Solar Risk Assessment: 2021

Quantitative Insights from the Industry Experts

kWh analytics

609 Mission Street, Fl 2 San Francisco, CA 94105 | contact@kwhanalytics.com | (415) 891-9601

Executive Summary

"In God we trust, all others must bring data." - American Statistician W. Edwards Deming

Rarely does a single investment yield both significant social and financial benefit. In this way, solar is unique: this rapidly growing asset class offers the promise of substantial returns on investment for both. Change comes gradually, then suddenly: in 2020, solar accounted for 43% of new capacity in the US, an industry record.

Rather than publishing “yet another” opinion, we -- the industry’s leading experts on the measurement and management of solar risk -- are committed to letting the data speak for itself. Designed intentionally for the non-technical solar financing community, this report has been and will continue to be refreshed every year to provide the latest insights on the evolution of solar risk.

As we release our third annual report, the data shows that the industry has significant work to do in terms of mitigating financial, operating, and natural catastrophe risks. We found:

- Project underperformance continues to worsen. This year’s contributions identify multiple causes of underperformance, including higher-than-expected degradation, terrain mis-modeling, and bankrupt manufacturers. Prudent investors will rely on these insights and actual field data to continuously calibrate their production assumptions.
- The combination of chronic project underperformance and increasing operating leverage is elevating default risk for newly issued loans, even when loans are sized at the traditional 1.30x debt service coverage ratio (DSCR). Sponsors and lenders will need to work together to structure around these difficult facts, even while still enabling projects to get built.
- Unforeseen impacts from natural catastrophes and a hardening insurance market is leading to increased exposure and costs for insurers and insureds alike. Both insurers and insureds must work together to find data-driven solutions to price, manage, and ultimately mitigate risk.

Allowing these risks to go unchecked harms investment returns and ultimately damage the industry’s collective credibility. It is now more important than ever for financiers, sponsors, insurers, consultants, lawyers, and engineers to reflect on our current trajectory and to build new solutions to manage these emergent risks.

We hope these key takeaways resonate with you and we look forward to the shared work of advancing our solar industry.

Cover Photo Credit: Nextracker NX Horizon on Javiera Power Plant, Chile. Photo: Atlas Renewable Energy.

2021 Contributors

Risk Management

Richard Matsui
Chief Executive Officer

Independent Engineer

Dana Olson
Global Solar Segment Leader

O&M Market Research

Daniel Liu
Principal Research Analyst

Power Price Market Research

Tara Narayanan
Senior Associate, Solar

Lab Testing

Max MacPherson
Associate Project Manager

Asset Management

Jackie Ahmad
Director of Technical Operations

Global O&M

Jonathan Fort, VP
Pierre-Alexandre Metaut, VP

Soiling

Catlin Mattheis, Founder
Bryan Fisher, Founder

Tracker Manufacturing

Kent Whitfield, VP Quality
Ray Casey, Sr. Director, Product Mgmt.
Alex Roedel, Sr. Director Project Eng.

Irradiance Forecasting

Skip Dise
VP of Product Management

Asset Management

Erik Orsino
Global Business Development Manager

Insurance Broker

Alex Post, SVP, Lockton Power
Peter McGoldrick, SVP, Lockton Power

Insurance Consultant

Sam Jensen
Partner

Table of Contents

FINANCIAL MODELING RISK

Topics Covered:

- **Asset Performance Trends**
- **Terrain Loss & Wind Stow**
- **Advanced O&M Techniques**
- **Equipment Material Selection**
- **Power Price Forecasting**

1-in-8 solar assets chronically underperform P99 estimates, exposing newer loans to default risk

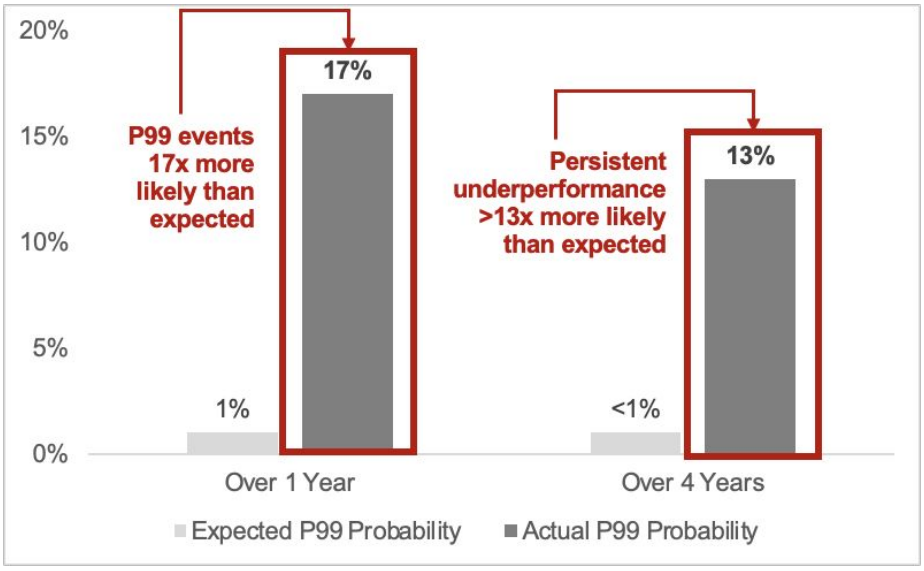
By: Richard Matsui, Chief Executive Officer & Sarath Srinivasan, Head of Risk Transfer Products

Solar financiers rely heavily on the accuracy of probabilistic scenarios (e.g., P50, P90, P99 estimates) to structure deal terms and identify appropriate risk mitigation strategies. Inaccurate estimates significantly increase the risk of default on solar loans as an asset class, meaning the project has insufficient operating cash flow to meet its debt service obligations. While only a limited number of material defaults have been disclosed to date, persistent underperformance combined with the increased operating leverage (driven by PPA rates falling faster than operating costs) is likely to drive an increase in defaults for newer vintage solar loans.

Last year's 2020 Solar Generation Index (SGI) report revealed that solar projects are on average underperforming their target production (P50) estimates by 6.3%. While the SGI report focused on average performance, the Solar Risk Assessment 2020 reported that "extreme downside ("P99") scenarios are occurring 1-in-6 years …far from the 1-in-100 per definition."

In an ongoing review of the data, we see these trends mostly continuing unabated. In fact, additional analysis reveals that many projects are facing not only one-off underperformance issues, but also *chronic* underperformance. Specifically, 1-in-8 projects persistently underperform their downside (P99) scenario over multiple years. As shown in Figure 1, **this means that projects are >13x more likely to persistently underperform over a multi-year period than expected**.

Figure 1. Expected vs. Actual P99 Performance for 1 Year and 4 Year Periods



Note: We determined the production required to meet debt service to be 87% (average P99 level) for a typical 100 MW solar project ($30/MWh PPA, $13/MWh in operating expenses, typical tax equity preferred structure, loan sized at 1.30x P50).

While projects may recover from underperformance in a single year, persistent underperformance across multiple years could drain project reserves, resulting in credit downgrades. The widespread occurrence of persistent underperformance indicates the need for industry stakeholders to be cognizant of underperformance risk and take mitigation measures, including careful scrutiny of target and downside production estimates (P50, P90, P99 scenarios).

