Bolted)**<br>1. Couples two torque tubes together end-to-end.<br>2. Performs as a round journal inside a round bearing race (“Simple Bearing”).<br>3. Friction of steel-on-steel provides natural damping in the wind.<br>4. Mechanical wind holding stops at both east and west tilt limits.<br>5. Provides and maintains electrical ground path from torque tube to post.<br>6. Bolts together in the field, clamping onto the torque tubes.<br>7. Performs as north-south thrust stop to keep torque tube in position north and south. |
| 3 | 16/363,303 (Pending) | 03/25/2019 | **JOURNAL-COUPLER FOR BEARING (Field Welded)**<br>1. Couples two torque tubes together end-to-end.<br>2. Performs as a round journal inside a round bearing race (“Simple Bearing”).<br>3. Friction of steel-on-steel provides natural damping in the wind.<br>4. Mechanical wind holding stops at both east and west tilt limits.<br>5. Provides and maintains electrical ground path from torque tube to post.<br>6. Complete unit (not two halves), holding torque tubes with compression pins, bolts, or field welding.<br>7. Performs as bi-directional thrust stop to keep torque tube in position north and south. |

# Our IP Solution (3 of 3)

| # | USPTO Application | File Date | Description and Value to Solar Farms |
|---|---|---|---|
| 4 | 17/203,400 (Pending) | 03/17/2020 03/17/2021 | **SLOPED PURLINS**<br>1. Sloped Purlins lower the center of gravity (CG) of top-heavy PV solar panels.<br>2. Two sloped purlin halves can attach to the sides of any shape of torque tube, further lowering CG.<br>3. Sloped purlins yield maximum strength near the torque tube where wind-induced bending forces are maximum.<br>4. Purlin indents or ends can hit against protruding weld seam on S&SS patent # 10845092.<br>5. Slope of the purlins are easily adjustable to any useful PV slope; from 0° (flat) to a practical 4° to 7° slope. |
| 5 | 63/108,069 (Pending) | 10/30/2020 10/25/2021 | **WINCH-CABLE-PULLEY DRIVE SYSTEM**<br>1. Allows small slew drive or winch to turn large tracker of solar panels with leverage.<br>2. Does not require strict alignment of slew drive and torque tube system; reliable with misalignments.<br>3. Allows slew drive to self-align and achieve self tautness.<br>4. Can attach to one post, or to a pair of posts for enhanced stability, strength and reliability.<br>5. Uses wire rope instead of rack & pinion, enhancing reliability, ease of installment and practicality.<br>6. Allows use of a redundant set of wire ropes for enhanced strength and reliability. |
| 6 | 63/129,128 (Provisional) | 12/22/2020 | **BEARING RACE**<br>1. Simple Bearing race made from two formed pieces of flat stock.<br>2. Simplifies fabrication of bearing race for a simple bearing.<br>3. Requires no fabrication welding, only simple folding and twisting with simple manufacturing tooling. |
| 7 | 63/165,556 (Provisional) | 03/25/2021 | **CONTROL SYSTEM**<br>1. One PLC for multitude of tracker motors.<br>2. Signal is carried on the existing AC powerline feeding the motors.<br>3. PLC reliably tells all motor control boxes to turn PV east or west for durations of time, or until E or W limit switch. |

# Solution Summary

## *Simplicity is the Ultimate Sophistication*

- ***Reliable***: Simple steel-on-steel bearings (no plastic bushings) with natural friction dampening, round torque tube, self-aligning leveraged drive with redundant pulley/wire rope, one-way go-east/west signal, no moving wires, sloped PV for A+ wind tolerance
- ***Uncomplicated*** with Truly Lowest Cost: Fewest and simplest parts, simple assembly, easy and loose alignment, pre-assembled PV attachment via industrial "PEZ dispenser", full aisle access, one timing-based off-the-shelf controller (PLC) for entire solar farm
- ***Balanced***: Sloped PV for low center of gravity, superior wind dynamics, unique aesthetics
- ***Size***: Appropriately large (5m x 66m row) and strong; not small, cumbersome, or costly

**Their Complication**

**Our "PEZ" PV Attachment**

SUN&STEEL solar

# Panelizing

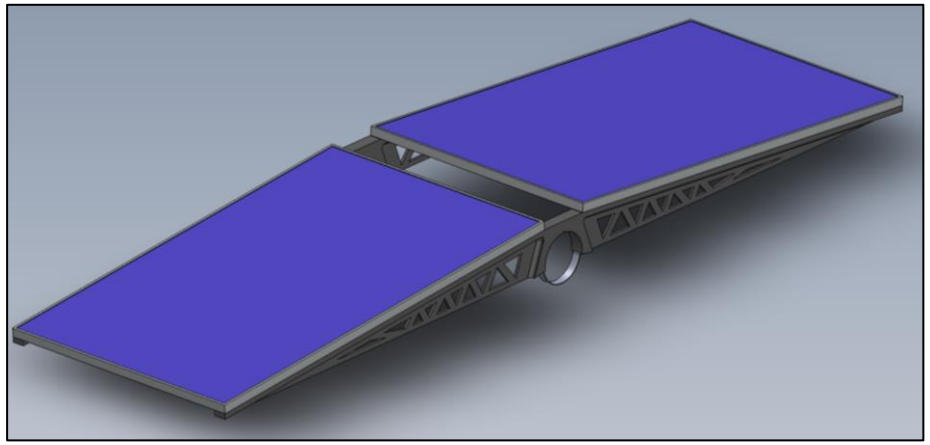
## Pre-Panelize

- *2 Purlins*
- *# of Modules*
- *3L, 4L, 5L, 2P*
  - *2P: Both purlins generally in-line with modules' long frame*
  - *Pre-panelized 2P requires twice as many purlins than shared purlin configuration/method*

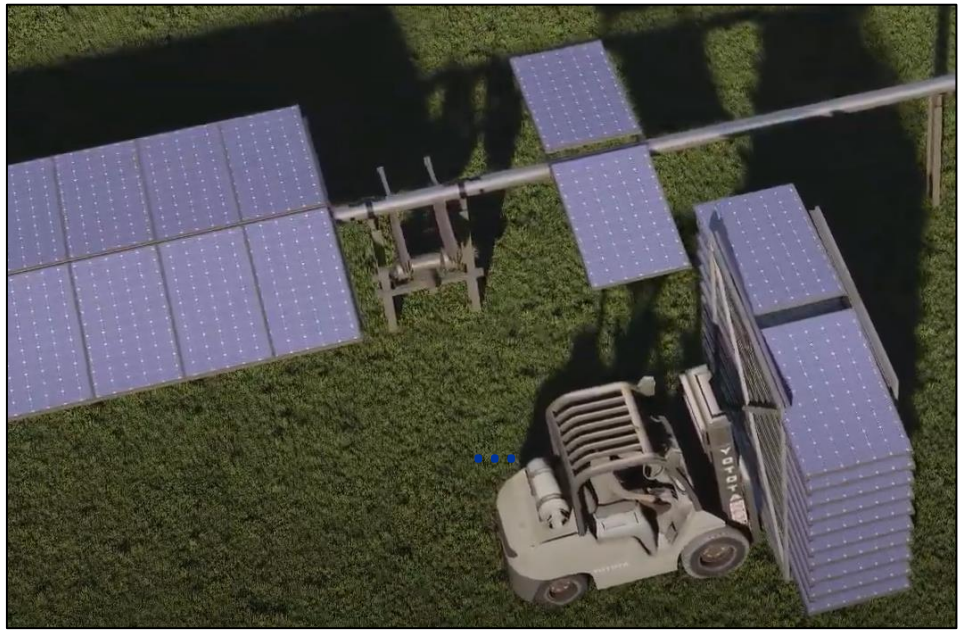
2004; 1 MW, Pre-Panelized "Panels" consisting of 2 CEE purlins & 6 Shell Solar PV modules of 0.55m width for a 3.3m chord

