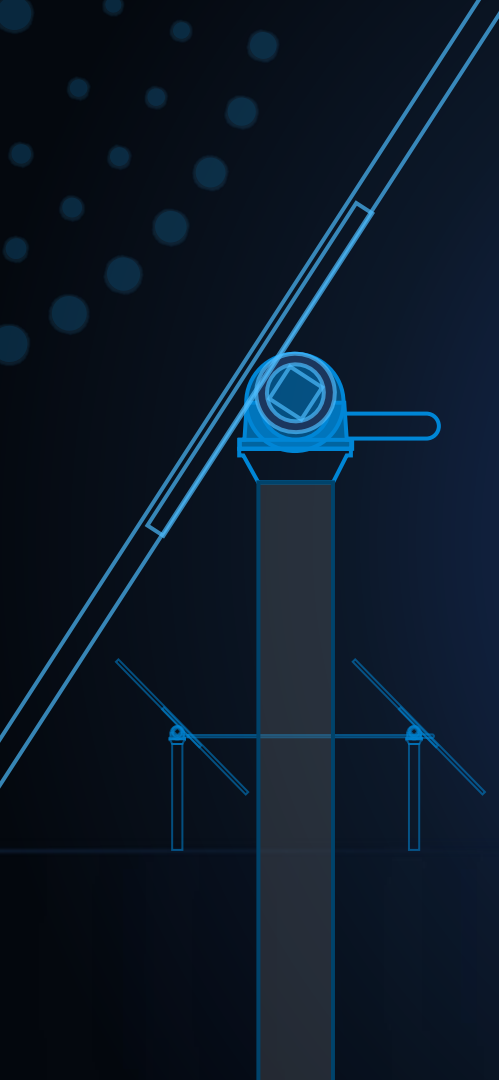
# Ensuring Tracker Stabililty in Extreme Weather Conditions

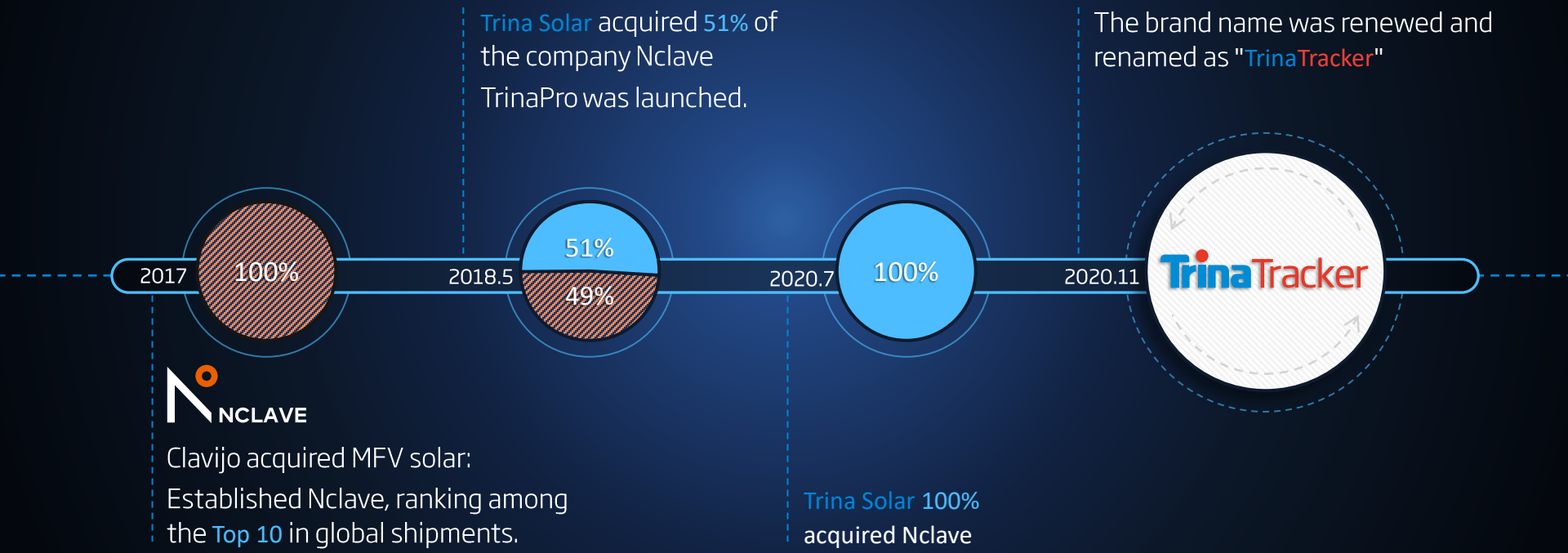
19th July 2021

# CONTENTS





# COMPANY DEVELOPMENT



TrinaTracker

# ACHIEVEMENTS

Over **17** Years
Experience

**40** COUNTRIES
Across 5 continents

**6 GW+**
GLOBAL INSTALLATIONS

● Offices & Branches

Spain / France / UAE / United States / Mexico / Brazil / Chile / Australia / China

