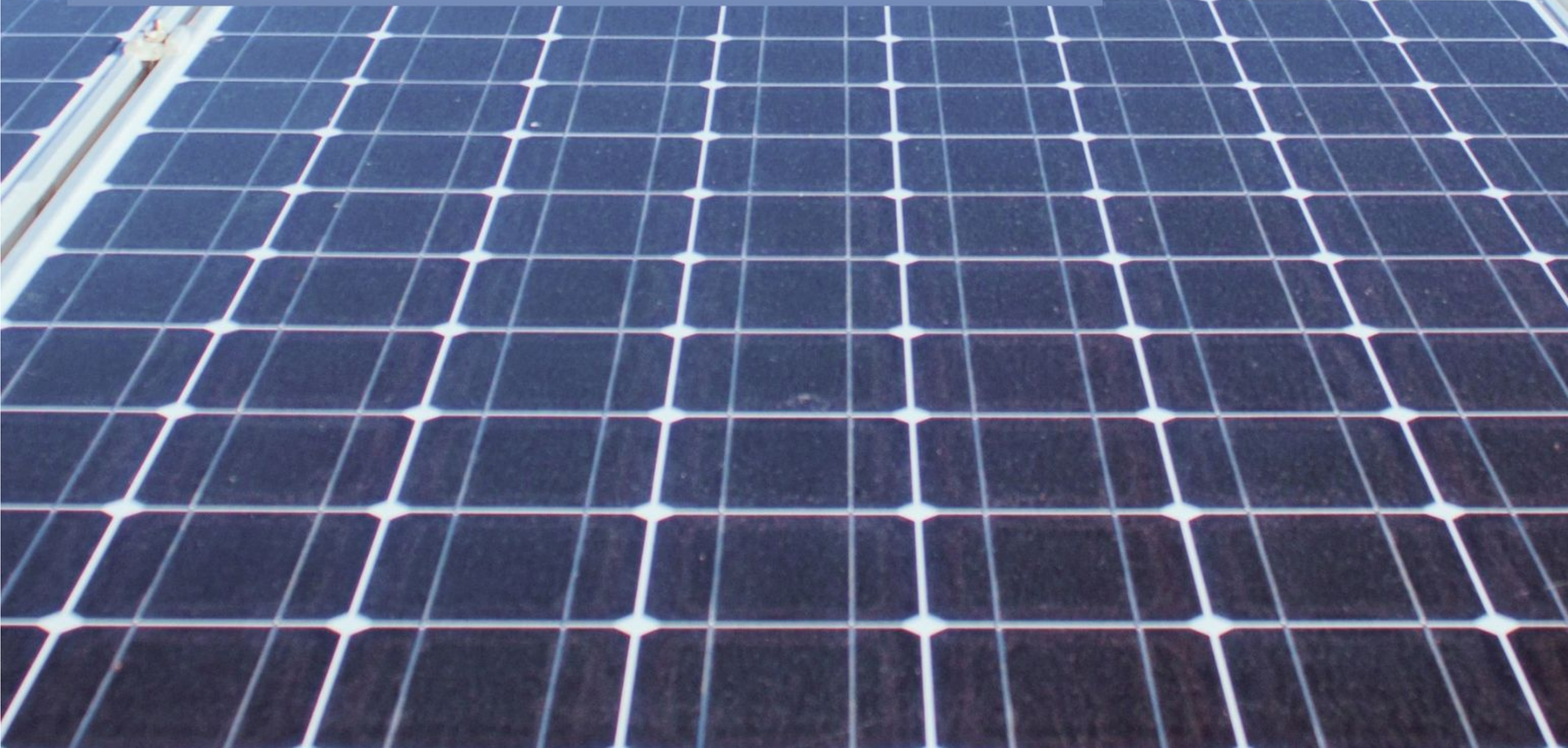
kWh analytics

SOLAR GENERATION INDEX

2022



Introduction

Despite facing significant challenges in the past year including global supply chain disruption and looming AD/CVD tariffs, the solar industry continued to deploy clean, renewable energy. The passage of the Inflation Reduction Act promises that this deployment will continue to accelerate, with some estimates targeting a 40% increase in solar development over the next five years. On the brink of such large-scale growth, it is now more important than ever that we ensure the industry is setting itself up for long-term success.

Solar assets will need to exhibit financial health and stability in order to achieve sustainable growth and secure access to necessary capital investment. In our third annual Solar Generation Index, we aim to provide a comprehensive assessment of the industry's ability to achieve stable, healthy production relative to expectation. Our hope is that the results continue to help asset owners and financiers monitor trends, benchmark performance, and improve future development efforts.