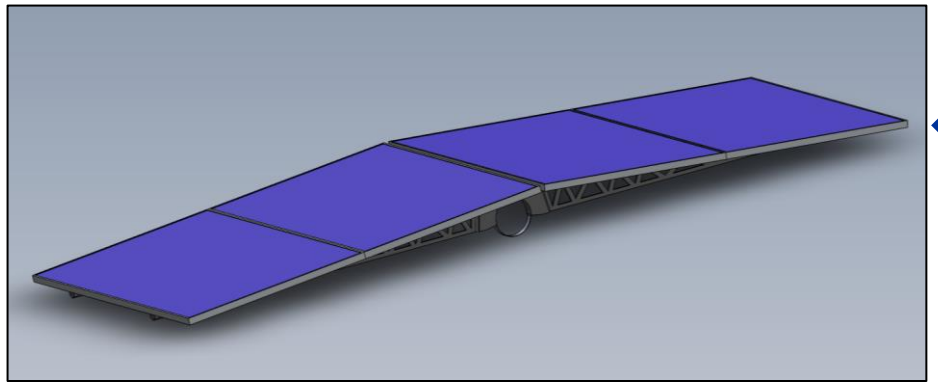
# Panelizing

## **Pre-Panelize** *(2 Purlins + # of Modules)*



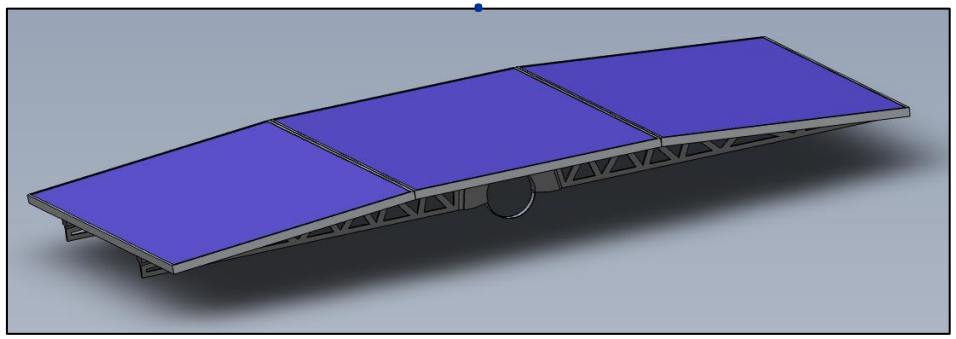
← 2P →





← 4L

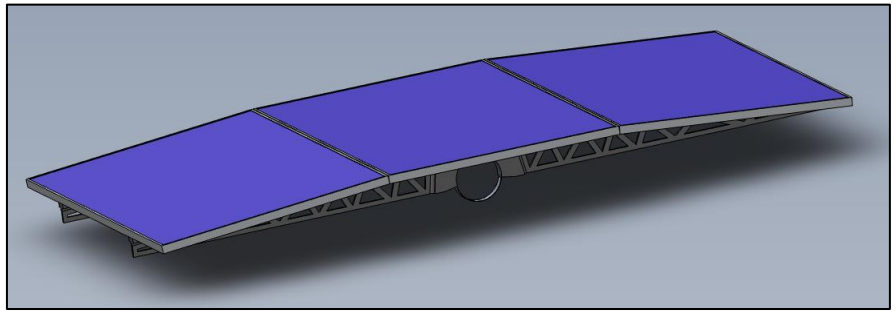
3L →

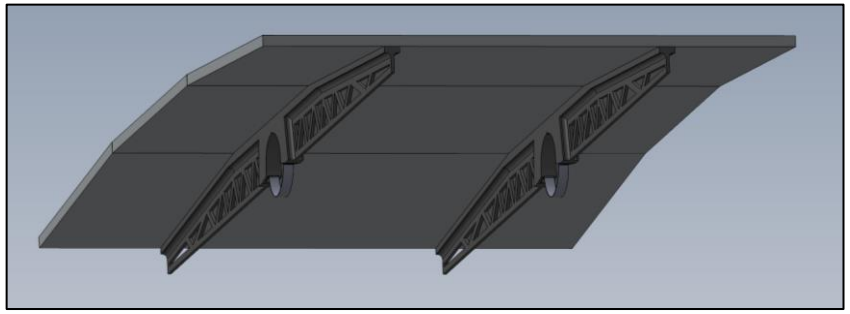


# Panelizing

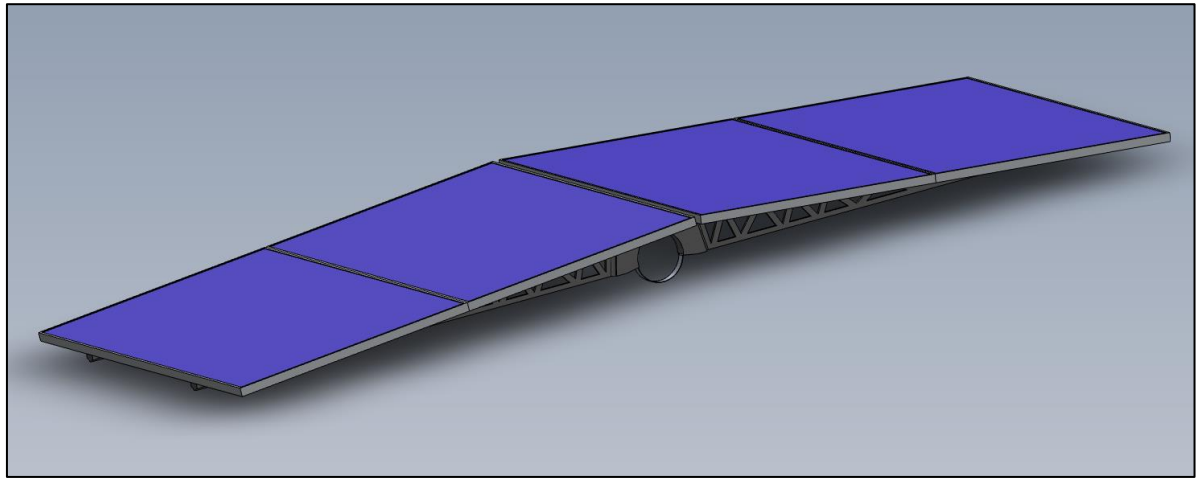
## Examples of *(sm & lg)* format ***3L*** *(3m, 3.9m)* & ***4L*** *(4m, 5.2m)*

