

Designing for Wind in the Age of Mass Solar Tracker Deployment

Presented By:



9/18/2018

Speakers:

Alex Roedel, Director of Design & Engineering, *NEXTracker*

Dr. David Banks, Principal, *CPP Wind Engineering Consultants*

Jake Morin, Structural Engineer, *Structurology LLC*

Moderator:

Benjamin Gallagher, Senior Analyst, *GTM Research*

gtm: WEBINAR

Today's Speakers



Alex Roedel
Director of Design & Engineering,
NEXTracker



Dr. David Banks
Principal,
CPP Wind Engineering Consultants



Jake Morin
Structural Engineer,
Structurology LLC



Benjamin Gallagher,
Senior Analyst,
GTM Research

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storage
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Speaker Bio

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A Flex Company

8/23/2018

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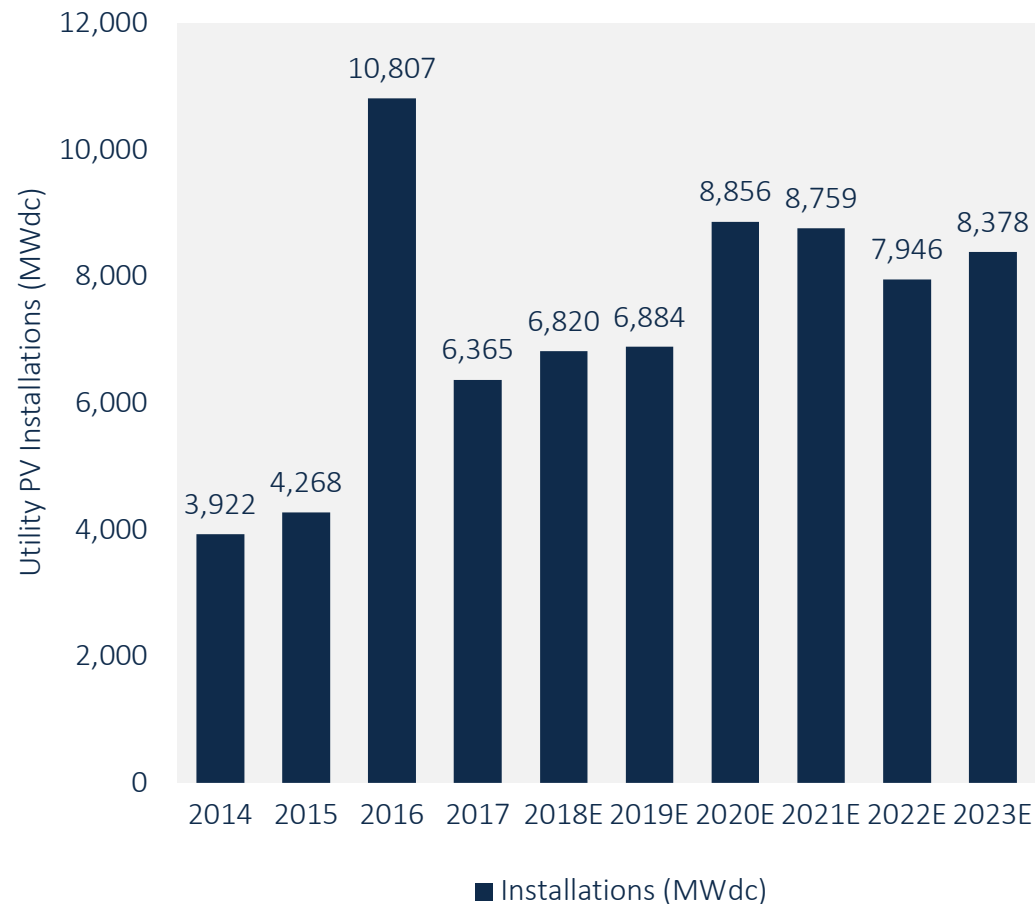
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Utility PV Market Outlook, 2018-2023

U.S. Utility PV Installation Forecast, 2014-2023E



Source: U.S. Utility PV Market Tracker

- GTM's 2018 - 2023 Forecast has grown by 1.9 GWdc over last quarter due to the surge in procurement of utility PV

Near Term: 2018 Remains Steady While Tariff Impacts Most Felt in 2019

- The 2018 forecast has increased from 6.6 to 6.8 GWdc as our confidence in projects' ability to come online increases. 38% of 2018 expected capacity has come online.
- GTM's 2019 forecast has fallen by 78 MWdc to 7.9 GWdc with relatively few projects targeting 2019 COD

Medium Term: Procurement Boom Targets 2020 and 2021 COD

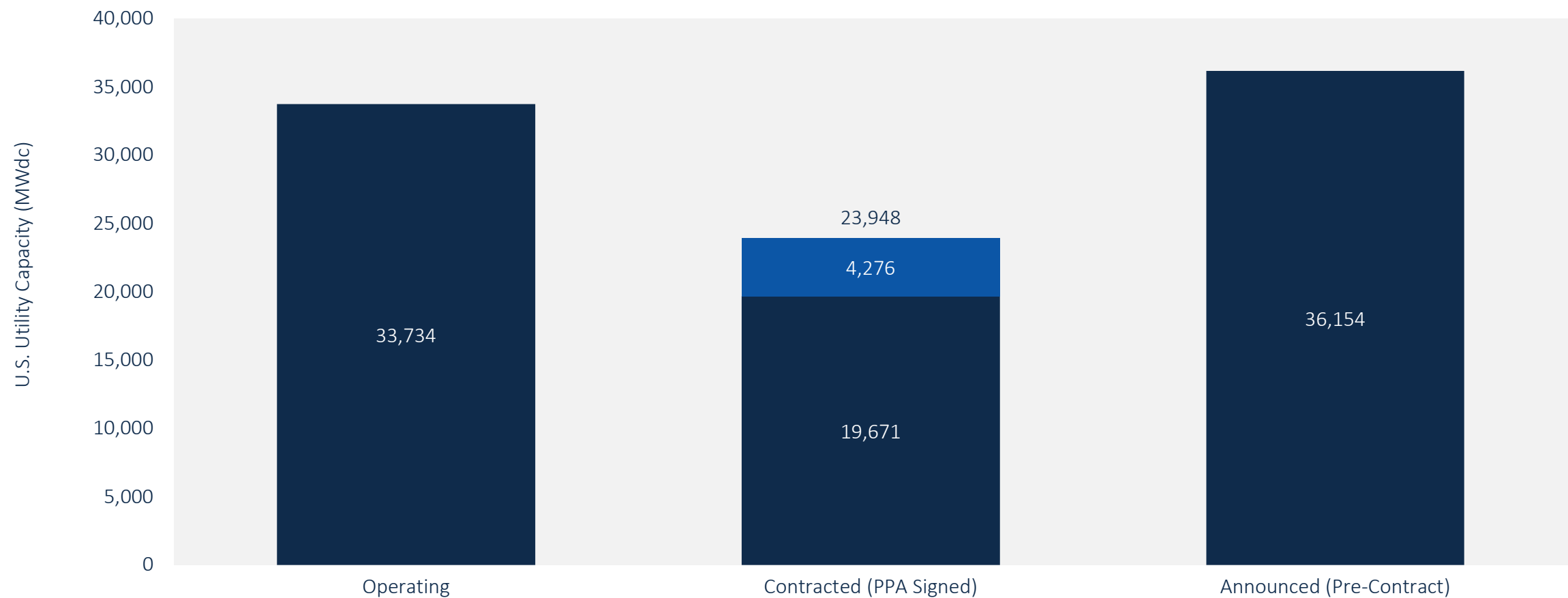
- GTM's 2020 and 2021 forecasts have seen a cumulative 1.4 GWdc increase due to the uptick in procurement from utilities like Wisconsin Public Service Corporation, NV Energy, Florida Municipal Power Agency and Dominion
- Most RFPs released target 2020 or 2021 COD, which will continue to drive growth in these years. Due to the ITC stepping down and the fear that interest rates may rise, several corporations have suggested that 2020 and 2021 may be the optimal time for them to sign an offtake agreement.

Long Term: The Last of The Investment Tax Credit

- The bulk of 2022 capacity additions will come from developers using ITC commencement provisions to leverage the 22% ITC before it steps down to 10%.
- The year 2023 will be the first year in which over half of all utility solar projects brought online will leverage a 10% ITC.
- By 2023, levelized cost of 20 MW utility PV will be less than that of onshore wind in 49 state markets resulting in more utilities turning to solar over wind for renewables generation.