Terrain loss and other factors can account for 2% or more of energy production losses for single axis tracker systems

By: Dana Olson, Global Solar Segment Leader

Several industry players have previously reported on the observed underperformance between actual production and pre-construction energy assessments for solar projects. Common factors that contribute to the observed energy shortfall include overly optimistic irradiance assumptions, higher-than expected equipment downtime, higher-than expected snow loss, sub-hourly clipping, tracker alignment accuracy, losses due to uneven terrain, and the impacts of tracker wind stow. We recently conducted research to quantify the losses from two of these factors in single-axis tracker systems (which comprise the majority of the US solar fleet): (1) uneven terrain and (2) wind stow.

Figure 1. Total Terrain Impact

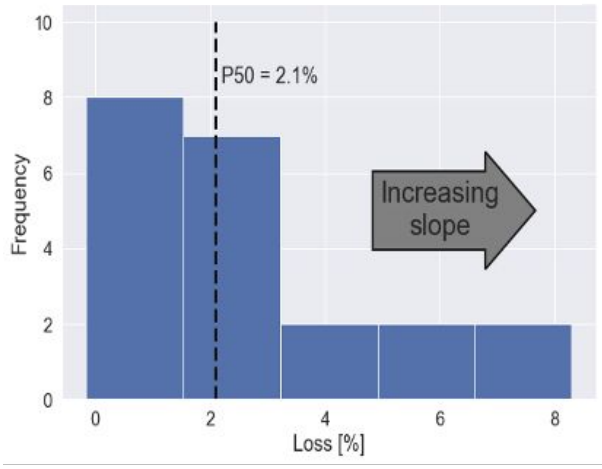
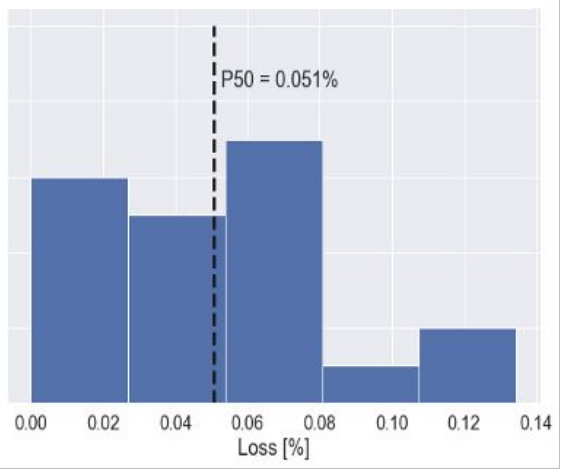


Figure 2. Total Wind Stow Impact



Terrain Loss

Uneven terrain often causes losses for north-south aligned single-axis trackers on east-west slopes and/or rolling terrain due to uneven row-to-row shading and electrical mismatch. Even the most sophisticated slope-aware backtracking cannot recover all of these losses. Furthermore, trackers installed on south- or north-facing slopes may see small gains or losses, respectively.

DNV estimated the net impact from rolling terrain by analyzing the east-west topography. Specifically, we developed a correlation between the mean absolute east-west slope, diffuse fraction of irradiance, and the ground coverage ratio (GCR) using over 200 different simulations of various combinations.[1] As shown in Figure 1, this model estimated terrain losses of over 6% in locations with increasing sloped land; the median loss was 2.1%. These losses are less likely when grading is performed, since it limits the variability in row-to-row tracker post heights.

Wind Stow

The potential for losses associated with wind stow has increasingly been raised in recent years, since adjusted tilt angles are less optimal for generating energy. However, the impact of wind stow is relatively minor when compared to other factors.

DNV developed a method to calculate annual percentage wind stow losses using typical meteorological year (TMY) data (or time-series wind speed data if available) and wind stow conditions specific to each manufacturer. Figure 2 details the losses from this analysis across the same sites used in the terrain loss analysis, showing a median (P50) wind stow loss of 0.05%, with losses up to 0.1% and over.

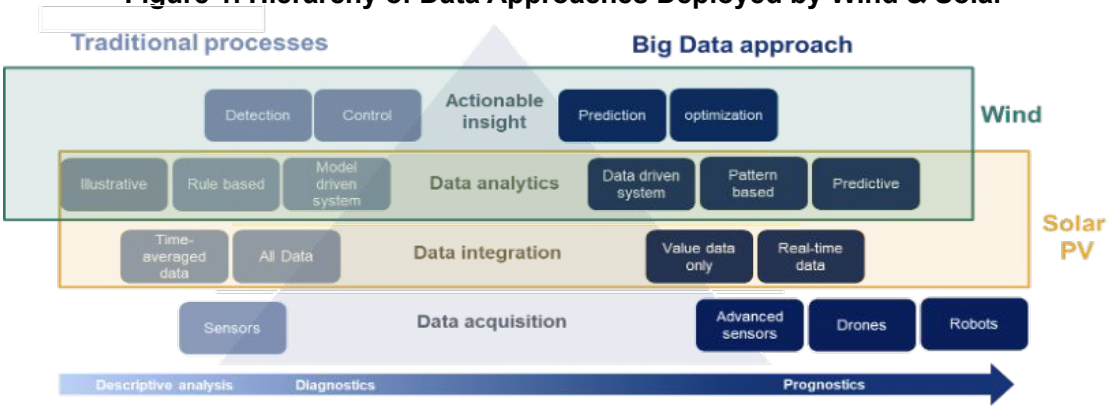
[1] DNV used topographical data from the USGS geological survey for the uneven terrain analysis. Additionally, DNV selected 21 tracker sites previously analyzed in our 2019 Solar Power Performance validation study for both analyses.

Digital and advanced technology shown to decrease inspection costs for PV by up to 60%

By: Daniel Liu, Principal Research Analyst

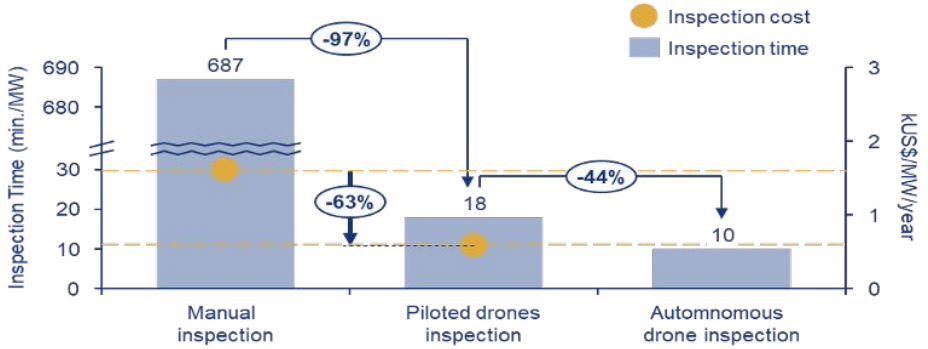
Digital technology has become an established tool of plant asset management for renewables operations, however solar lags behind wind in fully deploying these tools, as shown in Figure 1.

Figure 1. Hierarchy of Data Approaches Deployed by Wind & Solar



Deploying digital technology has several benefits, including 1) reducing production losses; 2) improving staff productivity; and 3) decreasing operating expenses, as shown in Figure 2. By not fully taking advantage of digital technology, solar plants are operating sub-optimally.

Figure 2. Estimated Time and Cost Savings by Inspection Type



Note: Cost estimates assumed on a utility scale project in the US, for a preventative maintenance inspection

The PV industry faces three challenges in achieving full deployment of digital technology:

1. Cost constrained environment: Declining bid tenders and low average PPA prices in many key markets place significant pressure on CAPEX and OPEX budgets. Asset owners in the current environment largely have limited budget to spare for digital technology.