● Production centers

Spain / Brazil / Argentina / China

TrinaTracker

# STATE-OF-THE-ART TRACKER DESIGN ADAPTED TO ANY CONDITIONS

Irregular Site Layout

Uneven Terrain

Strong Wind Region

Difficult Soil

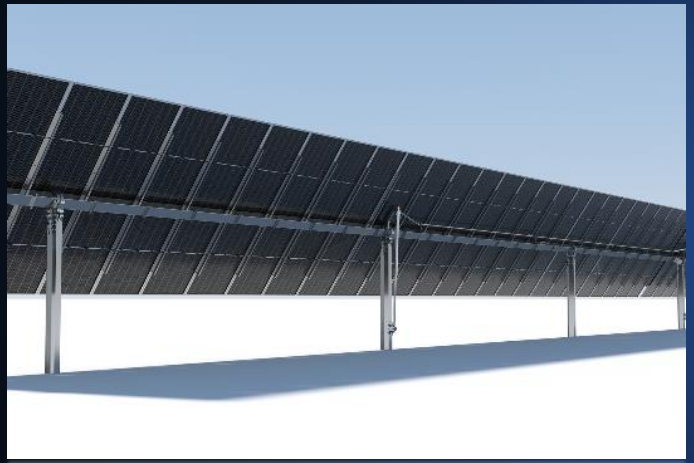
High Corrosive Area


**Reliable aerodynamic stability**

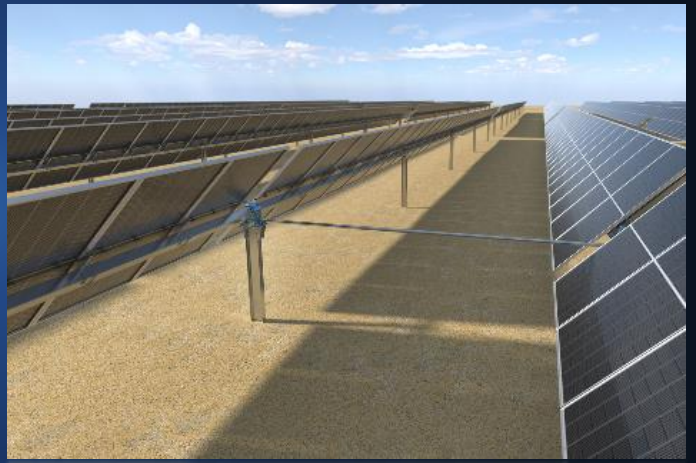
**Compatible** with all module formats

TrinaTracker

## Vanguard™ 2P Single row 2P

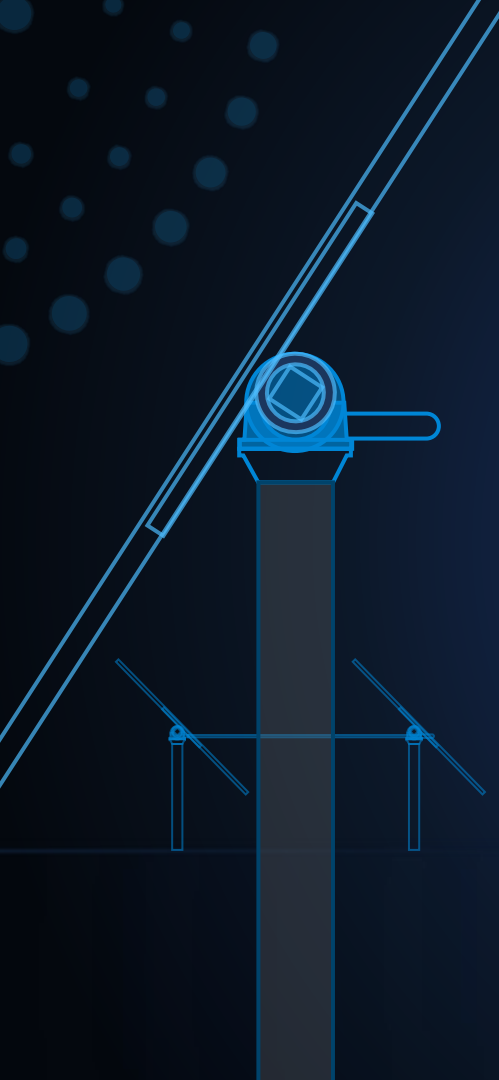


## Agile™ 1P Dual row 1P



# CONTENTS





TrinaTracker

# THE NEW ERA OF ULTRA-HIGH POWER MODULES (UHPM) CHALLENGES THE TRACKERS STABILITY

## HIGH DEMAND OF UHPM

- ✓ Higher energy production
- ✓ Reduction of BOS cost
- ✓ Availability in the market

LOWER LCOE

## IMPACT OF UHPM

- ✓ Aeroelastic and dynamic effects
- ✓ Lower Natural frequencies
- ✓ Higher torsional deflections
- ✓ Higher foundation reactions

STRUCTURE INSTABILITIES

## TRACKER DESIGN CHALLENGES

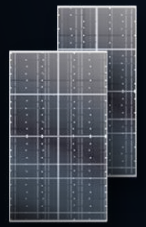
- ✓ Higher pressure of wind static loads
- ✓ Higher pressure of wind dynamic loads
- ✓ Extra weight of the structure

STABILITY ACHIEVEMENT

## UHPM REQUIREMENTS

- ✓ Longer rows
- ✓ Longer chord
- ✓ Stiffer structures
- ✓ Electrical adaptations (strings)
- ✓ Mechanical adaptations

TRACKER DESIGN ADAPTATIONS

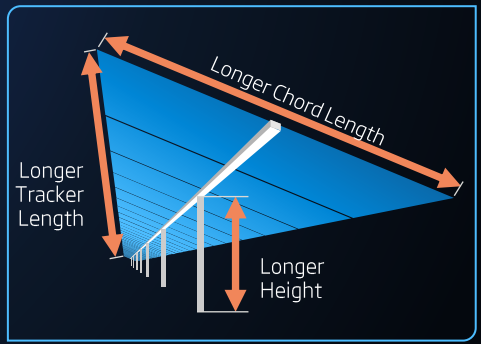


550W (210mm)

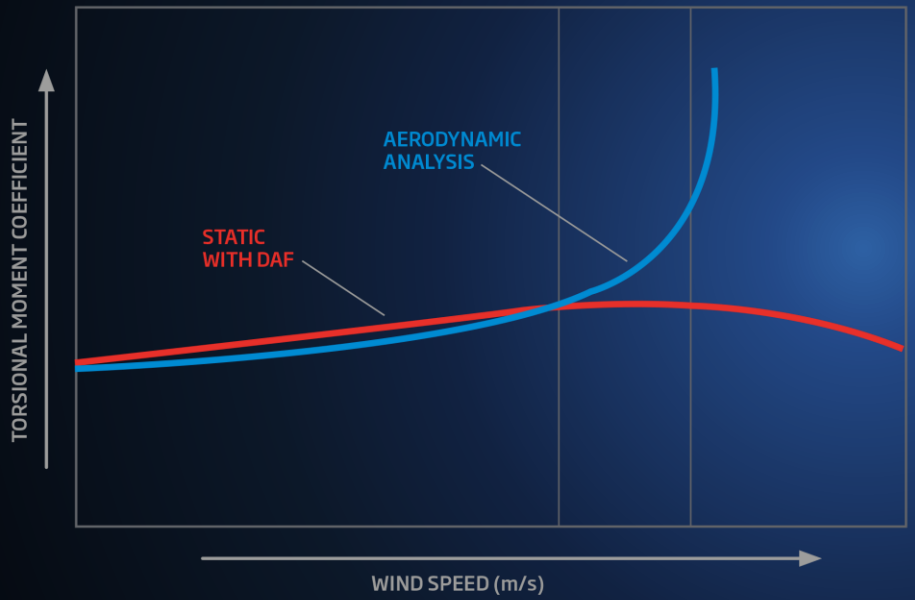
670W (210mm)

## RWDI-CPP WIND TUNNEL TEST:

- ✓ Validates trackers stability in extreme weather conditions
- ✓ Contribute to a more accurate tracker design adaptation to the sites



# POTENTIAL IMPACT OF WIND LOADS ON THE TRACKERS STRUCTURE




Torsional motion which occurs when wind speed exceeds the limit allowed by the tracker's structure.