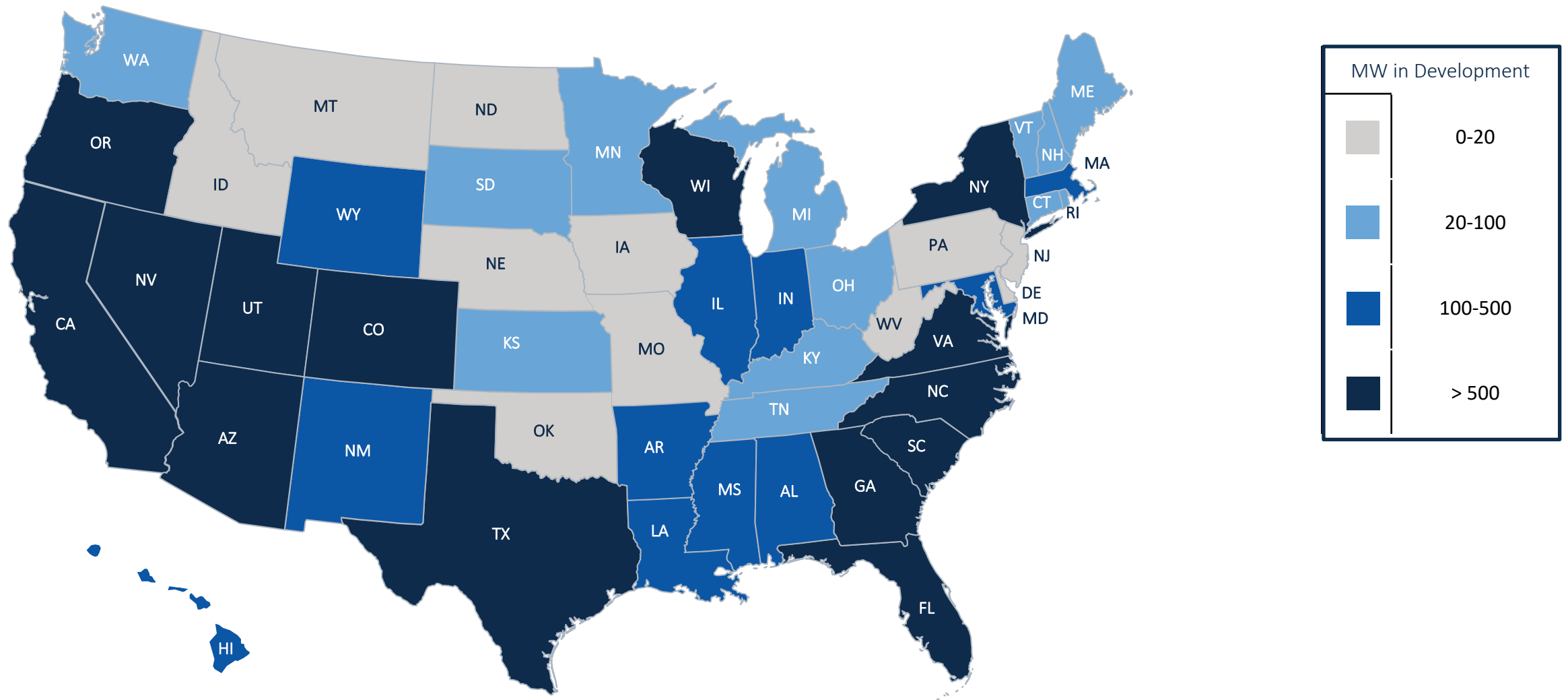
Overall Pipeline: Growth Through Q2 2018

Current U.S. Utility PV Pipeline



Source: U.S. Utility PV Market Tracker

Utility PV in Development by State as of Sept 2018



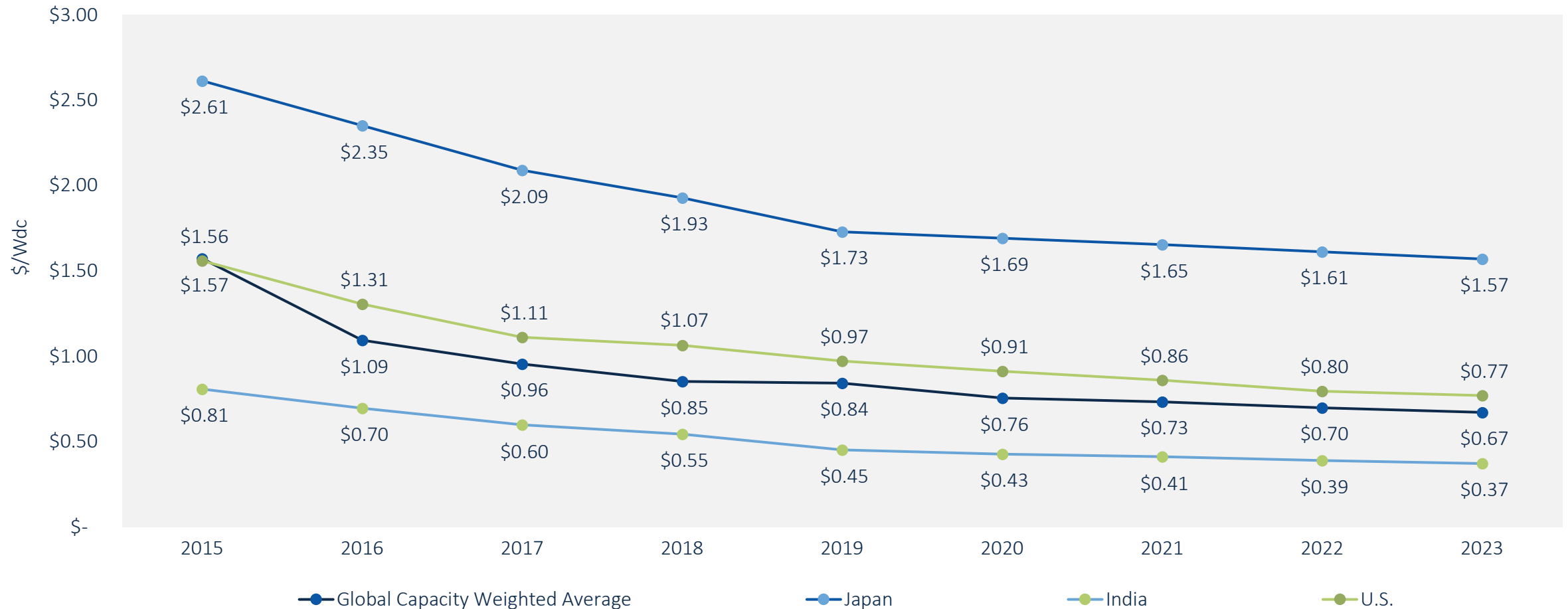
Region Breakdown

Rank (Contracted + Operating)	Region	In Development	Operating	2018-2023 Forecast (MWdc)
1	Southeast	9,122	9,219	17,631
2	California	3,068	12,575	7,249
3	Southwest	3,268	6,733	6,179
4	Texas	1,922	1,798	4,852
5	Midwest	1,135	990	4,464
7	Northeast	1,251	1,023	2,901
6	Northwest	1,135	764	1,709
8	Hawaii	207	122	626

Source: U.S. Utility PV Market Tracker

Global Capacity Weighted Average Utility PV System Prices Land at \$0.85/Wdc

Global Capacity Weighted Average, Japan, India and U.S. Utility PV System Pricing, 2015-2023E (\$/Wdc)



