OPTIMIZING YOUR ENERGY YIELD

TrueCapture Smart Control Technology Boosts Energy Production and Financial Returns

By Allan Daly and Venkata Abbaraju

The global solar market continues to grow at a brisk pace, with almost 100 GW of new systems deployed in 2017, according to GTM Research. Utility-scale ground-mount systems comprise by far the largest portion of the newly installed capacity, with single-axis trackers (SATs) chosen for the majority of those installations. The increasing popularity of trackers comes largely from their proven ability to harvest 15–25% more solar energy compared to fixed-mount systems. Pairing advanced photovoltaic (PV) technology such as bifacial modules with SATs is also attracting significant interest, given the even-greater potential energy gains. Moreover, when trackers using bifacial modules are integrated with DC-coupled energy storage solutions, energy production that might be lost to inverter clipping can be captured, opening the door for further optimized system designs. As power purchase agreement (PPA) prices continue to fall, asset owners are looking for ways to harvest even more energy—and further maximize their financial returns—from their solar investments.

Enhanced Solar Plant Performance with TrueCapture

Although SATs provide the best option for capturing more solar energy and increasing the power production of large solar fields, there is a significant opportunity to further boost performance. Most tracking systems employ a "backtracking" algorithm to help reduce inter-row shading when the sun is at low angles early in the morning or late in the afternoon. The algorithm factors in the position of the sun over the course of the year as well as the shape, size and layout of the arrays to minimize shading and allow for additional solar energy to be harvested. Backtracking has its limits though; since its introduction in the early 1990s, there has been little advancement in the technology. For example, it does not adequately compensate for uneven site topographies and less-than-optimal irradiance conditions. As a result, some potential additional energy production is left on the table.

In this paper, we focus on two leading areas for yield improvement:

- Differential elevations from one tracker row to the next that cause either inter-row shading and/or a backtracking algorithm that is set too loosely, reducing energy yield for most of the field.
- Diffuse light conditions that reduce energy yield when arrays follow standard astronomical tracking positions.

TrueCapture boosts energy yield up to 6%

To address these challenges, NEXTracker has developed an advanced solar PV control methodology—TrueCapture™. This machine-learning software technology boosts power plant production by

TrueCapture Performance Benefit

Terrain Variation (East-West)

Irradiance Conditions	Minimal Slope (3% slope)	Moderate Slope (4.5% slope)	High Slope (>6% slope)
Low Diffuse**	<2.0%	3.5%	5.0%
Medium Diffuse	2.5%	4.0%	5.5%
High Diffuse	3.0%	4.5%	>6.0%

3 Key Drivers:

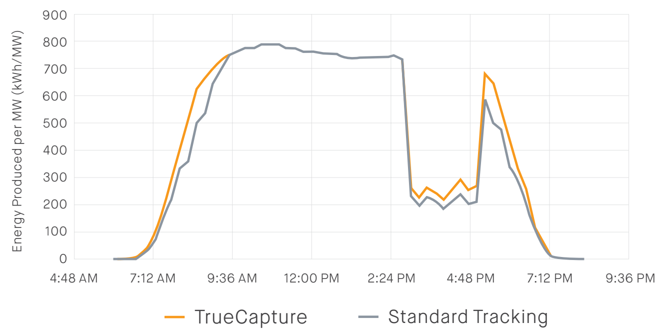
- Terrain profile
- Ground coverage ratio*
- Diffuse light fraction

*Assumes a 40% ground cover ratio site *Benefit values will vary slightly based on GCR **Based on California Central Valley weather profile* continuously optimizing the tracking algorithm of each individual row in response to site features and changing weather conditions. The software can be utilized at the vast majority of new or existing sites where NEXTracker trackers are installed and is fully compatible with both string and central inverter architectures. Extensive modeled and empirical field production data from multiple sites show energy yield increases of up to 6% when TrueCapture is utilized.

