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26 April 2022

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pv magazine
webinars

Are you tracking or stowing? – A financial analysis of stow strategies



Tim Sylvia

Editor
pv magazine USA



Pedro Magalhães

Director global engineering and R&D
Arctech




César Hidalgo López

Principal engineer for solar
DNV

Welcome!

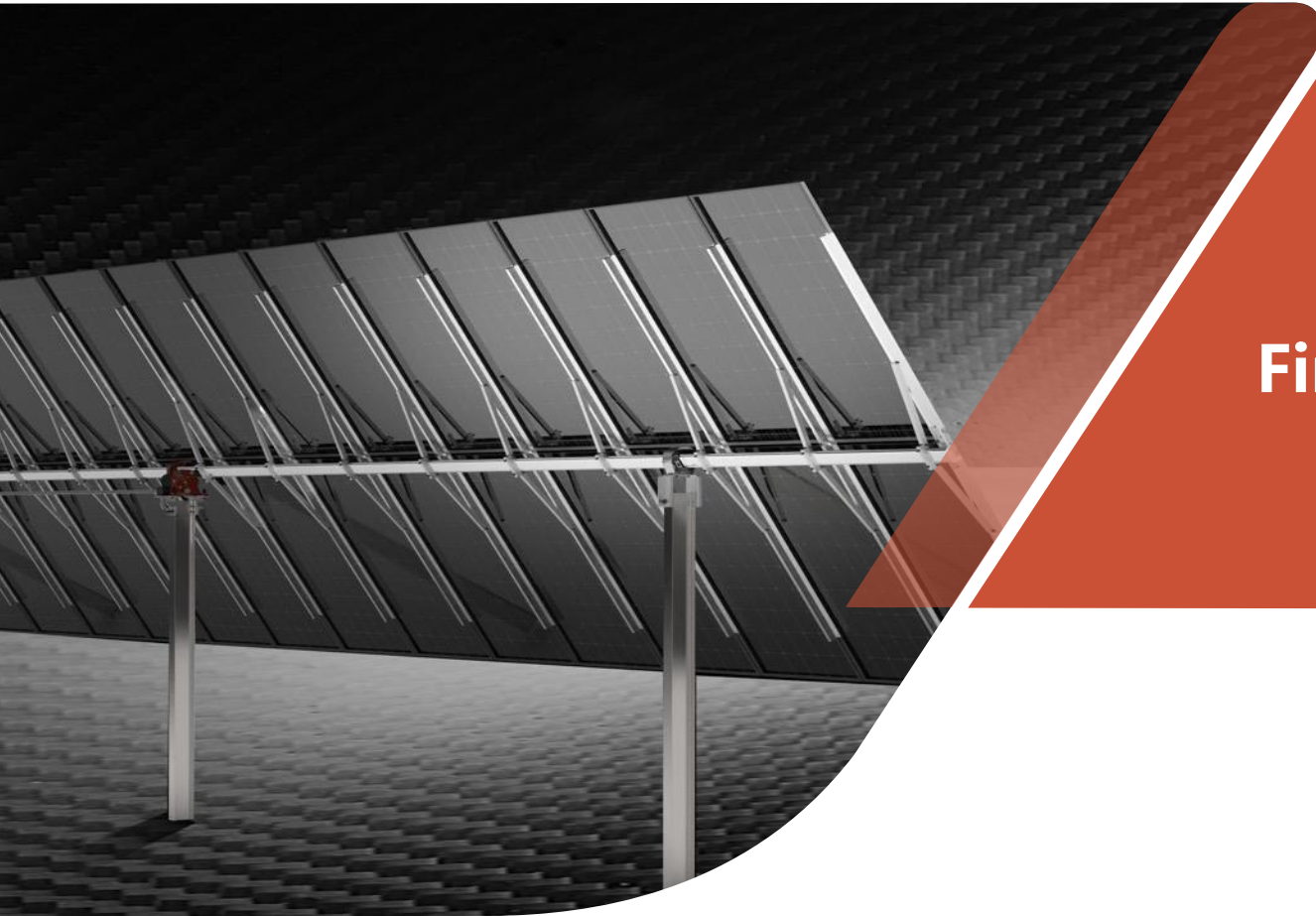
Do you have any questions? ? 

Send them in via the Q&A tab.  We aim to answer as many as we can today!

You can also let us know of any tech problems there.

We are recording this webinar today. 

We'll let you know by email where to find it and the slide deck, so you can re-watch it at your convenience.  



Tracking or Stowing?

Financial Impact of low stow thresholds

Pedro Magalhães
pedro.mag@arctehsolar.com
18th April 2022



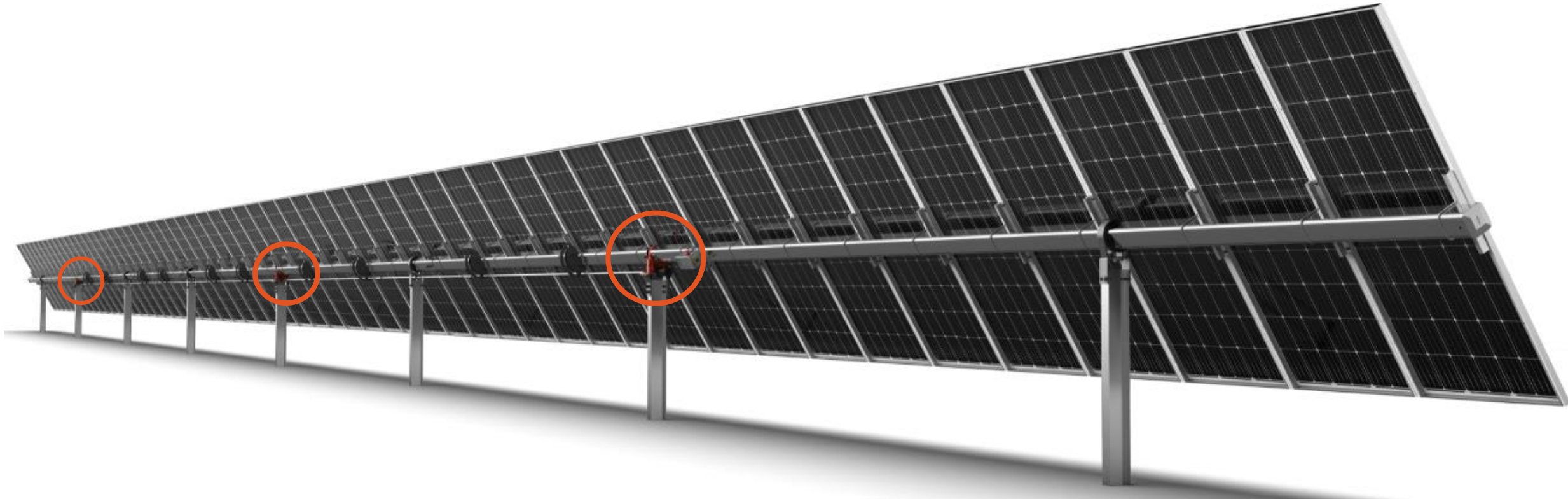
present

01

STIFF TRACKERS - the future of PV

SOLUTION = ARCTECH'S STIFF TRACKERS

Very Stiff Tracker – Wind Stow at 0 Deg

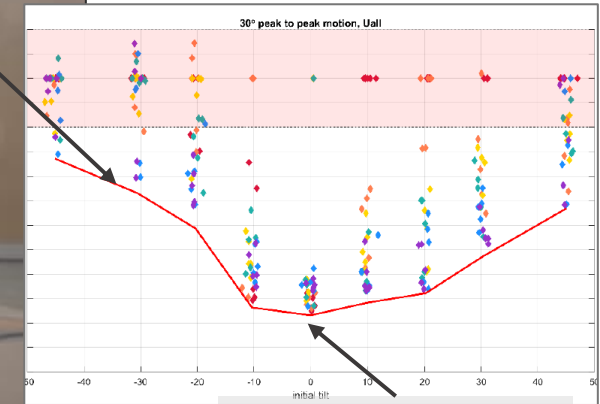


TRADITIONAL VS NOVEL (STIFF AND MODULAR)

Traditional Tracker - Wind Stow at **30 Deg**



2P: $U_{cr} = 50 \text{ m/s}$
 1P: $U_{cr} = 55 \text{ m/s}$

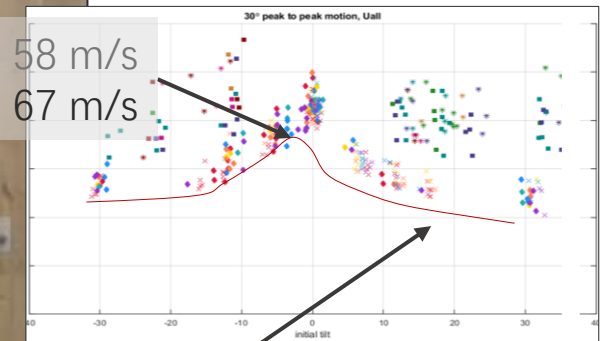


2P: $U_{cr} = 23 \text{ m/s}$
 1P: $U_{cr} = 20 \text{ m/s}$

Stiff Tracker – Wind Stow at **0 Deg**



2P: $U_{cr} = 58 \text{ m/s}$
 1P: $U_{cr} = 67 \text{ m/s}$



2P: $U_{cr} = 35 \text{ m/s}$
 1P: $U_{cr} = 40 \text{ m/s}$

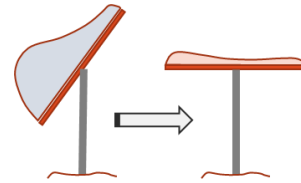
WHY VERY RIGID TRACKERS?