2. Equipment and data infrastructure: Many older plants use earlier generation data monitoring and infrastructure systems, which are sometimes incompatible with the latest advanced digital solutions. Problems with translating and interpreting data, data quality and resolution add to these issues, and limited support is available from equipment suppliers & SCADA providers.

3. Lack of consistent regulatory support for cybersecurity: Finally, compliance and regulations on data privacy and sharing differ from region to region. The lack of consistent regulations adds administrative and regulatory burden on digital technology developers who are also battling asset owner concerns on data sharing and privacy.

Unlocking further digital capabilities needs considerable investment by all players. Until such issues are addressed, the industry will be unable to deploy innovative solutions without a cost increase to the end-user.

Minute differences in raw materials impact system performance by up to 5%

By: Max Macpherson, Associate Project Manager

The global solar supply chain is in flux. Between the effects of a global pandemic, significant expansions in capacity and demand, shipping container shortages, wafer size increases, and policy changes restricting imports from different regions, the price of many materials used in making solar panels is unstable.

For example, after dropping below $8/kg during the global pandemic due to oversupply, polysilicon prices have risen sharply since Q4 2020 and are expected to stay high through 2021.[i] Meanwhile regulatory factors and growing demand for dual-glass bifacial modules have caused a glass shortage. Furthermore, the solar industry will require 15% -- up from 10% today -- of the global silver supply by 2025, likely impacting prices for that material as well.[ii]

These fluctuations in prices are impacting the number of suppliers in the market, as illustrated by the recent trends in encapsulant and backsheet suppliers in Figures 1 and 2. As shown below, the encapsulant supplier market has expanded to make way for new suppliers, while the top five backsheet suppliers' market share has gradually been reduced by the remaining 33 suppliers collectively.

Figure 1. Encapsulant Supplier Market Share

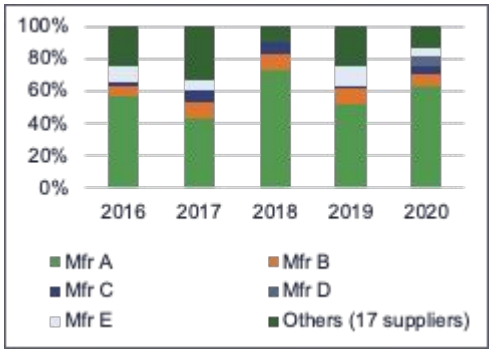
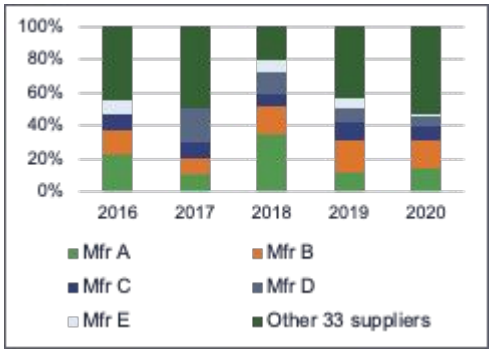


Figure 2. Backsheet Supplier Market Share



Manufacturers diversifying their supplier base is a net positive for buyers, as it drives down costs and increases supply availability. However, it also increases the need for technical due diligence and bill of materials (BOM) specification to ensure that buyers source reliable products. For instance, PVEL analyzed results from different BOMs with the same product code and found that for one manufacturer, there was a nearly five percent difference in potential-induced degradation (PID) between two BOM combinations, made with nearly identical materials, as shown in Table 1. Many site designs are susceptible to PID, so failing to procure a PID-resistant BOM could lead to significant underperformance in the field.

Table 1. Degradation Rates By Bill of Materials

BOM-1 Degradation	BOM-2 Degradation	BOM-3 Degradation
0.78%	2.82%	5.39%

Requiring independent, third-party testing and specifying the BOM(s) with the strongest lab and field performance is the best way to mitigate underperformance risk, particularly as the industry continues to undergo rapid change and exponential growth.

[i] Exawatt. (2021). Internal research. https://www.exa-watt.com/

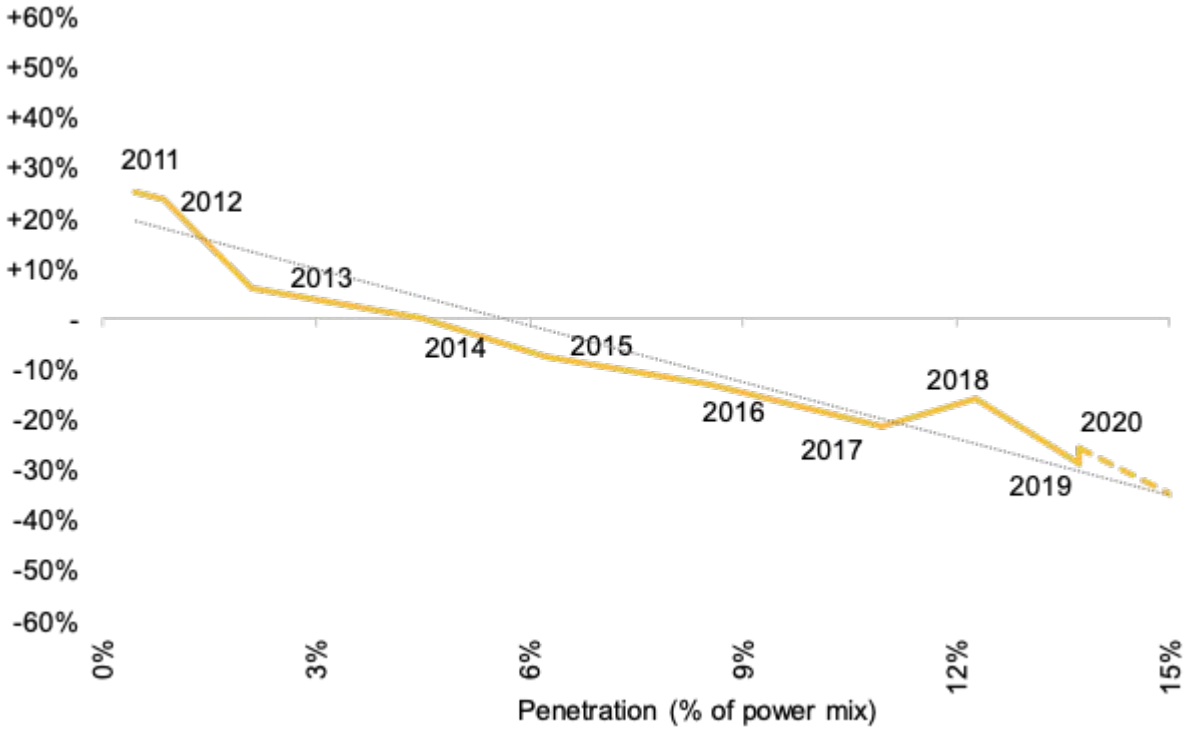
[ii] Bellini, E. (March 4, 2021). Silver accounts for 10% of PV module costs. *PV Magazine*. https://www.pv-magazine.com/2021/03/04/silver-currently-accounts-for-10-of-pv-module-costs/

Solar eats its own tail: 28-35% discounts for solar when compared to average CAISO hub prices

By: Tara Narayanan, Senior Associate, Solar

In California, the market with the 2nd highest solar penetration, the merchant value of solar project revenue has maintained a steady downward trend compared to around-the-clock (ATC) average power prices, and the trend is expected to continue. Solar represented nearly 14% of in-state generation in California in 2020, increasing the competition amongst power producers supplying energy at the same time and depressing prices for solar. The trend has amplified over time: average power prices were 28 – 35% higher than solar prices from the four California ISO (CAISO) hubs in 2020, as shown in Figure 1 below. By comparison, solar received a more modest discount of 15-33% at hubs outside CAISO, where solar levels are lower.