In addition, kWh Analytics generates this index to promote transparency and discussion within the industry. We hope you use the results to inform your work and look forward to the shared work of improving the solar industry.

Regards,

Jason Kaminsky
CEO, kWh Analytics

Executive Summary

In addition to refreshing the analysis presented in the 2021 report, kWh Analytics has added three new analyses to the 2022 Solar Generation Index: annual asset performance by project vintage, capacity, and mount type.

The two key takeaways highlighted in the report are:

1. Solar assets across the industry underperformed in 2021
2. Over the past ten years underperformance has impacted projects independent of capacity, region, and mount type

It is imperative that we find a way to course-correct to ensure the industry's long-term financial health. Actions stakeholders can take today include:

COLLABORATION

This report represents an example of how industry collaboration can improve transparency for everyone. To continue delivering valuable insights, we are always looking to grow our industry-leading performance database. If you are interested in contributing operational data to future analyses, please contact us at spm@kwhanalytics.com.

RISK MITIGATION

Underproduction risk affects investors and lenders throughout the industry. Smart investors should mitigate risk by reviewing modeling assumptions and ensuring production forecast assumptions are reasonable. To address residual risk, investors should consider production insurance options, including kWh Analytics' Solar Revenue Put.

Our Approach

kWh Analytics aggregated and anonymized operating data from industry contributors along with our existing Heliostats solar database to analyze the performance of utility-scale assets (defined as assets that are larger than 1MW) in the United States.

We used this data to develop an index, which compares historical actual generation versus the P50 expectations from as-built designs between 2011 and 2021. We used the P50 solar production estimates included in project financing as the basis for our comparison. This number is typically generated by asset developers and Independent Engineers using modeling software and additional assumptions found in the pro forma financial model (e.g. system availability and degradation). Financiers also use this number as the baseline for calculating expected revenue and returns on their investment. As a result, the P50 value is critical to understanding how well solar assets are performing in terms of financial returns and green electrons produced.

To ensure our comparison accurately reflected financial models, we used the following assumptions:

- **Annual system degradation:** We applied a 0.5% derate assumption
- **Annual system availability:** We applied the asset owner's assumed annual availability factor to the P50 across operational years or a 99% availability assumption when an availability factor was not provided.
- **Impact of weather:** We adjusted the results to factor in localized and temporal weather impacts by leveraging Clean Power Research's SolarAnywhere® weather database to assess weather anomalies against long-term historical averages for each asset location.

The Appendix provides additional information on our data and methodology.

CONTRIBUTORS

LEAD AUTHOR

kWh analytics

WEATHER DATA

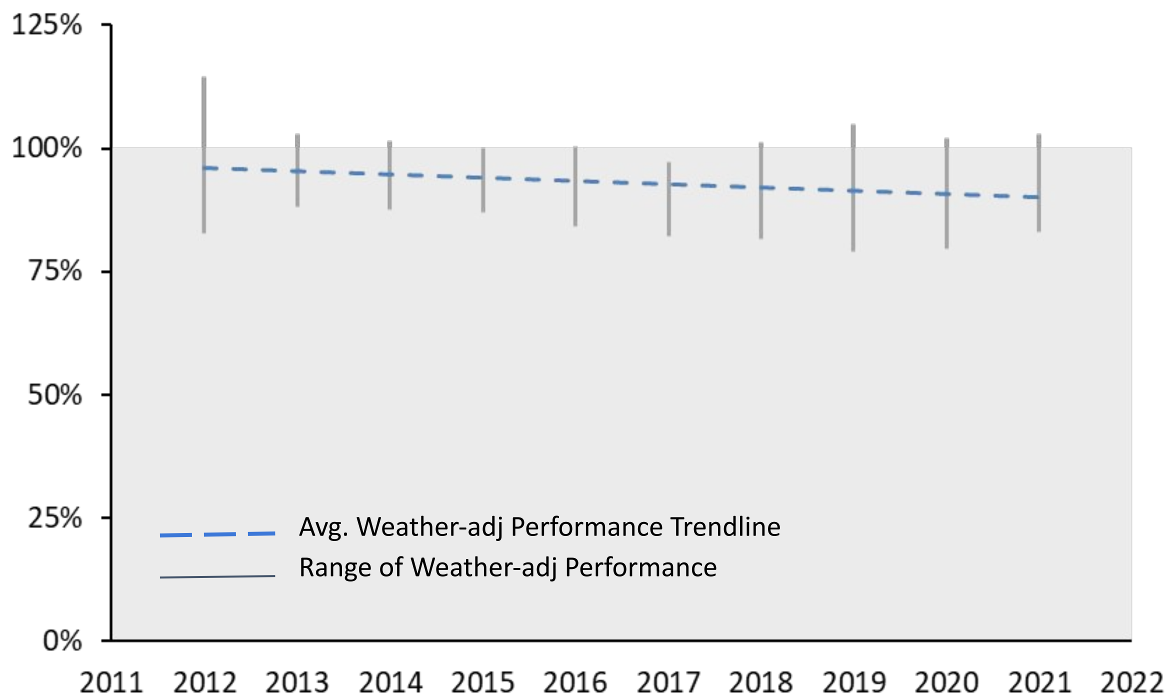
SolarAnywhere® powered by Clean Power Research