TrueCapture employs a detailed understanding of the as-built 3D layout of the trackers at a site in combination with real-time local weather data to modify individual row tracking algorithms to avoid power losses caused by module shading and diffuse light. TrueCapture's software engine can simulate expected energy gains for both new and existing projects. The TrueCapture engine uses high-fidelity models, some of them based on industry fundamentals used in tools like PVsyst, and some of them developed in-house specifically for this application.

TrueCapture addresses two fundamental problems that are common in utility-scale PV power plants: first, energy losses due to shading caused by undulating terrain or construction variances, and second, unrealized energy from suboptimal irradiance capture under diffuse light conditions.

1 MW Energy Production Standard Tracking vs TrueCapture



With select data inputs, the TrueCapture modeling engine outputs a set of row parameters that optimize individual tracking angles to minimize shade on a daily basis. These parameters are used by each individual tracker controller to guide row operation. On-site sensors supplement and further modify the tracker angles in response to local weather conditions.

Shade occurring on actual project site.

Row-to-Row Shading: The World Is Not Flat

Most participants in the utility-scale PV industry rely on PVsyst to model the energy production of their plants. Although PVsyst works well for many applications, it has not been feasible to precisely model single-axis tracker performance on undulating terrain. So, users have tended to model SATs with an assumption that terrain is flat. The reality of many sites is often quite different, and relatively modest variations in adjacent tracker row heights often produce significant inter-row shading. Therefore, it is extremely important to model the effects of undulating terrain on SAT systems or to use an "undulating derate factor" in PVsyst to account for inter-row shading.

TrueCapture implementation eliminates row-to-row shading caused by undulating terrain and/or as-built variance in pier heights.

The current practice to minimize row-to-row shading in the field is to program tracker controllers with an artificially increased ground coverage ratio (GCR) compared to the actual as-built ratio. This effectively "de-tunes" the entire array to avoid shading, but at the cost of valuable solar beam resource during backtracking hours. In this scenario, some sunlight can be wasted as it strikes the ground between rows rather than the PV panels. With TrueCapture, each row independently operates in a way that does not interfere with the row in front of or behind it and, at the same time, tracks as aggressively as possible to capture the maximum amount of irradiance. NEXTracker's independent row architecture allows TrueCapture to optimize performance on a 30 kW row-to-row basis; this is not possible with linked-row trackers with constrained block sizes of 500 kW or more.

Standard tracking (left-hand image) shows the illuminated ground between trackers, indicating trackers are not capturing as much light as they could. With TrueCapture (right-hand image), each row independently tracks at an optimal angle to capture more light without shading adjacent rows.

Diffuse Light Optimization

A second limitation in energy production potential arises from natural variances in irradiance caused by weather conditions. Solar irradiance mainly consists of three components: direct normal irradiance (DNI), circumsolar irradiance, and diffuse irradiance. DNI and circumsolar irradiance come in a direct path from the sun or within a close acceptance angle to the sun. Single-axis trackers are designed to harvest this by rotating to the closest normal incidence angle to the sun and perform quite well in this regard.

Independent-row trackers like NEXTracker's are very accurate, tracking the sun's position to within a few degrees and therefore capturing as much available DNI and circumsolar irradiance as possible. Under diffuse light conditions, however, when the sun is obscured by clouds, fog or haze, light is scattered isotropically, meaning it originates from all directions of the sky dome. In this case, maximum irradiance is not captured by pointing toward the sun's position behind the cloud layer. Because irradiance is coming from all directions, the tracker is not "seeing" as much of the sky dome when tilted at a steep angle, leading to less-than-optimal production.

Today's trackers use their geographical location and time of the day to determine the sun's position and corresponding tracker angle. On cloudy days, trackers still point directly at the sun's location, although there is no direct sun visible. This is a widespread but suboptimal practice. A better approach is to position the solar modules in a more horizontal orientation on cloudy or other diffuse light days, capturing 10–20% more irradiance instantaneously. Modeled and field data indicate and prove annualized energy gains of 0.5%–2% in hazy and cloudy locations when this tracking strategy is used for diffuse light optimization.

Actual diffuse conditions observed at a real-world project site.

