



Proprietary and Confidential

A Practical Approach to Comparing Actual and Budgeted Production of Solar Sites: **Solar Waterfall Analysis**

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*2024 PVPMC - Salt Lake City
05/08/2024*

Univers - Bazefield

- Global software company within renewables. Roots back to 1991 as an industrial IT company
- OEM independent offering within renewables since 2010
- Market leading Bazefield Operations Management System. Based on the same foundation that has shown its scalability, performance, reliability and robustness for many clients over many years in different industries
- Support all renewable technologies
- More than 150 GW installed capacity



Alamo 7
(Texas, US)

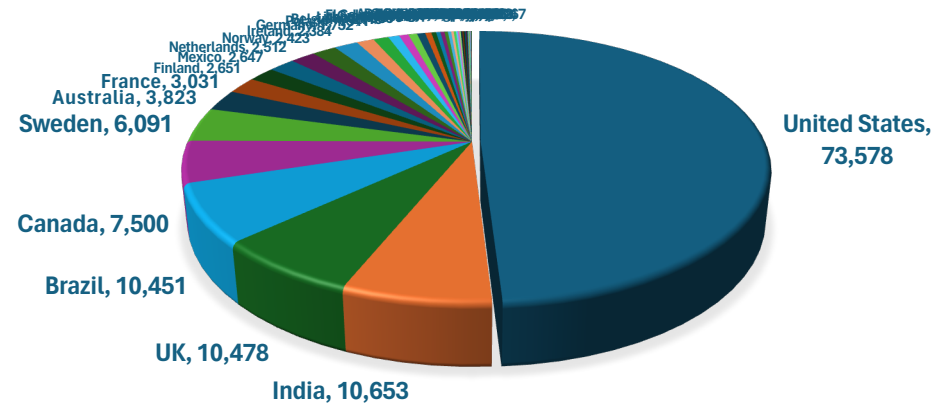


Hornsedale Power Reserve
(Australia)

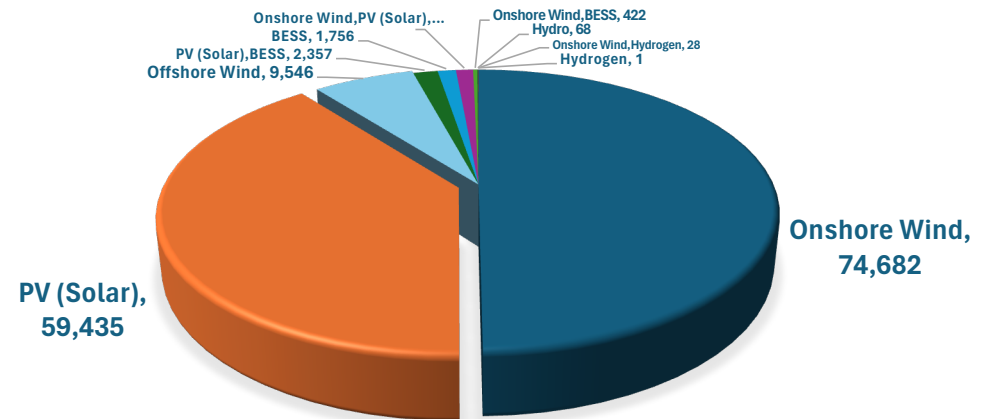


Kingfield Solar Portfolio
(Excelsior Energy, Minnesota , US)