Figure 1. Discount to ATC Power Prices for Solar at CAISO SP15



Note: SP15 is a benchmark hub in CA.
Source: BloombergNEF.

This trend is important, because BNEF predicts the solar fleet across the U.S. will quadruple by 2030, pushing asset owners to consider the impact of their generation on power prices. A growing discount to average power prices worsens the economics for an electricity buyer locked into a virtual power purchase agreement (VPPA). Furthermore, for projects considering merchant opportunities in a market like Texas, the discounts would steadily erode the value of their generation.

OPERATING RISK

Topics Covered:

- **Degradation**
- **Inverter Performance Trends**
- **O&M Trends for Defunct Manufacturers**
- **Soiling Trends**

Double the degradation: Observed annual degradation is approximately 1%

By: Adam Shinn, Director of Data Science & Jimmy Dunn, Data Scientist

Since project revenue is tied to solar generation, understanding how a solar plant will perform over its lifetime is essential to estimating an asset's revenue generation. One key input to estimating a project's "P50," or expected power generation, is **degradation**, the quantification of a system's decline (and thus revenue) over time. Today, the industry uses a single degradation assumption from a 2016 study. However, recent research from the National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Laboratory (LBL), and kWh Analytics shows that the 2016 assumption is outdated and underestimates degradation by up to 0.5% annually in some cases, as shown in Table 1.

Table 1. Degradation Research (2016 - 2020)

Authors & Date	Analysis Type	Site Type	Measurement Point*	Yearly Degradation
Current Industry Assumption				
NREL (Jordan et al.) 2016	Meta-analysis (200 studies)	C&I, Resi, and Utility	25% System 75% Module	Median: -0.5%
Latest Research				
NREL (Deceglie et al.) 2018	RdTools	C&I and Resi	System	Median: -1.0% non-resi -1.2% resi
LBL (Bolinger et al.) 2020	Fixed effects regression	Utility	System	Mean: -1.1% Sigma: +/-0.2%
NREL (Deline et al.) 2020	RdTools	C&I and Utility	Inverter	Median: -0.72%
kWh Analytics 2021	RdTools	C&I, Resi, and Utility	System	Median: -1.09% resi -0.80% non-resi

**Note: Module degradation focuses on solar panels, while inverter and system degradation focuses on the system as a whole (inverters, transformers...etc.)*

While NREL's 2016 meta-analysis described a wide range of degradation rates, the solar industry has almost exclusively used a single statistic from that report: the median rate of 0.5% degradation per year. Notably, this rate corresponds primarily to panel, or module-level, degradation, rather than system-level degradation. Module-level degradation is a subset of system-level degradation, so using this singular data point inaccurately accounts for long-term system degradation and by extension revenue.

More recent studies have applied robust time series analyses to measure system degradation on a fleet-scale, increasing the accuracy of system-level measurements. These updated studies show that system-level degradation ranges from 0.72% - 1.20% per year, depending on market segment. This means current project degradation estimates may be underestimated by up to 14% over a twenty year life, resulting in overestimated (P50) performance and revenue. The systemic misalignment between actual and estimated degradation hurts the industry as a whole, underscoring the need to re-evaluate and re-calibrate P50 modeling assumptions immediately.

80% of performance tickets linked to inverters in 2020 due to reliance on OEM warranty service, extreme weather, and COVID

By: Jackie Ahmad, Director of Technical Operations

An analysis of nearly 2 GW of utility and commercial solar plants in 2020 shows that 80% of performance-related plant tickets are caused by inverter outages, as shown in Figure 1. These inverter outages result from a continued reliance on the original equipment manufacturer (OEM) warranty services and extreme weather. Additionally, pandemic travel restrictions significantly impacted mean time to repair (MTTR), as shown in Figure 2, further impacting project performance and underscoring O&M challenges. These issues are described further below.

Figure 1. Tickets by Asset Type

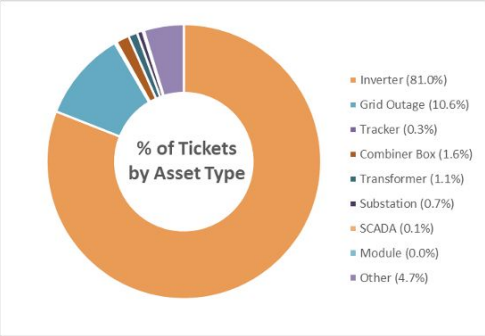
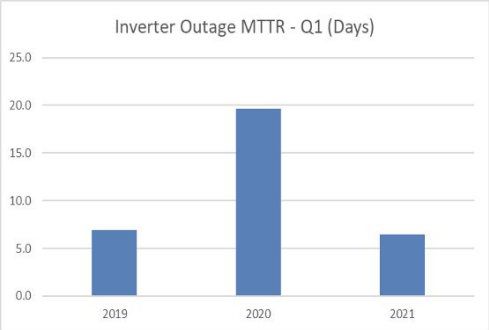


Figure 2. Inverter Outage Mean Time to Repair



Drivers of Inverter Outages

1. Reliance on OEMs: Many inverter manufacturers are reluctant to offer training and certification to O&M providers to allow them to independently change out failed subcomponents without voiding the warranty. It is also rare to have cost-effective, efficient service level agreements (SLAs) in place with the OEM; many of these service agreements are more expensive than the losses associated with downtime. This often causes delays in repairs and long outage times due to OEM tech unavailability. These inverter repair delays were exacerbated in 2020 and 2021 with extreme events: the global pandemic and Texas Winter Storm Uri.

2. Pandemic: Lockdowns on travel became widespread in the US in March of 2020 due to the COVID-19 pandemic. While utility workers were generally exempt from the lockdown, travel by OEM techs came to a near standstill unless the techs lived within driving distance from site. This phenomenon resulted in longer repair times. For example, inverter outages that required OEM on-site support went from a MTTR of 6.9 days in Q1 of 2019 to 19.6 days in Q1 of 2020. This number went back down to 6.5 days in 2021 as travel restrictions eased.

3. Extreme Weather: In February 2021, Winter Storm Uri caused approximately 70% of Texans to lose power. While solar performed better than natural gas and wind plants, most site and equipment designs did not anticipate the severe weather, causing inverters to trip offline and require OEM intervention. While most inverters were restored to service fairly quickly, some repairs were delayed due to flight cancellations. Even a day or two delay resulted in millions of dollars of lost revenue due to the $9,000/MWh ERCOT scarcity market price.

Conclusion

Notably, the best time to negotiate warranty SLAs with OEMs is prior to the purchase of the equipment, however the project sponsor is often not yet involved. Warranty negotiation would then fall to the EPC who may not have the same incentives, since they're excluded in the long-term ownership of the site. Therefore, it's important for financiers to review site design and SLAs closely. Specifically, we recommend considering the history of OEM response times, reviewing the revenue structure of the project in the context of service agreements with inverter OEMs, and asking potential O&M providers about their training and certifications with OEMs.