Implementing and Operating TrueCapture

The TrueCapture model requires the following specific plant inputs:

- *Ground cover ratio (GCR).* GCR as used by tracker manufacturers to determine row-to-row spacing typically assumes a perfectly flat surface. However, NEXTracker can automatically determine as-built row-to-row distances while accounting for construction variations and ground elevation changes.
- *As-built pier heights.* Obtaining the pier heights is more complicated but can be established with several techniques. For operating and in-progress projects, NEXTracker has established a highly accurate manual technique to obtain pier height measurements. For future projects, NEXTracker will utilize its patent-pending SmartModule technology. The SmartModule not only powers NEXTracker's self-powered controller (SPC), but also acts as a sensor to inform the model when shading occurs, eliminating manual input during the commissioning process.
- *Diffuse light.* NEXTracker has designed a plug-and-play solution to enable diffuse light measurement via existing NEXTracker weather stations. Using real-time data, the TrueCapture model informs NEXTracker's SPCs about how much to adjust the tracking angle at periodic intervals.

Once these tasks are completed, the TrueCapture settings are propagated throughout the tracker field so that each row can track at its optimum angle. NEXTracker utilizes a distributed control architecture in which the control programs are always housed in the individual SPCs. Even if there's a communication system loss, each SPC maintains its ability to continue tracking with its individual parameters. Site performance is further monitored, measured and verified at NEXTracker's NERC-CIP compliant Network Operations Center and can be remotely improved with future software updates, keeping each plant up to date with the newest product release. Even plants built before the release of TrueCapture can benefit from the most current software updates.

"Not only do we get more production, 3.5% in this case, we can take our 30 or 35 years of cash flow, bring that extra spread forward and actually create current net present value. For an owner like us, that is super valuable."