The resulting effect is an uncontrollable torsional vibration that causes instability in solar trackers.

✓ Instability is avoided by calculating critical wind speed.

IMPORTANCE OF PERFORMING WIND TUNNEL TESTS ON TRACKERS

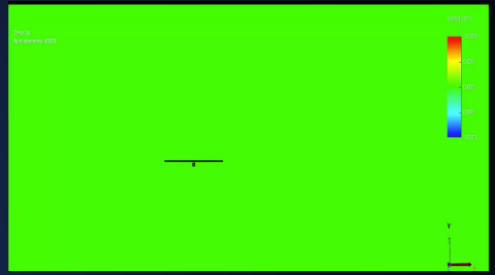
# POTENTIAL IMPACT OF WIND LOADS ON THE TRACKERS STRUCTURE

## RESONANT VIBRATION

Wake effect resonance caused by turbulence generated from the first row of array causing resonant vibration of subsequent rows.

## TORSIONAL DIVERGENCE

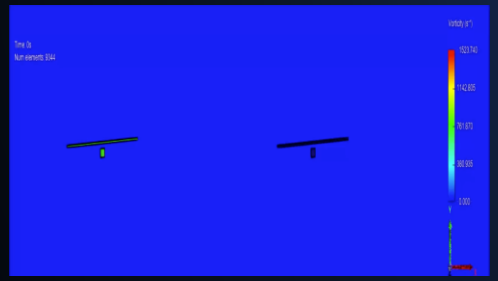
For systems relying on a highly flexible central torque tube, the change in torque applied to the row as it rotates can overpower the torque tube's ability to resist, resulting in an effect known as torsional Divergence.



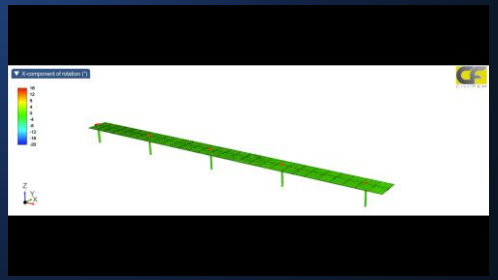
Torsional divergence Video

## FLUTTER

Flutter is a self-excited aerodynamic oscillatory instability in which the aerodynamic forces depend on the motion of the structure itself and can lead to very large amplitudes in torsional motion or coupled torsional and vertical motions.

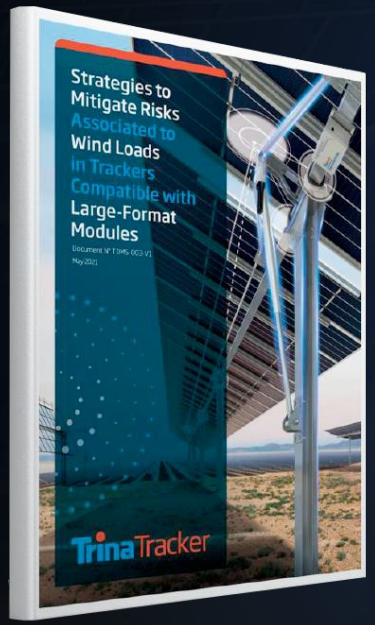


Buffeting Video



Flutter Video

# TRINATRACKER WIND TESTS IMPLEMENTED BY THE TWO WIND ENGINEERING CONSULTANCY LEADERS




## RWDI
(Rowan Williams Davies & Irwin Inc.)

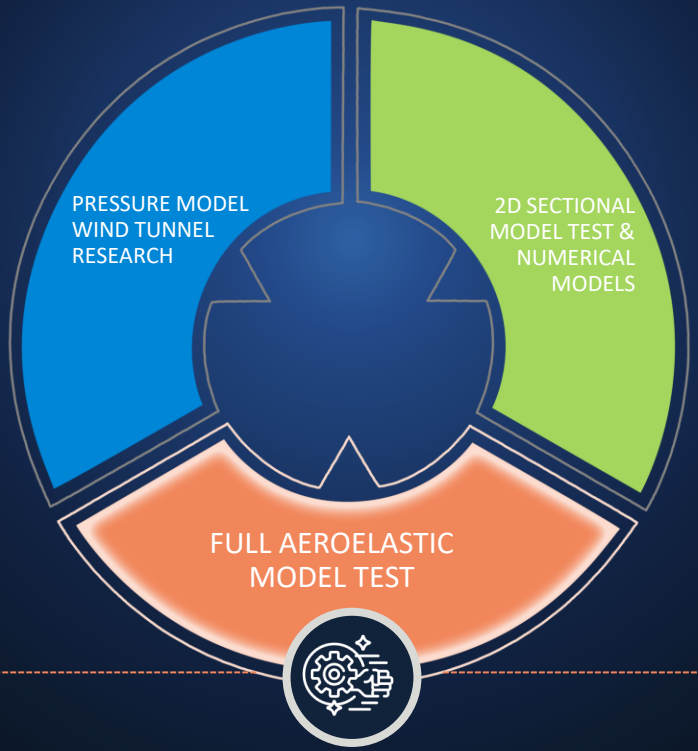
- ✓ Global leading wind engineering company established in 1972
- ✓ Offices in Canada, USA, United Kingdom, India, China, Singapore and Hong Kong
- ✓ State-of-the-art wind tunnels and models
- ✓ RDWI use sophisticated tools and proprietary data sets include wind tunnels, computational fluid dynamics modelling, extensive meteorological databases and solar modelling tools

## CPP
(Cermak Peterka Petersen Inc.)

- ✓ Internationally renowned wind engineering firm founded in 1981
- ✓ Wind tunnels in Colorado, USA and Sydney, Australia and offices in key regions around the world
- ✓ Pioneered many of the current best practices design for wind.
- ✓ CPP is the largest, most experienced US wind engineering company.

# THE MOST COMPLETE TEST PERFORMED IN THE HIGHEST TECHNOLOGICALLY ADVANCED LABORATORIES

- ✓ TrinaTracker carried out an additional 2 Sectional Model test that allow to calculate critical wind speed not only for the exact prototypes tested but for a variety of different tracker parameters
- ✓ The data gathered from the Full Aeroelastic Model Test corroborates the output obtained from the 2 Sectional Model Test and Numerical Models.