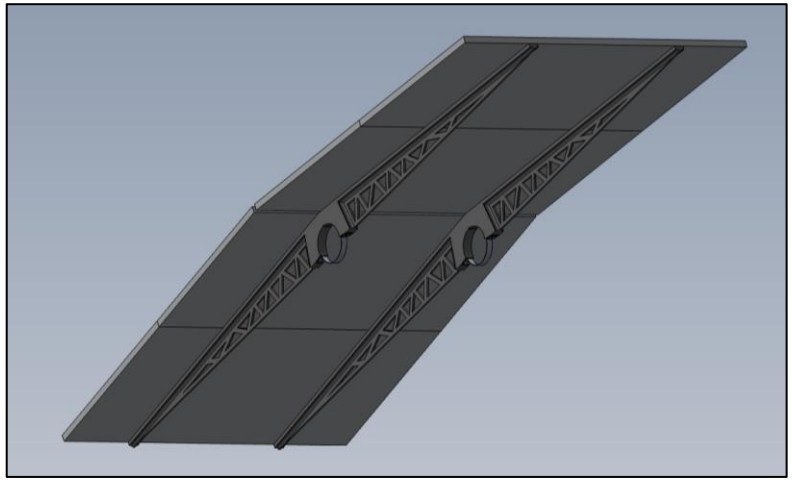
**3L:**





**4L:**



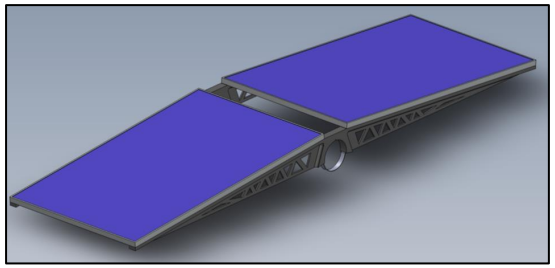


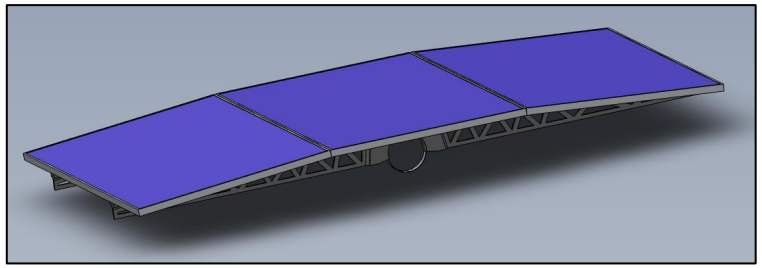
# Panelizing

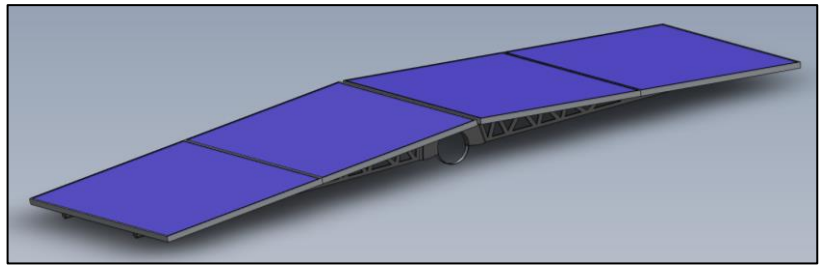
## Examples of *"Panels"* *(2 purlins + # of modules)*

*Width & Chord in meters:*

| 2P | 3L | 4L |
|---|---|---|
| 1.0m x ***4.0m*** | 2.0m x ***3.0m*** | 2.0m X ***4.0m*** |
| 1.0m x ***4.1m*** | 2.2m x ***3.9m*** | 2.2m x ***5.2m*** |
| 1.3m x ***4.4m*** | | |
| 1.3m x ***4.5m*** | | |