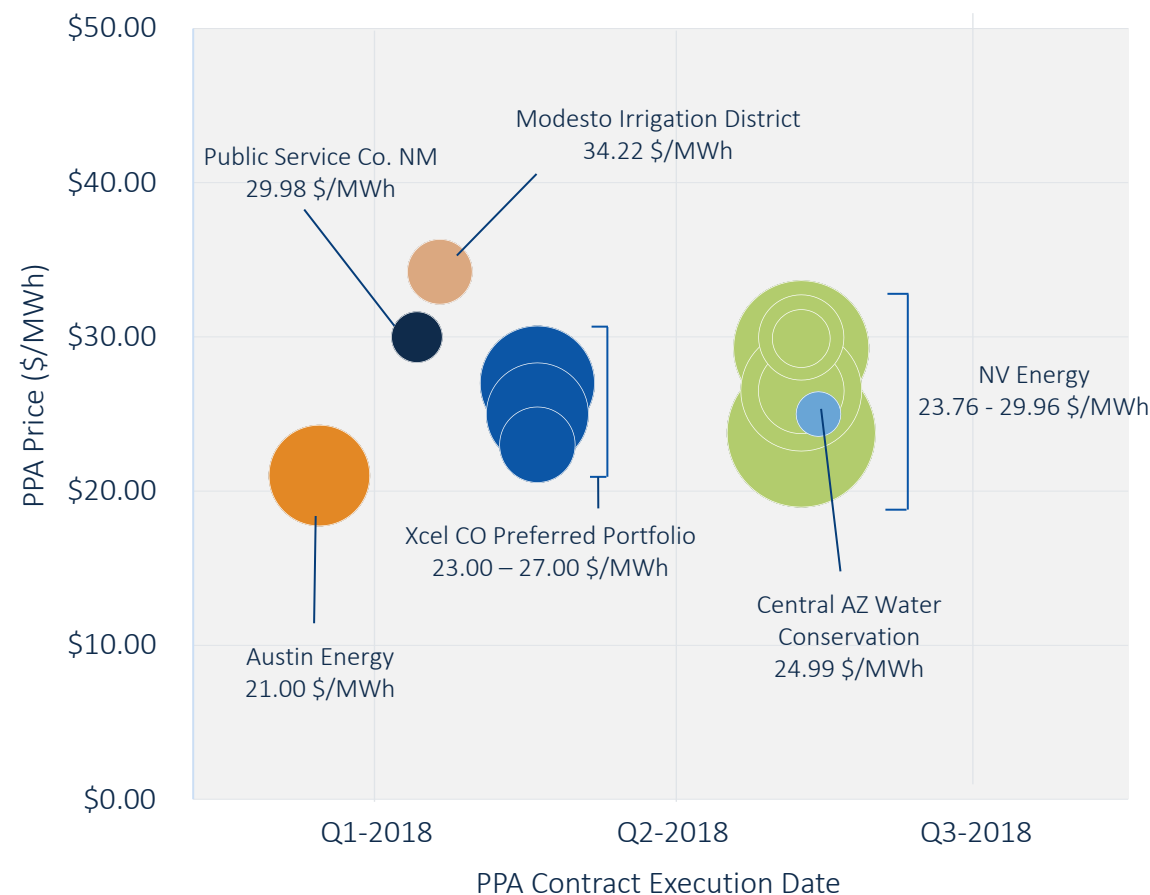
Source: GTM Research

US Utility PPA Prices Now Between 35.00 \$/MWh – 21.00 \$/MWh

A series of record low PPAs were announced in Q2 2018. While Austin Energy's 21.00 \$/MWh PPA in Q4 2017 is still believed to be the lowest, GTM has not yet confirmed from Austin Energy if the 21.00 PPA price is levelized or the year 1 price for an escalating PPA. Recent projects in both NV and CO were also paired with utility battery storage, a growing trend among project announcements.

State	Developer	Offtaker	PPA Term Length (years)	Price \$/MWh
AZ	Origis Energy	Central Arizona Water Conservation District	20	24.99
CA	NextEra Energy Resources	Modesto Irrigation District	20	34.22
CO	Undisclosed	Xcel CO	Unknown	23.00 – 27.00
NV	Multiple	NV Energy	25	23.76 – 29.96
NM	NextEra Energy Resources	Public Service Co. NM	25	29.98
TX	Intersect Power	Austin Energy	15	21.00

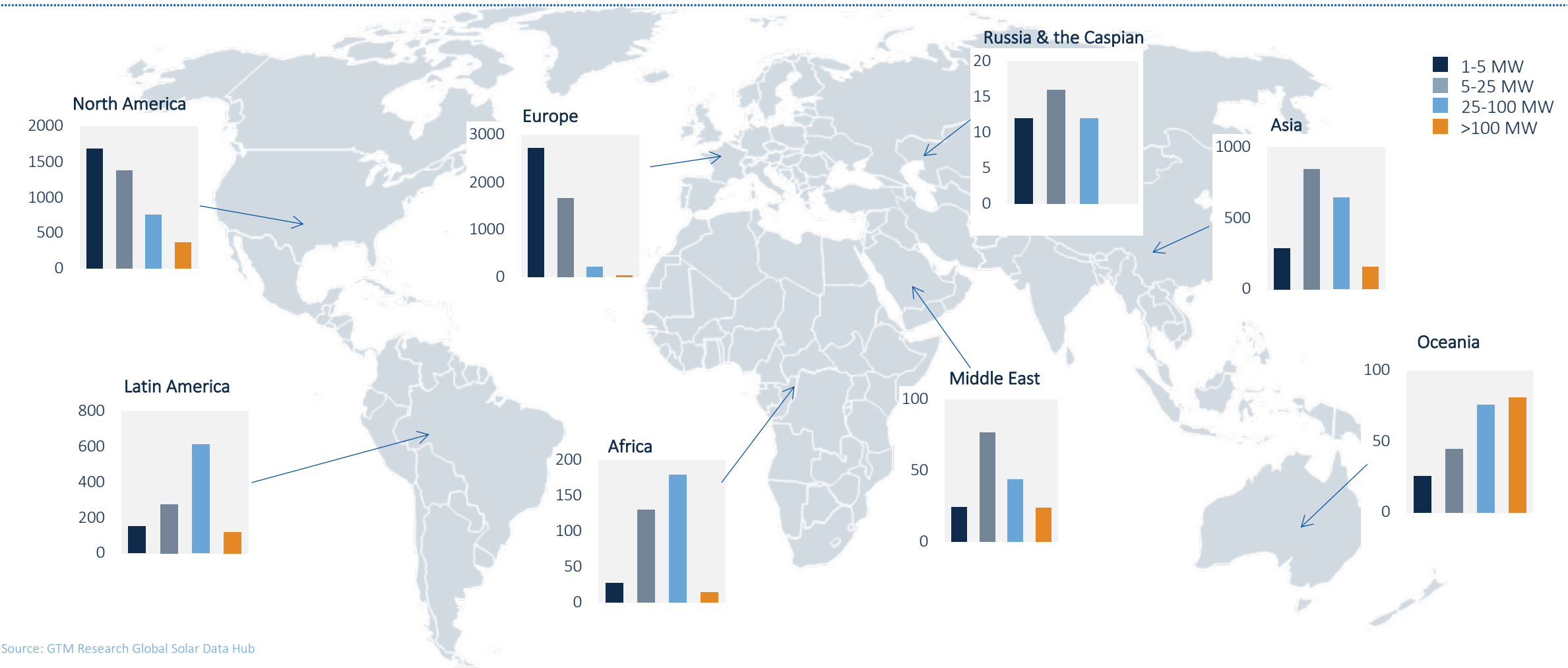
Utility PV PPA Price by Contract Execution Date Highlights Q4-2017 – Q2-2018



Source: U.S. Utility PV Market Tracker

Different-Sized Projects Work in Different Regions: Australia Will Be Dominated by Ultra-Large PV Projects

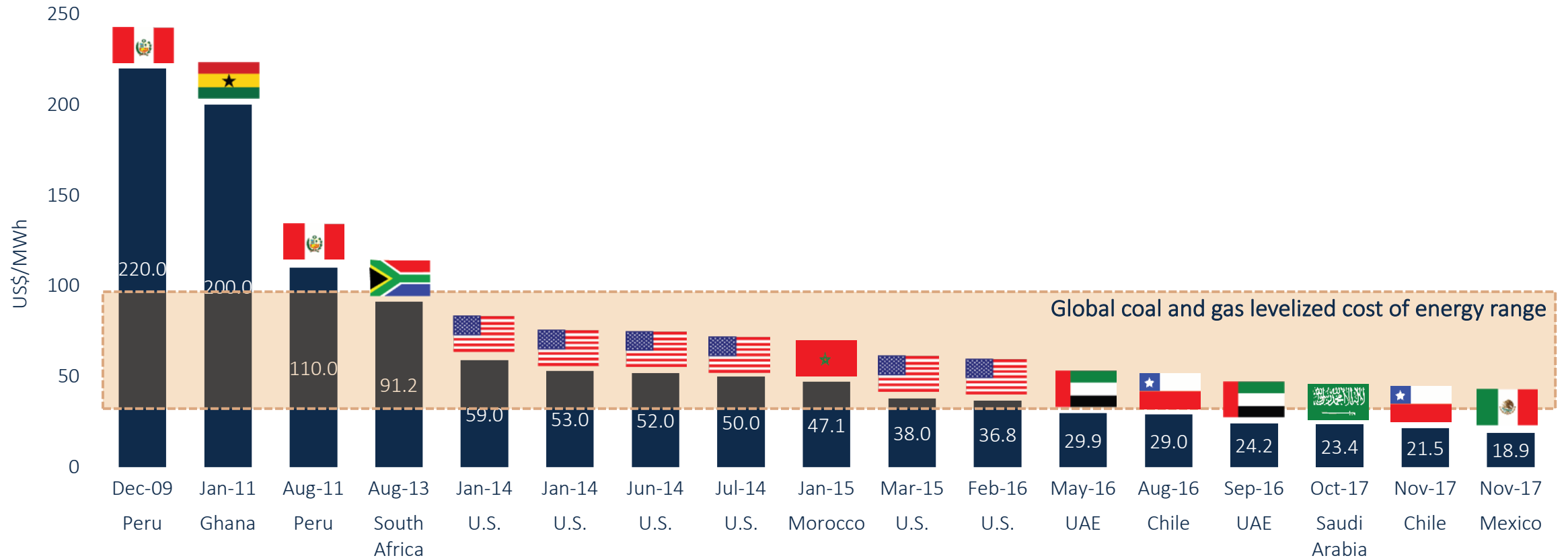
Regional Utility-Scale PV Project Development Pipeline by Region (bars show no. of projects in development)