1. Highest **stability** at **all tilts**

2. Stow a **0deg**

- Less steel

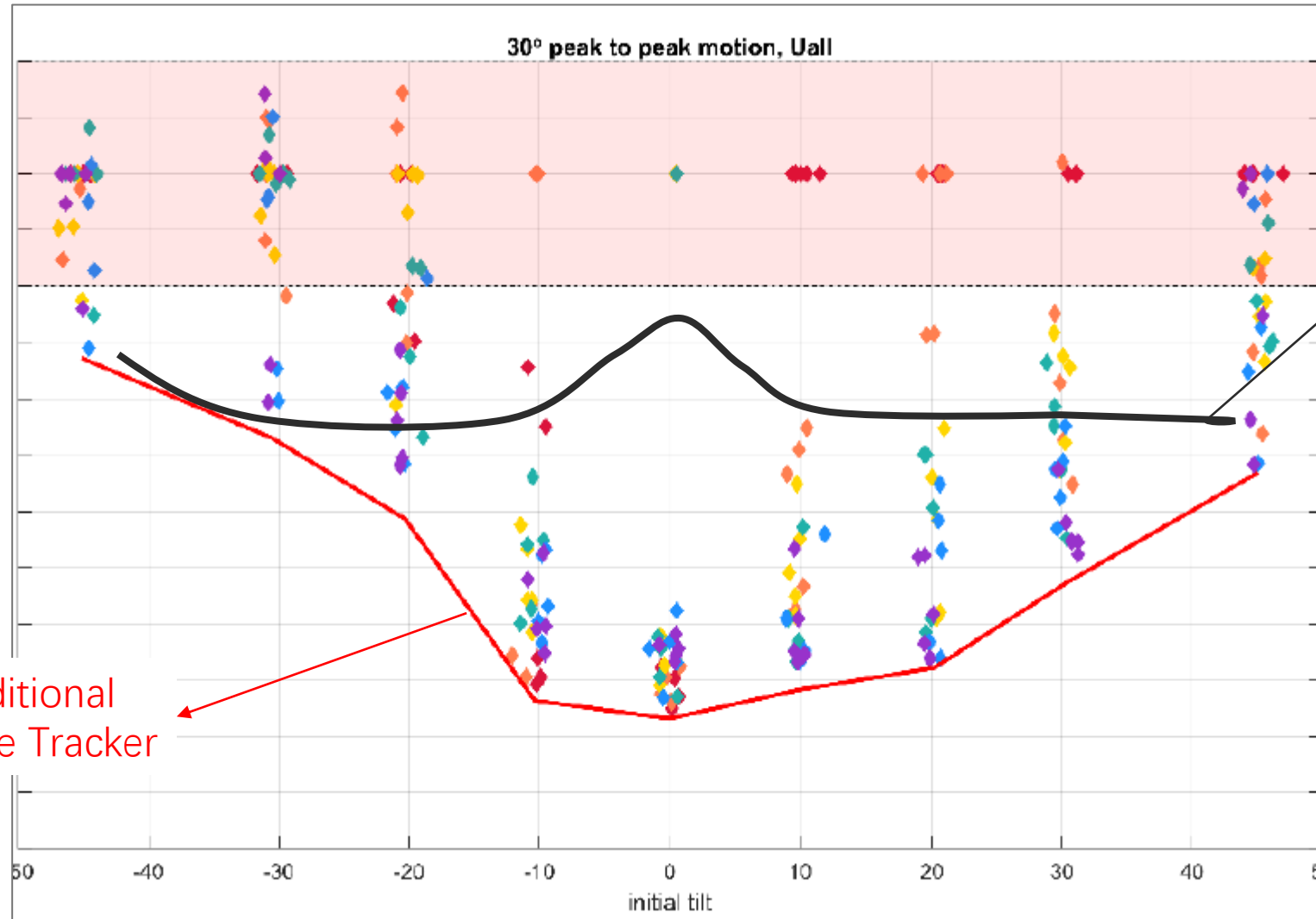
- **Lower Panel pressure**



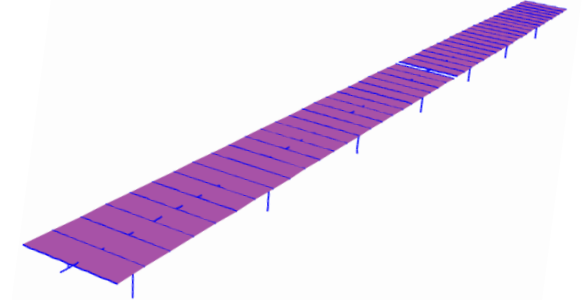
3. **Highest Stow** in the market – **22 m/s** – more energy yield



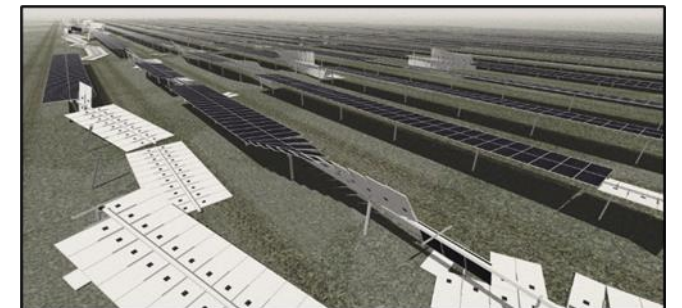
1. HIGHEST STABILITY AT ALL TILTS



Rigid Tracker

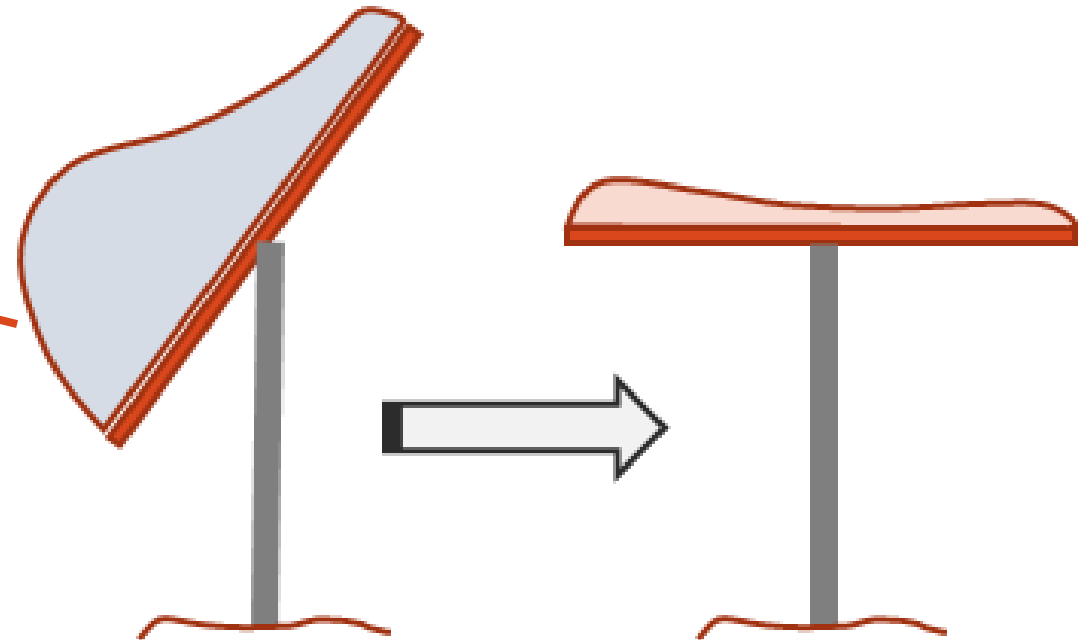


Traditional Flexible Tracker

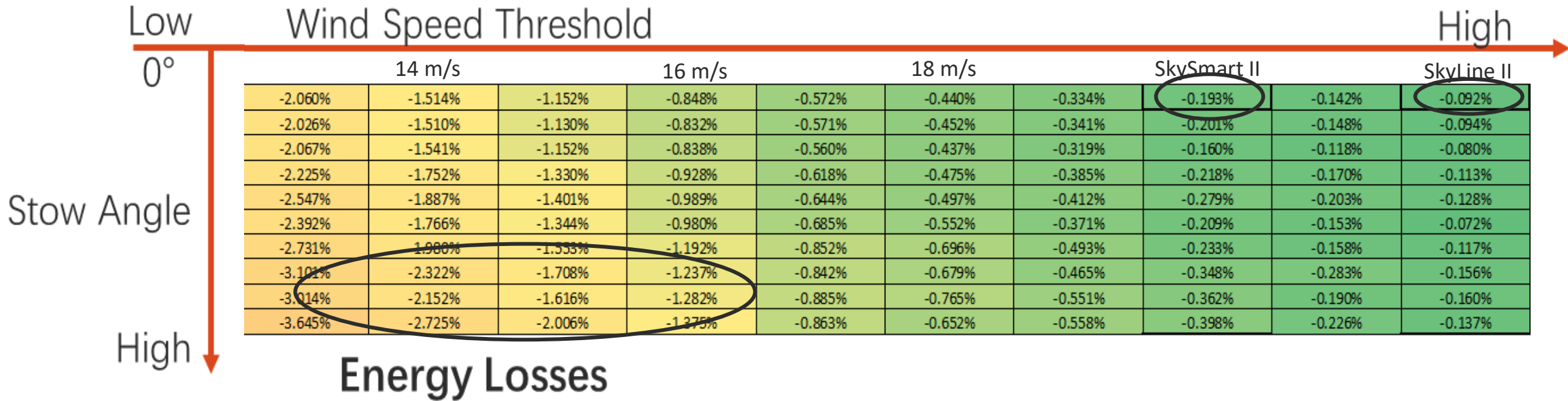


2. STOW HORIZONTALLY (0° TILT)

- Less steel
- Lower Panel pressure



3. HIGHEST STOW IN THE MARKET – 22 M/S





02

CASE STUDIES – Energy Yield & Financials

CASE STUDY – TEXAS, USA

Nearest town	Amarillo, Texas, USA
Coordinate	35.48°N, 101.34°W
Capacity	100MWdc

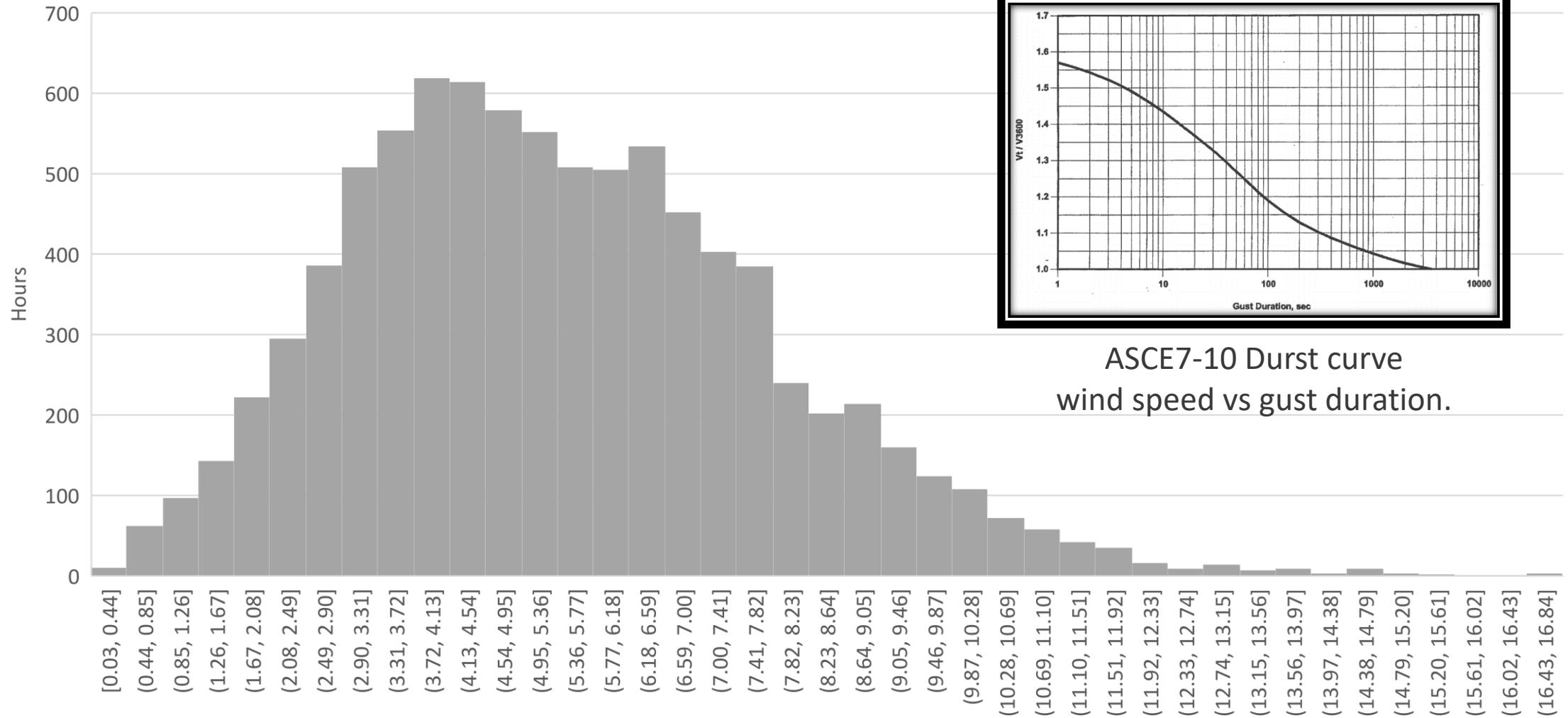


Model	Stow Angle (°)	Wind speed threshold (m/s, 3s gust at 10m height)	Representative
SkyLine II	0	22	Arctech 1P stiff tracker
SkySmart II	0	20	Arctech 2P stiff tracker
A	30	16	Well maintained traditional tracker
B	30	14	Flexible traditional tracker
C	45	12	Worst scenario