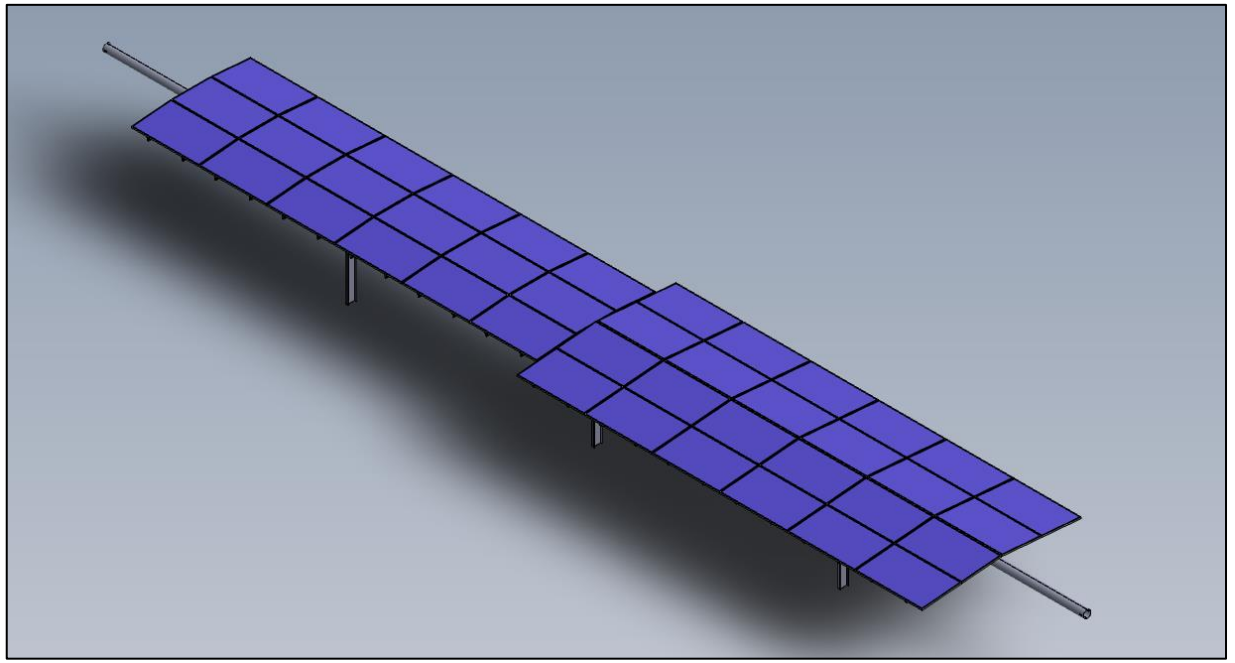


# Panelizing

**Examples of *"Panels"*** *(2 purlins + # of Lg Format modules)*

*Chord in meters:*

| **3L** | **4L** |
| --- | --- |
| ***3.9m*** | **5.2*m*** |



# Panelizing

**PV Power per Row Length (Watts/Meter)**

**1. 833 W/M**
100% *(Baseline)*
4.0 m chord
**1m x 2m PV**
Mono-facial
4L
6’ TT

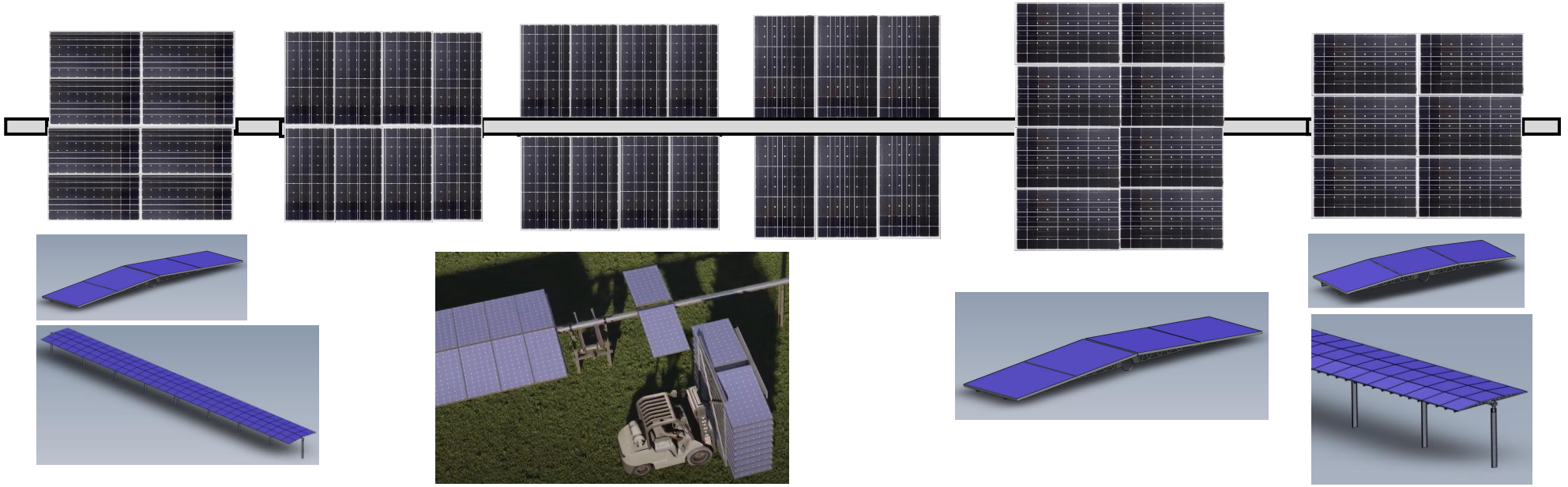
**2. 833 W/M**
100%
4.0 m chord
**1m x 2m PV**
Mono-facial
2P
6’ TT

**3. 833 W/M**
100%
4.2m chord
**1m x 2m PV**
Bi-facial
2P
6.4’ TT

**4. 915 W/M**
110%
4.4 – 4.6 m chord
**1.3m x 2.2m PV**
Mono or Bi-facial
2P
6.8’ TT

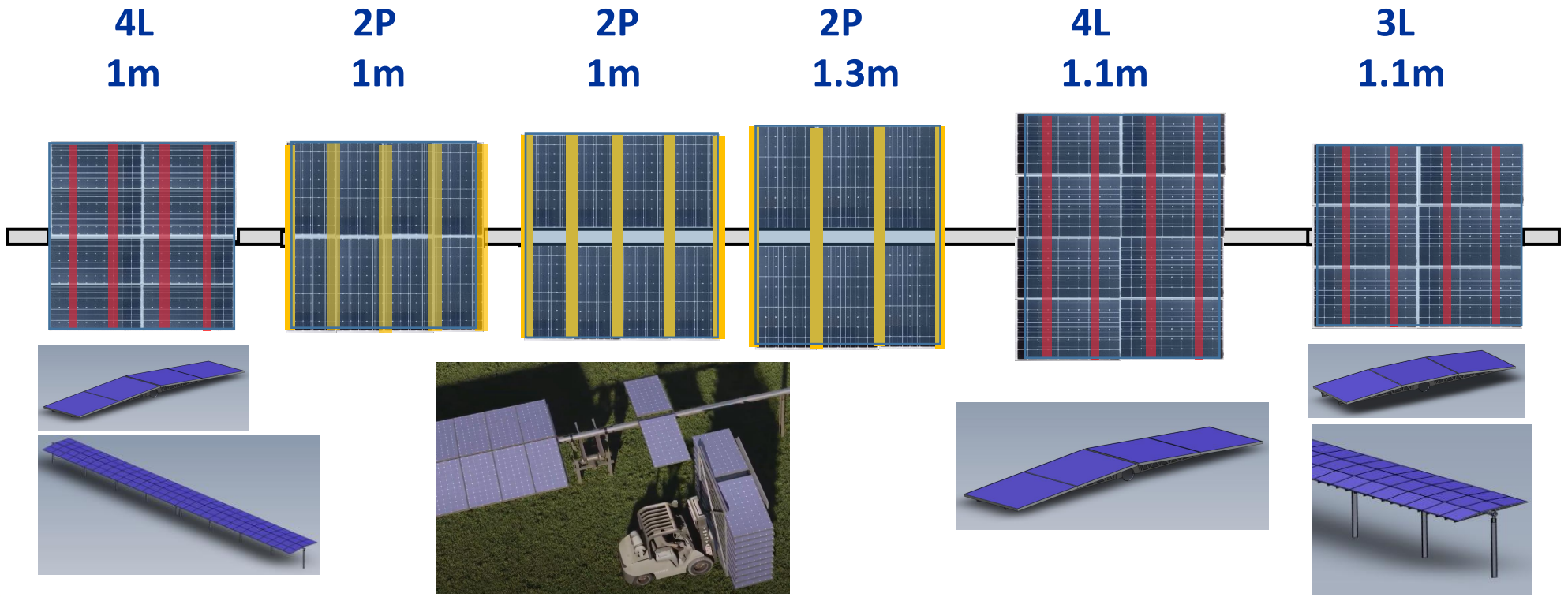
**5. 1082 W/M**
130%
5.2 m chord
**1.3m x 2.2 m PV**
Mono-facial
4L
7.5’ TT