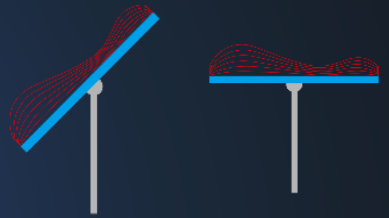

## HIGH-TECH WIND TUNNEL Laboratories

- ✓ Boundary layer wind tunnel
- ✓ Test section: 7.3 m wide - 2.4 m high & 22.5 m long.
- ✓ Modern closed-return wind tunnel with a horizontal circuit that operates at atmospheric pressure and constant temperature.
- ✓ Wind tunnel contraction ratio1.9:1 and 1:20
- ✓ Speed range is 0.5 to 15 m/s.

# PRESSURE MODEL WIND TUNNEL RESEARCH

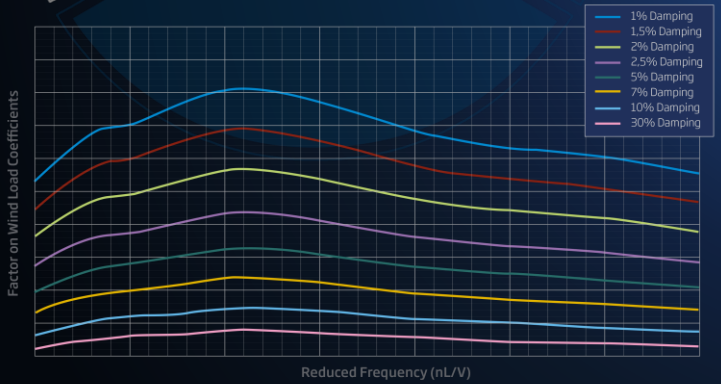
PRESSURE MODEL WIND TUNNEL RESEARCH

**DAF**
Dynamic Amplification Factors



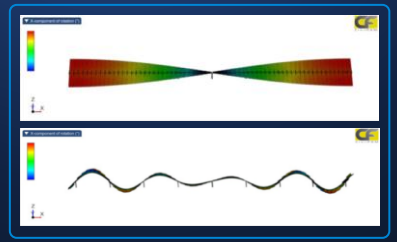
$$F_N = q \times (CP_{Static} \times DAF) \times A$$

$$T_{torque} = q \times (CP_{Static} \times DAF) \times A \times L$$




ADDITIONAL **INPUT DATA** REQUIRED TO OBTAIN DAF

Definition of natural frequencies



ADDITIONAL **INPUT DATA** REQUIRED TO OBTAIN DAF

Free vibration test - damping ratio

# 2D SECTIONAL MODEL TEST & NUMERICAL MODELS

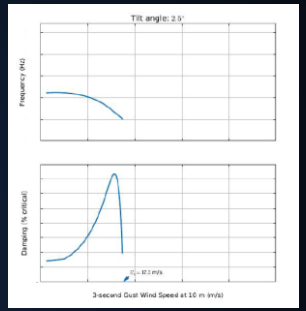

## Additional Model

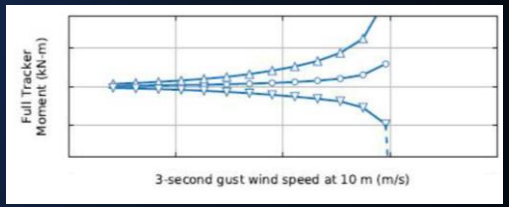
Allows to calculations with different trackers parameters

OUTPUT

## Critical wind speed to define the stow position and torsional moment

- Aerodynamic Analisys obtains dynamic actions of the wind caused by aerodynamic instability phenomena
- Buffeting Response Analisys combine mean, gust and inertial wind loads to obtain an equivalent static design wind load




Internal structural response — External dynamic load

$$[M]\{\ddot{Z}\} + [C]\{\dot{Z}\} + [K]\{Z\} = \{F\}_{SE} + \{F\}_{BUFF}$$

# ADDITIONAL FULL AEROELASTIC MODEL TEST

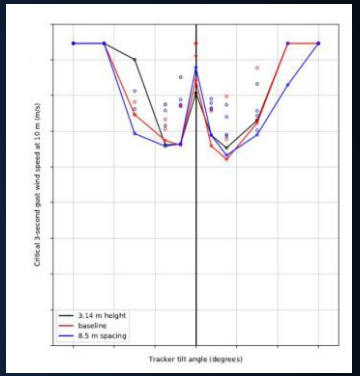
FULL AEROELASTIC MODEL TEST

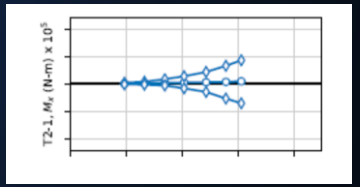
Corroborates the output obtained from the 2 Sectional Model Test and Numerical Models

OUTPUT

## CRITICAL WIND SPEED THAT DEFINES STOW POSITION AND TORSIONAL MOMENT

- Full Aeroelastic Model results validate the data obtained from the 2D Sectional Model Test and Numerical Tests.