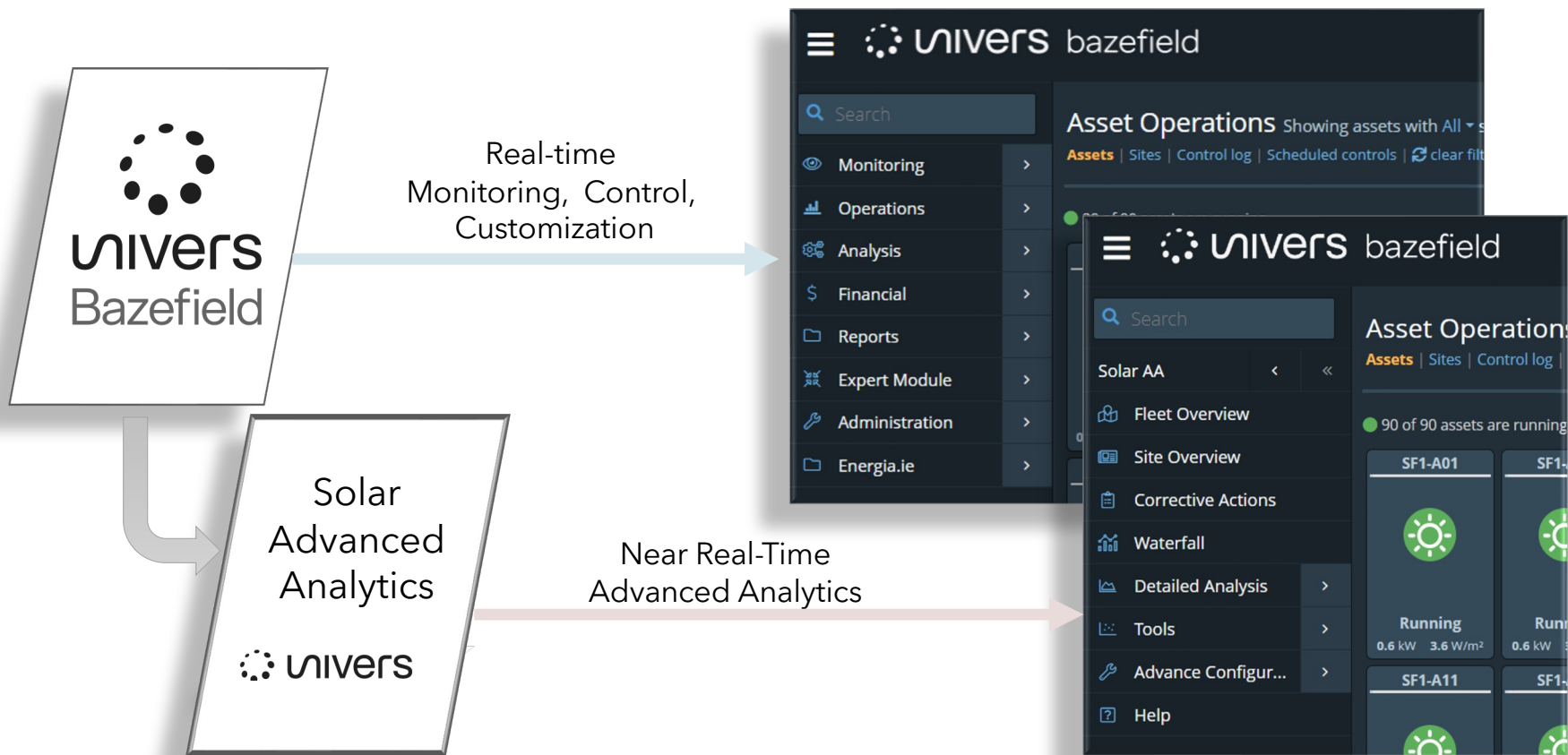
INSTALLED CAPACITY BY COUNTRY



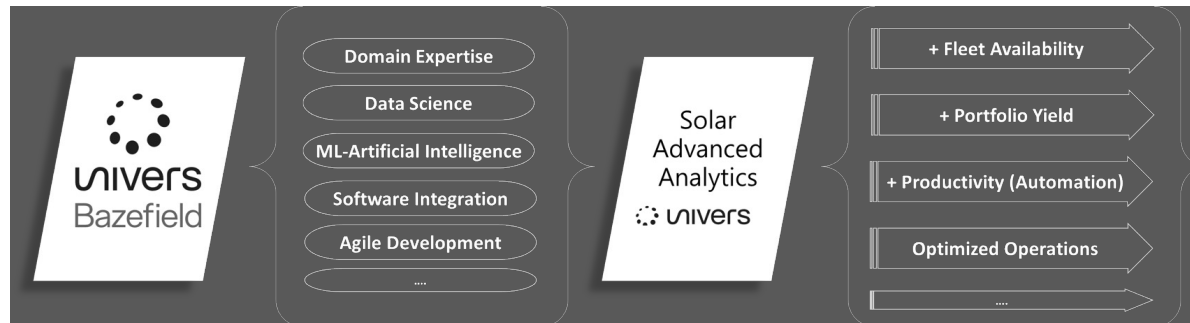
INSTALLED CAPACITY BY TECHNOLOGY INCL. HYBRID INSTALLATIONS



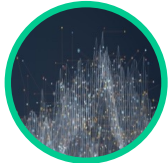
Bazefield + Solar Advanced Analytics (Solar AA)



What Solar AA is?



Raw Data



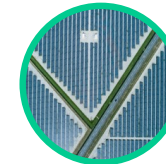
- DAS & SCADA data
- Design & config parameters
- Weather data
- Energy meters
- Inverter data
- Combiner box data
- OEM Alarms

Intelligent Analysis



- Data quality checks
- Advanced big data analytics
- Comprehensive KPIs
- Loss breakdown
- Expected power
- Sensor checks
- Downtime event analysis

Corrective Actions



- Increase generation
- Risk management
- Predictive maintenance
- Timely diagnosis
- High O&M efficiency
- O&M contract compliance

Contents

- ❖ Introduction to Waterfall
- ❖ Weather Adjustment
- ❖ Loss Breakdown
- ❖ Recoverable Production
- ❖ Conclusion

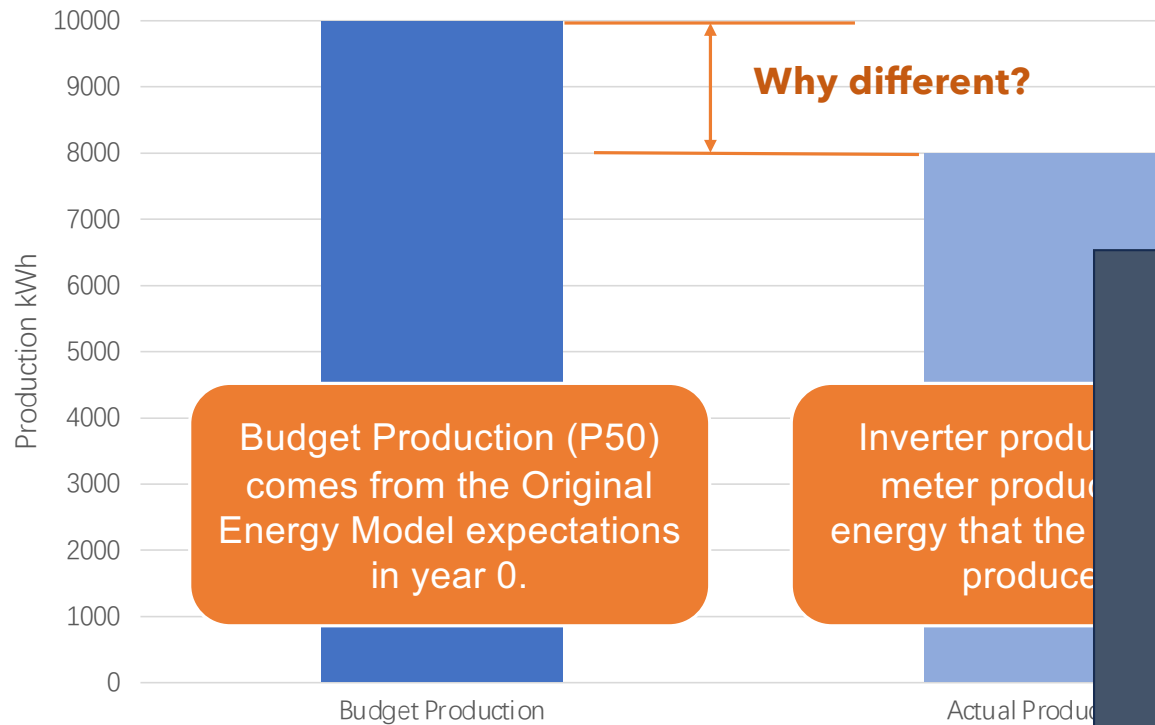


Introduction to Waterfall

Questions that every solar asset manager would ask:

- How are my solar sites performing?
- How is the actual production comparing to budget production?
- What are the causes of the delta between actual production vs budget production?