**6. 813 W/M**
97%
3.9 m chord
**1.3m x 2.2 m PV**
Mono-facial
3L
6’ TT



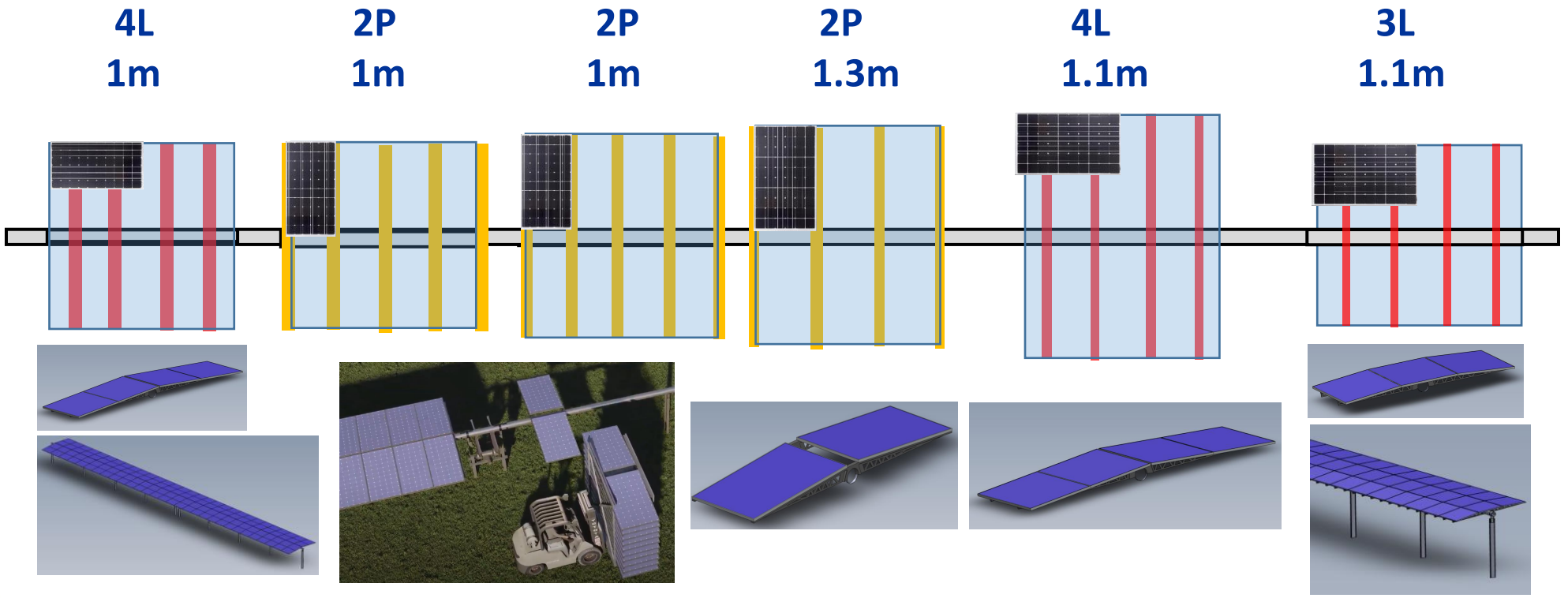
# Panelizing

## Purlin Location/Spacing



# Panelizing

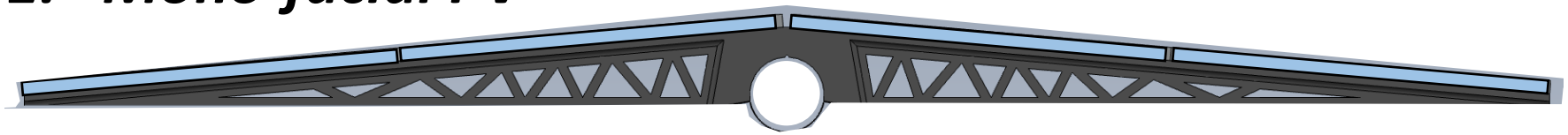
## Purlin Location/Spacing

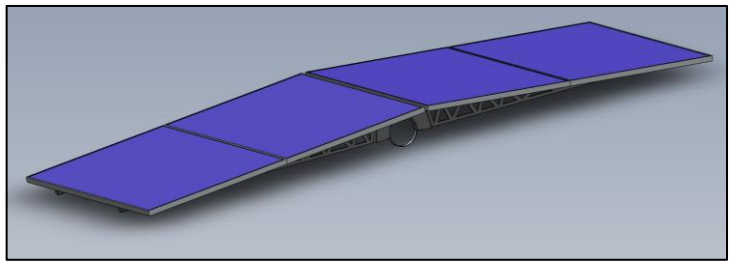


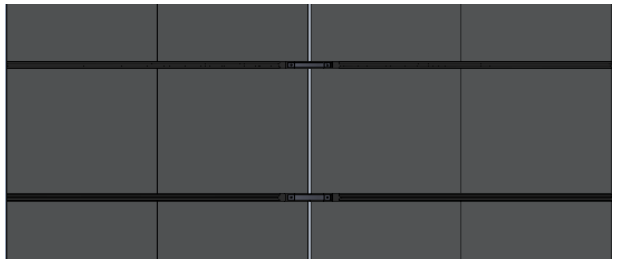
# Panelizing

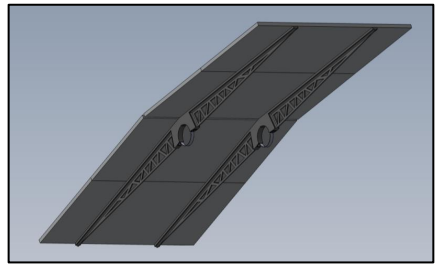
Examples of ***4L*** for both ***Mono & Bi-facial PV Modules***

## 1. *Mono-facial PV*



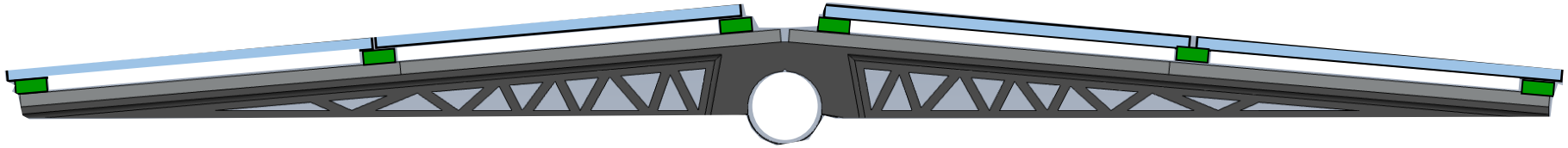






## 2. *Bi-facial PV*

***Spacers*** lift PV a few cm to ***soften &/or prevent hard purlin shadows***



# Company Overview

## Key Facts

- Sun and Steel Solar LLC is a Nevada based solar mounting technology startup to deliver a single-axis tracker mounting system for PV solar farms
- The company has developed a proprietary single-axis tracker to address a $30 billion/year market opportunity
- The team includes highly experienced engineers from aerospace, PV solar farm and construction industries
- The inventor's two prior versions have been used in over 600 MW of solar farms (~$100+ million SAT revenue)
- The company has tested a prototype, advanced its IP and is poised to deliver a superior, cost-effective product
- Two issued patents, five pending

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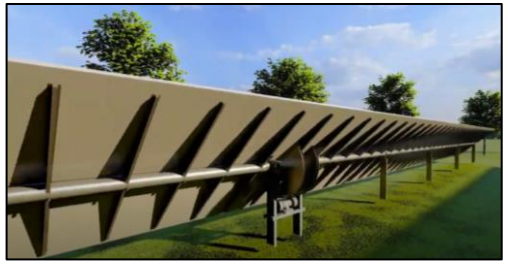
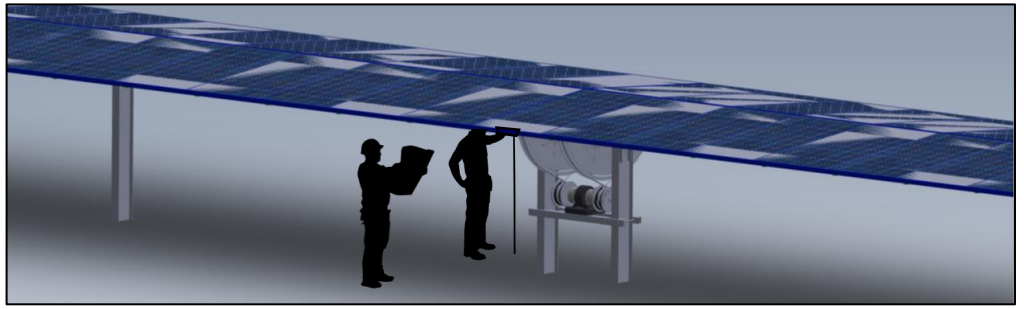
# Our Fresh Solution

## A Fresh Approach

- Ideas from ***extensive experience*** in PV, engineering, construction, single-axis tracking, continuous measurable improvement (CMI) and watching contractors struggle with competitors' trackers
- Our ***simplicity***, engineered throughout our mechanical and electrical systems, ensures all labor markets worldwide can and will build flawless consistency in quality, safety, cost effectiveness and ease of O&M
- Our ***up-down PV attachment*** delivers superior wind dynamics, the lowest center of gravity, unique aesthetics, a lower PV operating temperature and no sediment ponds when stowed horizontally
- Avoiding pointless complexity, we improved upon our ***heritage of simplicity***