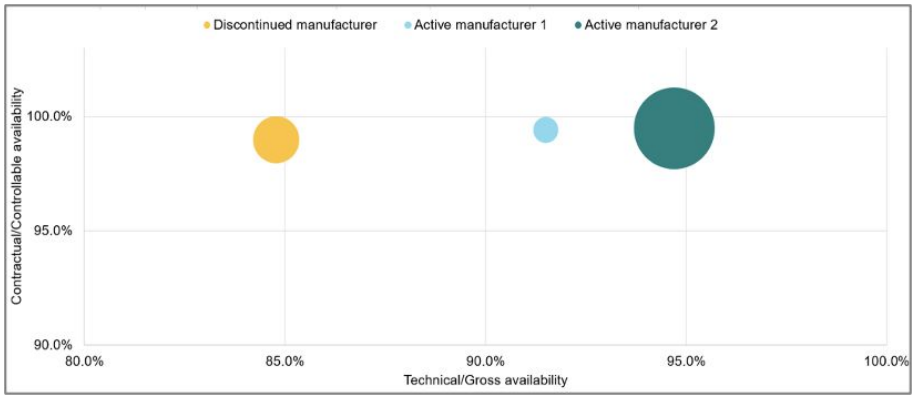
Using equipment from discontinued manufacturers decreases availability by up to 15%

By: Jonathan Fort, VP of DG Asset Management & Pierre-Alexandre Metaut, VP of DG Performance Analytics

In the past decade, hundreds of solar firms have gone bankrupt, closed, or simply exited the industry. Though this is normal – or at least to be expected – in the maturation process of any industry, this has created some unanticipated service challenges. One of the biggest questions an owner or operator might face is "How do I ensure the continuity of the operation of inverters whose manufacturer is no longer in business?"

One metric for assessing the impact of a defunct manufacturer on system performance is availability. *Availability* is a very commonly used metric in measuring system performance and is most simply defined as the percentage of time that the generating equipment (typically the inverter) is online and able to produce electricity. More specifically, *technical / gross availability* is the total uptime inclusive of the entirety of any outage from the occurrence of an issue to the final resolution, most notably including the lead time for obtaining the failed components or to replace the unit. As shown in Figure 1 below, this metric varies by manufacturer.

Figure 1. Technical Availability of Active Vs. Discontinued Manufacturers



Note: This chart uses 2020 performance data to compare availability metrics for three inverter manufacturers in a managed fleet. Sample size: ~500 sites, 8,500 inverters representing ~350MW in the US. The size of the bubble represents the total MW of each manufacturer in the fleet.

As shown above, the inverters from a discontinued manufacturer generated a Technical / Gross availability of approximately 85%, meaning that on average the devices were unable to produce power for 15% of the year. When comparing that to the Technical Availability of the active manufacturers – 92% for Manufacturer 1 and 95% for Manufacturer 2 – it's clear that the portion of the fleet comprised of the defunct manufacturer's equipment significantly underperformed that of the fleet with OEM support.

What accounted for the additional downtime for the unsupported inverters? The disparity is almost entirely due to two factors: 1) the inability to get effective technical support and 2) the delay in locating and procuring replacement parts. The average interruption was 7 days for Manufacturer 2, 20 days for Manufacturer 1, and *over 60 days* for the discontinued inverter manufacturer. For an average 1MW site in CA, this surplus downtime can add up to >$10,000 in lost revenue annually.

One of the most cost-effective ways for managing this issue is to partner with an O&M provider with the requisite technical resources and a comprehensive supply chain strategy. There are other strategies to mitigate the issues noted above, though most options have additional cost. One possible solution to this issue is *repowering* the site or replacing the unsupported inverters with new units from manufacturers still in the industry. Another solution is to hire inverter technicians specialized in servicing stranded assets and to maintain a warehouse of spare components. Unfortunately, both come with a significant price tag. Asset owners and financiers should think carefully about these issues in the development process.

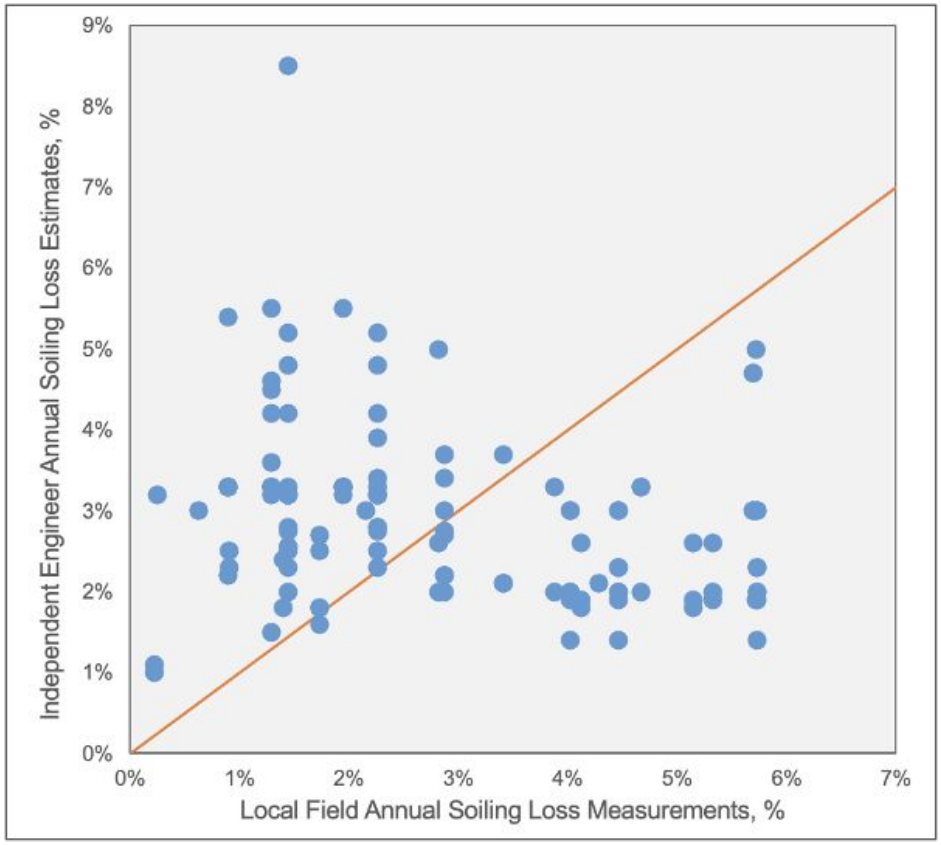
Independent engineer soiling estimates have a 99.5% error rate when compared to ground estimates

By: Catlin Mattheis, Founder and Bryan Fisher, Founder

During a solar project's development phase, project sponsors and financiers must forecast a project's expected production, expenses, and overall cash flow to determine whether or not a project should be built. An important piece of the production and expense forecasts is the project's operations and maintenance (O&M) expense, of which plant cleaning costs can weigh heavily. These cleaning costs vary greatly depending on environmental conditions (e.g., how quickly the plant accumulates soiling material), difficulty to clean, water availability at the site, local labor rates, etc. On the production side, stakeholders must determine how and when to clean the plant to mitigate losses due to preventable issues (like soiling), using only location and historical meteorological data. Both forecasts are usually provided by an independent engineer (IE) hired by the project sponsor.

Once a plant is commissioned, asset owners can measure production and losses, including soiling, on-site to determine how and when to clean the system. Comparing these on-site measurements of soiling to original IE estimates shows that there is mean relative error of 99.5%, as illustrated by Figure 1 below.