Production Comparison

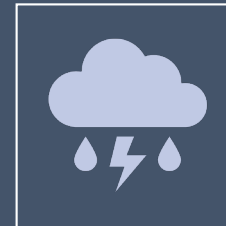


Understanding the gaps will help:

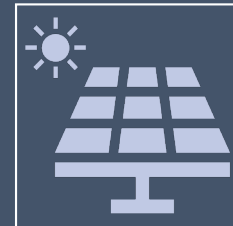
1. O&M Decisions
2. Resource Allocations
3. Better Planning

Possible Causes

Weather



Degradation



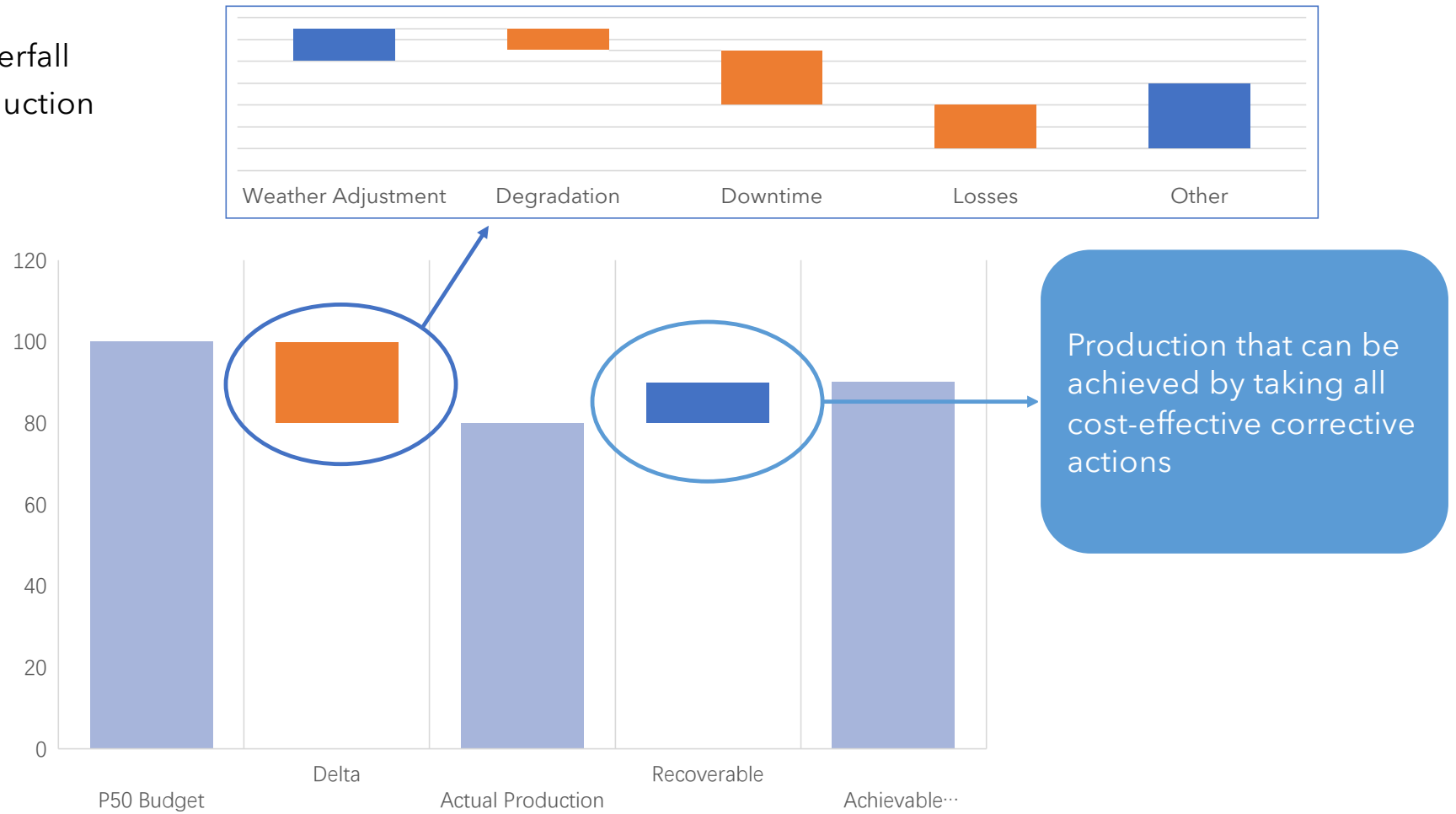
Downtime



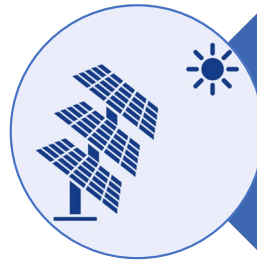
Losses



Waterfall Introduction



Solar Waterfall Chart



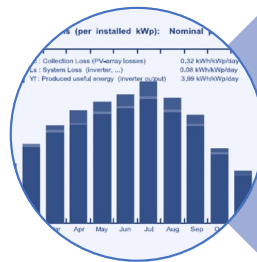
Why

- Compare Actual vs Budgeted Production
- Understand the production difference
- Potentials to improve performance