Source: GTM Research Global Solar Data Hub

Record low tariffs are being delivered for renewable energy awarded around the world

Seven world record-low solar PV PPA prices since the start of 2016



Source: GTM Research

Solar is NOT Maintenance Free



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DESIGNING FOR WIND IN THE AGE OF MASS SOLAR TRACKER DEPLOYMENT

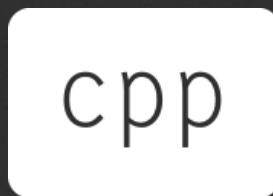
Dynamic Wind Analysis and Protective Stow Strategies

Greentech Media Webinar Series

SEPTEMBER 18, 2018

AGENDA

- Benjamin Gallagher, Senior Analyst, GTM
- Alex Roedel, Director of Design & Engineering, NEXTracker
- Dr. David Banks, Principal, CPP Wind Engineering Consultants
- Jake Morin, Structural Engineer, Structurology LLC
- Q&A



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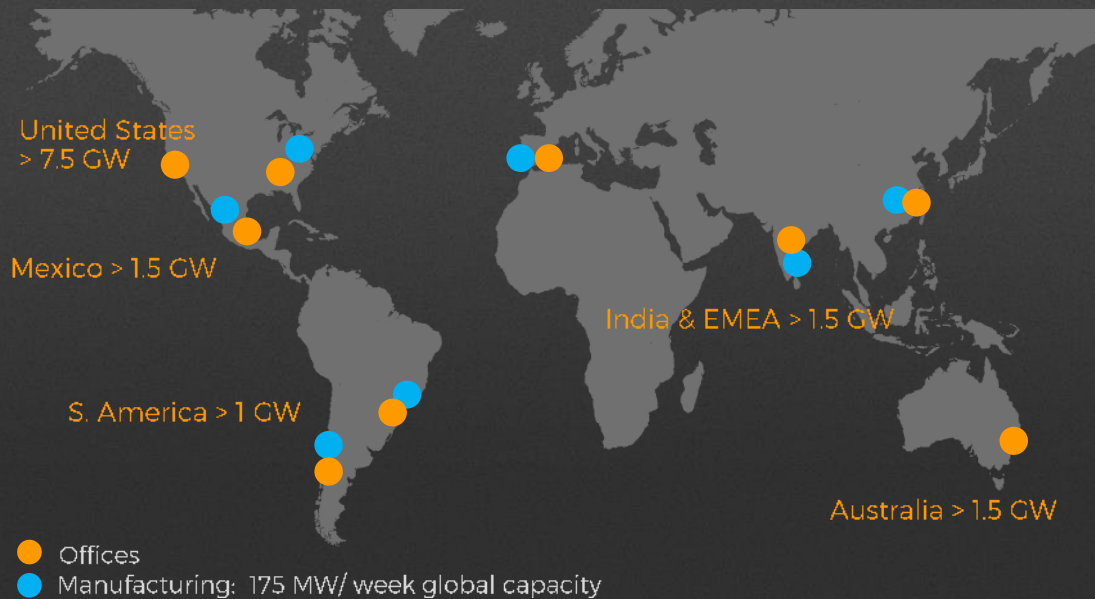




NEXTrackerTM

A Flex Company

NEXTRACKER, A FLEX COMPANY



flex

An investment grade company

- \$25B revenue
- \$13B balance sheet
- > \$400M free cash flow

14 GW trackers delivered globally
10 GW of Gen2 NX Horizon, zero wind events

NEXTRACKER PRODUCT & SERVICES ECOSYSTEM

SOLAR TRACKING SOLUTIONS

TRUECAPTURE™

Smart control system increases output of NX trackers by 2-6% via advanced machine learning technology.



NX HORIZON™

Industry's Most Advanced Single-Axis Solar PV Trackers



ENERGY STORAGE SOLUTIONS

Best-in-class energy storage systems for any application. Can be paired with NX Horizon trackers and other existing generation assets, or used on standalone basis.

NX FLOW™

Integrated Vanadium Flow Battery + DC-Coupled Storage Inverter



NX DRIVE™

Standardized Container Platform for Lithium Ion Battery Systems

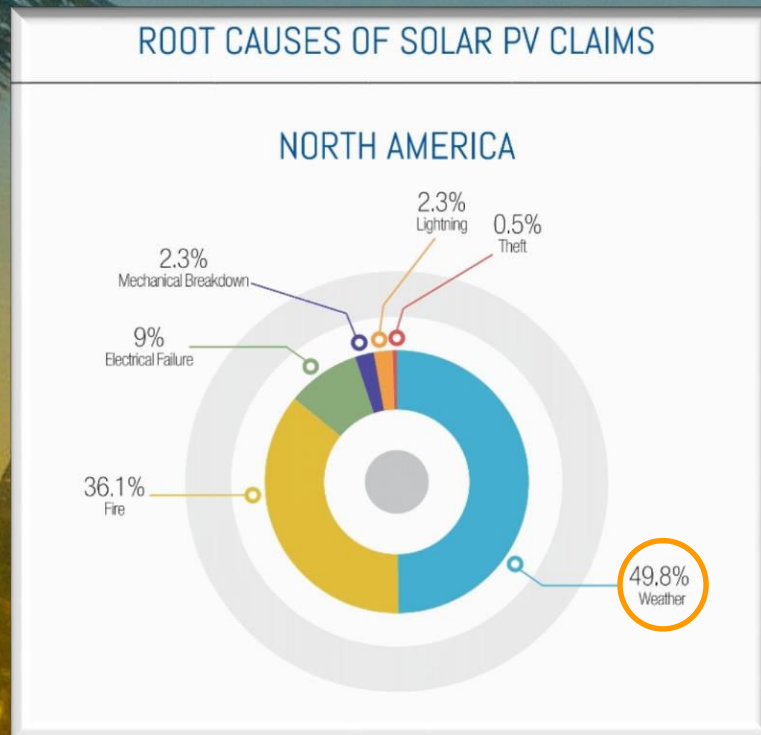


NX DATA AND MONITORING CONTROL SERVICES

Suite of advanced data and software-driven digital services available for both tracker and storage systems to dramatically improve asset management efficiency and lower operating costs.

ROOT CAUSES OF PV FAILURE

- Weather is the #1 source of PV insurance claims
- Climate change leading to a rise in extreme weather