*Solar irradiation data: NREL NSRDB 2020

*Wind data: MERRA-2 2020

THE WIND SPEED DISTRIBUTION



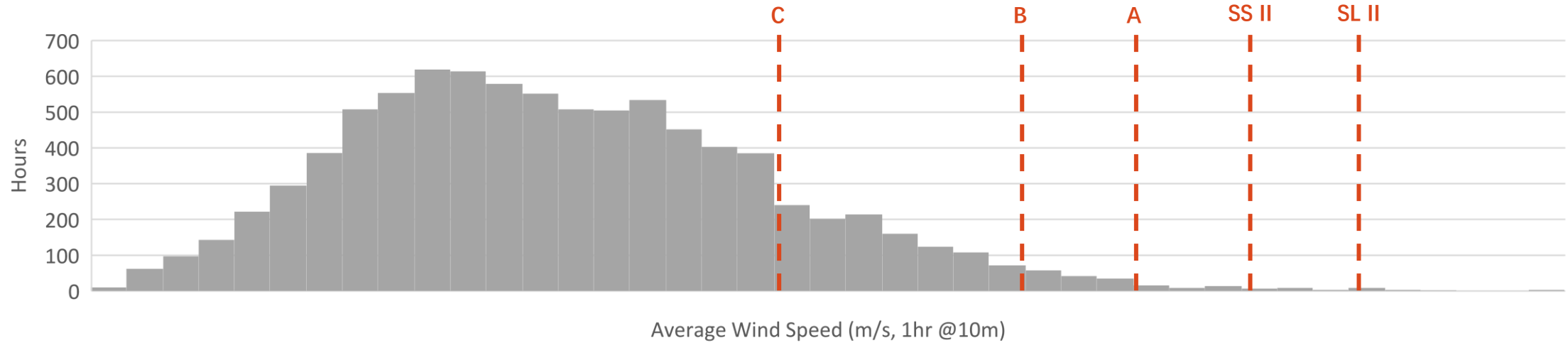
ASCE7-10 Durst curve
wind speed vs gust duration.

*Solar irradiation data: NREL NSRDB 2020

Average Wind Speed (m/s, 1hr @10m)

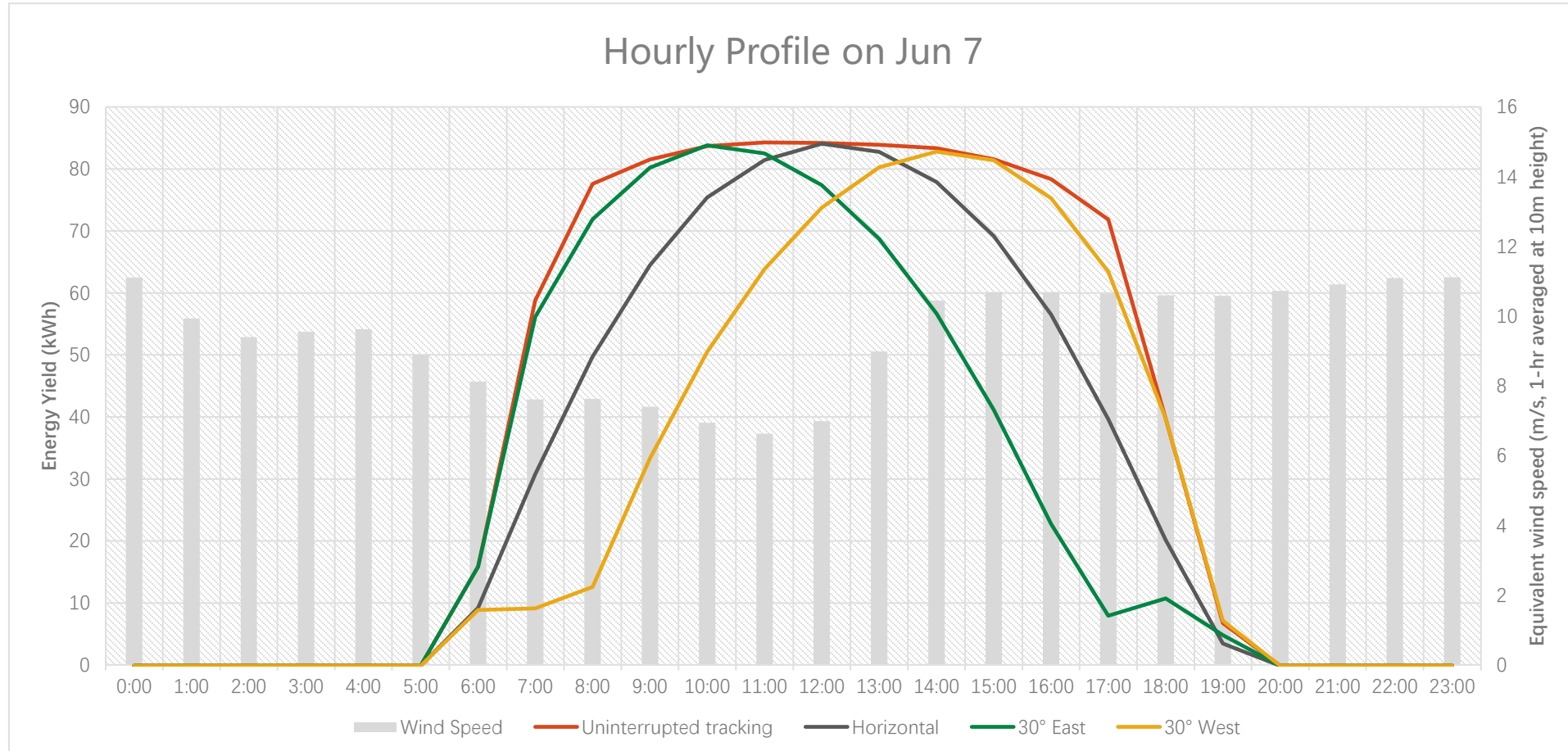
*Wind data: MERRA-2 2020

AMOUNT OF HOURS IN STOW



Model	Wind speed threshold (m/s, 3sec at 10m height)	Equivalent wind speed (m/s, 1-hr at 10m height)	Stow hours in total	Stow time per year (%)
SkyLine II	22	14.47	15	0.17%
SkySmart II	20	13.16	38	0.43%
A	16	10.53	243	2.77%
B	14	9.21	608	6.94%
C	12	7.89	1288	14.70%

THE HOURLY PROFILE

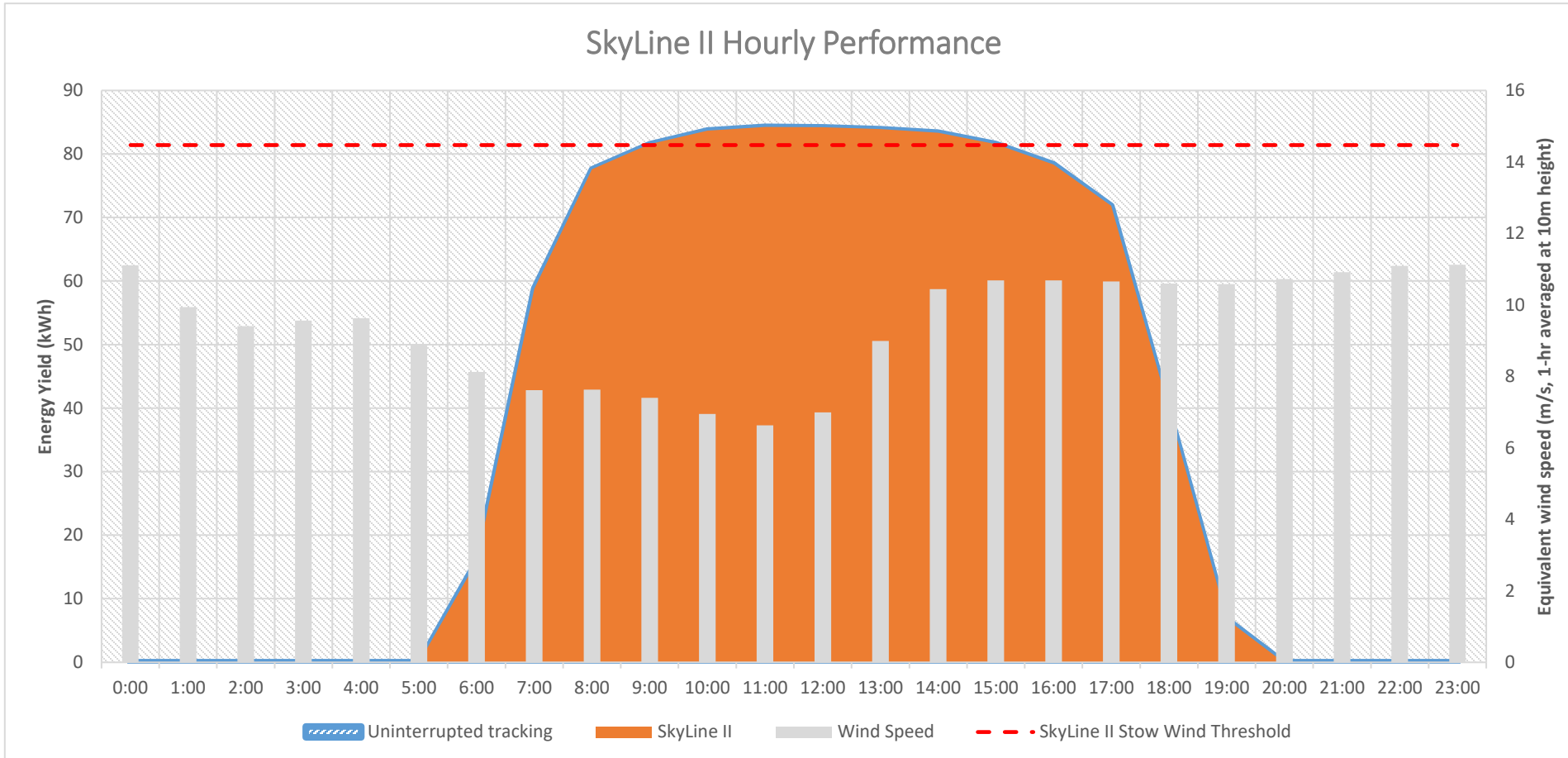


June 7th selected as a sample due to clear sky and high wind conditions.