Who

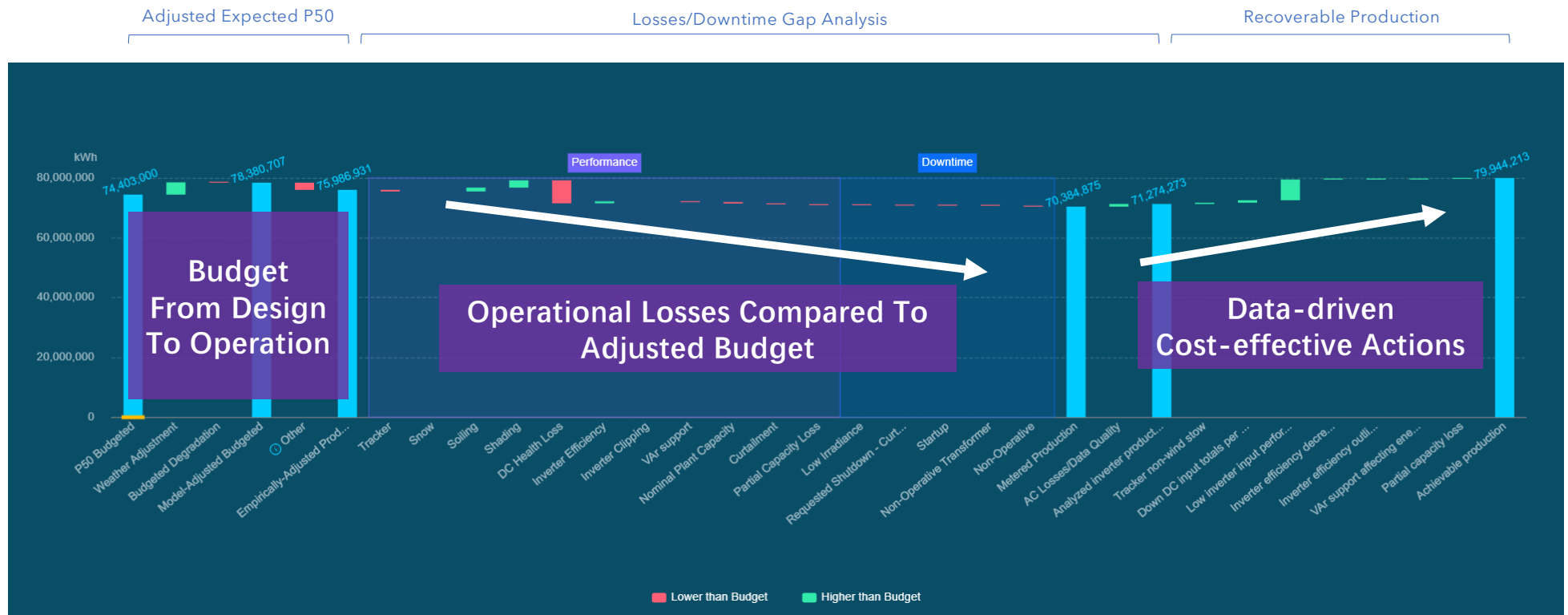
- Asset Managers
- Financial Analyst
- Performance Engineers