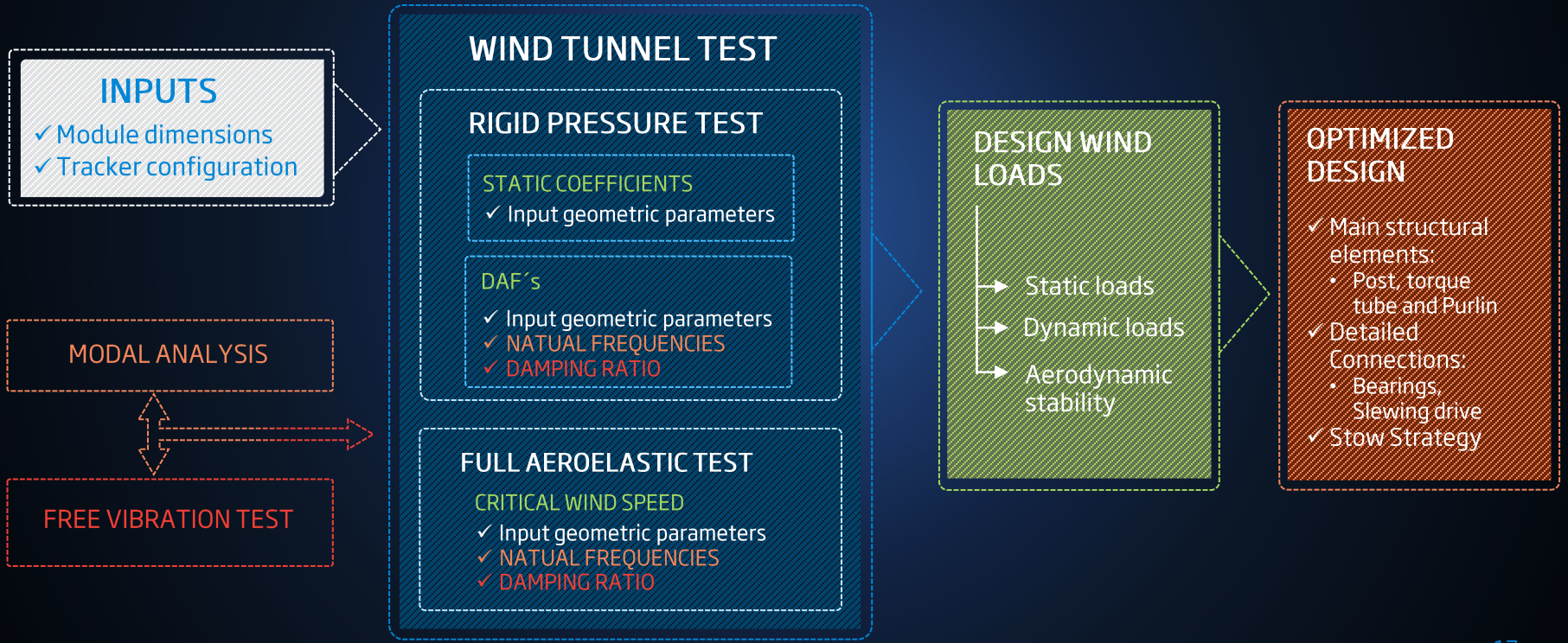



Flexible model test Video

# CONTENTS

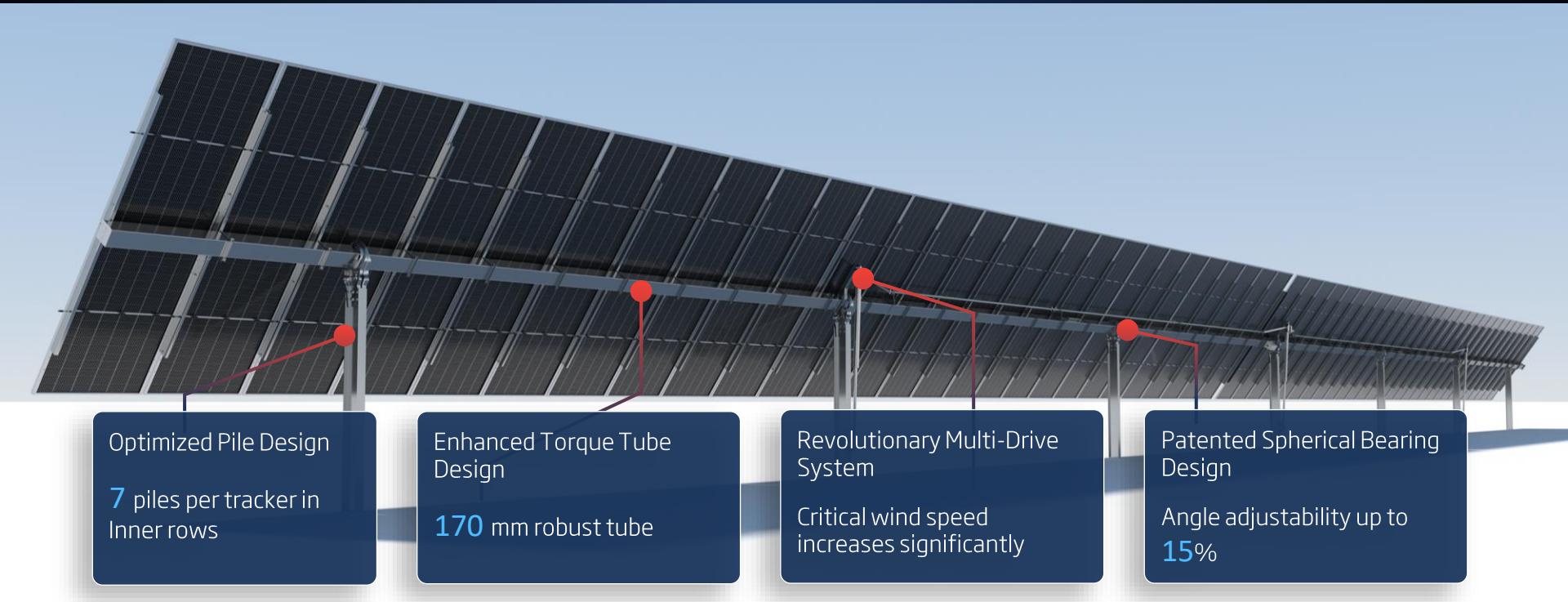
# WTT: VALIDATES TRACKERS' STABILITY, DRIVES NEW SOLUTION DEVELOPMENTS AND GUIDES DESIGN ADAPTATION TO THE SITES



# Vanguard™ 2P OVERALL PERFORMANCE

- Compatible with all Modules
  400W to 670W+
- Tracking Range
  ±55°(110°)
- Upgraded 2-in-Portrait Design
  Up to 4 String / 120 Modules Per Tracker
- Flexible Terrain Adaptability
  Up to 15% N-S
- Higher Power Density
  Up to 68KW Per Tracker

# Vanguard™ 2P KEY COMPONENTS



**Optimized Pile Design**

7 piles per tracker in Inner rows

**Enhanced Torque Tube Design**

170 mm robust tube

**Revolutionary Multi-Drive System**

Critical wind speed increases significantly

**Patented Spherical Bearing Design**

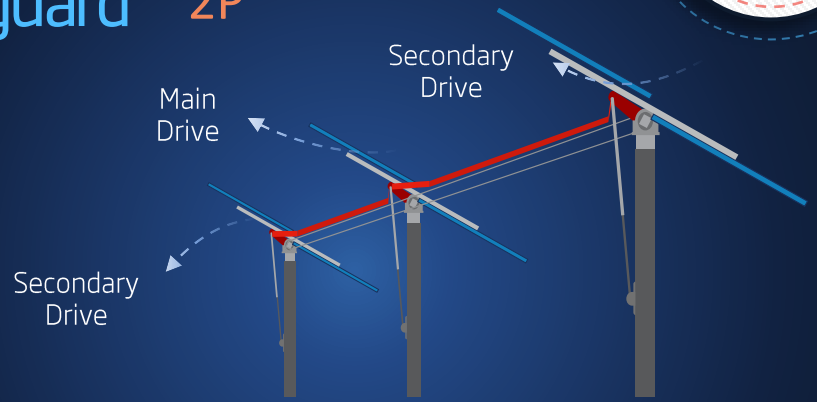
Angle adjustability up to 15%

TrinaTracker

# INCREASING SUPPORT

Stability
Reliability

## Vanguard™ 2P




**Single Drive** → Higher torsional loads

**Multi Drive** → Lower torsional loads

- ✓ Higher Critical Wind Speed
- ✓ Higher Power Density
- ✓ Reduce torque tube twist
- ✓ Higher torsional stiffness
- ✓ Lower aerodynamic loads