Figure 1. Soiling Loss Variance – IE vs. Field Measurements



Source: Fracsun ARES soiling station hardware from 40 locations; compared to IE estimates

The orange line in this chart represents the boundary of over- and under-estimation. As illustrated, there is no region of the chart where estimations come close to measured values. This means that stakeholders are consistently misestimating production and therefore, cash flows. The analysis shows that more data on actual soiling losses during the development stage would enable higher quality production estimates.

EXTREME WEATHER RISK

Topics Covered:

- **Hail Stow**
- **Wildfire Impact on Production**
- **Property Insurance: Broker Perspective**
- **Property Insurance: Asset Manager Perspective**
- **Property Insurance: Financier Perspective**

Stowing modules at 60° increases module survivability to 99.4% in hailstorms

By: Kent Whitfield, VP Quality, Ray Casey, Sr. Director, Product Mgmt, & Alex Roedel, Sr. Director Project Eng.

For much of the world where large utility-scale solar project development activities are now taking place, climate risks are intensifying. Catastrophic weather events are especially costly, as a small number of incidents account for a majority of the monetary loss represented in solar insurance claims.

In May 2019, for example, a hailstorm swept across a 1,500-acre solar generating facility in West Texas. The visible and hidden damages associated with this single storm—including shattered glass and cracked PV cells—resulted in an insurance claim on the order of $80M. Responding to these historic losses, the renewable energy insurance market hardened as carriers increased rates and reduced underwriting levels.

Recent hail cannon tests show that panel vulnerability to hail events, like West Texas, varies based on hailstone diameter, impact velocity, and module-impact angle. Importantly, project owners can only control one of these features: module-impact angle.

The test results determined that 300% more kinetic impact energy is required to shatter framed PV glass in modules stowed at 60° versus a flat (0°) stow position. Specifically, statistical analysis of this module breakage data indicated that stowing modules facing into the wind at 60° during a hailstorm increased PV module survivability from 81.6% to 99.4%.

This data can be directly incorporated into equipment design. For instance, some tracker manufacturers can update their firmware in connected portfolios to allow trackers to tilt panels to 60° in hailstorms. By means of this update, asset owners can retroactively add defensive hail stow functionality—even if it was never anticipated at the time of construction—to legacy and newly fielded assets. Figure 1 below shows how this hail testing data and other weather testing data can be incorporated into tracker and other equipment design to improve extreme weather survivability.

Figure 1. Example Tilt Angles for Improved Extreme Weather Survivability

	Hurricane Stow	Hail Stow	Wind Stow	Snow Shed	Flood Stow
Priority Order	1	2	3	4	5
Action	Moves all trackers to maximum tilt angle facing east or west (per user) for maximum wind protection	Moves all trackers to maximum tilt angle facing east or west (per user) to minimize hail impact force	Moves trackers to a defensive stow position, based on site configuration, facing into the wind	Moves all trackers to maximum tilt angle to dump snow; normal tracking resumes after snow shed	Selectively moves trackers in flood zones to 0° tilt (flat) angle for maximum ground clearance

Source: Nextracker, Mitigating Extreme Weather Risk whitepaper Part 1 and Part 2.

This type of data-driven approach to project risk assessment and mitigation benefits all project stakeholders. Developers and engineers can use hail resistance test data to select appropriate technologies based on site-specific risk profiles. Meanwhile, quantitative analysts can use these enhanced stress test results to develop databases, deterministic models and loss forecasts that account for long-term, location-specific weather data.

Wildfires reduced energy production by up to 6% in the Western U.S. in 2020

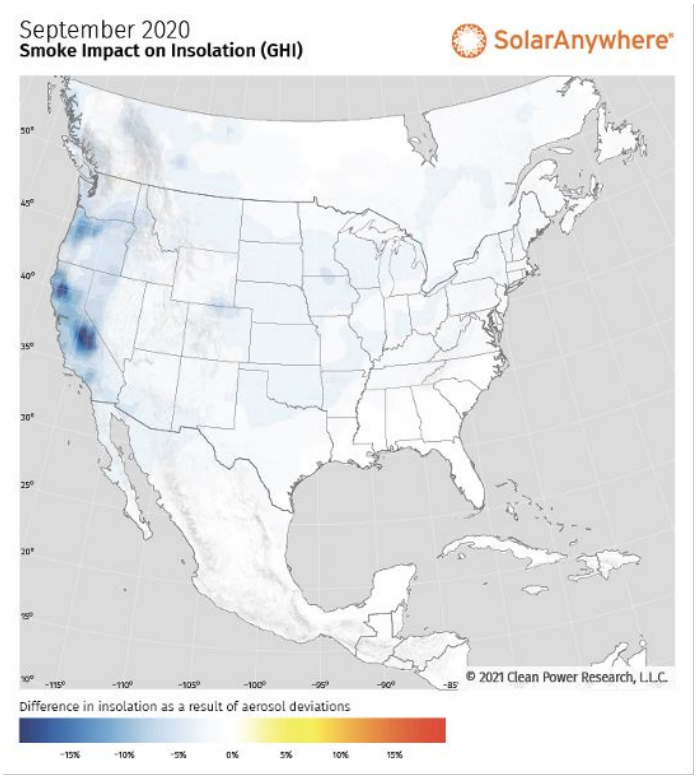
By: Skip Dise, VP of Product Management

Accurate solar photovoltaic (PV) output forecasts can make the difference between millions in losses, or profitable net cash flow on a project. Recently, forecasting output has become more complicated as extreme weather occurrences have increased. In 2020 alone, NOAA recorded 22 separate disasters, each exceeding $1B in total damages. One significant type of disaster impacting PV is large-scale wildfires.

This past year, 2020, was the most active wildfire season in the Western U.S., as measured by acres burned and fires detected. Wildfires can cause problems for PV production, since the smoke from fires blocks out sunlight during the summer when production should be the highest. Additionally, residual soiling reduces production over an extended period. These issues are exacerbated by the industry's nascent ability to accurately predict the duration and impact of wildfires on PV production in forecasting models.

Looking at the Western U.S. region in 2020 provides an example of the potential wildfire impact: peak wildfire season happened during the first few weeks of September where regions like the California Central Valley and Columbia River Basin in Oregon experienced a reduction of nearly 20% in monthly insolation, as shown in Figure 1.

Figure 1. Regional Insolation Deviation



This insolation reduction was driven by both the duration and severity of the smoke created by the fires. In total, the three-month period of August to October 2020 amounted to -122 MWh/MW-DC or -5.8% of the typical-year energy output in the Central Valley. This means that 2020 was the second-worst insolation year on record since 2001. It also means that certain PV projects' financial performance loss was dominated by wildfire smoke, not clouds, and could continue to be going forward.

While extreme weather impacts on North American PV projects were notable in 2020, the ability to predict these occurrences into the future remains uncertain. Climate models are predicting drier conditions in the coming decades, meaning that conditions favorable to wildfires will persist. However, it's challenging to forecast how exactly this trend will impact projects over a twenty-year life.

Despite this added long-term uncertainty, project owners can make more intelligent decisions by looking at historical data to quantify wildfire impact and extreme weather on PV plant generation. By updating assumptions in revenue forecasts that includes the most recent data, owners can more accurately assess annual generation variance conditions (i.e. P90, P99). This analysis will result in a better understanding of project risk for both equity *and* debt investors across their full portfolio.