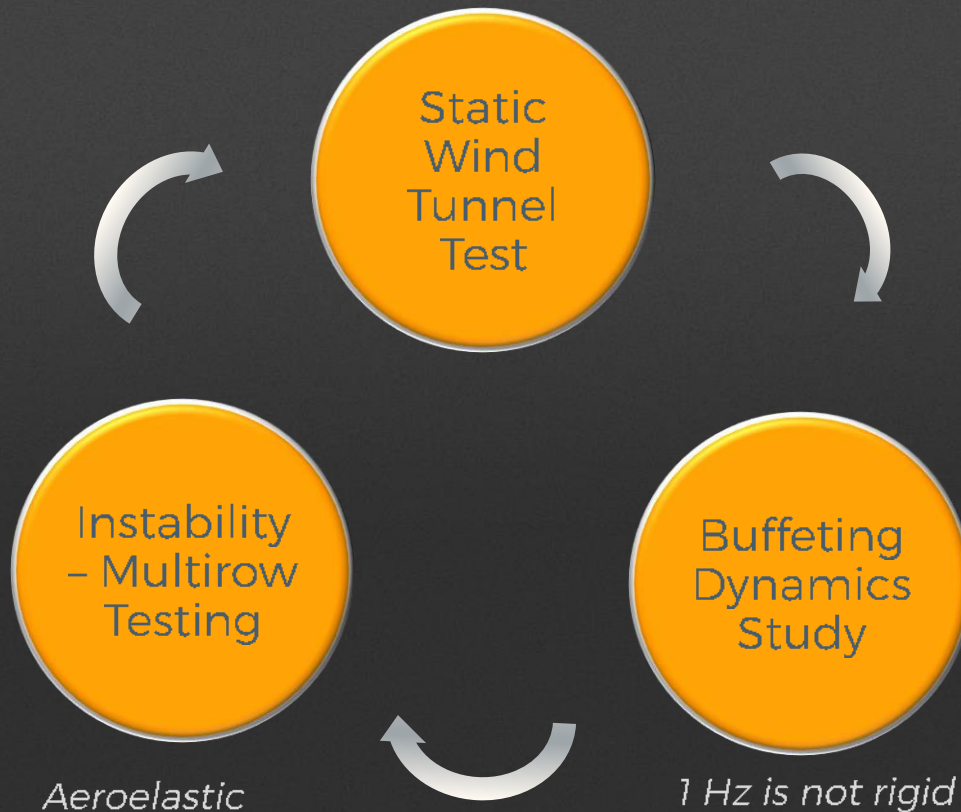


Source: GCube

RECOMMENDED WIND TUNNEL TESTING

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DYNAMIC WIND ANALYSIS

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INSTABILITY AT 0 DEGREES

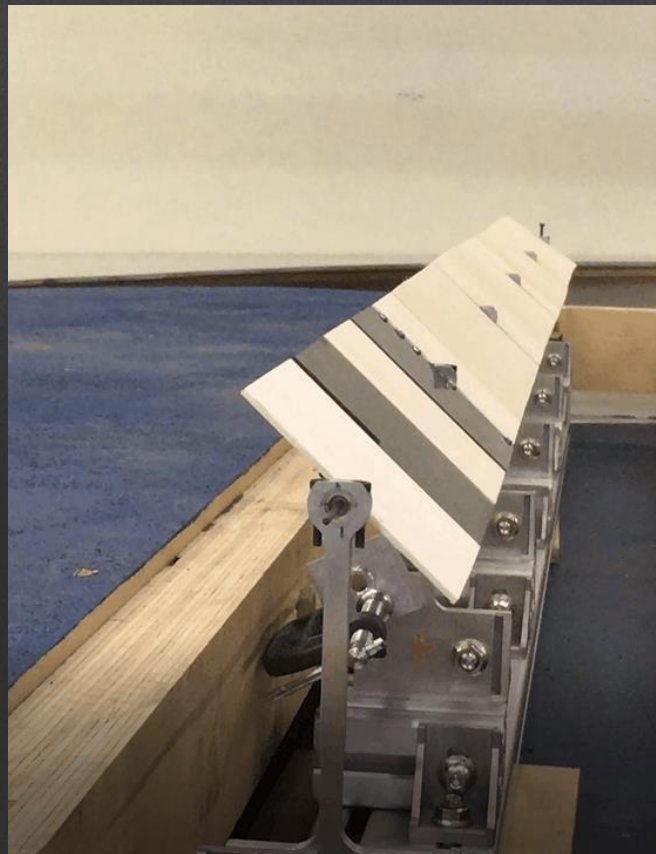


DYNAMIC WIND ANALYSIS

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STABILITY AT HIGH TILT ANGLES