Multi-point drive has self-locking function for → MAXIMUM WIND STABILITY

TrinaTracker

# Agile™ 1P SYSTEM DESIGN OVERVIEW

**Dual**-Row
Single-Axis

**1P**
Configuration

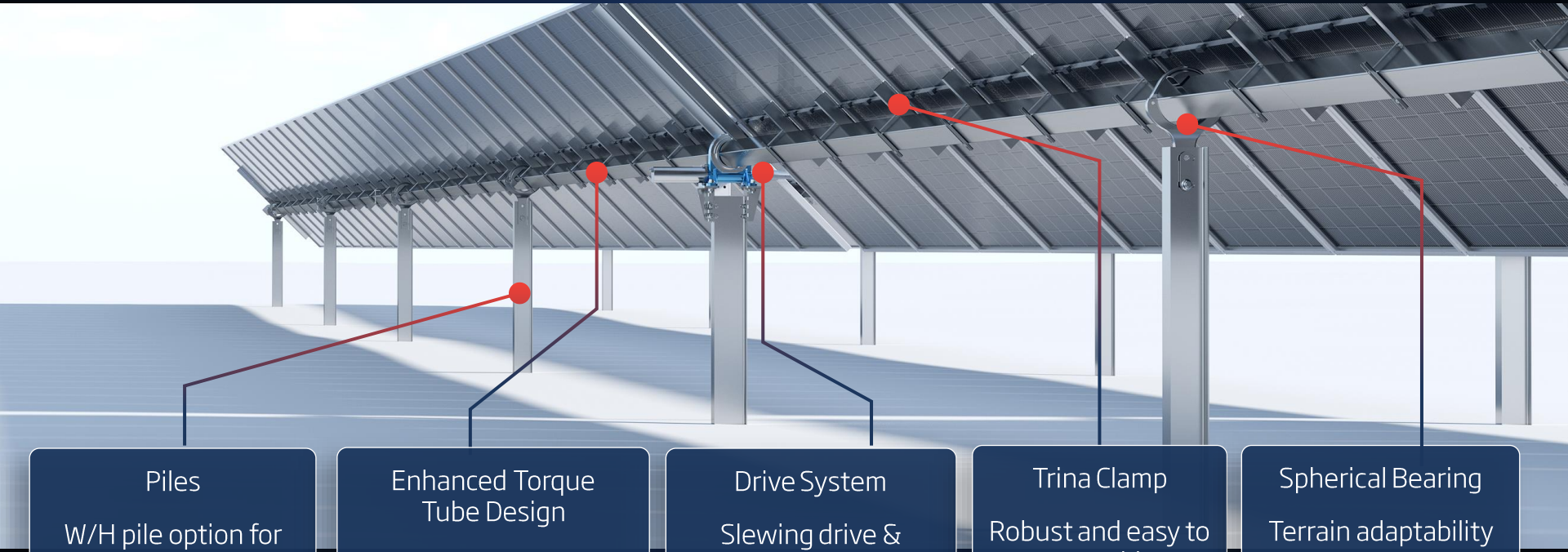
UP TO **120**
Modules per tracker

**New Drive** System
Dual Slewing Drive

Tracking Range
**±60°**(120°)

Flexible Terrain Adaptability
Up to **15%** N-S

# Agile™ 1P KEY COMPONENTS



**Piles**

W/H pile option for difficult ground conditions

**Enhanced Torque Tube Design**

120 mm robust tube

**Drive System**

Slewing drive & cardan design: simple assembly process

**Trina Clamp**

Robust and easy to assemble

**Spherical Bearing**

Terrain adaptability up to 15%

TrinaTracker

# ENSURING SAFETY SOLUTIONS

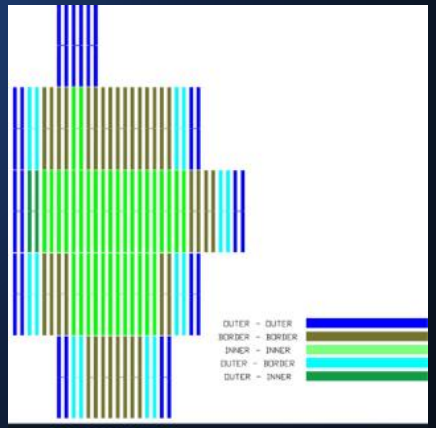
Stability
Reliability

## Wind Stow Strategy

- ✓ Vanguard 2P: Critical wind speed designed at low tilt angles
- ✓ Agile 1P: Critical wind speed designed at high tilt angles in order to achieve aerodynamically stability
- ✓ Integrated alarm systems commanded by NCU sensors and /or operator criteria

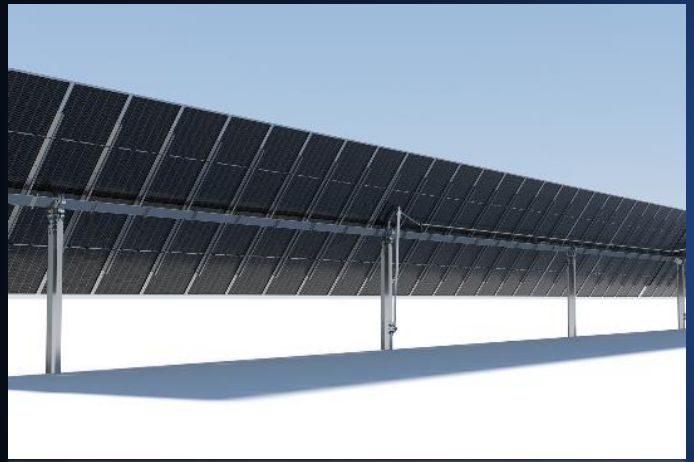
## Tailored Tracker Layout

- ✓ Mitigation of weather-related risks
- ✓ Tracker's discretization according to the location on the plant