Wind velocity stronger in the afternoon.

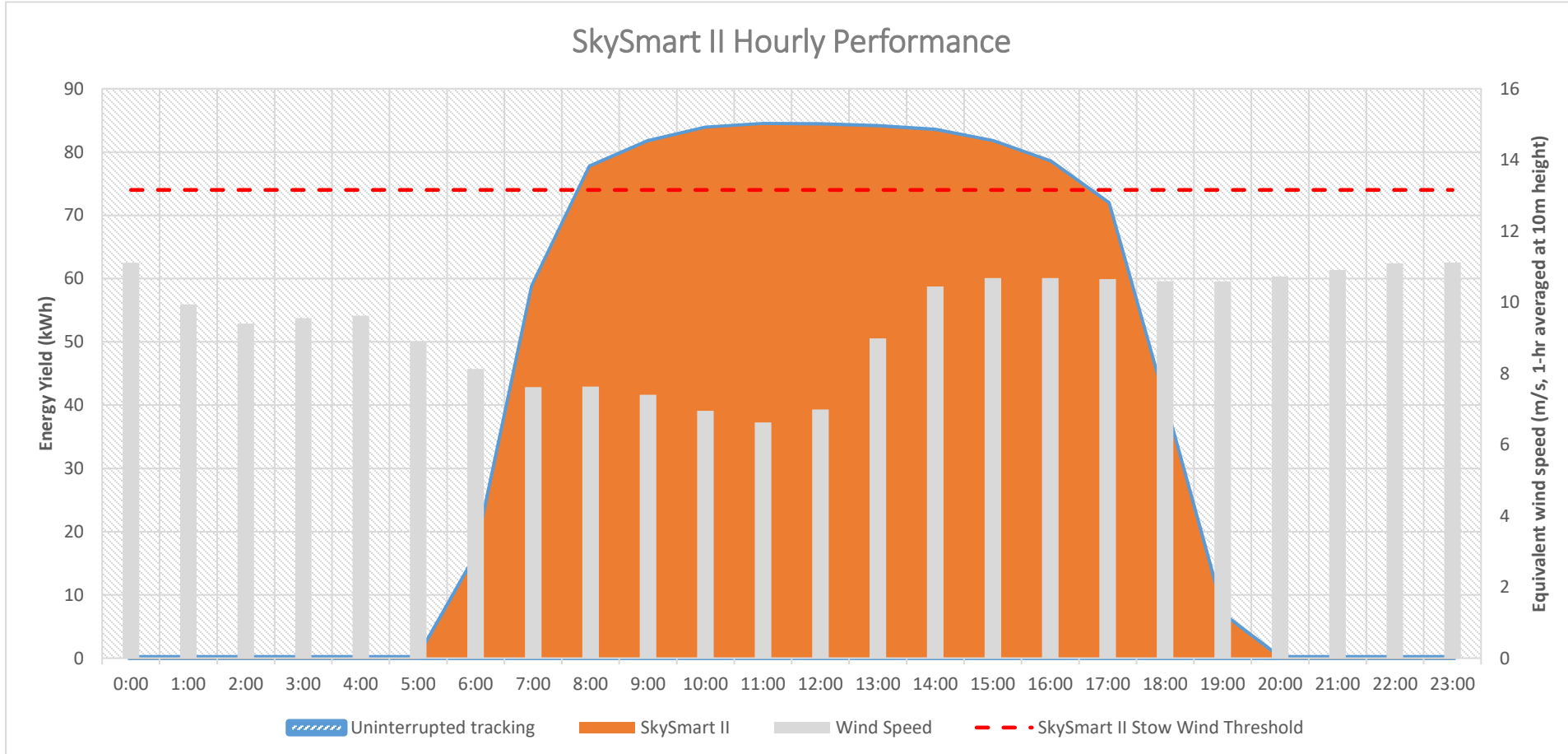
Northwestern wind direction the whole day except between 13:00 and 15:00.

SKYLINE II (22M/S, 0°)



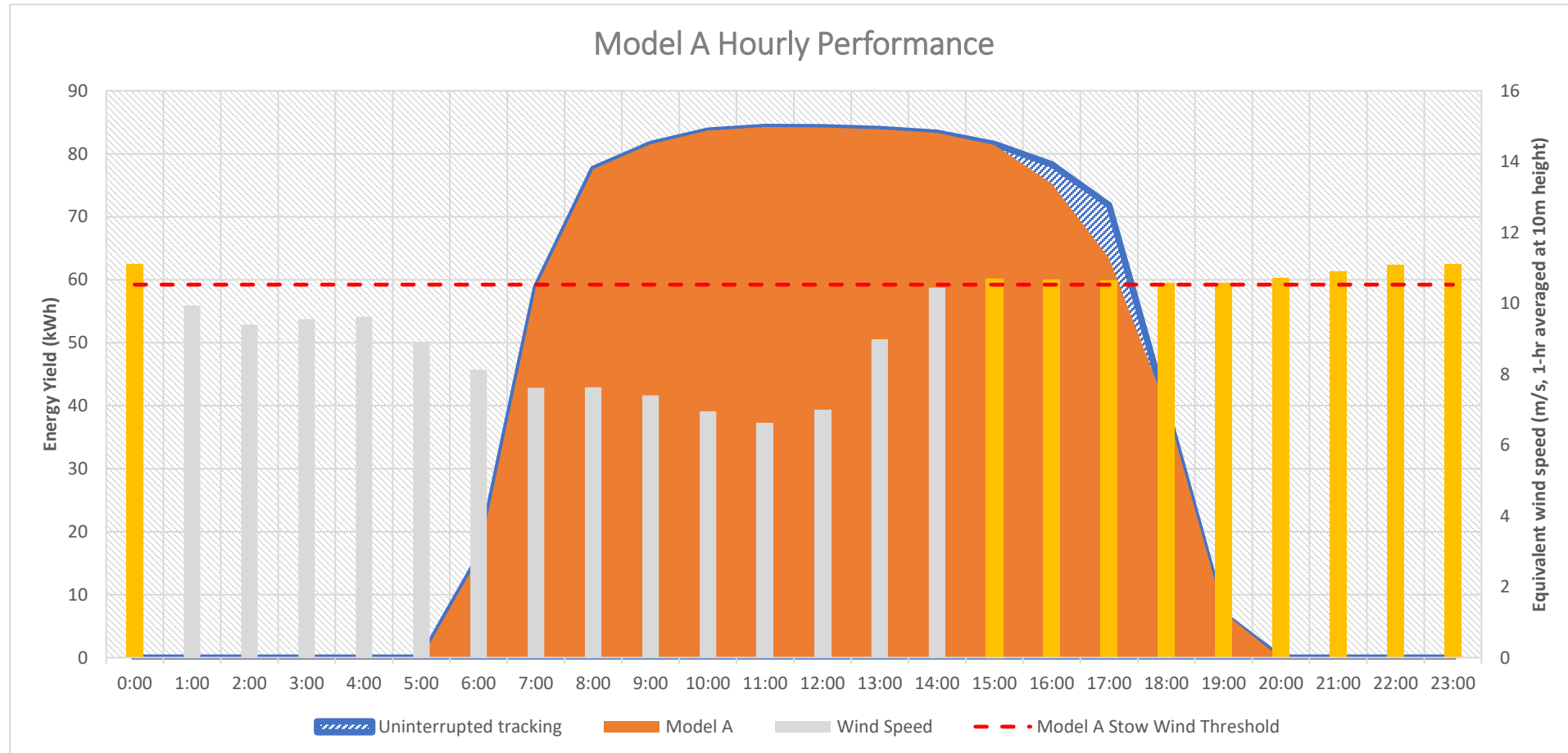
Wind speed was not high enough to reach SkyLine II and SkySmart II's threshold
So both trackers did not need to stow.
Energy output curve was the same as the uninterrupted tracking curve

SKYSMART II (20M/S, 0°)



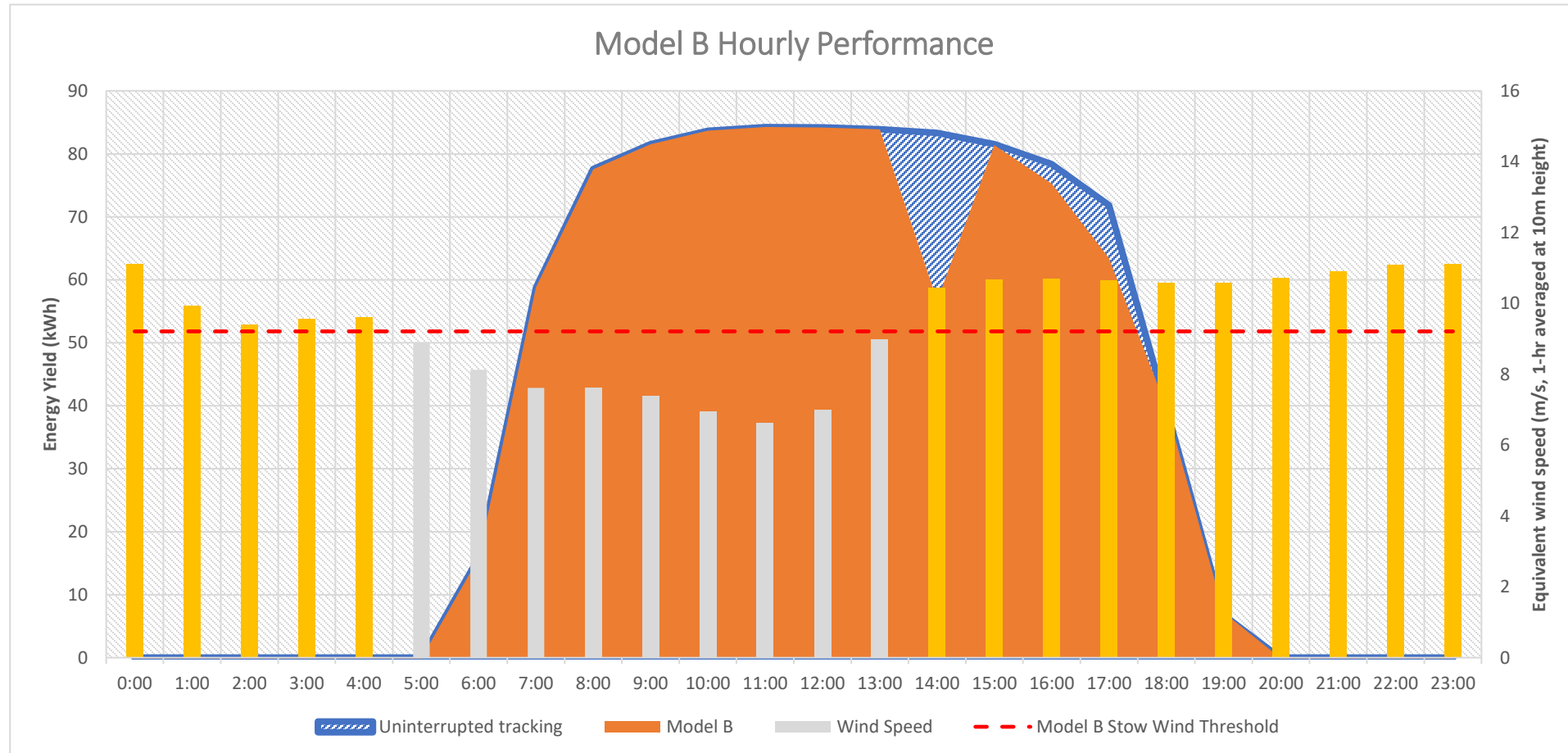
Wind speed was not high enough to reach SkyLine II and SkySmart II's threshold
So both trackers did not need to stow.
Energy output curve was the same as the uninterrupted tracking curve