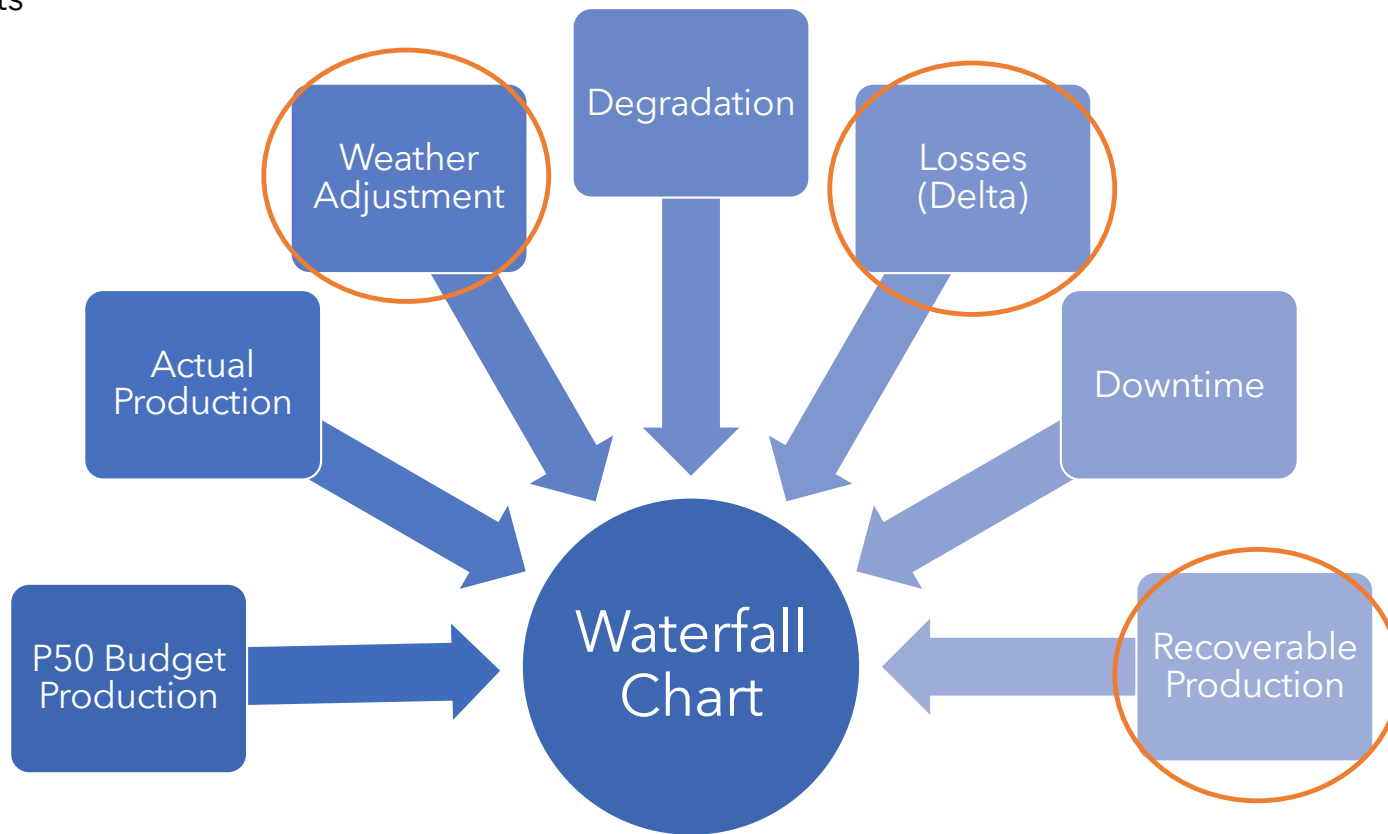
Key Components

- Weather Adjustment
- Degradation
- Loss Categories

Waterfall Chart in Solar Advanced Analytics - Full Performance Story



Waterfall Inputs



Weather Adjustment

Why Weather Adjustment?



Original energy model is usually conducted based on Typical Meteorological Year (TMY) data, which is an average weather profile of the past 30/20 years (depending on the data source).



Solar site production is highly dependent on irradiance, and affected by temperature and wind speed.



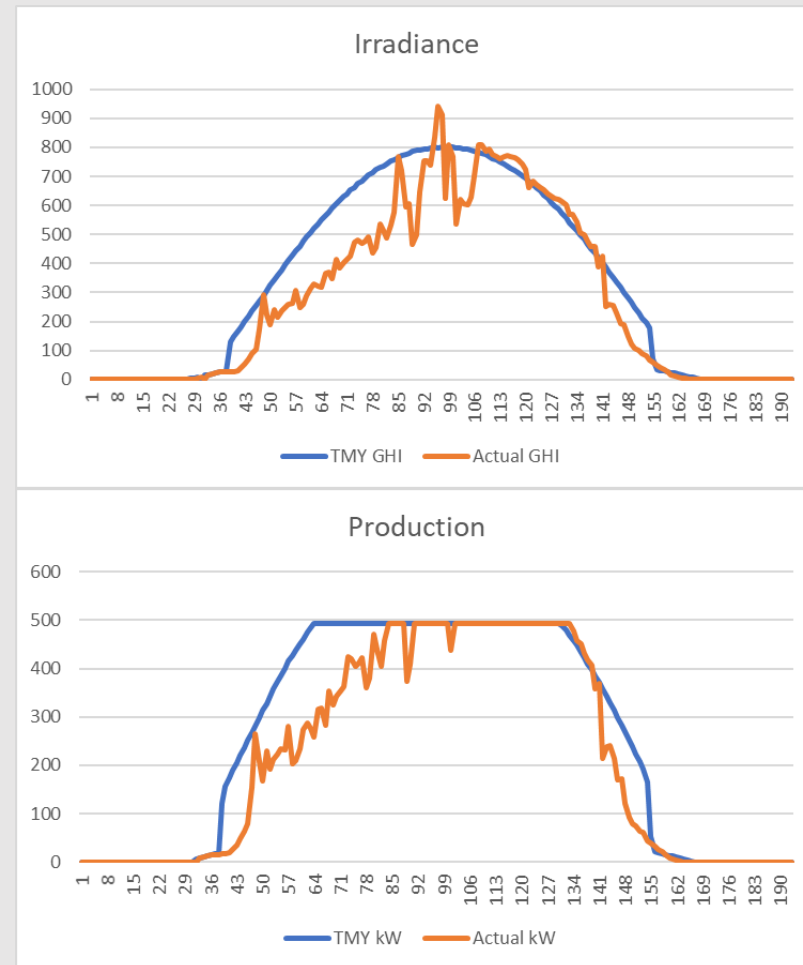
To obtain a more accurate and realistic target production, we do weather correction to the original energy model, so we know how much energy production is expected based on the actual weather.