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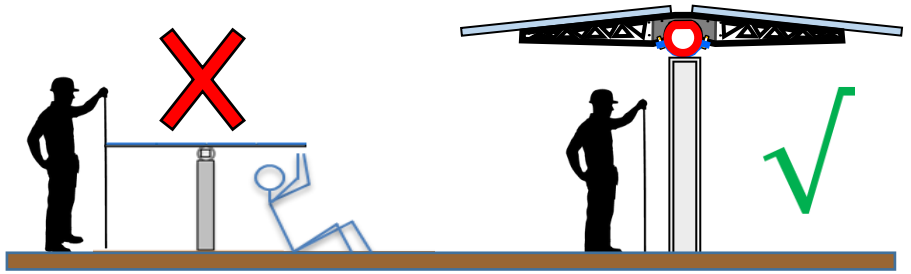
# Your Best Solution

## A Best-Value Approach

- We have ***extensive experience watching trackers fail*** for all the unnecessary reasons, be they poor wind dynamics, plastic bushings, after-thought add-ons, contractors beating in latent defects and fanciful designs with hidden costs and risk
- For 13 years ***Robert Dally engineered solar panels for satellites***, reduced cost from $170/W to $110/W for Silicon PV, and helped transition space PV panels to high efficiency gallium-arsenide (GaAs) to deliver enhanced power and value
- Our vision of ***faster-better-cheaper***, inherent robustness and ***absolute reliability*** for terrestrial PV began in 2017, with a focus on developing and offering the most risk-free, lowest total cost single-axis tracker for PV solar farms
- We built our prototype, tested it, proved our vision, refined our design, secured valuable IP, avoided others' IP and are poised to show the world what leap-frogging is really about in bringing ***best-value to all grid and C&I PV stakeholders***



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# Market Opportunity

- Global tracker market, excluding China, is currently ~20 GW/year, or $2-3 billion/year, with a forecast to grow at double digit percentages for the foreseeable future
- The International Energy Agency ("IEA") estimates one large PV solar farm is needed per day through 2030
- We estimate that 50% would be utility scale, 75% tracked and at $0.12/W yields a $30 billion/year market
- Customers are asset owners looking to minimize risk and cost and are highly influenced by all stakeholders
- Stakeholders include asset owners, EPCs, bankers, insurers, PV module suppliers, O&M providers
- Sun and Steel Solar has the simpler solution to minimize long term risk and system cost of ownership
- Our SAM is the global market, our TAM is the 95% of PV solar farms destined for the flat lands of deserts, fields, and agriculture farms, not the challenging 5% fated for difficult and costly hilly terrains
- Recently, Array Technologies Inc. and FTC Solar have gone public with market capitalizations of $2.4 billion and $780 million, respectively
- Our large, robust platform is ready for the latest introduction of large format and bifacial PV solar modules

Large !

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- ***Our large, robust tracker is ready for the latest introduction of large format and bifacial PV solar modules***

# Current Status

## Prototype Tested, Final Design in Process

- **Seed investment** and company launch in **2017**
- ***Two full-size test rows*** at California Polytechnic University San Luis Obispo verified product's constructability, robustness, durability, reliability, wind resistance, accessibility, simplicity and IP value
- ***Seeking Round A*** financing for final design, wind tunnel and other tests, final engineering and market launch

# Business Model

## Consider all Stakeholders

- All stakeholders aware that the total cost of single-axis tracker ownership includes material, installation, 30+ years of operation and daily risk of failure
- Our protype verified the marketability of our design and our IP
- With Round A funding we will finalize the design, retest, obtain relevant certifications, staff up, establish supply chains and market the product via webinars, exhibit hall displays and sales personnel
- Revenue options include ***license agreements, partnerships, direct and indirect sales***
- ***Initial sales price will be in the cost-competitive $0.15/W range*** with 30% margin, as shown in the conservative pro-forma
- Costs and price will continue downward in $/W via volume and ever increasing PV module efficiency
- Round A investor will realize a low risk, high return

# Traction

## Go-To Market Strategy is in Development

- As Director and CTO, Robert Dally has nurtured a trusting set of internationally based engineers and project managers who are now senior leaders aware of Sun and Steel Solar and our tracker intention
- This set of loyalists have expressed interest to use their bankable companies to simultaneously finance the supply and procurement, effectively licensing the product for self-use on future projects
- The sales plan is conservative in volume, especially given the large size of the market
- A professional sales team will be hired
- Word will spread via webinars, exhibit halls, and C-level contacts who are becoming sensitive to the total cost of ownership, factoring in the cost of wind failure, complexity, and local labor variances
- The difficulties are conquered by delivering a better story that tracks the truth
- Our strategy is developing and THE MARKET is conquerable

# Financials

## Management's Plan

- Conservative sales projections for a product with many unique selling propositions (USP)
- Sales price is competitive @ $0.15/W (with high efficiency PV)
- Lowest cost sales approach via licensing agreements
- Mostly virtual personnel and consultants
- ***Exit Strategy:*** Options to be explored in conjunction with achieved growth, either ***M&A or IPO*** which has been successfully demonstrated by several tracker companies

| INPUTS | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
|---|---|---|---|---|---|---|
| **Sales: 1750 MW:** | | 10 MW | 50 MW | 200 MW | 500 MW | 1000 MW |
| Sales Price ($/W): | | $0.15/W | $0.15/W | $0.15/W | $0.14/W | $0.14/W |
| Cost ($/W): | | $0.12/W | $0.11/W | $0.11/W | $0.10/W | $0.09/W |

**CASH FLOW (Pre-Tax)**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Investment:** | **$2,500,000** | **$0** | **$0** | **$0** | **$0** | **$0** |
| Development: | ($1,051,000) | ($951,000) | $0 | $0 | ($200,000) | ($200,000) |
| Sales: | | $1,500,000 | $7,500,000 | $30,000,000 | $70,000,000 | $140,000,000 |
| COGS: | | ($1,200,000) | ($5,500,000) | ($22,000,000) | ($50,000,000) | ($90,000,000) |
| Misc: 2% Procure: | | ($24,000) | ($110,000) | ($440,000) | ($1,000,000) | ($1,800,000) |
| Payroll: | | ($400,000) | ($400,000) | ($1,175,000) | ($1,175,000) | ($1,175,000) |
| Office: | | ($60,000) | ($60,000) | ($80,000) | ($120,000) | ($120,000) |
| 5% Overhead: | | ($23,000) | ($398,000) | ($1,562,750) | ($3,564,750) | ($7,064,750) |
| 10% G&A: | | ($46,000) | ($796,000) | ($3,125,500) | ($7,129,500) | ($14,129,500) |
| | | | | | | |
| | | | | | | |
| **End of Year Cash:** | **$1,449,000** | **$245,000** | **$481,000** | **$2,097,750** | **$8,908,500** | **$34,419,250** |

# The Ask

## $2.5 million

- We seek ***$2.5m for 25% equity*** in early stage financing
- Previously raised $800k from 18 investors, many in renewable energy
- Use of funds:
  - Complete a final, bankable design
  - Secure and increase our IP
  - Staff up
  - Commence broader marketing