TRACKER "A" (THRESHOLD=16 M/S, STOW TILT=30°)



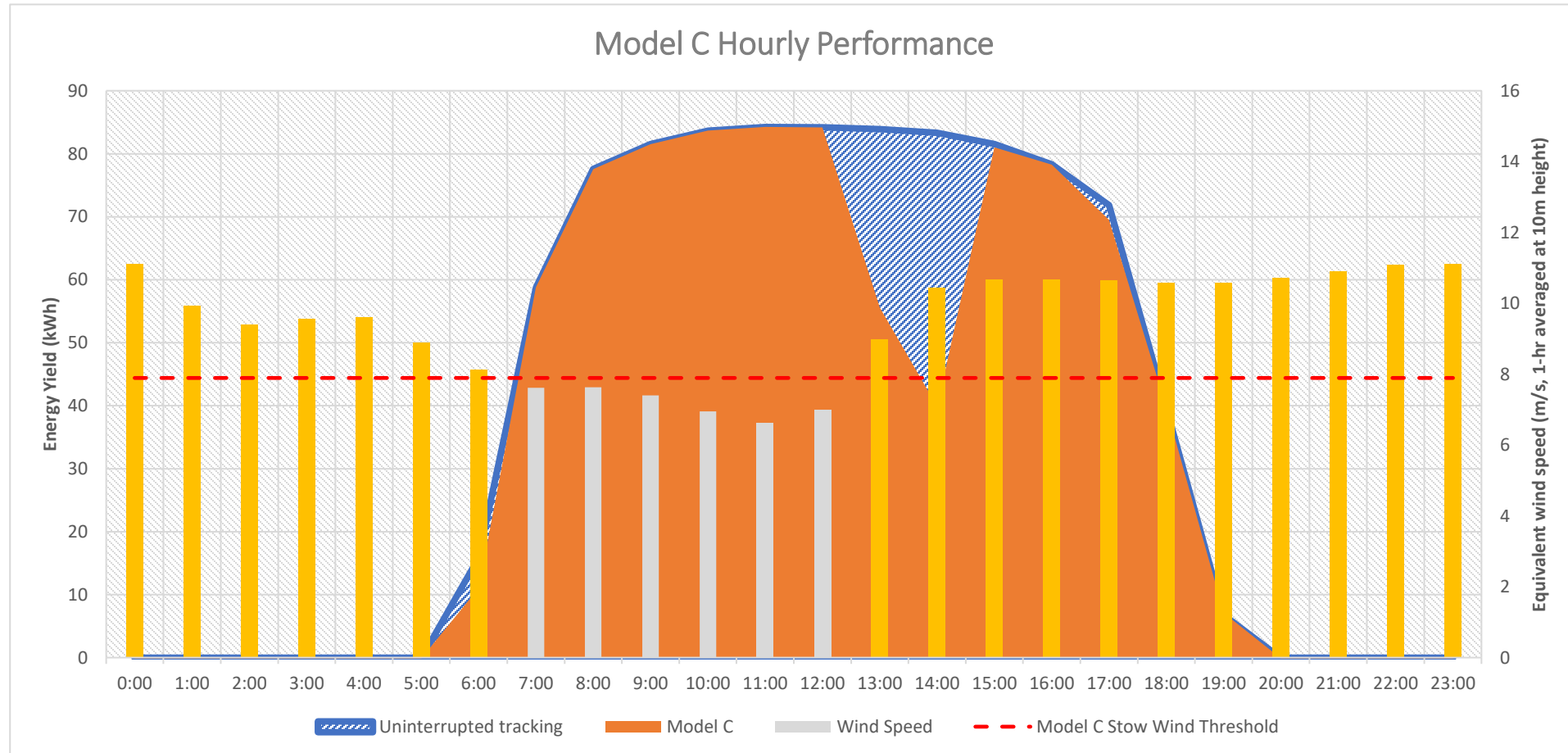
Tracker A saw its threshold exceeded after 15:00 (16m/s 3-s gust = 10.53m/s hourly, at 10m)
Tracker A stowed for several hours at 30-degree west, missing some kWh of energy (blue shade).

TRACKER B (THRESHOLD=14 M/S, STOW TILT=30°)



Tracker B has a lower threshold, hence a worse outcome. Not just the tracker had to stow from 14:00 rather 15:00, the stow position in that hourly were likely to be east facing, causing more energy loss.

TRACKER C (THRESHOLD=12 M/S, STOW TILT=45°)



As for Tracker C, stow time included early morning and 13:00-14:00.

45-degree stow caused more energy loss at the hour 14:00-15:00.

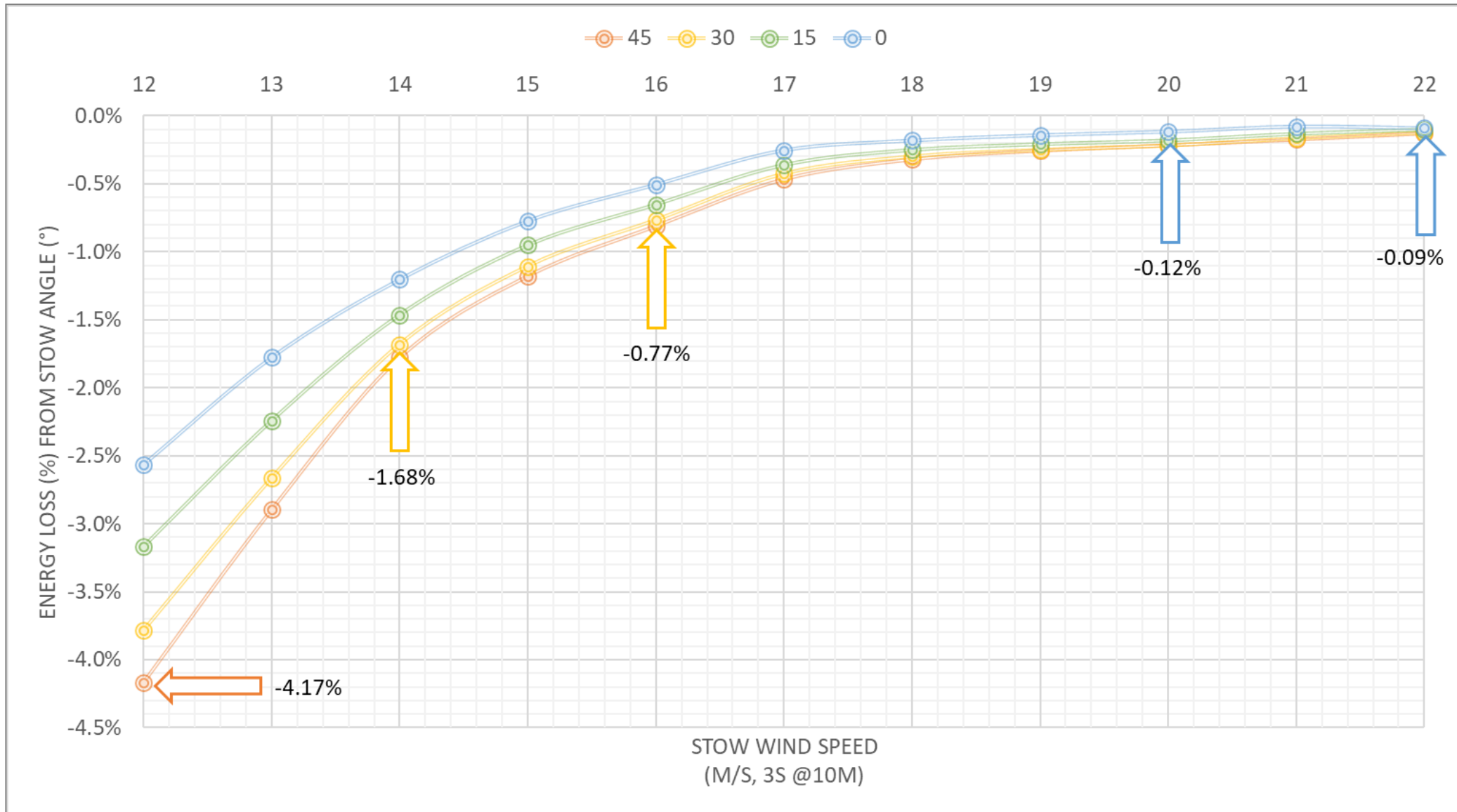
But steep west-facing tilt improved energy yield a bit in the afternoon, when compared to tracker B.