Older projects continue to outperform new builds relative to P50 estimates

With the addition of another year of data, kWh Analytics refreshed its analysis of average annual performance and performance variance by vintage - defined based on the asset's commercial operation date (COD) - from 2012 - 2021.

The latest iteration of this analysis shows that the underperformance trend identified in previous reports persisted in 2021. While the average performance of projects constructed last year represents a minor improvement compared to 2020, we continue to see newer projects performing worse than those constructed in the early 2010s relative to their P50 estimates.

Figure 1. Average Performance by Vintage



2020 and 2021 mark historically poor performance for all assets

To elaborate on the results presented in the previous analysis, kWh Analytics also evaluated asset performance by vintage and operational year. This provides a unique view of performance over time as a function of when projects were deployed.

As shown in Figure 2, effectively all project vintages experienced significant underperformance in 2020 and 2021. That being said, the past two years actually marked an increase in performance for assets constructed after 2015. These projects missed their P50 estimates in Year 1 by anywhere from 7-13%, showing little-to-no improvement in the following years.

Figure 2. Average Performance by Vintage and Operational Year

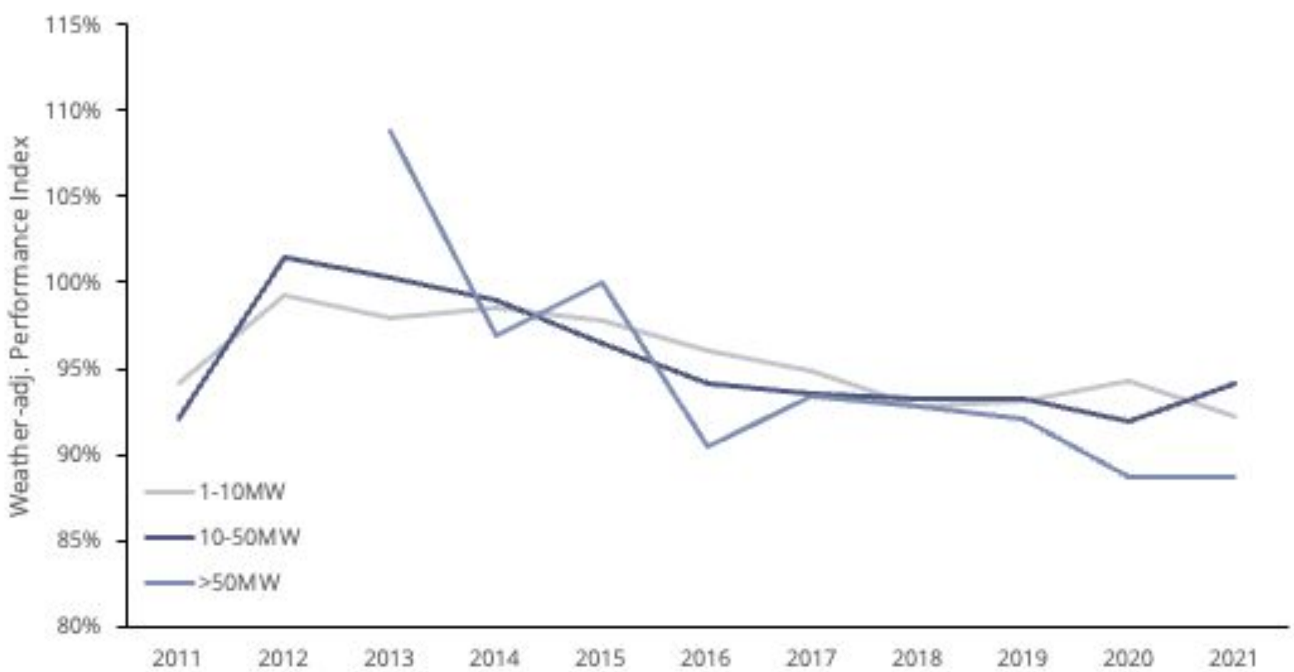
	Operational Year									
Vintage	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
2012	99%	96%	99%	94%	101%	103%	99%	100%	98%	96%
2013		95%	99%	99%	97%	96%	94%	96%	92%	91%
2014			94%	96%	96%	95%	94%	95%	93%	93%
2015				96%	94%	95%	94%	95%	91%	88%
2016					89%	93%	93%	93%	92%	91%
2017						87%	89%	88%	92%	93%
2018							89%	88%	94%	95%
2019								90%	93%	93%
2020									90%	91%
2021										93%