TORSIONAL GALLOPING

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*Panels stowed near flat

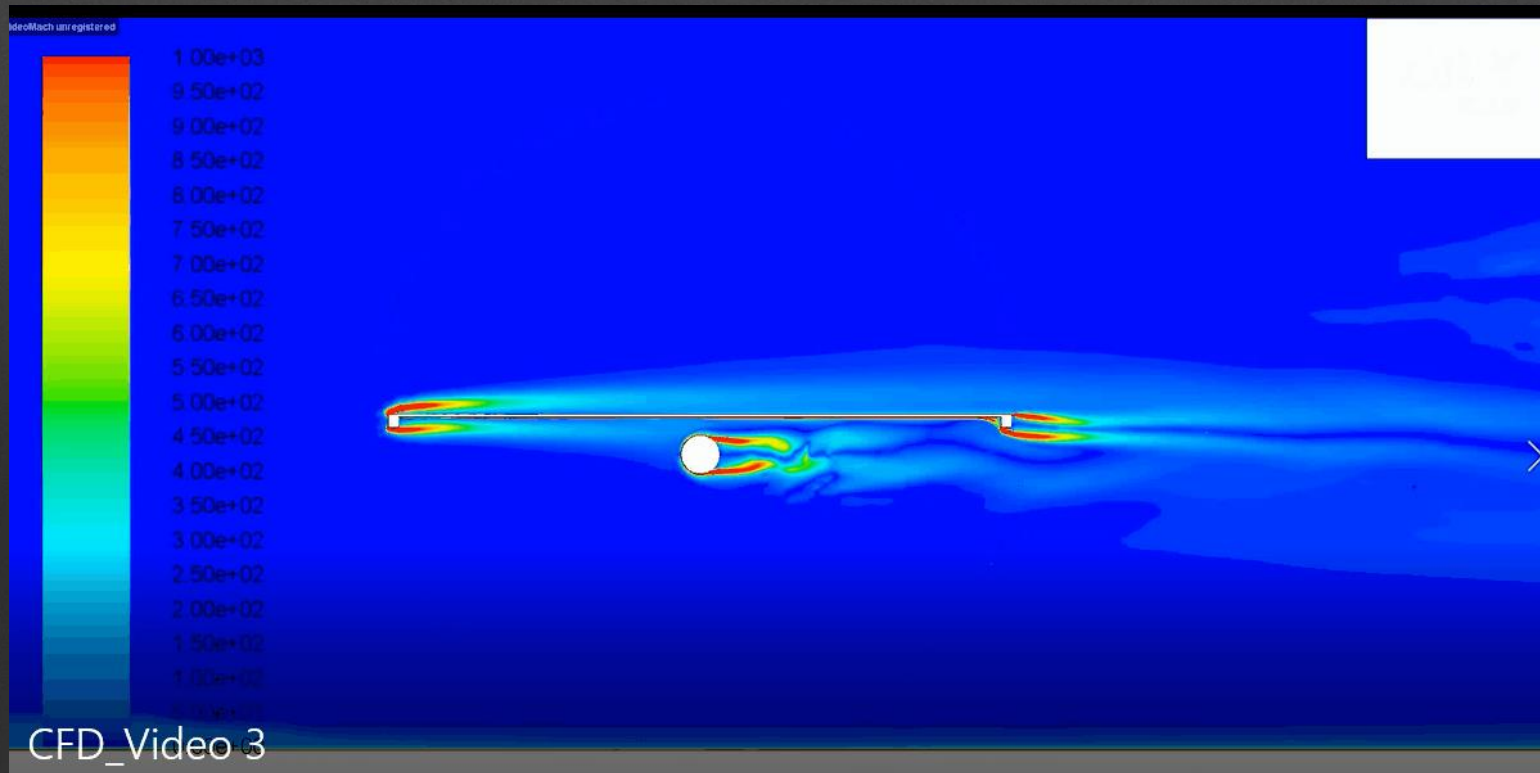


group test

DYNAMIC WIND ANALYSIS

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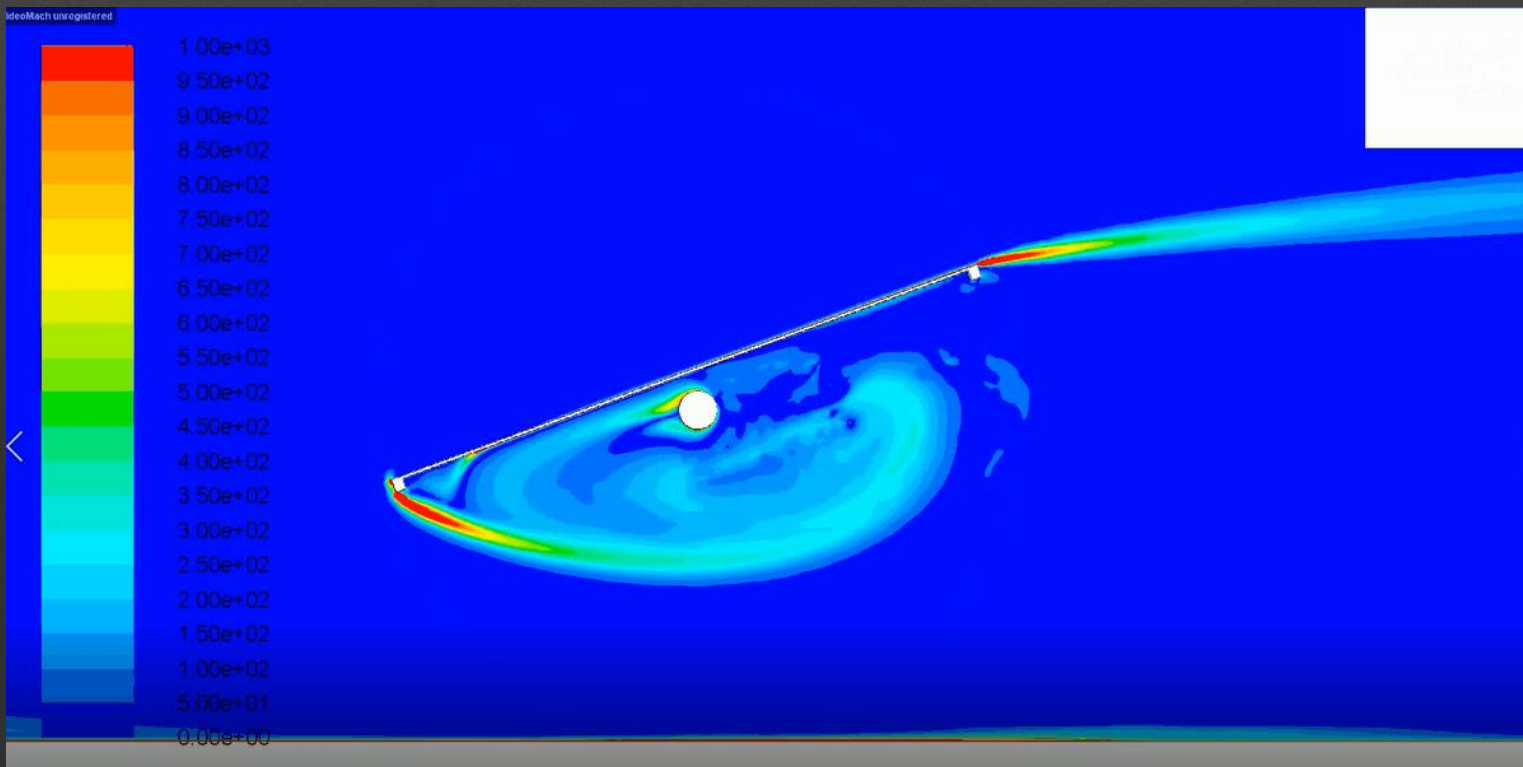


STOW AT 0 DEGREES – TORSIONAL GALLOPING

DYNAMIC WIND ANALYSIS

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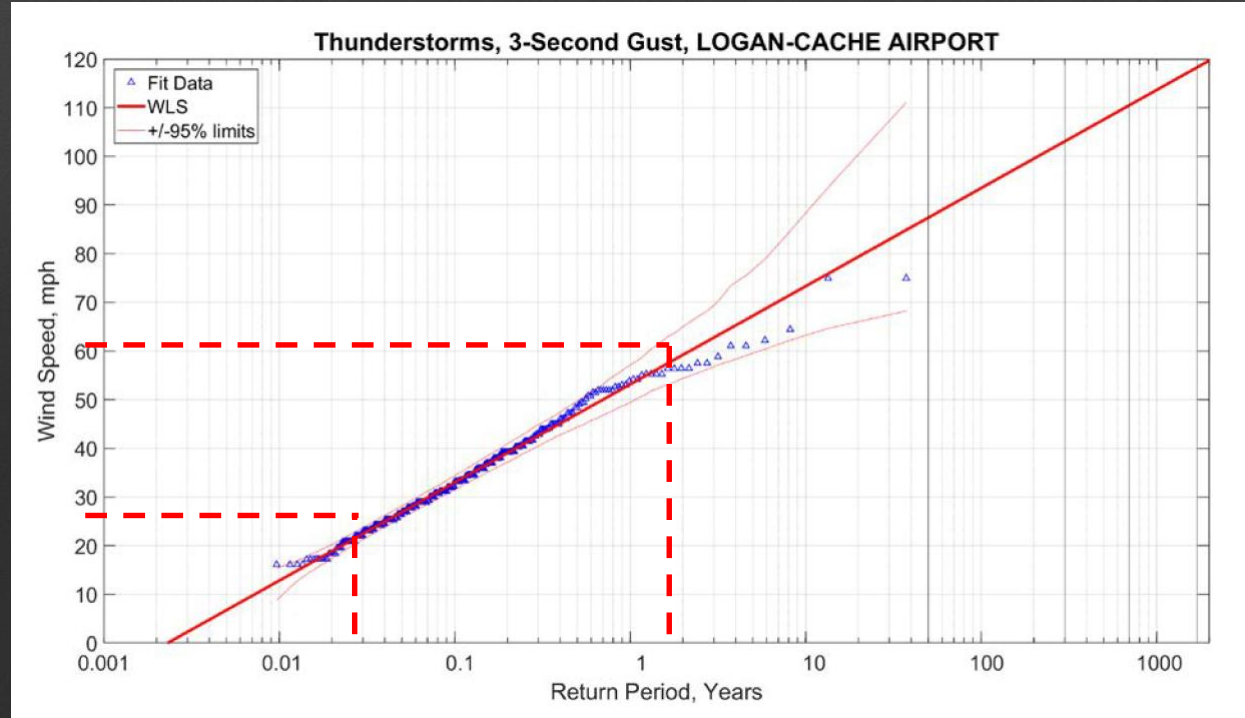
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STOW AT HIGH ANGLES – VORTEX LOCK-IN

COST OF DOWN TIME IN TRACKER REPAIR

- Instabilities and failures can occur at low to moderate wind speeds (25mph - 60mph)
- These wind events can occur several times a year to every few years depending on location
- Downtime due to failures leads to loss of revenue to owners

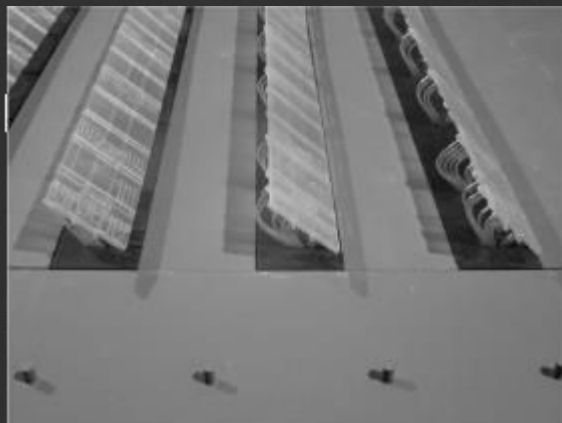
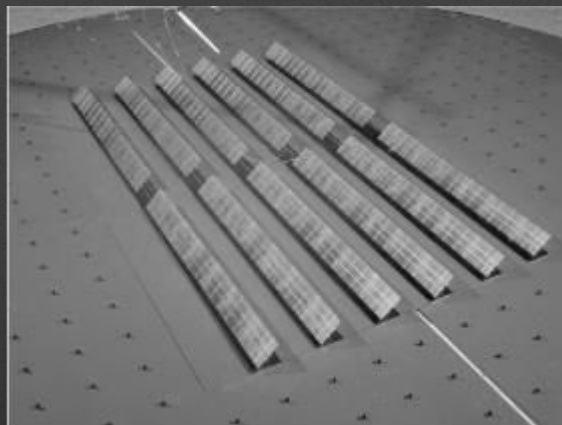