COMPARISON OF ENERGY OUTCOME

Model	Wind speed threshold (m/s, 3s gust at 10m height)	Stow hours in total	Est. energy loss at stow mode (%)	Est. energy loss per year (MWh)	Est. financial loss per year at \$28/MWh
SkyLine II	22	15	-0.09%	-204	-\$5,719
SkySmart II	20	38	-0.12%	-262	-\$7,335
A	16	243	-0.77%	-1711	-\$47,920
B	14	608	-1.68%	-3752	-\$105,059
C	12	1288	-4.17%	-9299	-\$260,371

1. The lower the wind speed threshold, the less energy produced;
2. Wind induced energy loss is much higher in traditional trackers than in rigid trackers

SUMMARY CHART – AMARILLO, TEXAS, USA



SIMPLE FINANCIAL COMPARISON – AMARILLO, TEXAS, USA



14 m/s @ 30 deg

~10% tracker cost saved upfront

	Project (SkyLine II)	Project (Tracker B)	Delta	Project (Tracker B)+	Delta
Size (MWp)	100	100	-	100	-
Cost (\$/Wp, ITC incl.)	\$0.7030	\$0.7030	-	\$0.690	\$0.013
Capex investment (\$M)	1.6% more	\$70.30	-	\$69.030	\$1.270
1st yr Energy Yield (MWh)	223,027	219,479	3548	219479	3548
PPA (\$/MWh)	\$28.00	\$28.00	-	\$28	-
O&M Rate (/Wp/year)	\$0.0070	\$0.0070	-	\$0.007	-
35-year Revenue (\$M)	\$175.38	\$172.20	\$3.181	\$172.202	\$3.181
Unleveraged/Project IRR	6.609%	6.440%	0.168%	6.609%	0.000%
NPV (6% dscnt rate) (\$M)	\$4.595	\$3.314	\$1.281	\$4.512	\$0.083

SIMPLE FINANCIAL COMPARISON – AMARILLO, TEXAS, USA

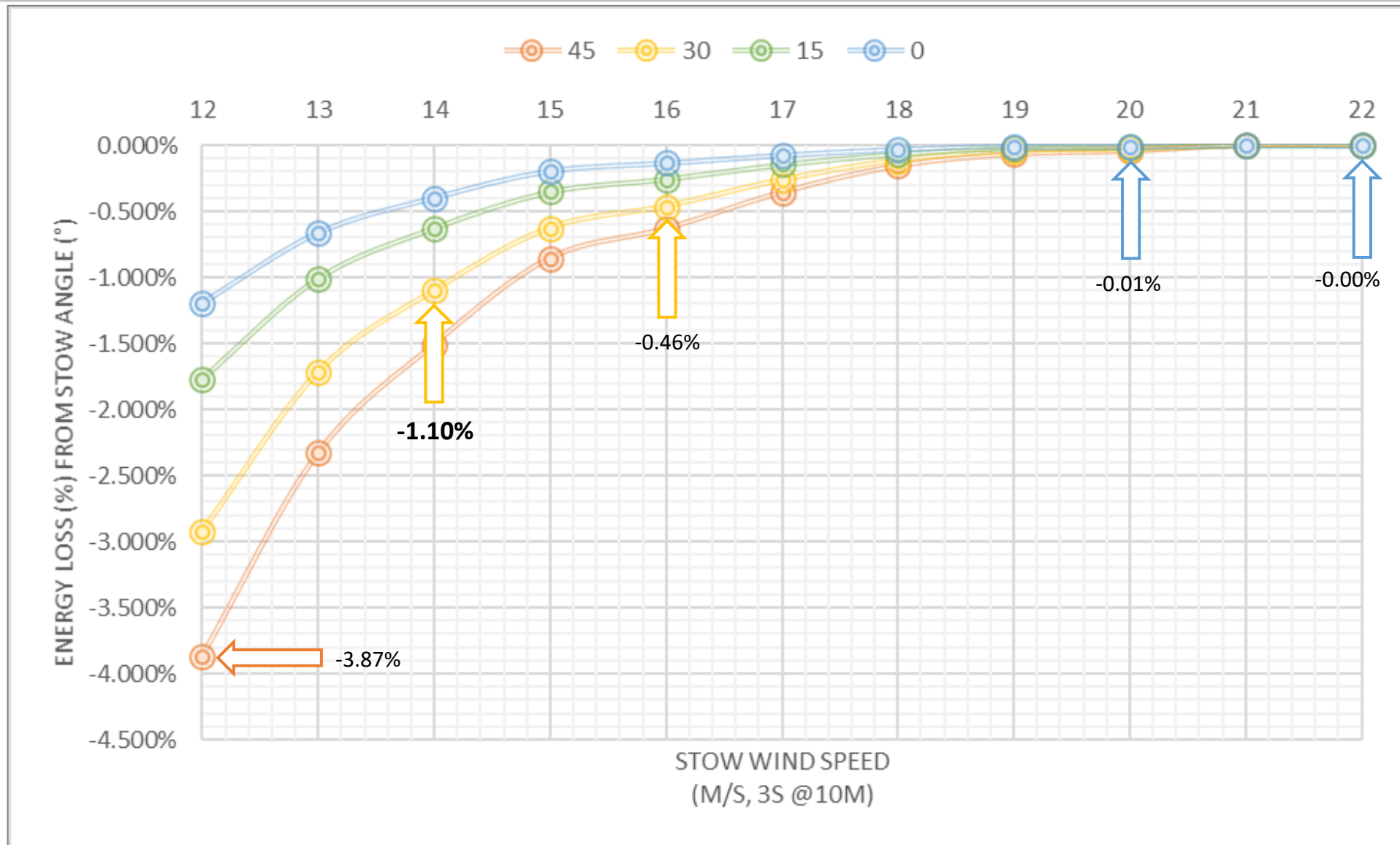


12 m/s @ 45 deg

~25% tracker cost saved upfront

	Project (SkyLine II)	Project (Tracker C)	Delta	Project (Tracker C)+	Delta
Size (MWp)	100	100	-	100	-
Cost (\$/Wp, ITC incl.)	\$0.7030	\$0.7030	-	\$0.670	\$0.033
Capex investment (\$M)	4.2% more	\$70.30	-	\$67.046	\$3.254
1st yr Energy Yield (MWh)	223,027	213,933	9095	213933	9095
PPA (\$/MWh)	\$28.00	\$28.00	-	\$28	-
O&M Rate (/Wp/year)	\$0.0070	\$0.0070	-	\$0.007	-
35-year Revenue (\$M)	\$175.38	\$167.23	\$8.155	\$167.228	\$8.155
Unleveraged/Project IRR	6.609%	6.175%	0.434%	6.609%	0.000%
NPV (6% dscnt rate) (\$M)	\$4.595	\$1.311	\$3.284	\$4.381	\$0.214

SUMMARY CHART – MAKKAH, SAUDI ARABIA



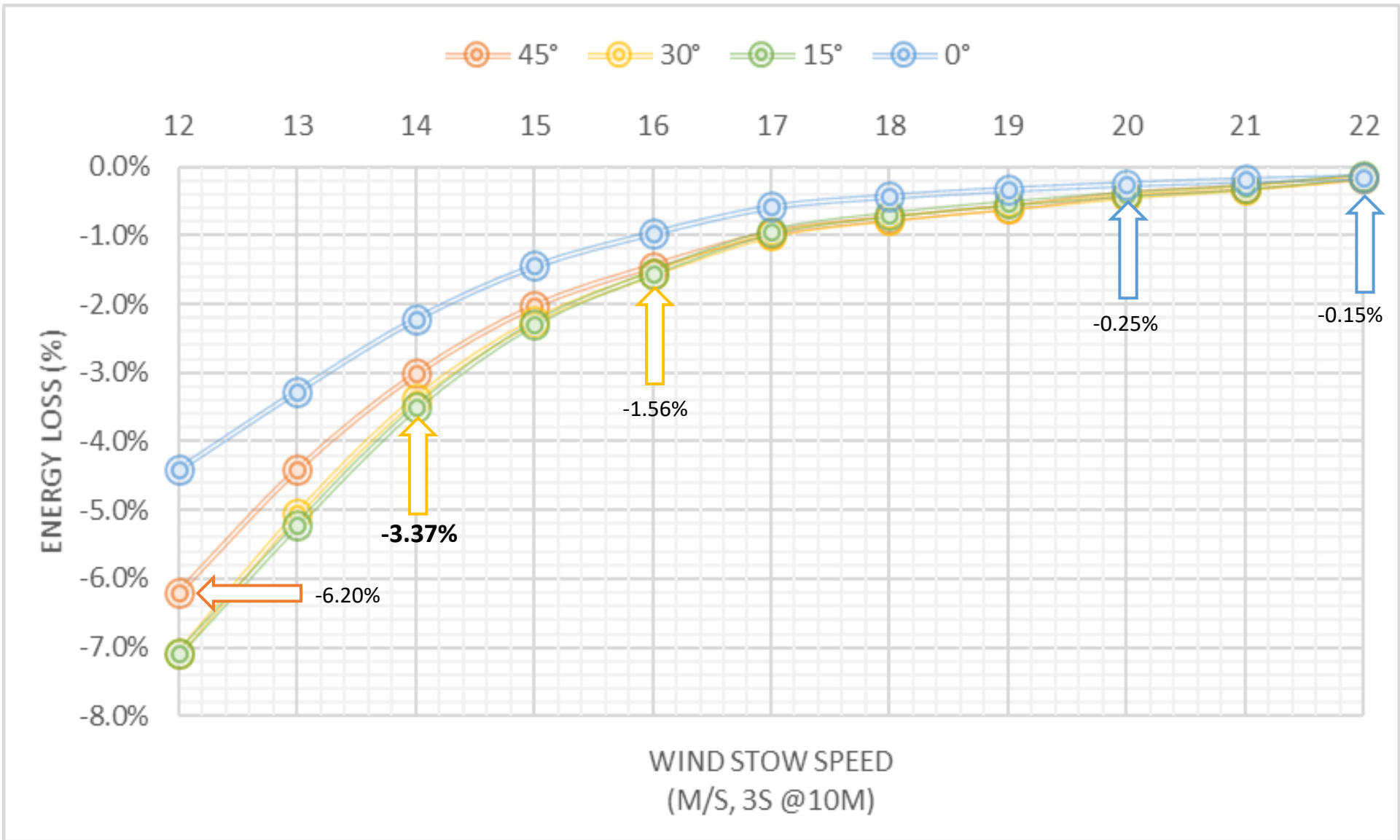
SIMPLE FINANCIAL COMPARISON - MAKKAH, SAUDI ARABIA

14 m/s @ 30 deg

Same ~10% tracker cost saved upfront

	Project (SkyLine II)	Project (Tracker B)	Delta	Project (Tracker B)+	Delta
Size (MWp)	100	100	-	100	-
Cost (\$/Wp)	\$0.5500	\$0.5500	-	\$0.5430	\$0.0070
Capex investment (\$M)	1.1% more	\$55.00	-	\$54.305	\$0.695
1st yr Energy Yield (MWh)	230,080	227,558	2522	227558	2522
PPA (\$/MWh, w/ Whtg)	\$19.00	\$19.00	-	\$19.00	-
O&M Rate (/Wp/year)	\$0.0055	\$0.0055	-	\$0.006	-
30-year Revenue (\$M)	\$105.14	\$103.80	\$1.333	\$103.804	\$1.333
Unleveraged/Project IRR	5.010%	4.895%	0.115%	5.010%	0.000%
NPV (4.5% dscnt rate) (\$M)	\$3.088	\$2.383	\$0.705	\$3.049	\$0.039

SUMMARY CHART – SAN PEDRO DE ATACAMA, CHILE



SIMPLE FINANCIAL COMPARISON - SAN PEDRO, CHILE

Whopping ~25% tracker cost saved upfront

14 m/s @ 30 deg

	Project (SkyLine II)	Project (Tracker B)	Delta	Project (Tracker B)+	Delta
Size (MWp)	100	100	-	100	-
Cost (\$/Wp, ITC incl.)	\$0.6800	\$0.6800	-	\$0.656	\$0.024
Capex investment (\$M)	3.3% more	\$68.00	-	\$65.620	\$2.380
1st yr Energy Yield (MWh)	300,883	291,168	9715	298023	2860
PPA (\$/MWh)	\$30.00	\$30.00	-	\$30	-
O&M Rate (/Wp/year)	\$0.0068	\$0.0068	-	\$0.007	-
15-year Revenue (\$M)	\$120.46	\$116.24	\$4.219	\$116.240	\$4.219
Unleveraged/Project IRR	8.312%	7.719%	0.593%	8.312%	0.000%
NPV (7.5% dscnt rate) (\$M)	\$3.176	\$0.851	\$2.325	\$3.065	\$0.111