Common Approach of Weather Adjustment

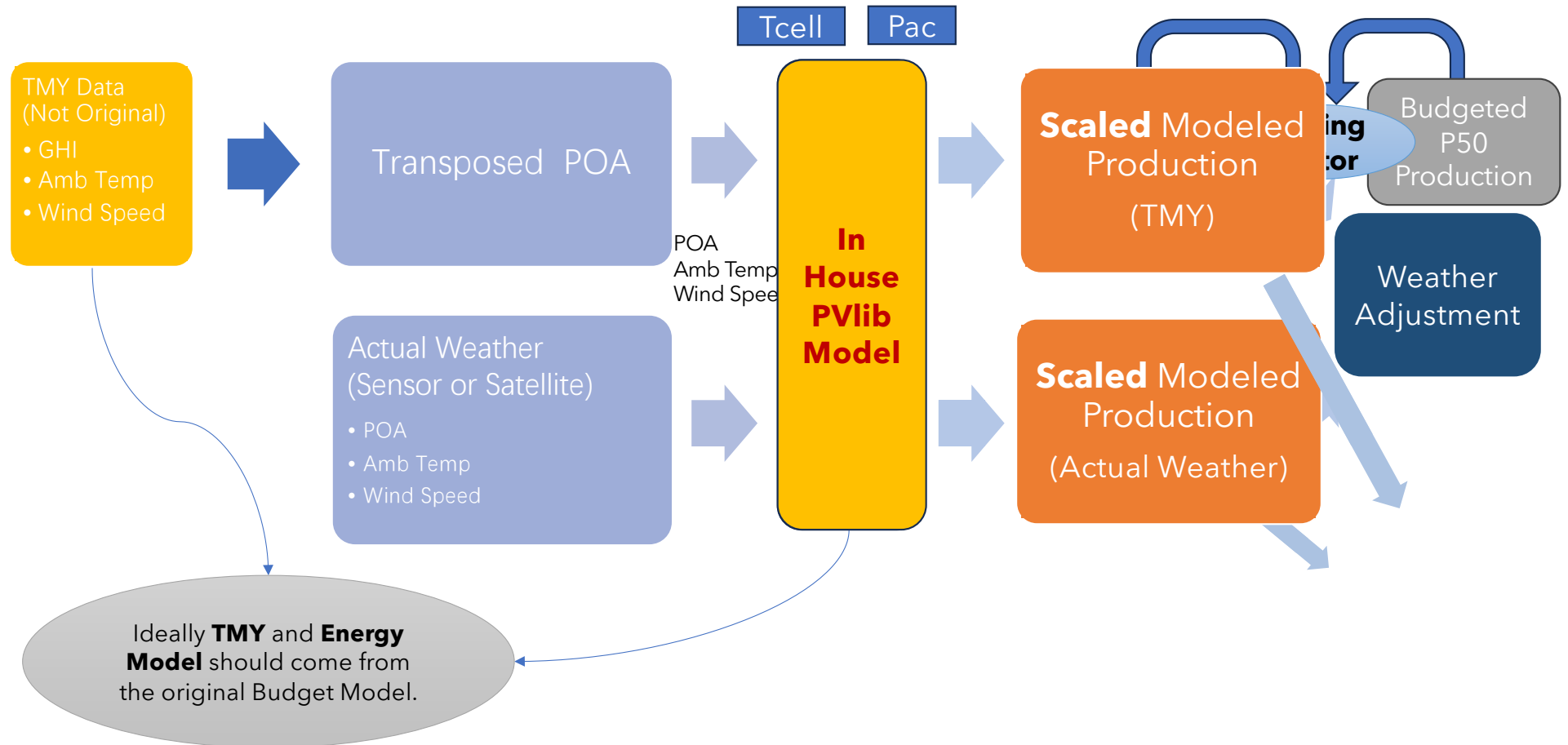
**Adjust solely
based on
irradiance**



Not
Accurate
enough



Weather Adjustment Algorithm - Practical Approach without Original Model



Reference Model Selection

1. Consistency along value chain
(design/financing/.../operations)
 - a) Consistency of Energy Model
 - b) Consistency of TMY data
2. Assumptions directly from Model
3. Better Customization