— Bryan Martin, CEO,
D.E. Shaw Renewable Investments

DE Shaw & Co

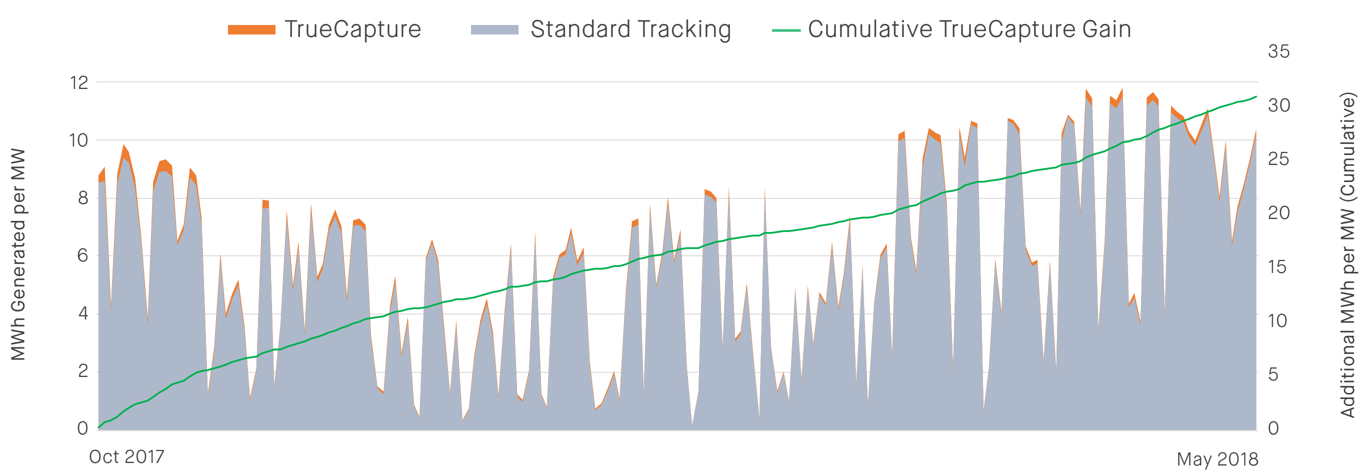
TrueCapture Field Data

NEXTracker has been field testing TrueCapture at multiple large PV sites in various geographies and irradiance conditions, accumulating ample data to validate that the core TrueCapture engine is robust and valuable. Data shows that the extra energy generation created by TrueCapture's diffuse and row-to-row optimization techniques is additive. Data also reveals that inverter clipping experienced during peak production hours has virtually no impact on the additional yields realized by TrueCapture compared to standard tracking. Results from sites with a wide range of DC:AC ratios show that there is little if any effect on TrueCapture's additive benefits, since row-to-row shading and diffuse conditions occur during off-peak times. The results seen thus far have demonstrated power plant production increases, which have been verified by third-party independent engineers.

One of the test sites, a 74 MW_{DC} solar power plant equipped with 26 inverter blocks of crystalline silicon modules on NX Horizon™ trackers in Mississippi, has been employing both the row-to-row and diffuse-light TrueCapture capabilities. This is an undulating site with irregular boundaries, which favors individual rows for the design layout. On-site GCRs range from 30.5% to 38.9%. There's also significant diffuse irradiance content, which offers the potential to harvest more energy during cloudy conditions.

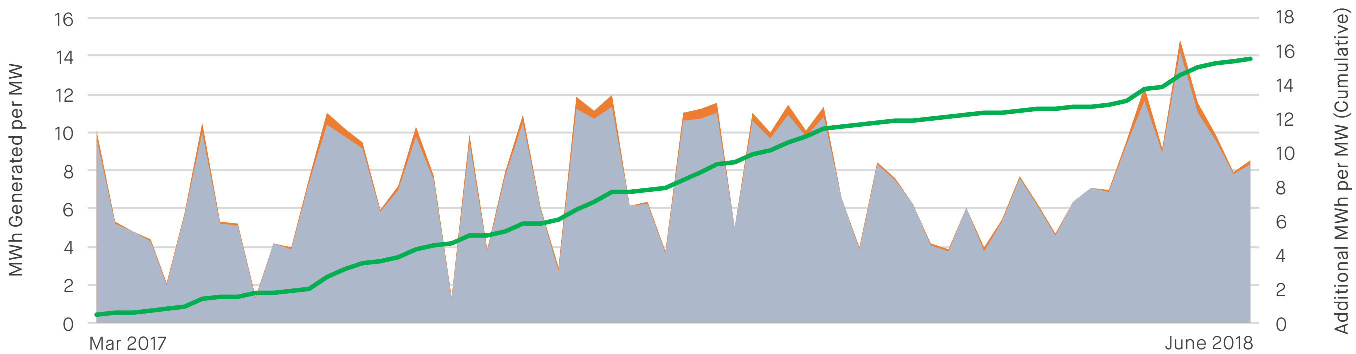
As the data below shows, after the first nine months of comparing the performance of TrueCapture-enhanced inverter blocks with standard tracking inverter blocks, the Mississippi site has seen 3.5% more production adjusted for solar irradiance.

NEXTracker's Control Algorithm Generates 3.5% More Energy at 74 MW Plant in Mississippi