Property insurance base rates have increased over 10% annually on average in the past three years

By: Alex Post, Senior Vice President, Lockton Power & Peter McGoldrick, Senior Vice President, Lockton Power

For many years, renewable energy insurers have focused their attention on the physical and technological aspects of the young and rapidly evolving energy sector. While technical and physical inputs are still an integral part of underwriting and mitigating risk across renewables projects, the last several years have produced catastrophic losses driven not by equipment breakdown, but natural perils like wind, flood, wildfire, and hail. In 2020 alone, the US experienced 22 climate disaster events. As renewables projects expand in size and number, they are increasingly being developed in geographies that are untested against certain weather conditions.

Impacts from these events routinely range from several millions of dollars up to nearly $100 Million. The latter figure is currently the largest single solar loss event stemming from a Texas hailstorm in 2019. For insurers, this has created an unsustainable environment, since a single claim event could out-strip years' worth of policy premiums and may materially impact insurers' overall books of business.

Now, as insurers drastically try to re-align their underwriting models to remain viable, their pain is being passed on to project developers, owners, and financing parties. The expectation of more "skin in the game" translates into higher minimum deductible levels for physical damage and in some cases material levels of self-retained risk – up to 2-5% of project value -- associated with weather driven events like wind, hail, earthquake and wildfire. Additionally, premium rate level increases in each of the past two years have averaged over 10% to well over 100% on projects with loss activity or challenging exposures. Table 1 below provides an overview of these recent changes.

Table 1. Property Insurance Premium Rate Trends

	2018	2019	2020	2021
"All Risk" Premium Rates	Flat Rates / Slight Increases	10% + rate increases	20% + rate increases	10% + rate increases
What is driving market changes?	• Market transitioning due to profitability challenges • Losses driven by weather related and construction losses • Pressure around deductible adequacy, etc.	• Weather related and construction losses continue. Large hail loss. • Focus on increasing deductibles and restricting coverage. • Focus on pricing NAT CAT and managing exposure. • Markets moving away from writing 100% solutions	• New Focus on Secondary NAT CAT Perils (severe convective storms & wildfire) • Continued focus on deductibles and coverage restrictions. • Weather related losses continue with material wildfire and mechanical breakdown losses.	• Continued focus on managing NAT CAT exposure. • New capacity from traditional power markets.

Key project stakeholders must now reassess the impacts of these changes on projects' contractual obligations. To mitigate premium impacts, stakeholders should pay special attention to project location, layout, and construction contractors when building and designing the project. Additionally, it's imperative to provide insurers with robust information on engineering reports, equipment, and operation and maintenance plans to help them accurately price risk.

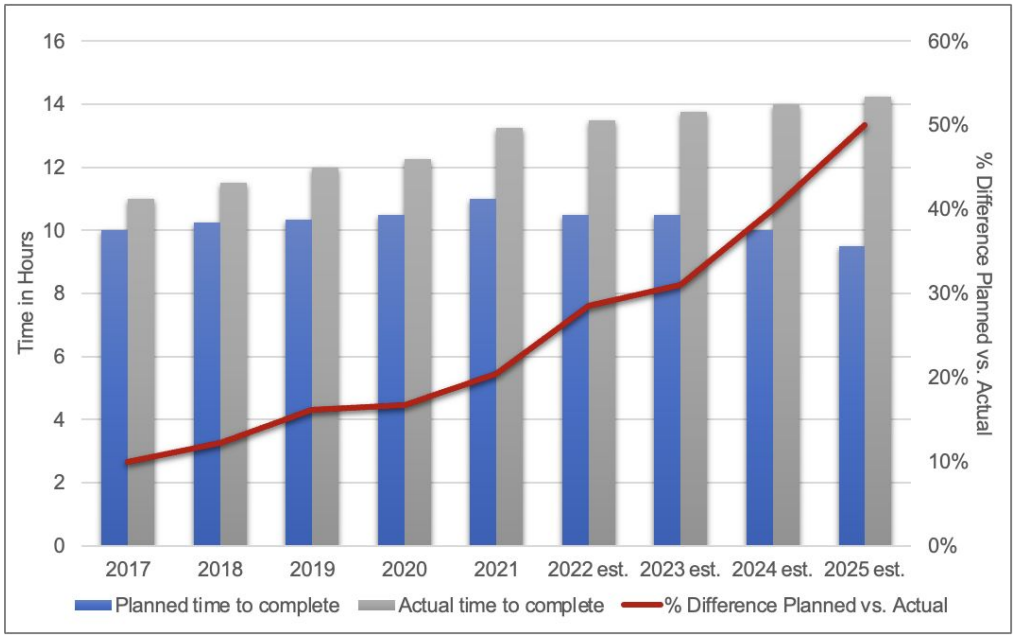
Hardening insurance market leads to 20% increase in workload for asset managers, expanding OpEx budget

By: Erik Orsino, Global Business Development Manager

Increasing insurance premiums and exposure and reduced capacity availability are causing significant challenges for solar asset managers. Given that the renewable energy market is expected to rapidly expand through 2050, the industry needs to remain cognizant of pitfalls and collaborate to solve these issues. Recent changes in the insurance market have introduced 3 new risks: (1) human capital impacts, (2) financial impacts, and (3) coverage impacts.

In terms of human capital impacts, asset managers' workload is taking 20% longer than planned and continues to increase when looking at timecards and as shown in Figure 1. The additional time is being spent on requests for waivers, answering follow up questions on claims, resubmittal of claims paperwork, identification of new insurance providers due to coverage gaps, and changes to operating agreements. This dramatic increase is extremely problematic for both asset owners and operators, since work is billed on an hourly basis and therefore, impacts project expenses.

Figure 1. Planned vs. Actual Time Allocated to Insurance Related Work



Additionally, changes in the insurance markets have strained tax and cash equity providers. These providers are becoming more hesitant to invest in new projects, because the cost to insure them is negatively impacting financial feasibility tests. Specifically, projects are increasingly being rejected by financiers due to less favorable return on investments (ROIs) caused by premiums increasing up to 25%, increasing insurer uncertainty as they decline to cover more projects, decreasing coverage options for natural catastrophes, such as flood and fire, and growing administrative costs as highlighted earlier.

Finally, mixed technology portfolios with wind, solar, and/or storage are creating new risks for asset owners, financiers, and insurers. Each of these technologies represent different risk profiles that need to be better understood individually; therefore, bundling the technologies adds an additional layer of complexity when pricing risk. For example, fire damage is very costly for battery storage and the probability of this risk is higher than other technologies, like wind. Given these variances, the risk associated with insuring these projects is becoming more difficult to analyze and needs to be explored more diligently.