- **Traditional** trackers are getting **obsolete** with the penetration of large PV modules
- With **Large panels**, trackers must **stow at 0 deg** to avoid module damage
- For that, **tracker must be stiff**
 - Span lengths within controlled intervals enabled by multiple mechanisms
- **Rigid Trackers** fix challenges and **create value**

SUMMARY AND CONCLUSIONS

- **Highest stow** in the industry at **22 m/s**, enables **more energy** generation

	Amarillo, TX		Makkah, Saudi Arabia		San Pedro Atacama, Chile	
	14m/s@30deg	12m/s@45deg	14m/s@30deg	12m/s@45deg	14m/s@30deg	12m/s@45deg
Loss of energy vs. 22m/s@0deg	1.62%	4.25%	1.11%	4.02%	3.34%	6.45%
Value created upfront (USD/W)	\$ 0.013	\$ 0.033	\$ 0.007	\$ 0.025	\$ 0.024	\$ 0.045
Tracker Cost Savings upfront (%)	10%	25%	10%	30%	25%	50%

- <https://www.arctechsolar.us/alwhitepaper.html>



Thank you!

pedro.mag@arctehsolar.com



WHEN TRUST MATTERS

Tracker bankability

How to mitigate investment risk in tracker technology

César Hidalgo, DNV, Barcelona, Spain

26 April 2022

Bankability of PV trackers

- DNV
- What is bankability?
- What are the aspects to review?
- Zooming into the main aspects:
 - Are existing building codes enough for structural calculation of trackers?
 - Is it necessary to undertake dynamic analysis for trackers?
 - Are certifications enough to guarantee 25-year lifetime?
 - Is the tracker manufacturer responsible for an inappropriate installation?
 - Are the new backtracking algorithms increasing significantly the energy yield?
 - Are the stow positions impacting the energy yield?
- CONCLUSIONS

An independent assurance and risk management company

158
years

~12,000
employees

100,000
customers

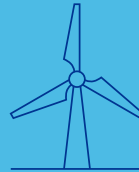
100+
countries

5% R&D
of annual revenue

**Ship and offshore
classification and advisory**



**Energy advisory, certification,
verification, inspection and
monitoring**



**Management system certification,
supply chain and
product assurance**



Software, platforms and digital solutions



Broad and deep expertise in solar projects



FEASIBILITY

- > Feasibility studies
- > Utility grid integration
- > Environmental permitting
- > Component technology reviews
- > Component qualification testing
- > Type and component certification of PV inverters

ENGINEERING & DEVELOPMENT

- > Due diligence / Independent engineering
- > Owner's engineering
- > Energy assessment
- > Pre-construction engineering
- > Interconnection support
- > Project certification

CONSTRUCTION & COMMISSIONING

- > Due diligence/ Independent engineering
- > Owner's engineering
- > Construction oversight
- > System testing and inspection
- > Project certification and grid code compliance
- > Declaration of conformity
- > Module batch testing
- > Project certification

OPERATION

- > Performance validation
- > Resource and energy forecasting
- > Existing asset consulting, inspections and decommissioning
- > Refinancing and mergers and acquisitions advisory services
- > Forensic investigations
- > Monitoring, control and asset management
- > Project certification



Bankability

Bankable= stable and secured Cash Flow

“Bankability means that the bank is convinced to the greatest possible extent that the cash flows are stable and the loan will be repaid.”

Credit Risk Manager, Structured Finance, Energy, Major bank

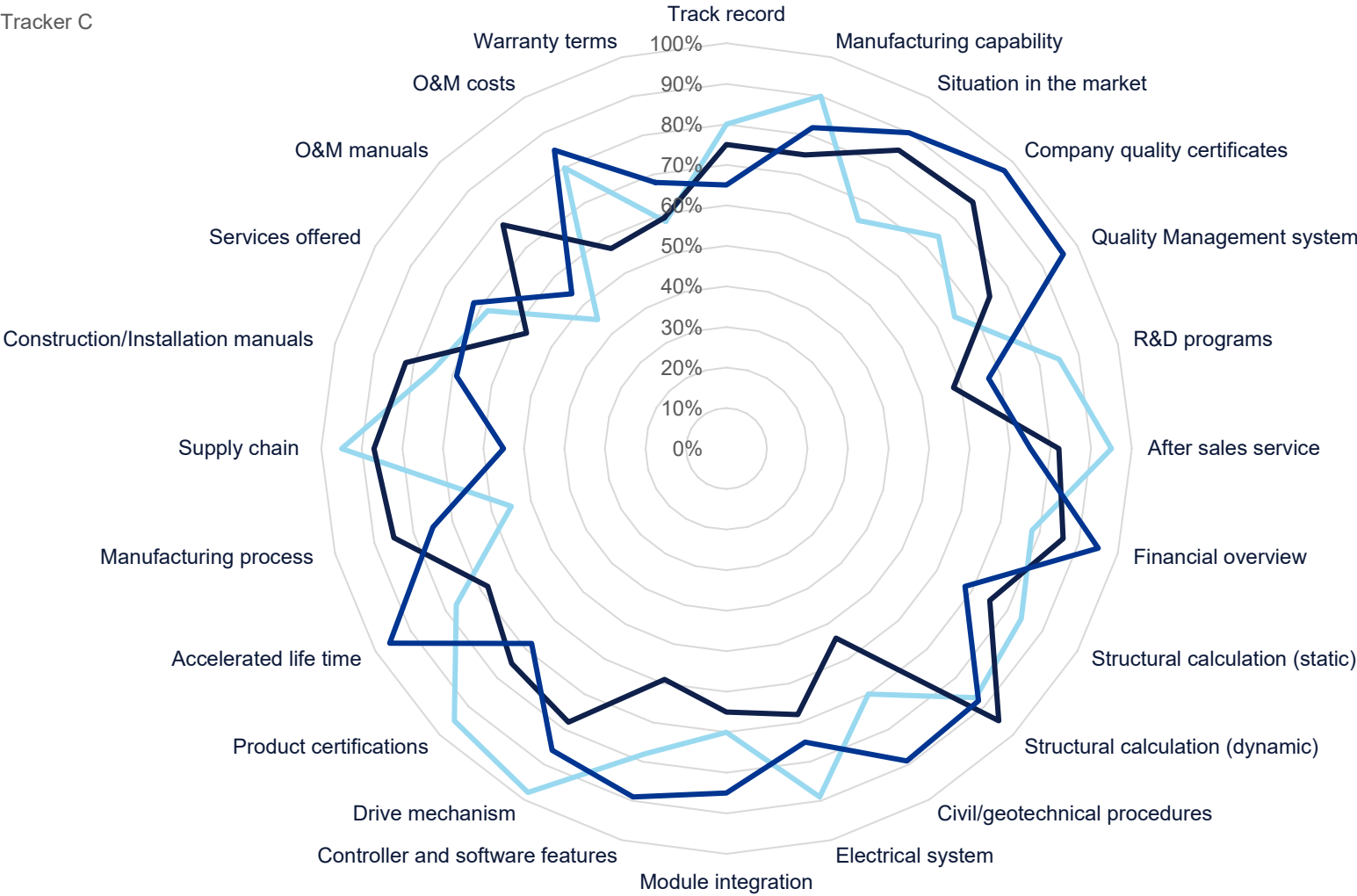
Aspects to review in a PV tracker bankability process



Zooming into aspects

Tracker A Tracker B
 Tracker C

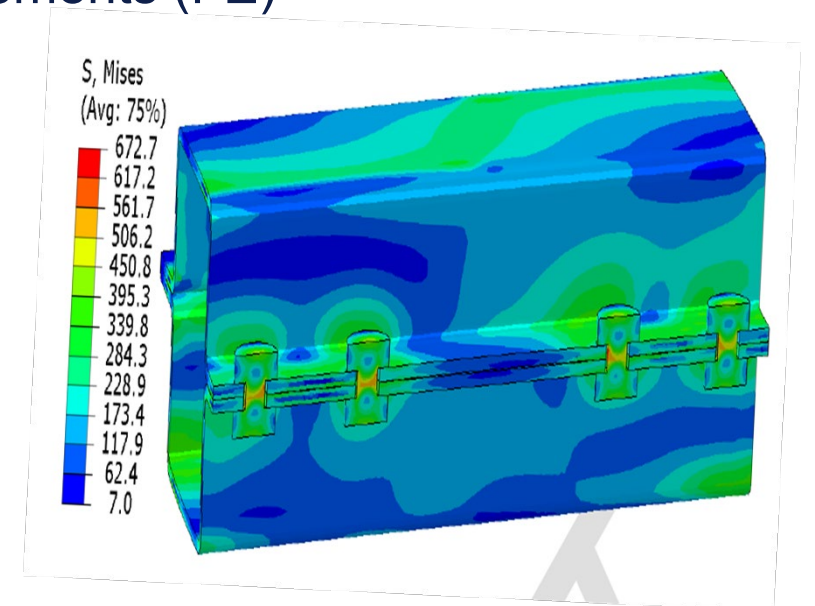
COMPARISON OF TRACKERS
 24 items



Existing building codes used for PV trackers

1) Existing building codes like the Eurocode in Europe or ASCE in USA were never intended for solar. Therefore, compliance with those codes is not a total guarantee of lifetime. Natural frequency: buildings at 1Hz
PV trackers between 1.5 Hz and 3 Hz in most of cases. Finite Elements (FE)

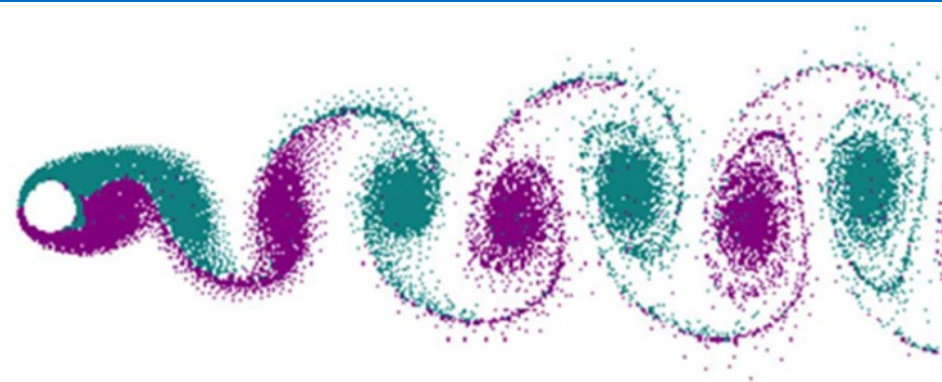
2) Wind tunnels are required for an accurate structural assessment (static and dynamic wind tunnels)



Aeroelastic instability in PV trackers

Buffeting, vortex-induced vibrations, aeroelastic deflection, torsional fluttering/galloping, torsional divergence

Catastrophic failures occurred in Spain due to winter storms in 2020 and 2021: many PV plants involved, and several manufacturers affected. Damages have occurred at much lower wind speeds than maximum design wind speeds, so it does demonstrate that the amplification function of these instabilities



: Vortex shedding around a cylinder (courtesy Cesareo de La Rosa Siqueira).