Plant and Model Performance Waterfall

Reference Model: **Simulation Model** ▼ ⓘ

In-house method based on given P50 budget

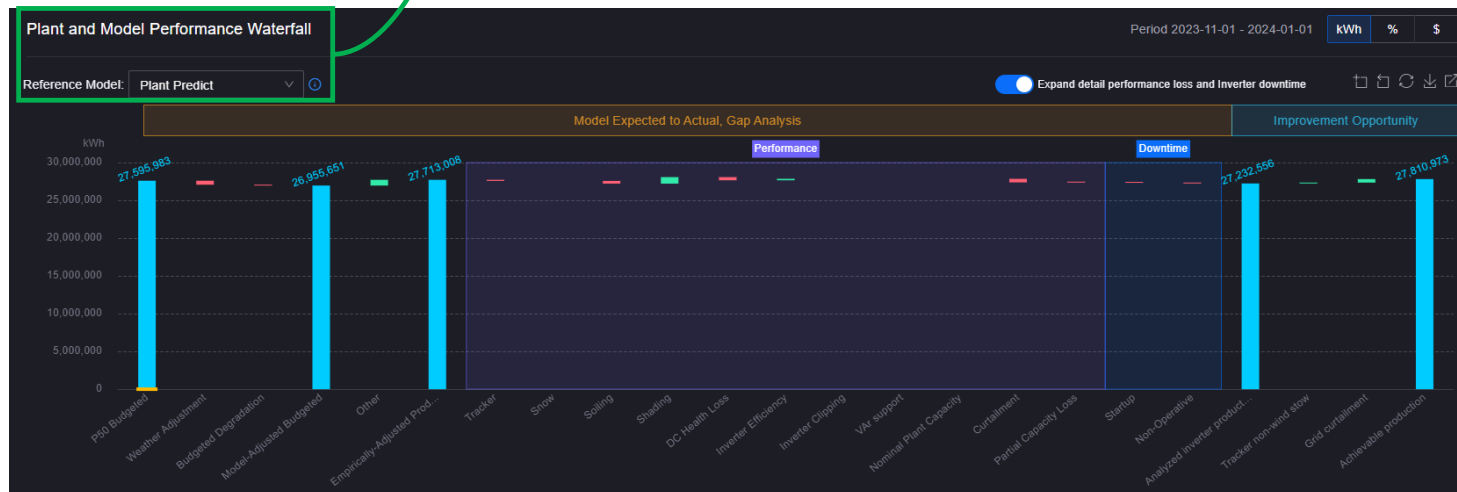


Reference Model: **Plant Predict** ▼ ⓘ

Seamless integration with 3rd party Solar design software apps

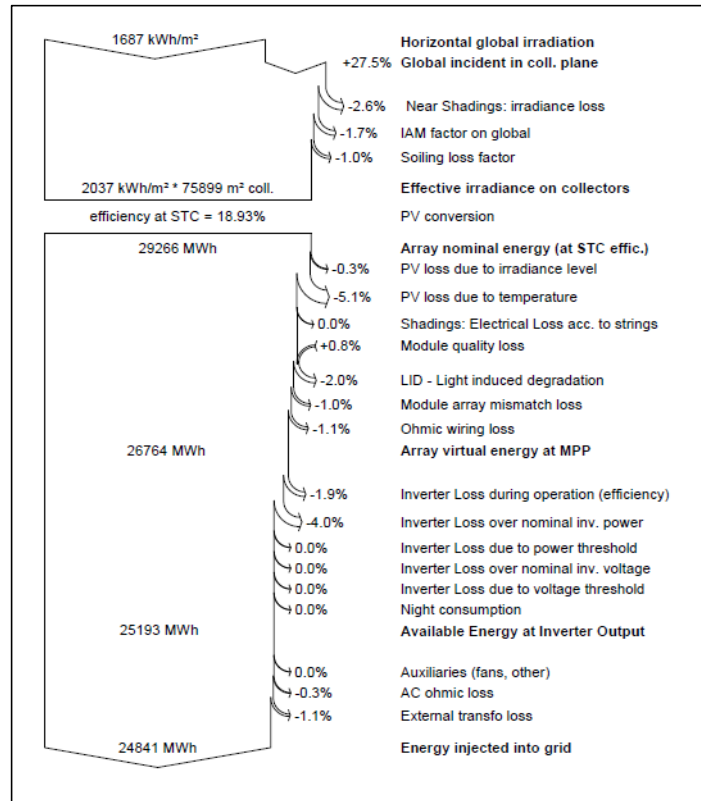


PLANT PREDICT



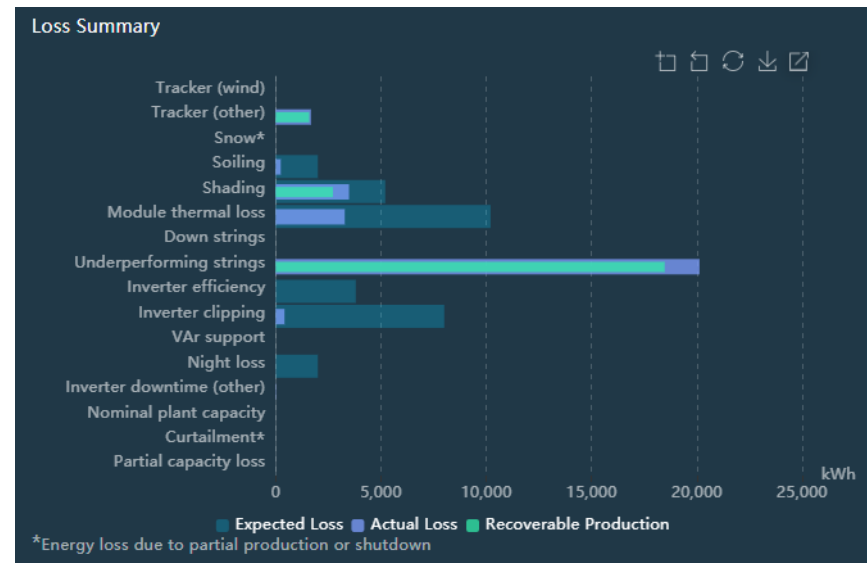
Losses Breakdown Gap Analysis

Losses Comparison (Gap Analysis)



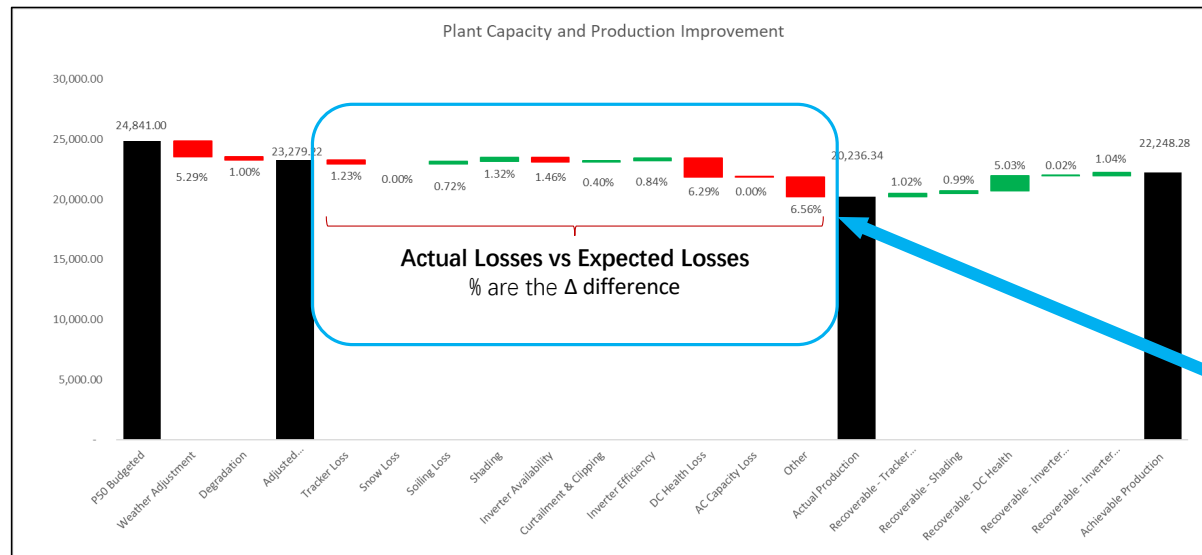
Expected Losses
From Model (PVsyst, Plant Predict, SAM, etc)

Understanding how losses are different in each category can be critical for O&M and Financial Planning



Actual Losses
From Advanced Analytics

Losses Δ difference - Example



Losses better or worse than expected?

- Is the model assumption realistic?
- Any extreme weather conditions?
- Any abnormal issues found in operations?

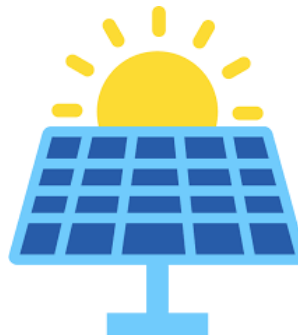
	Actual %	Model %	Model/Actual Diff
Tracker Loss	-1.23%	0.00%	-1.23%
Snow Loss	0.00%	0.00%	0.00%
Soiling Loss	-0.28%	-1.00%	0.72%
Shading Loss	-1.28%	-2.60%	1.32%
Inverter Availability	-1.46%	0.00%	-1.46%
Curtailment & Clipping	-1.61%	-4.00%	0.40%
Inverter Efficiency	-1.06%	-1.90%	0.84%
DC Health Loss	-6.29%	0.00%	-6.29%
AC Capacity Loss	0.00%	0.00%	0.00%

Recoverable Production

Recoverable production is the production that could be added to the actual production by taking all cost-effective corrective actions.