Assets continue to underperform, independent of system size

kWh Analytics also segmented the dataset by project capacity to investigate whether performance over time has been dependent on the scale of the asset. For this analysis, systems are separated into three groups: (1) 1-10 MW, (2) 10-50 MW, and (3) >50 MW.

The data in Figure 3 show that the downward trend in asset performance is affecting projects of all sizes. Since 2019, projects with capacity >50 MW have actually performed worse relative to their P50 estimates than projects with capacity between 1-50 MW.

Figure 3. Average Performance by System Size

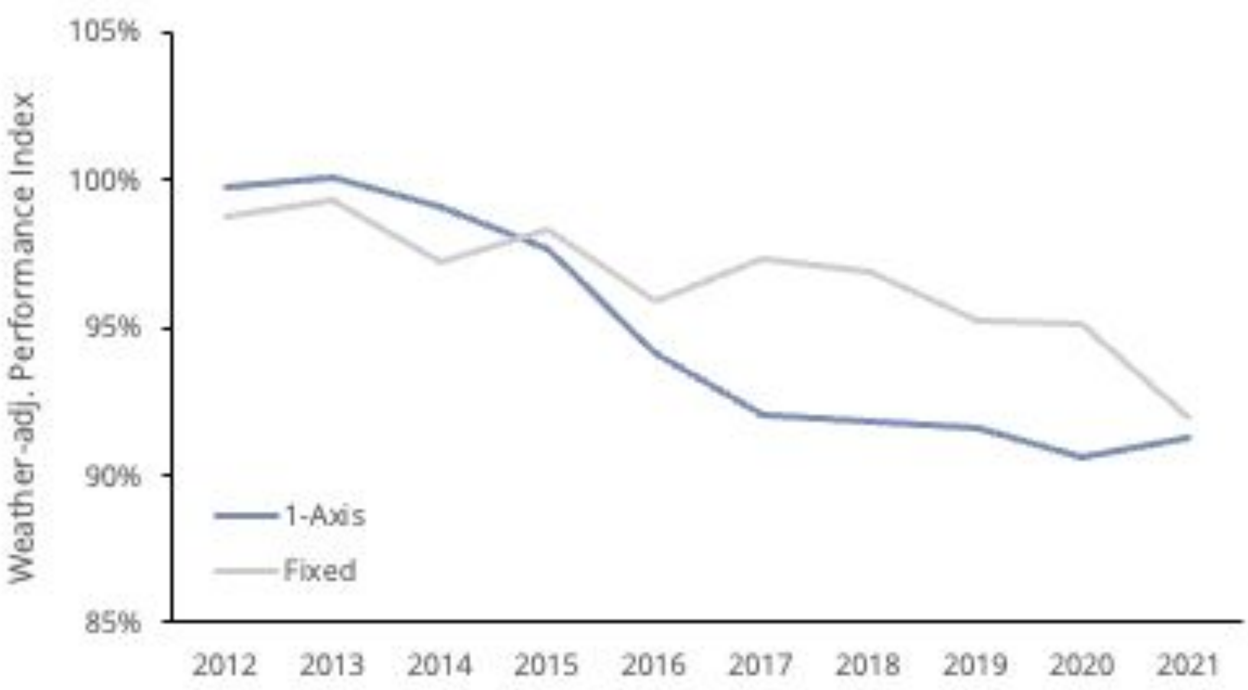


Tracker and fixed-tilt systems underperform by 8% in 2021

Recent project development has seen an increase in systems with single-axis trackers. To investigate whether the introduction of more trackers has made an impact on project performance, kWh Analytics separated the dataset by mount type - single-axis tracker versus fixed-tilt systems - and compared performance relative to P50 estimates over the past ten years of operation.

As shown in Figure 4, performance for both single-axis tracker and fixed-tilt systems have followed a similar trend. Although both have steadily declined, up until 2021 fixed-tilt systems maintained slightly better performance than single-axis tracker systems. Unfortunately, in 2021 both cohorts saw performance converge at 92% of their P50 estimates.