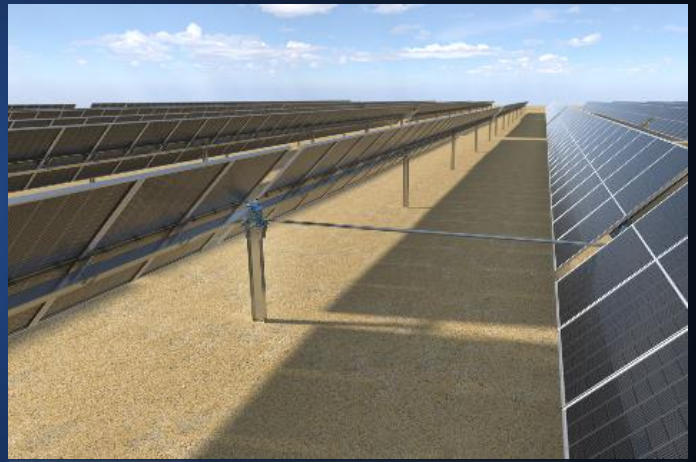


TrinaTracker

## Vanguard™ 2P Single row 2P



## Agile™ 1P Dual row 1P



DNV, leading independent energy expert and certification provider validates Vanguard 2P and Agile 1P technical advancement, high reliability and significant system performance when accommodating large-format modules 600+ Wp

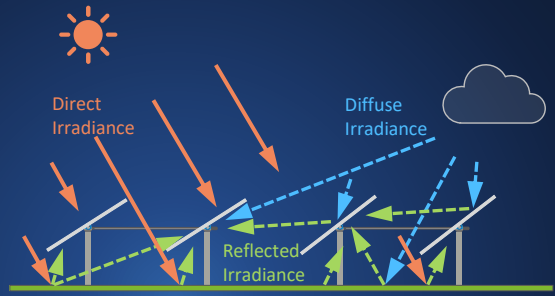
# SOFTWARE: SUPERTRACK ALGORITHM

## STA

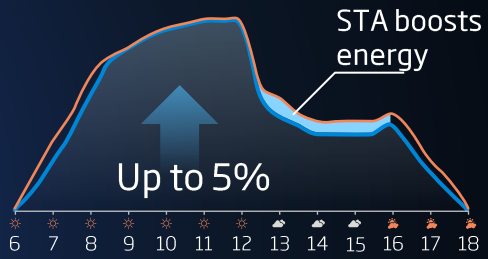
### Smart Tracking Algorithm

- Designed for bifacial modules
- Accounting for diffuse and reflected irradiance
- Always ensure optimised tracker position for max yield gain
- More effective under cloudy and overcast weather

STA can boost the energy gain by up to 5% on cloudy and overcast days




*the above diagram illustrates the application of bifacial modules

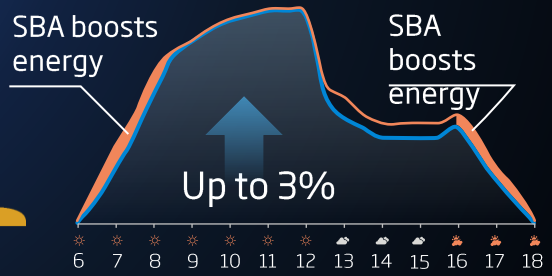



## SBA

### Smart Backtracking Algorithm

- Ensure module shading avoidance at all times
- Accounting for complicated terrain variations
- Most effective during dawn and evening periods

SBA can boost the energy gain by up to 3% during early morning and late afternoon



# SMART O&M SCADA SYSTEM*

## TrinaSCADA = Tracker Monitoring & Alarm + System Diagnosis + Intelligent Control

# LOWERING LCOE, CAPEX AND OPEX

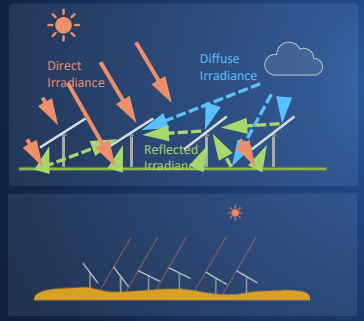
## TrinaTracker Desing

- Optimised Post Design
- Optimised Purlin Design
- Stiffer Torque Tube
- Wind, Snow & Hail Stow Alarms
- Multi-drive Sistems
- Tailored Tracker Layout

+

## High-tech Software Solutions

- SuperTrack algorithm




- TrinaScada

+

## Optimized solution & Quality control

- Components optimization
  1. N° Motors per MWp
  2. N° Actuators per MWp
  3. N° Bearing per MWp
  4. N° TCUs per MWp
  5. N° Bolted unions per MWp
- Quality control