LIMITATIONS OF CODE BASED DESIGNS

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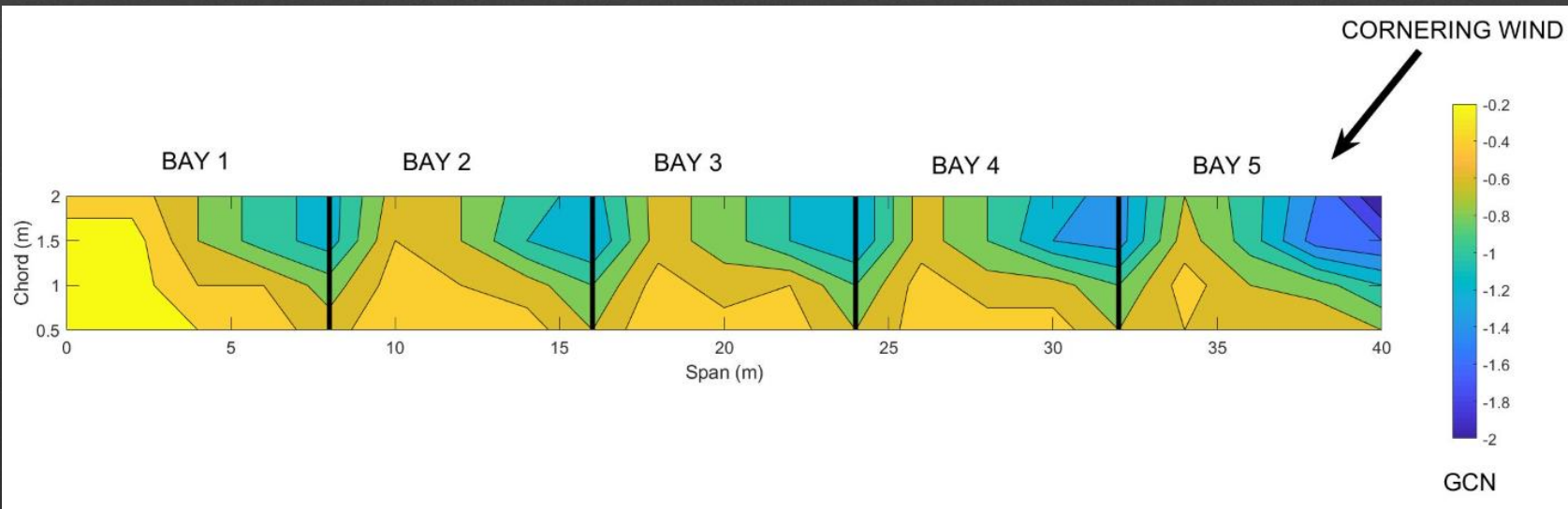
- ASCE 7: “Wind tunnel method may always be used for determining wind pressures for any structure. This method is considered to produce the most accurate wind pressures of any method specified in this standard.”
- Mono-slope roof coefficient grossly oversimplifies a PV structure



STATIC WIND TUNNEL TESTING RESULTS

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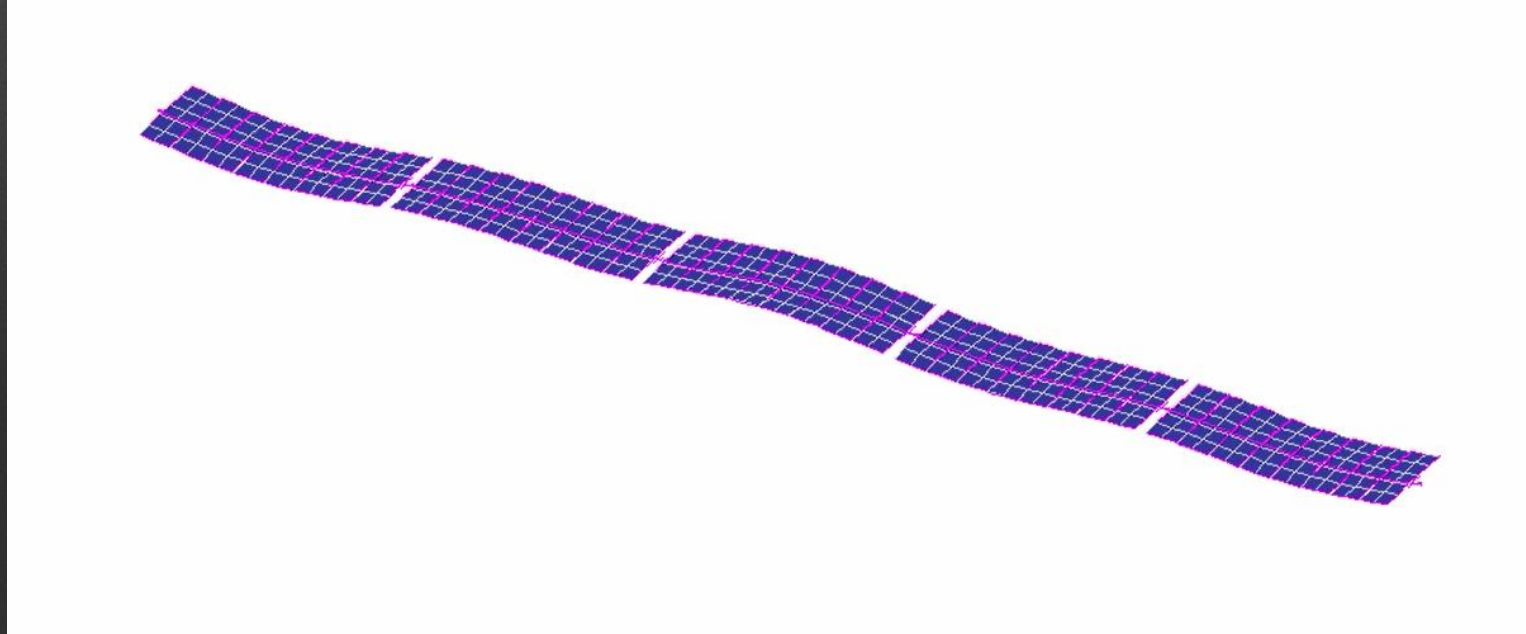
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BUFFETING DYNAMICS

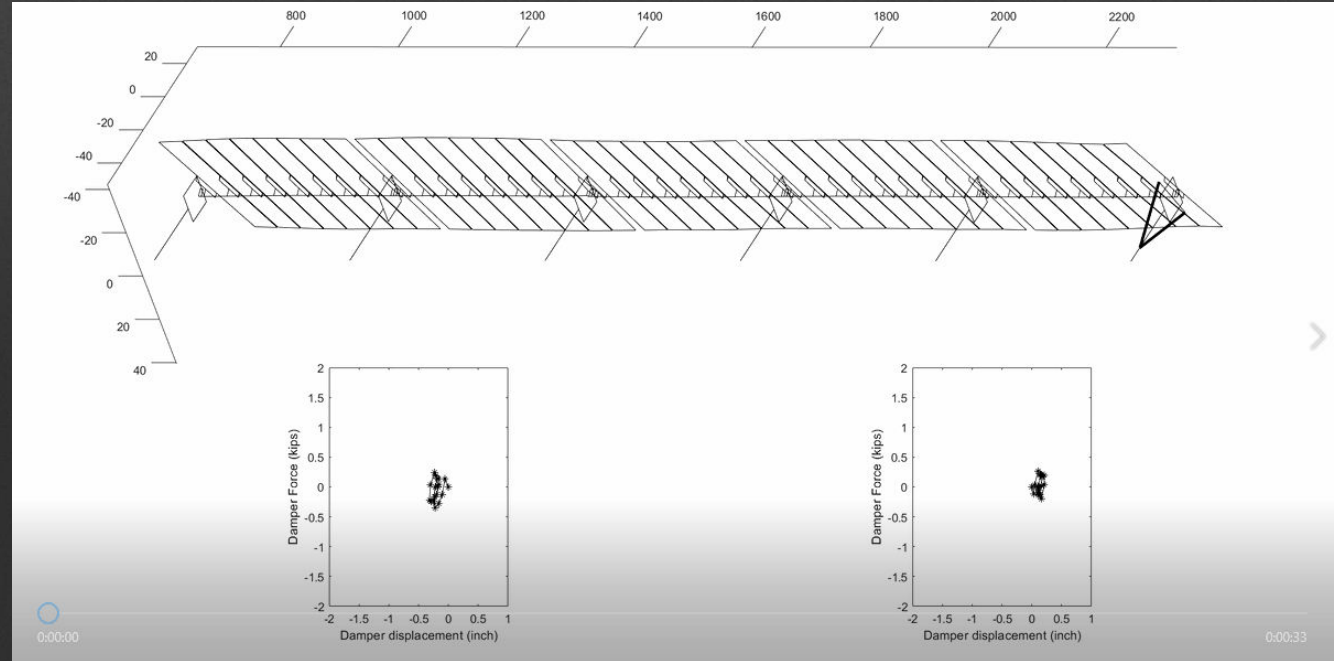
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IMPORTANCE OF DAMPERS

- Dampers reduce oscillations
- Dynamic Amplification Factor (DAF) can be determined via finite element analysis
- Must be verified by field testing