Figure 4. Average Performance by Mount Type, Operational Year

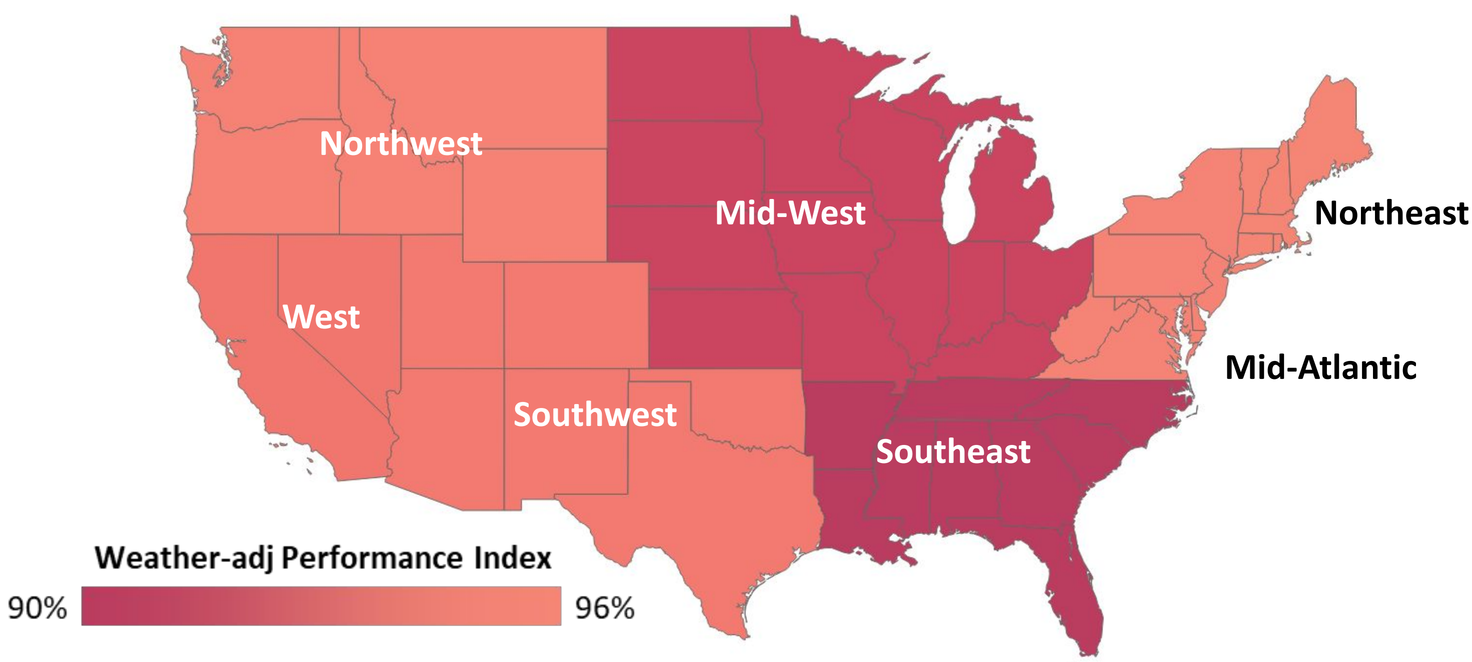


Underperformance trend is a nationwide phenomenon

Finally, kWh Analytics updated its analysis of project performance by region and operational year from 2012 - 2021.

Figure 5 shows that the underperformance trend is a nationwide phenomenon. With ten years of operational data, average lifetime performance ranges from 5-10% below initial P50 estimates across the seven regions. Year after year, performance has continued to decrease in each region, with the only exceptions in 2021 being the Northwest and Southeast regions, which improved by 1% and 2%, respectively.

Figure 5. Average Lifetime Performance by Region



Conclusion

The results are clear: solar assets are not meeting performance expectations. As the delta between actual and expected generation (and revenue) continues to grow, underperformance risk is jeopardizing investors' returns and the industry's ability to achieve sustainable growth.

It is imperative that we find a way to course-correct to ensure the industry's long-term financial health. Actions stakeholders can take today include:

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APPENDIX

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Detailed Data

kWh Analytics aggregated and anonymized operating data from industry contributors along with our existing Heliostats solar database to analyze the performance of utility-scale assets (defined as assets that are larger than 1MW) in the United States.

The data included over 500-utility scale systems and over 2,000 system-years across a ten-year period. The table below provides more detail on the type of assets included in the dataset.

Dataset Metrics	
Number of solar assets	**500+**
Number of operating years	**2,000+**
Average operating years per project	**3.7**
Maximum operating years per project	**10**
Total installed capacity [GWdc]	**11+**