=

- Low BOS cost
- Low O&M cost
- High energy yield

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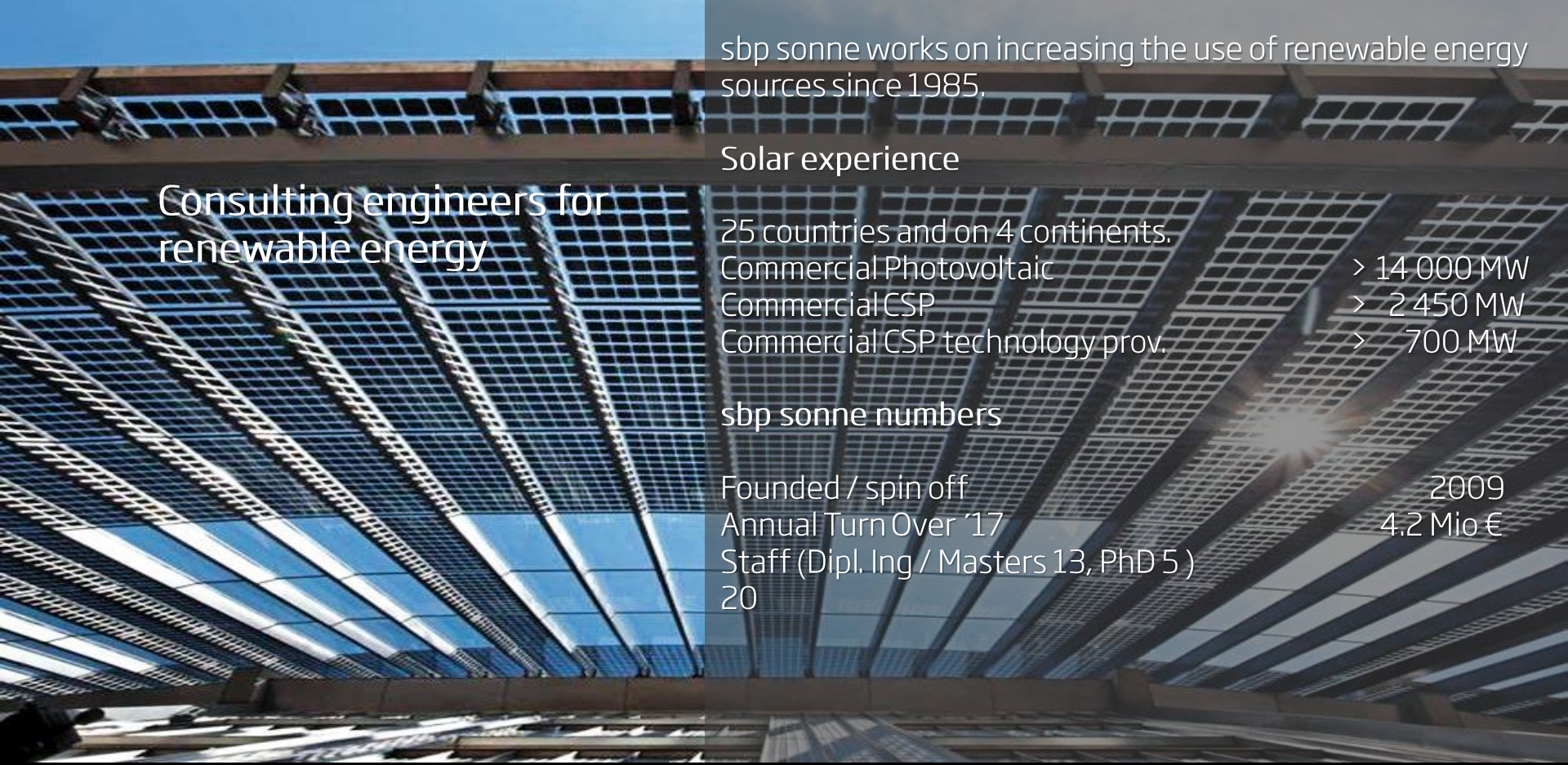
# sbpsonne

Structural Engineering Experts

schlaich bergermann partner - sbp sonne gmbh



# Consulting engineers for renewable energy

sbp sonne works on increasing the use of renewable energy sources since 1985.

## Solar experience

25 countries and on 4 continents.

| | |
|---|---|
| Commercial Photovoltaic | > 14 000 MW |
| Commercial CSP | > 2 450 MW |
| Commercial CSP technology prov. | > 700 MW |

## sbp sonne numbers

| | |
|---|---|
| Founded / spin off | 2009 |
| Annual Turn Over '17 | 4.2 Mio € |
| Staff (Dipl. Ing / Masters 13, PhD 5 ) 20 | |

# Consulting engineers for renewable energy

sbp sonne designs and optimizes solar applications

## Photovoltaic systems

- fixed tilt,
- one and two axis tracking,
- building integrated photovoltaics (BIPV),
- we further develop Argi PV and Floating PV systems

Dish-Stirling systems, Central receiver systems, Parabolic trough and the solar updraft tower technology are the large scale Concentrated solar power applications.

Our highly qualified, motivated and constantly growing team is willing to contribute in research and development of any kind of technologies.

# Consulting engineers for renewable energy

Structural Engineering

Mechanical Engineering
- Drives
- Thermodynamics

Electrical & Cabling Engineering
- Control system
- PV solar field

Series Production / Automotive mass manufacturing

Software Development
- Energy output optimization
- FEM
- Optics & solar tracking

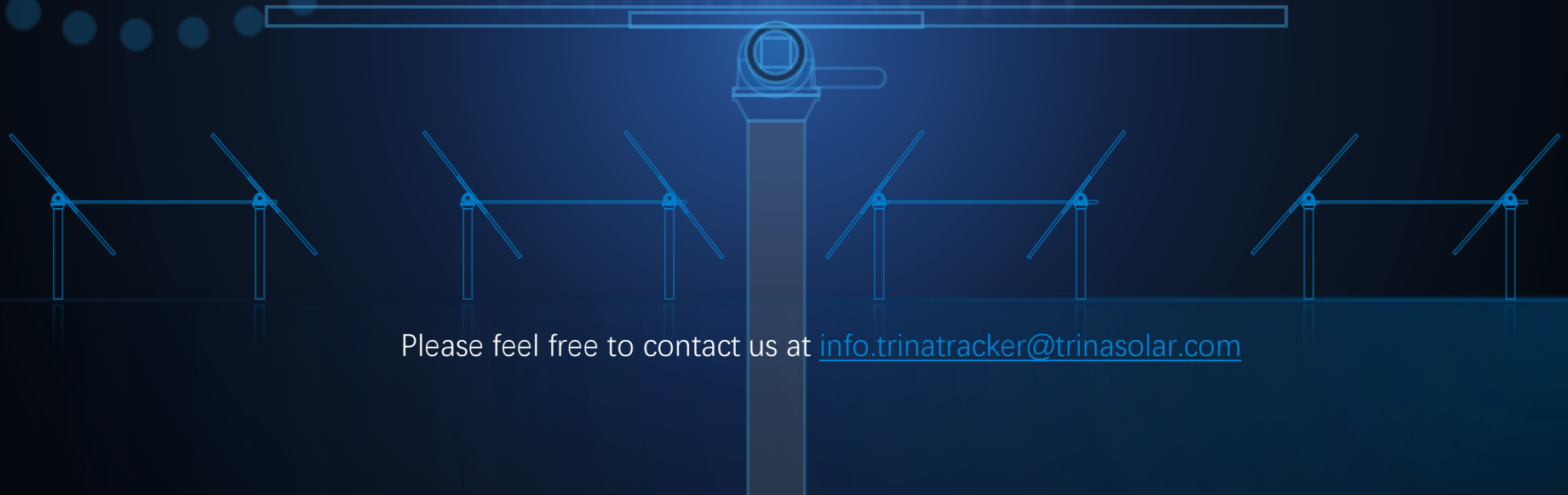
Meteorology
- Solar radiation and wind statistics

# sbps check of Trina Vanguard 2P system

The Vanguard Multi Drive system ensures:

- Vanguard enables that the torsional moments are shared between several posts (without having to take the soft load path to the drive via a long torsion tube)
  - Result in a high torsional stiffness, preventing most aerodynamic instabilities (divergence)
  - The high natural frequency that can be achieved reduce the susceptibility to forms of aerodynamic instability and thus allow a zero-degree stow strategy without excessive rocking
  - The zero degree stow strategy can minimize capex

# THANK YOU!



Please feel free to contact us at info.trinatracker@trinasolar.com