Are certifications enough?

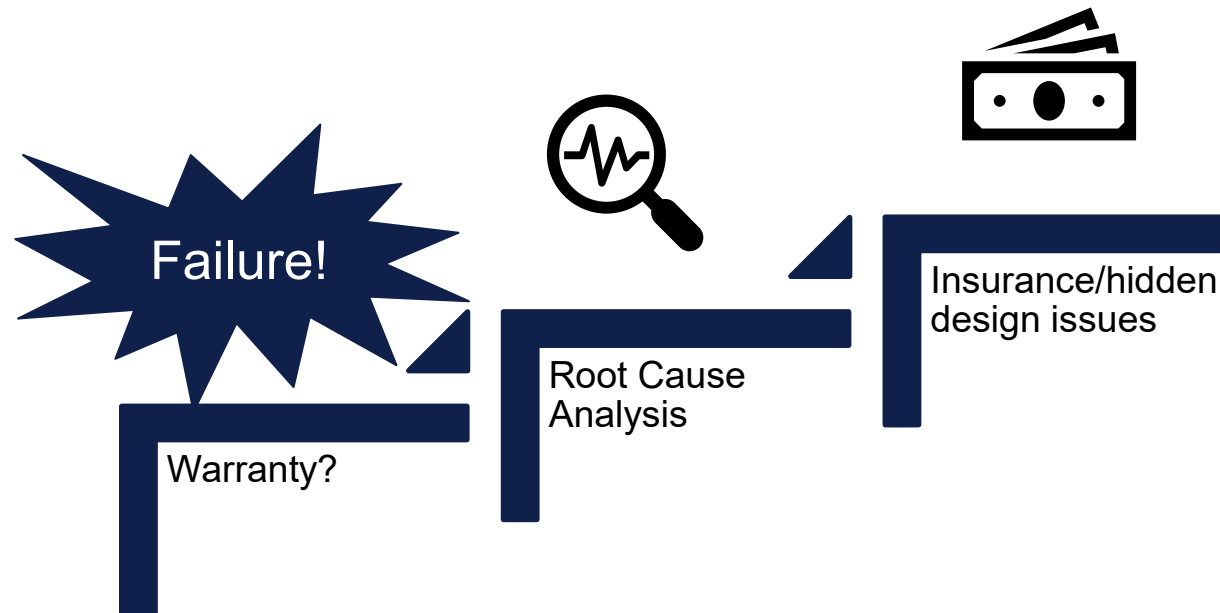
- UL 3703 ensures that a solar tracker has met the safety requirement of the National Electrical Code, NFPA 70. It also refers to the mechanical hard. However, the mechanical or structural integrity of the tracker under wind and seismic conditions, and uplift conditions of the tracker is not covered by the standard.
- IEC 62817 has two objectives:
 - It ensures that the tracker parameters reported in the specification sheet have been measured by consistent and accepted industry procedures.
 - Several passed/failed criteria are engineered with the purpose of spotting tracker designs that are likely to have early failures from those designs that are suitable for use. However, the mechanical testing is not intended to certify structural design.

Desert?

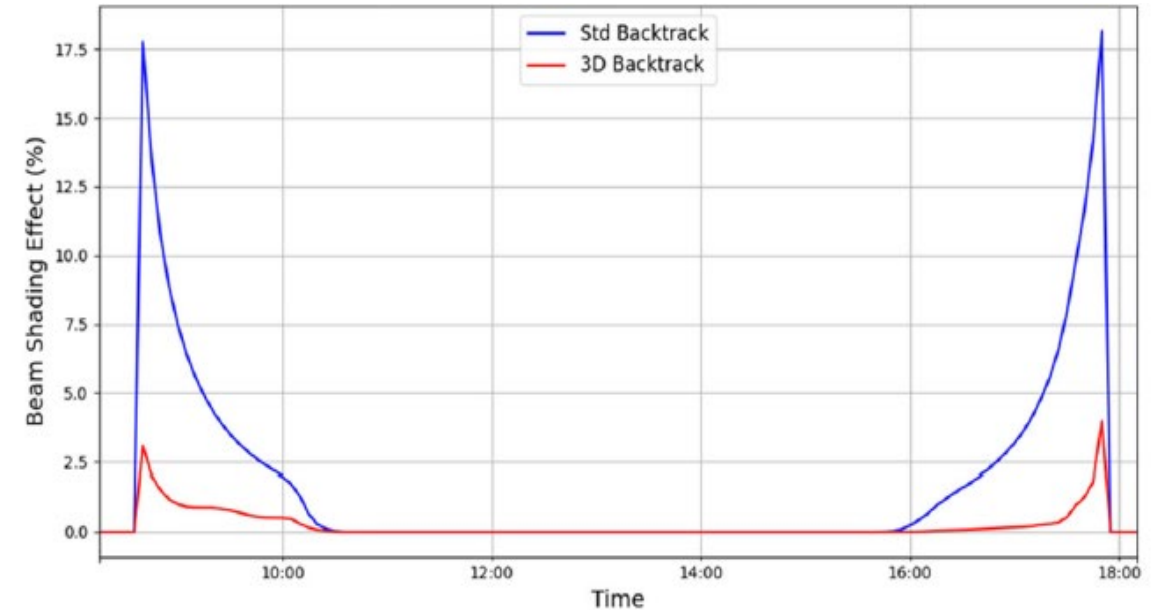
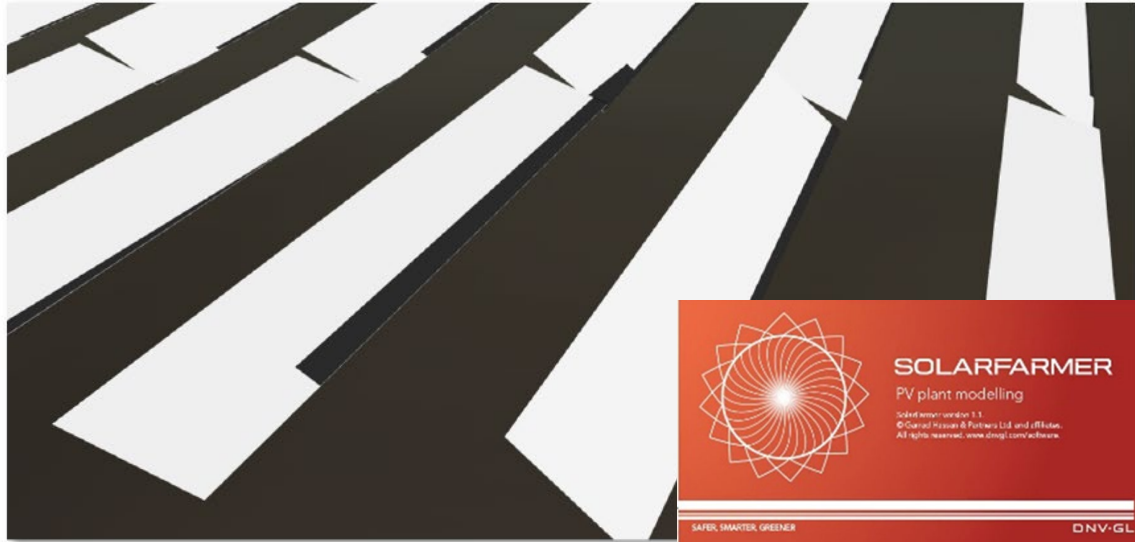
Electrical
consumption?

Is the manufacturer responsible for inappropriate installation?

- Legally, not responsible. The contract is between the Owner and the EPC contractor. However, some questions are:
 - Were the installation manuals provided to the EPC contractor?
 - Were the commissioning inspections properly undertaken?
 - Has been the soil well studied for the best selection of foundations?



New 3D Backtracking algorithms



DNV has used SolarFarmer with 5 min data to simulate the shadings of conventional backtracking algorithm compared to new 3D backtracking algorithms

DNV has found net energy gains of 0.4% in relatively benign sites and 1% in site with medium topography complexity (slopes up to 4%-6%).

Stowing energy losses

- This energy loss estimation is not well considered or directly neglected by the industry
- DNV is currently checking the methodology applied by Arctech to estimate the associated energy production losses to the stowing strategy. This is considered a very innovative approach.

Conclusions

- PV tracker industry is lacking of standardization
- Bankable trackers are good quality trackers but this concept involves many parameters to be reviewed
- Hot topics in the today industry of trackers: optimum design for aeroelastic instabilities, new backtracking algorithms, certification not enough, responsibility of the manufacturer during installation/commissioning
- Stowing energy production losses are frequently neglected in the industry and more effort is required. The initiative from Arctech is considered very positive for the development of the tracker industry
- DNV has been undertaking PV tracker bankability reports for the last years with a guideline published in 2018

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Q&A



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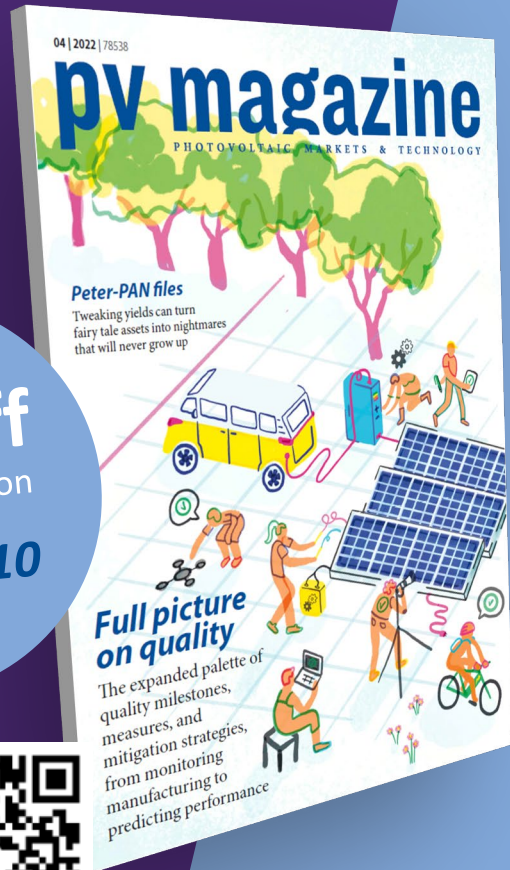


César Hidalgo López

Principal engineer for solar
DNV

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Natural hydrogen – how it works and why companies are interested
by Bella Peacock



Texas solar is booming, but batteries are not included
by Ryan Kennedy



Coming up next...

Thursday, 28 April 2022

11:00 am – 12:00 pm CEST, Berlin

2:30 pm – 3:30 pm IST, Delhi

Tuesday, 3 May 2022

3:00 pm – 4:00 pm CEST, Berlin

9:00 am – 10:00 am EDT, New York City

Many more to come!

**How automation
can deliver
sustainable solar
project O&M in an
uncertain
environment**

**Seven proven ways
to improve LCOE in
PV and storage:
new Proteus
inverters from
Gamesa Electric**

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**Thank you for
joining today!**