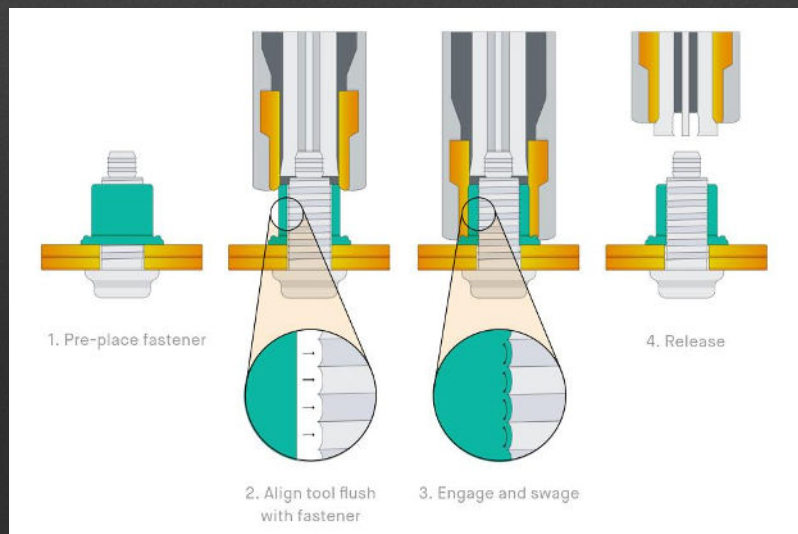
TRACKER ARCHITECTURE

- Chord length is East/West exposure to wind
- Chord length has a squared effect on torque
- 2P trackers experience 400% load increase



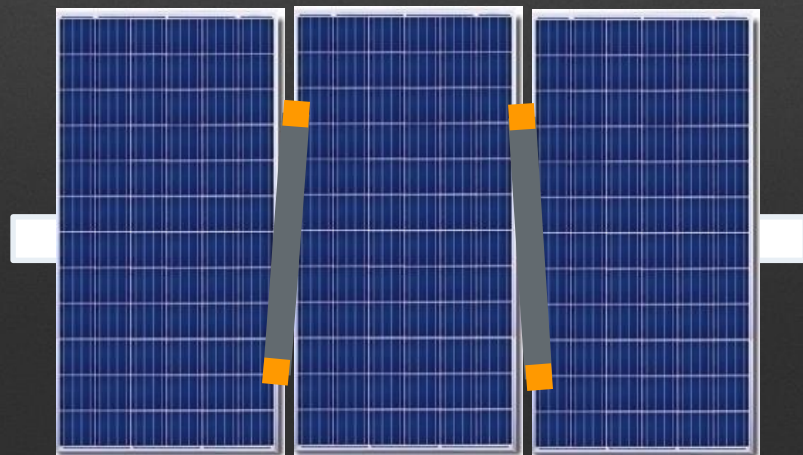
FASTENERS & MODULE TYPES

Key wind-mitigation component: tension fasteners improve reliability by not loosening over time.



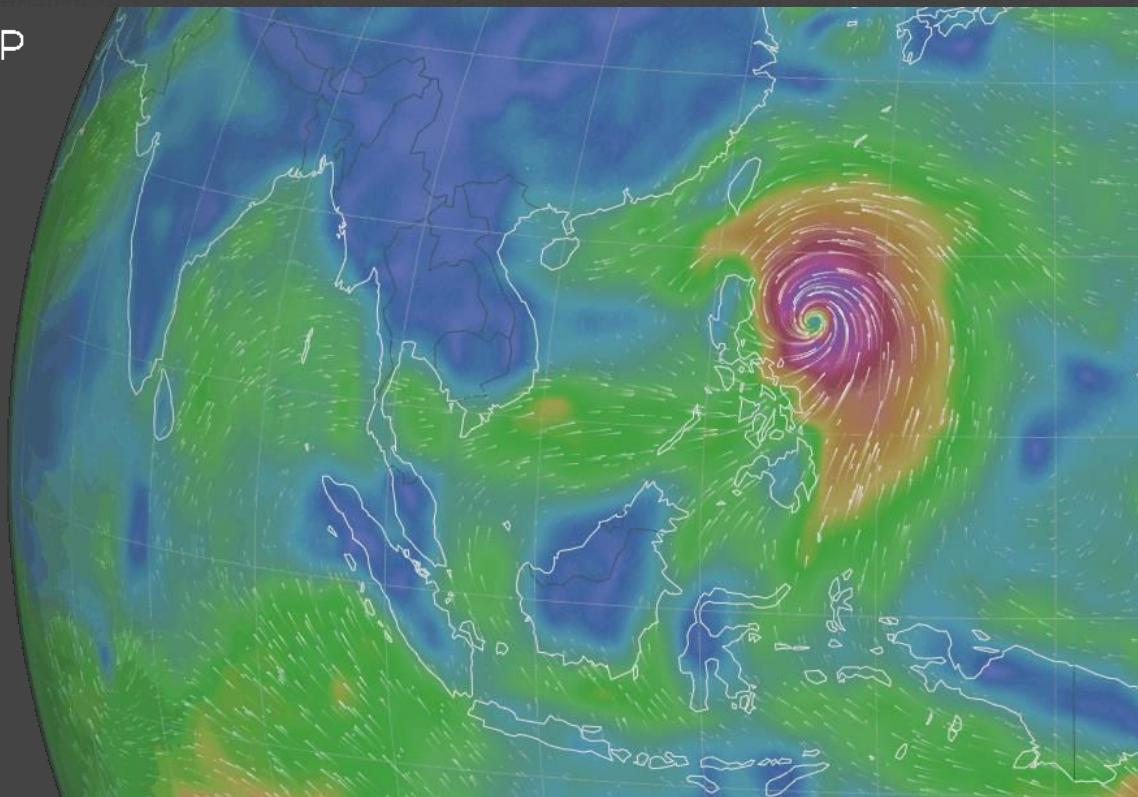
White paper: "Tracking your Solar Investment: Best Practices for Solar Tracker O&M," by Marty Rogers, NEXTracker 2017

Portrait frameless modules on a tracker risks slippage and breakage over time.



FORGING THE STANDARD

- NEXTracker along with CPP has changed the industry with respect to dynamic analysis & wind stow strategies
- NEXTracker has sustained hurricanes Matthew, Harvey, Maria, Irma, Florence and others without failures



VALUE OF RELIABILITY AND QUALITY DESIGN

- Levelized Cost of Energy (LCOE) need to take into account O&M costs and downtime due to tracker failures
- Owners and EPCs need to require proper wind tunnel testing and dynamic analysis



Actual site with NX Horizon post-Hurricane Matthew.
Slew gear, motor and electrical components untouched.

SAND AND FLOOD CLEARANCE

NEXTracker Design

All NX components sealed and positioned well above grade to avoid contact with water and sand



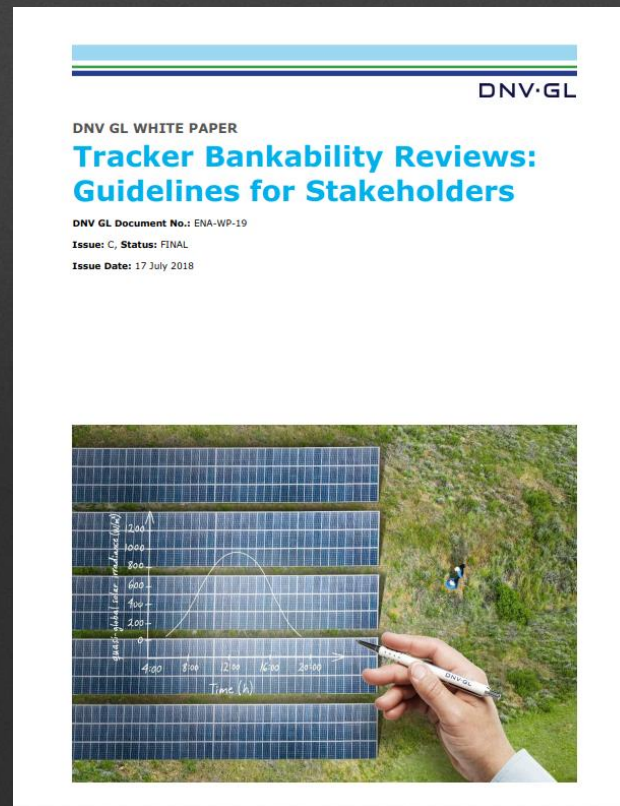
Extreme Weather Events

Actual NEXTracker site enduring harsh flood. Along with hurricanes, floods can be extremely damaging to sites



DNV-GL BANKABILITY STUDY

- The Industry needs to mature in effort to ensure the quality and reliability of solar trackers
- DNV has recently released a white paper outlining best practices for the Independent Engineers (IE) community for performing unbiased technology evaluations for solar PV trackers



IMPORTANCE OF PEER REVIEW



NEXTRACKER SURVIVING WIND EVENT



Q & A