Contact *Robert Dally (rdally@sunandsteelsolar.com)*

# Round A Budget

| | | Final Development | | | | | | Sales | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Description** | **Q1** | **Q2** | **Q3** | **Q4** | **Q5** | **Q6** | **Q7** | **Q8** | **Total** |
| 1 | R Dally, Managing Member, salary | $50 k | $50 k | $50 k | $50 k | $50 k | $50 k | $50 k | $50 k | $400 k |
| 2 | CEO | $50 k | $50 k | $50 k | $50 k | $50 k | $50 k | $50 k | $50 k | $400 k |
| 3 | Contract Engineering | $20 k | $30 k | $40 k | $40 k | $40 k | $35 k | $25 k | $25 k | $255 k |
| 4 | Material Sourcing | $10 k | $20 k | $30 k | $10 k | $10 k | - | - | - | $80 k |
| 5 | Travel (Sales, Marketing, Testing, Misc.) | $10 k | $10 k | $15 k | $20 k | $20 k | $20 k | $15 k | $15 k | $125 k |
| 6 | Patent Work | $10 k | $30 k | $15 k | $10 k | $15 k | $5 k | $10 k | $5 k | $100 k |
| 7 | Prototyping | - | - | $20 k | $50 k | $10 k | $10 k | - | - | $90 k |
| 8 | System Testing | - | - | - | $30 k | $30 k | $10 k | $10 k | - | $80 k |
| 9 | UL Testing & Other Certifications | - | - | $10 k | $30 k | $20 k | $30 k | - | - | $90 k |
| 10 | Bankability Report | - | - | $10 k | $10 k | $10 k | $30 k | - | - | $60 k |
| 11 | Manager, Marketing and Sales | - | - | - | $30 k | $30 k | $35 k | $35 k | $40 k | $170 k |
| 12 | Project Buy-in & Support | - | - | - | - | - | $100 k | $100 k | - | $200 k |
| 13 | Office | $3 k | $3 k | $5 k | $12 k | $12 k | $15 k | $15 k | $15 k | $80 k |
| 14 | Exhibit Halls (Attendance, then Exhibit Booth) | $10 k | $10 k | $10 k | $15 k | $60 k | $60 k | $60 k | $10 k | $235 k |
| 15 | Other Legal, Misc | $15 k | $5 k | $5 k | $10 k | $10 k | $10 k | $5 k | $5 k | $65 k |
| 16 | Misc. | $10 k | $10 k | $10 k | $10 k | $10 k | $10 k | $10 k | - | $70 k |
| | **Total:** | **$188 k** | **$218 k** | **$270 k** | **$377 k** | **$377 k** | **$470 k** | **$385 k** | **$215 k** | **$2.5 million** |
| | Accumulating Expenses: | $188 k | $406 k | $676 k | $1,053 k | $1,430 k | $1,900 k | $2,285 k | $2,500 k | |

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# Summary

## Sun and Steel Solar Offers Value Throughout

- Lowest possible CAPEX, EPC, OPEX (O&M) for an upcoming single-axis tracker
- Two patents, five pending, more in process
- Robert Dally, 42 years in PV, 17 years single axis tracking, long career of continuous improvement
- Comprehensive and strategic SWOT analyses on competing trackers
- Unique design of marketability to leapfrog the status quo
- 18 months maximum to launch via $2.5mm Round A
- Income from licensing, sales and partnerships
- Excellent Round A opportunity for any investor with our preference for a strategic investor
- Growth via Rounds, M&A, IPO

# Thank You

Robert Dally

Managing Member

Sun and Steel Solar, LLC

Tel: +1 805 452 4128

rdally@sunandsteelsolar.com

www.sunandsteelsolar.com

YouTube Video: https://youtu.be/l_JwZ58Txs

# Appendix 1

Patent pending sloped PV allows chimney effect cooling for more PV energy, lowest center of gravity to reduce torque, best wind tolerance for stability and reliability, prevention of sediment ponds when stowed flat overnight, and best aesthetics for PV solar farms

## 4m Chord

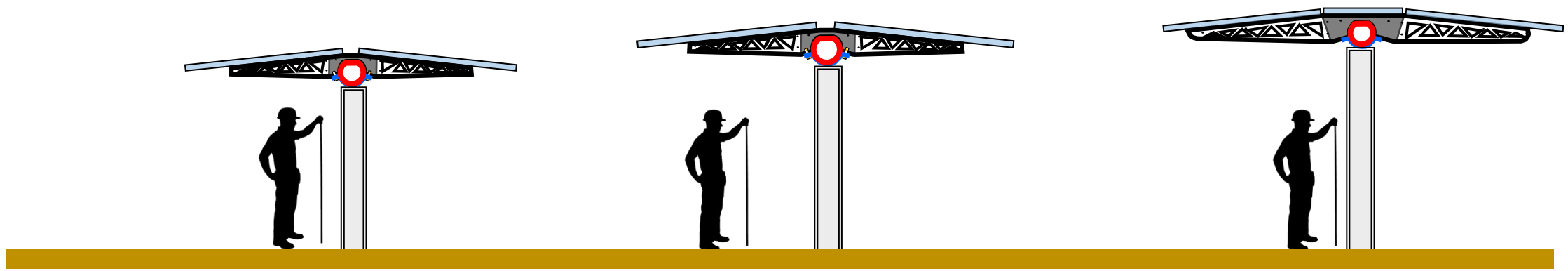
- *2P or 4L or 3L (Lg Format)*
- *50% ± GCR w/4m-5m aisle*
- *4.25m chord with center gap for small format (1m x 2m) bifacial PV*

## 4.6m Chord

- *2P Lg Format, Bifacial PV*

## 5m Chord

- *5L or 2P+1L Small Format, Mono*
- *5.2m with 4L Lg Format, Mono*
- *55.5% GCR w/4m aisle (11% more PV)*
- *62.5% GCR w/3m aisle (25% more PV)*



# Appendix 2

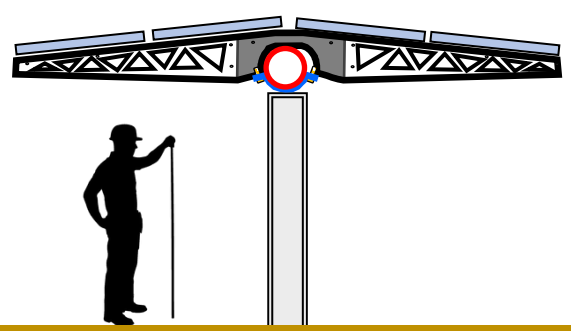
Place large format (1.3m x 2.2m), mono-facial PV modules in 4L, with two purlins at quarter points.

Place lg format, bi-facial PV in same 4L, with 2” (5 cm) risers at each frame/purlin connection point.

Standard four (4) connection points per module. This extends the solar cells’ backside view to the albedo and reduces the “hard shadow” of otherwise very close purlins over the backside solar cell area.