Cost to fix
an issue



Production
gained if
the issue is
fixed

(We use Payback Period to measure)



Recoverable
Production

Statistics of Recoverable Production

+450 sites

~12GW

1 year data

CORRECTIVE ACTIONS – IMPROVEMENT OPPORTUNITIES

Tracker non-wind stow
Backtracking schedule
Down string totals per inverter
Down DC input totals per inverter
Low combiner string performance
Low inverter input performance
Inverter efficiency outlier
VAr support affecting production
Inverter self-restart
Inverter down for several days
Multiple invs down for > 1 day event
Grid curtailment
Partial capacity loss

Mean Values

0.5 %
0.4 %
0.1 %
0.1 %
0.1 %
0.9 %
0.1 %
0.1 %
0.1 %
0.3 %
0.1 %
2.0 %
0.3 %

Sum Agg. w/o Curtailment

3.2 %

Sum Agg. with Curtailment

5.2 %



Conclusion

Conclusion

Waterfall analysis is a practical tool to help users understand how the **actual performance** of solar sites are **compared to the budget**.



It provides comprehensive information of **weather adjustment, loss breakdown gap and improvement opportunities**, to help asset managers make O&M decisions, resource allocations and better planning.



Integration with external modeling software is exciting and very important! It helps consistency in energy models, TMY data and loss assumptions.

Acknowledgement



Julian Ascencio

Head of Solar
Advanced Analytics



Ray Hickey

Senior Solar
Performance Engineer



Sascha Lindig

Senior Solar
Performance Engineer



Xuanji Yu

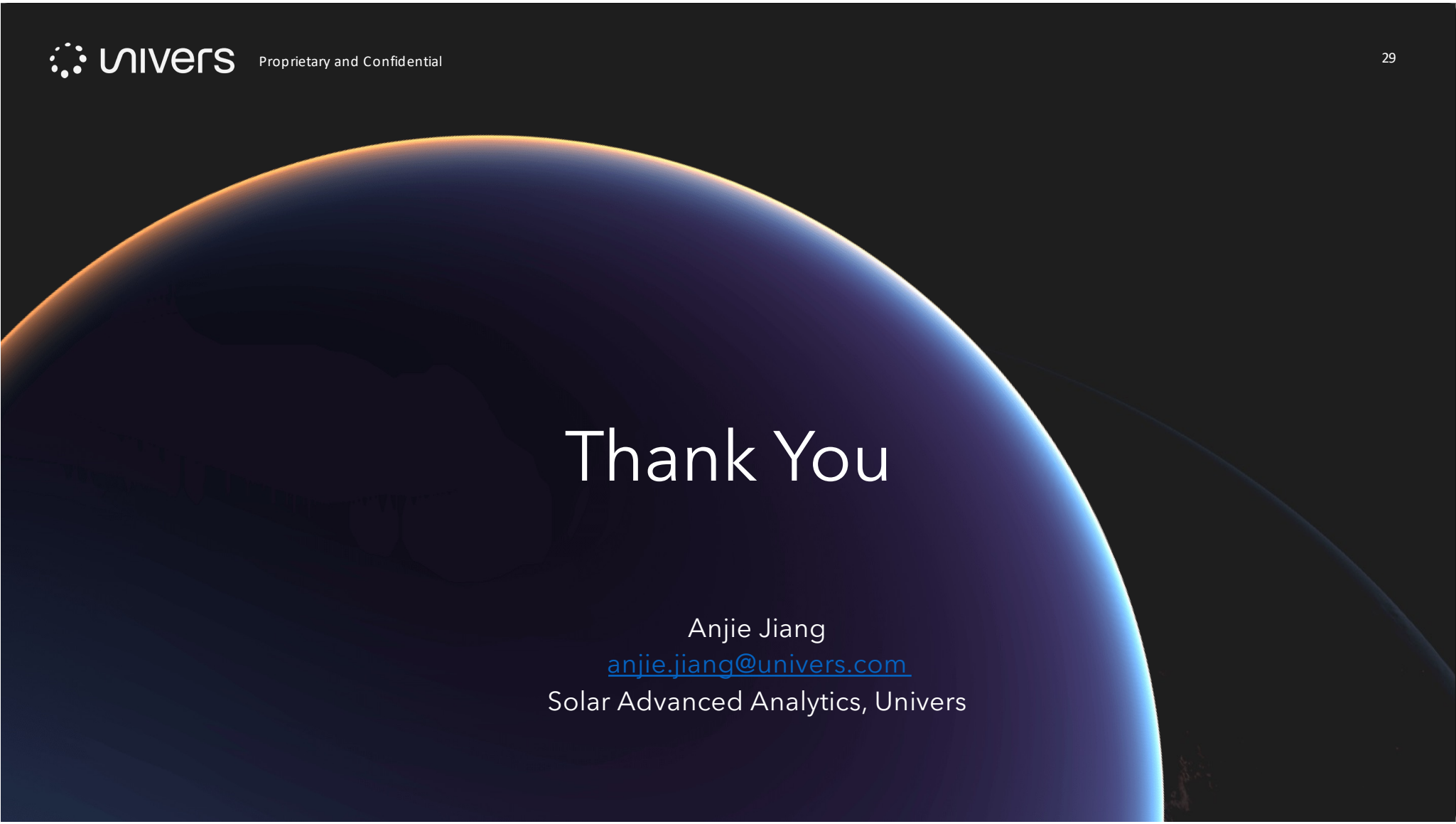
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Thanks to my team for continuous support - Solar Advance Analytics Product Team



Thank You

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