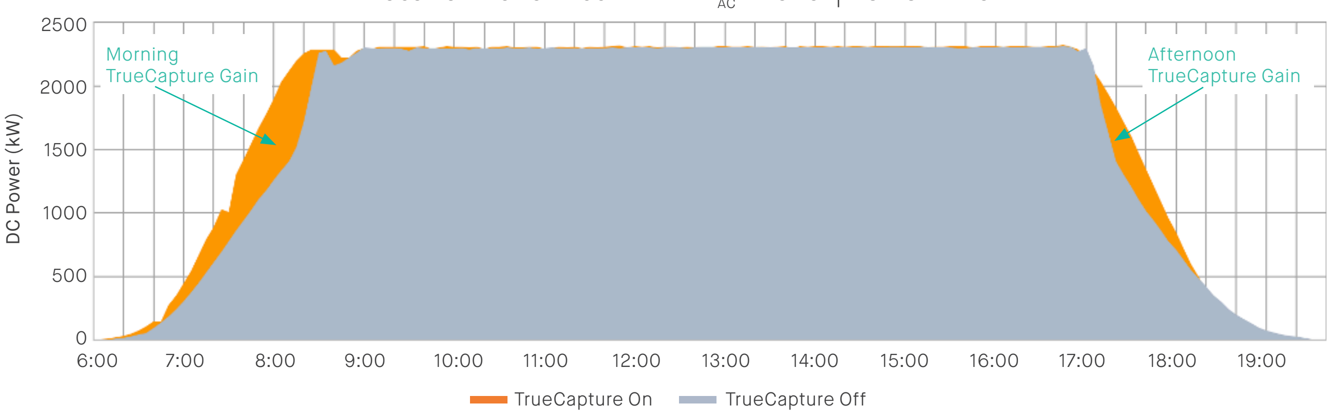
Several other solar power plants, including a 115 MW_{DC} site in Alabama, have been testing TrueCapture. The Alabama plant was built on undulating topography with east-west slopes varying from 3% to 15%, which significantly increases row-to-row shading. So far, the TrueCapture row-to-row optimization algorithm has cumulatively increased energy yields by 3.2%. On clear sunny days, the yield improvements have been even higher, reaching 4.3% or better. In addition, early data collected during cloudy days from the Alabama site shows a production boost of approximately 1.5% from TrueCapture's diffuse-light functionality, which translates to more than 4.7% overall additive yield.

TrueCapture Row-to-Row Optimization Generates 3.23% More Energy at 115 MW Alabama Site



TrueCapture Generated 4.3% More Energy Production (R2R Only) on Clear Sunny Day

Alabama Inverter Block: 2.2 MW_{AC} Inverter | DC:AC = 1.45



"TrueCapture presents the first significant advancement in the single-axis tracking algorithm since general backtracking. From the perspective of a developer, owner and operator, TrueCapture uses the data acquisition and processing of today to increase energy generation and revenue."

— **Dustin Shively, Director of Engineering, Clēnera - Renewable Energy**

TrueCapture Increases Project Financial Returns

Given the significant increases in power plant performance, TrueCapture will maximize returns on project equity to owners over the lifetime of their solar assets. Four key inputs are factored in when assessing the potential valuation of TrueCapture's impact on financial returns: baseline energy production, power purchase agreement (PPA) or wholesale rates, annual PV module degradation, and the TrueCapture production benefit percentage. While regional differences in weather, site conditions, and other factors can impact the calculations, models consistently show that just a few percentage points of extra production enabled by TrueCapture will add millions of dollars of additional production revenue to asset owners' bottom lines.

For example, a typical 100 MW_{DC} solar plant in the U.S., modeled for 25 years with a 3.5 cent per kilowatt-hour (kWh) PPA and a 2% TrueCapture benefit, would generate an estimated $3 million in additional revenues over the contracted lifetime of the site. With a 5 cent per kWh PPA, the additional revenue amounts to $4.25 million. As one would expect, when TrueCapture provides an even higher energy production benefit, so too does the revenue generation increase; for a 4% energy yield improvement, the above revenue gain scenarios would double.

A typical 100 MW_{DC} solar plant in the U.S., modeled for 25 years at a 3.5 cents per kilowatt-hour PPA and a 2% TrueCapture benefit, would generate an estimated $3M in additional revenues.

Actual site with integrated TrueCapture. Location: Lafayette, Alabama.

Conclusion

Since backtracking was introduced to the market in 1991, there has been very little innovation in control technologies for PV tracking systems—until now. By using a model-based approach and leveraging the individual row tracking architecture that is inherent to NEXTracker's system design, the TrueCapture smart control system optimizes tracking algorithms to eliminate shade, track more aggressively when possible, and adjust tracking dynamically to account for changing weather conditions. Initial empirical field testing results and modeling show that TrueCapture can increase energy generation by up to 6%, depending on the characteristics of a particular site. This enhanced energy yield translates into a healthy additional return on the solar asset owners' investment.

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A Flex Company