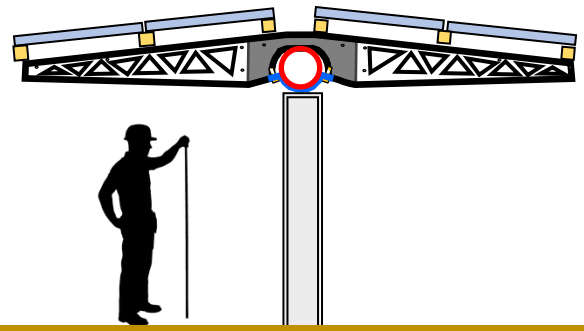
5.2m Chord in 4L

*Lg Format, **Mono-Facial***



5.4m Chord in 4L

*Lg Format, **Bi-Facial** on 2” risers*

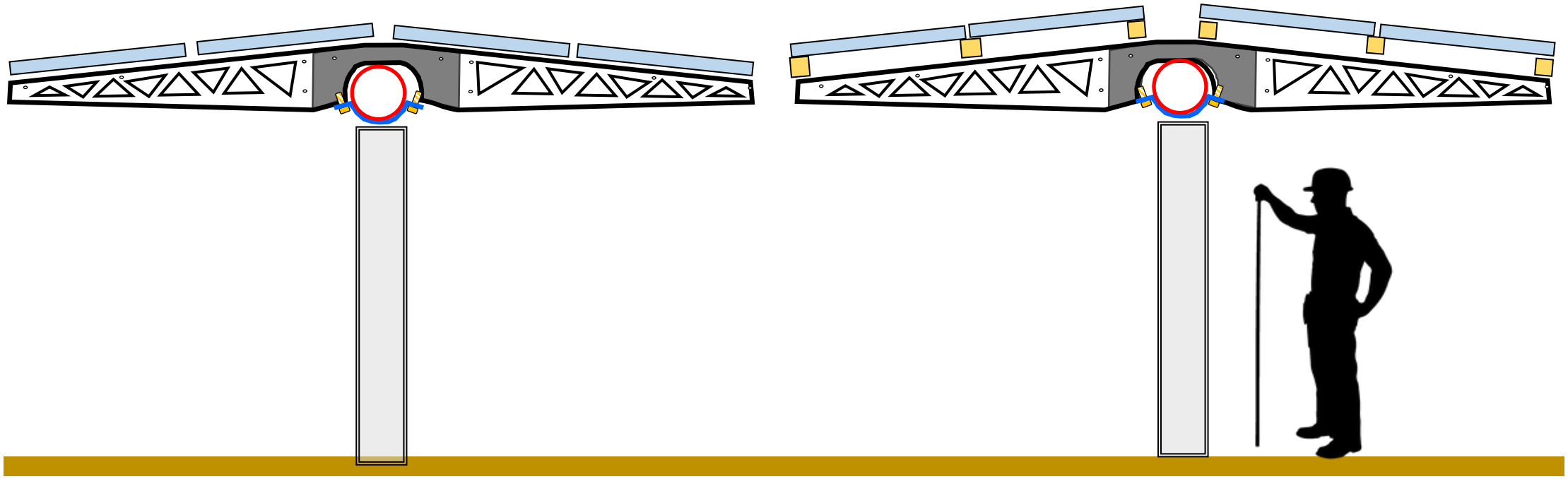


# Appendix 3

## Large Format Modules (1.3m x 2.2m) in 4L

Mono-Facial (5.2m)

Bi-Facial (5.4m)

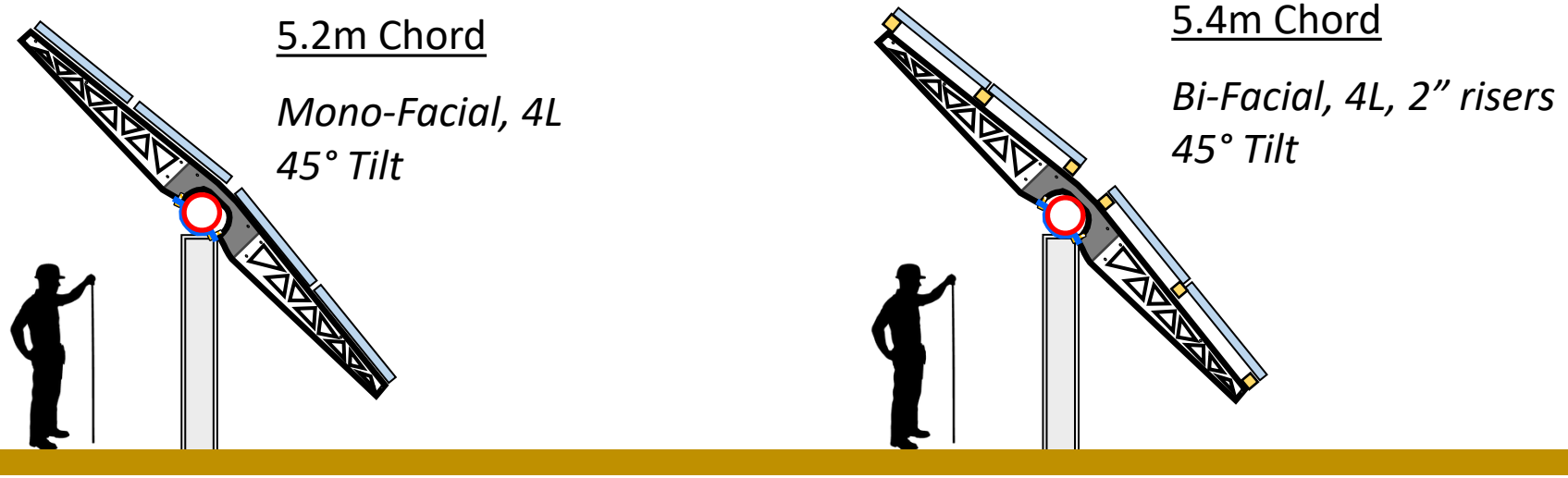


# Appendix 4

Place large format (1.3m x 2.2m) PV modules into 4L for large 5.2m (mono-facial) or ~5.4m (bi-facial) chord.

The bottom of the torque tube is ~ 7’ above ground.

Yields ~18” ground clearance when tilted 45°.  Purlins stop against the ground at ~65° tilt.



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Place large format (1.3m x 2.2m) PV modules into 4L for large 5.2m (mono-facial) or ~5.4m (bi-facial) chord.

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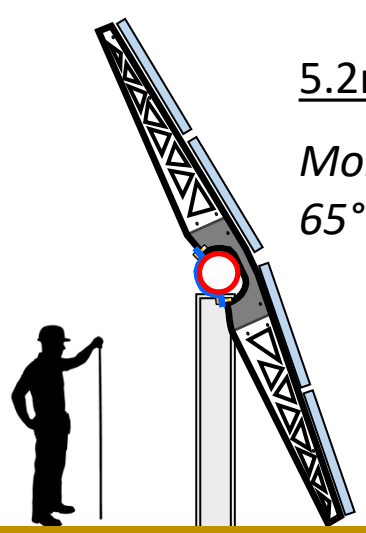
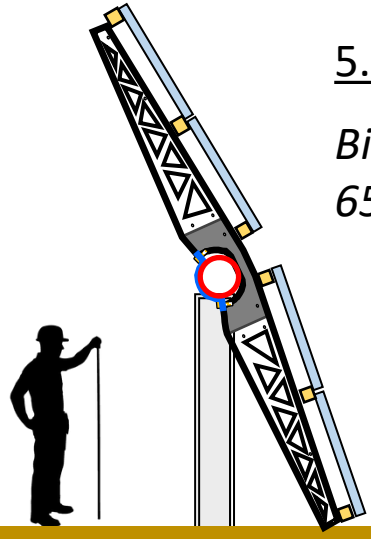


5.2m Chord

*Mono-Facial, 4L*
*65° Tilt*



5.4m Chord

*Bi-Facial, 4L, 2” risers*
*65° Tilt*

# Appendix 6

## 4.6m Chord, Multiple Rows @ 45° Tilt