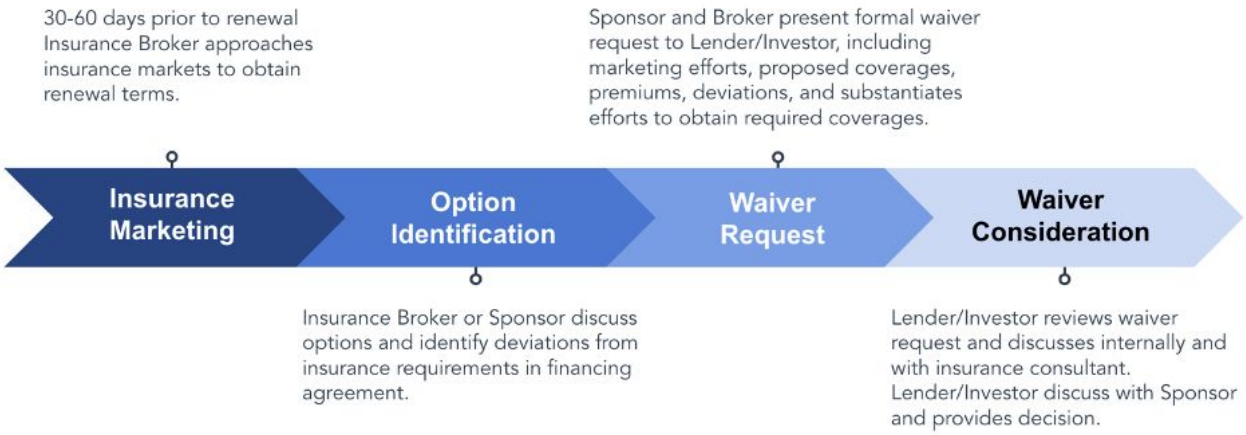
Over 50% of investors have received property insurance waiver requests in the past 12 months

By: Sam Jensen, Partner at STANCE and Jason Kaminsky, Chief Operating Officer at kWh Analytics

Solar tax equity and debt agreements have minimum property insurance requirements for the asset owner to maintain; however, due to changes in the insurance markets since 2019 and challenges in procuring full coverage, projects are increasingly forced to be in default of insurance agreements. When a project is in default of these agreements, the asset owner must ask the financing counterparty (e.g., tax equity providers and lenders) to temporarily waive the requirements.

According to a recent survey, over 50% of tax equity providers and lenders stated they received such "waiver requests" in the past year from solar asset owners. Survey respondents indicated that waivers are being requested due to inadequate limits and deductibles for solar projects. The problem is particularly acute for large assets in regions that have exposure to natural catastrophes, such as hurricanes, hailstorms, tornadoes, or wildfires. For projects requiring waivers, sponsors must work closely with brokers and financiers to identify acceptable waiver terms and options, as shown in Figure 1.

Figure 1. Typical Property Insurance Waiver Process



Source: kWh Analytics and Stance

While it is best practice to provide waivers to the financing parties with adequate time to collaborate on potential solutions, in the current market this is sometimes infeasible and financing parties are only informed after coverage has been bound. This process presents an area of operational improvement for the industry; insureds, brokers, underwriters, and insurance consultants must cooperate to develop solutions when policy placements are difficult and complex.

The prevalence of insurance waivers has heightened banks' scrutiny on insurance as part of the underwriting process. For example, investors indicated that insurance availability has become an important screening criterion for project investments, and insurance requirements are more heavily negotiated than they were just a few years ago. Even so, most financiers have preferred to maintain their insurance requirements, because most financing institutions are optimistic that insurance availability will increase in future years.

The prevalence of insurance waivers shows that layering insurance into project finance structures and appropriately allocating the risk between bank, asset owner, and insurer is an area ripe for innovation. This innovation must be enabled by both improved underwriting on behalf of the insurers and intelligent risk management by the asset owner.

Contributors

kWh Analytics: kWh Analytics is the market leader in solar risk management. By leveraging the most comprehensive performance database of solar projects in the United States (30% of the U.S. market) and the strength of the global insurance markets, kWh Analytics' customers are able to minimize risk and increase equity returns of their projects or portfolios. Website

DNV: DNV provides assurance to the entire energy value chain through its advisory, monitoring, verification, and certification services. As the world's leading resource of independent energy experts and technical advisors, the assurance provider helps industries and governments to navigate the many complex, interrelated transitions taking place globally and regionally, in the energy industry. DNV is committed to realizing the goals of the Paris Agreement, and supports customers to transition faster to a deeply decarbonized energy system. Website

Wood Mackenzie Power & Renewables: Wood Mackenzie Power & Renewables delivers actionable insight into the state and the future of the global electricity sector, from wind and solar to power markets and grid edge technology. Wood Mackenzie research is backed by exclusive relationships with industry partners, proprietary models, and an ever-expanding executive network. Website

BloombergNEF: BloombergNEF (BNEF) is a strategic research provider covering global commodity markets and the disruptive technologies driving the transition to a low-carbon economy. Our expert coverage assesses pathways for the power, transport, industry, buildings and agriculture sectors to adapt to the energy transition. We help commodity trading, corporate strategy, finance and policy professionals navigate change and generate opportunities. Website

PV Evolution Labs: PV Evolution Labs (PVEL) is the leading independent lab for the downstream solar and energy storage industry and a member of the Kiwa Group. As a bankability testing pioneer, PVEL has accumulated more than a decade of measured reliability and performance data for PV and storage equipment. Today, PVEL provides developers, investors and asset owners with a suite of technical services for mitigating risk, optimizing financing and improving system performance throughout the project lifecycle. Website

Radian Generation: Radian Generation provides technology enabled asset management solutions and advisory services to developers and owners of renewable energy power plants with a focus on risk management and optimal portfolio performance. Website

Novasource Power Services: Novasource Power Services is a diversified national solar services company, delivering unparalleled expertise to the nation's distributed generation infrastructure. We provide safe, professional, and reliable operations and maintenance services enabling the growth of C&I (Commercial and Industrial) and Residential renewable energy sectors. Website

Contributors Cont.

Fracsun: Fracsun specializes in PV soiling monitoring solutions for solar array owners, operators, and developers. By providing onsite soiling loss measurement, as well as soiling loss data, Fracsun has aided over 1.5GW of solar assets in improving operational strategies in mitigating and anticipating soiling losses. Website

Nextracker: Nextracker, a Flex company, is a leader in the renewable energy transition, providing critical yield-enhancing PV system technology, expertise and strategic services to capture the full value and maximize the efficiency of solar plants. Delivering the most comprehensive portfolio of intelligent solar tracker and control software solutions for solar power plants, Nextracker is transforming PV plant performance with smart technology, data monitoring and analysis services. Website

Clean Power Research: Clean Power Research has delivered award-winning cloud software solutions to utilities and industry for more than 20 years. Our PowerClerk®, WattPlan® and SolarAnywhere® product families allow our customers to make sense of and thrive amid the energy transformation. Website

Canadian Solar: Canadian Solar was founded in 2001 in Canada and is one of the world's largest solar technology and renewable energy companies. It is a leading manufacturer of solar photovoltaic modules, provider of solar energy and battery storage solutions, and developer of utility-scale solar power and battery storage projects with a geographically diversified pipeline in various stages of development. Over the past 20 years, Canadian Solar has successfully delivered over 53 GW of premium-quality, solar photovoltaic modules to customers in over 150 countries. Website

Lockton: As the world’s largest privately owned, independent insurance broker, Lockton Companies serves more than 60,000 clients across six continents with risk management, insurance, employee benefits consulting and retirement services. Lockton’s 8,000+ Associates are committed to helping clients achieve the goals that make their businesses safer, smarter and more profitable. Our private ownership is the foundation for the entrepreneurial culture which drives our unique client service approach manifested in our 10% organic growth rate and 96% client retention. Website

Stance Renewable Risk Partners: STANCE's expertise is in the area of renewable energy insurance due diligence. We work with a number of equity investors, lenders, and developers to not only help those businesses succeed, but to sustain the green revolution push in energy generation across the planet. We are the company that is making insurance consulting a smarter, faster, better experience for everyone. We believe that being imaginative and thoughtful is the best way to serve our clients. Website