



FLUKE®

From Aging to Cutting-Edge:

Guide to Repowering Utility-Scale Solar



Aging solar arrays show decreased performance, but repowering offers a solution by upgrading key components for better returns and longer operational life.

Why Repower a PV System?

Since the solar industry's massive growth is relatively new, we're just beginning to see what will soon become a wave of aging solar arrays. In 2023, more than 67 GW of solar capacity turned 20 years old – and their performance showed their age as components became less efficient and more problematic, especially compared to newer technologies designed to withstand harsher environmental conditions and last longer.

Underperformance issues also impact many newer PV systems; U.S. utility-scale solar assets' average lifetime performance is 5-10% below their initial P50 value. Since utility-scale projects are much larger than residential or commercial ones, this rate of underperformance can significantly impact investors' returns. Optimizing the ROI of existing PV systems – and building confidence among potential investors for new solar projects – will






require increasing their long-term operational health. Often, this can be accomplished by addressing system deficiencies through a process known as 'repowering' .

Repowering suitable solar systems as they age retains the value of the power purchase agreement, helping stakeholders avoid the expenses of both system decommission and the commission of a new solar project. Repowering consists of upgrading or replacing key components of a solar array, such as photovoltaic (PV) modules, inverters, and/or transformers. Using existing solar farm structures along with newer, more advanced components offers PV systems a longer operational life with improved efficiency and electricity production, making partial or full repowering a financially attractive path forward.

When to Repower a Utility-Scale PV System

PV systems can either undergo a full repower where all key elements are replaced, or a partial repower where only certain ones are. Significant retrofit packages and software upgrades can also count as partial repowering. Some key indicators and metrics will help operators assess when repowering a system can provide significant ROI – and which elements to repower. Regular performance audits are essential to monitor

When the signs point towards declining performance and increased maintenance demands, it's time to consider repowering your utility-scale PV system. Assessing these indicators will guide you in determining the most beneficial repowering strategy to enhance system efficiency and ensure long-term operational success.

-  **Energy output:** Watch for a >10% decline from initial performance.
-  **Inverter efficiency & failures:** Inverters with a high failure rate and/or low efficiency may need to be replaced.
-  **Module condition:** Module degradation exceeding 20% from original efficiency may indicate a need for replacement.
-  **System downtime:** Increased frequency and duration can signal deteriorating system health.
-  **Need for repairs:** Note when repairs get more frequent and costly. A major tell is when it becomes difficult to source replacement parts for a component, since they're no longer being produced.



How to Create a Utility-Scale PV System Repowering Strategy

Different parts of a utility solar installation tend to wear down out of sync instead of all at once. To lower costs and minimize downtime and lost revenues, conduct a thorough site assessment that evaluates each component's current conditions. Identifying core areas for improvement and assessing the feasibility of implementing several upgrades at the same time can lead to less piecemealing of solar repowering, improving the project's ROI.

What Components to Repower in a PV System

When choosing which components to repower, use the performance, repair, and efficiency data gathered from your performance audits to determine which components' replacement will generate the most ROI. Prioritize elements with the most significant performance impact, such as outdated or underperforming components. Common replacements to consider include:



■ Inverters

Repowering the inverter often has significant potential for increasing performance, and can be relatively straightforward as well. When the new inverter's technical specifications (power, MPPT-window, AC-voltage, AC-current, size, and connection area) align with the existing equipment, often only minor adjustments to the central inverter are needed.



■ PV Modules

Solar modules typically degrade at a rate of about 0.5% to 1% per year, which significantly reduces the overall efficiency and output of the solar array over time. Newer PV modules often have efficiencies above 20% (compared to older models at 15-18%), in addition to being more resilient against environmental extremes. For utility-scale solar arrays with thousands of modules, the replacement of underperforming ones with high-efficiency modules can drastically increase production. For instance, WiseEnergy's replacement of 12MWp of panels, previously from defunct manufacturers, led to an internal rate of return above 12%.

The same project also showed significant ROI from coating 10MWp of existing modules with an anti-reflective layer to increase solar irradiation absorption. This option also reduces downtime, since it doesn't require the modules to be taken offline.



■ Trackers

Replacing outdated trackers or fixed racking with advanced models offers improved tracker accuracy, resulting in a higher energy yield, and better resistance to environmental factors. Modern solar trackers significantly outperform older models by incorporating advanced sensors and actuators to dynamically adjust panels towards the sun, optimizing energy capture and significantly reducing reflection and absorption losses. In some cases they can boost energy production by up to 25% compared to static systems, minimizing the need for extensive (and expensive) land use.

Smart tracking systems can further refine efficiency through predictive analytics and machine learning, adjusting to real-time environmental conditions for maximized output and operational savings.

■ Electrical Infrastructure

Assess whether wiring, junction boxes, and/or combiner boxes should be updated to handle increased power throughput and increase worker safety. Upgrading electrical infrastructure helps prevent issues such as equipment overheating, nuisance tripping, system failure, and reduced power generation.

In addition, check for proper sizing of overcurrent protection devices, which make PV systems safer

and more productive by addressing challenges related to internal operating temperatures and stress on components. This helps ensure that the system remains operational during extreme conditions.



■ Monitoring Systems

If your current monitoring system doesn't provide real-time performance tracking and automated control for optimized energy production, it may be time to switch to an updated version. Modern PV monitoring systems enable efficient, real-time oversight and control of solar energy systems by using digital control rooms and sophisticated software to support instantaneous, data-informed decision-making. This helps streamline the identification and correction of performance issues. Many of these systems are designed for seamless integration with existing hardware, making replacement both straightforward and cost-effective.



■ **Battery Storage Integration**

Integrating energy storage into utility-scale PV systems is quickly becoming crucial for grid stability and flexibility. By capturing and storing excess solar energy during peak production times, grid-scale battery storage systems help avoid the dreaded “duck curve” by providing power during peak demand times – usually evening – when solar energy production is low. This supports grid stability and helps PV system stakeholders benefit from selling electricity to the grid at peak demand times, when energy prices are highest.

Even if your PV system already includes energy storage, it’s worth analyzing the potential ROI of upgrading or expanding your battery system. Modern units often offer advantages like ramp control, peak load compensation, capacity firming, and enhanced ability to recover from blackouts. If repowering other components of your system will significantly increase its energy production, an expanded battery system will also help maximize the benefits of this added capacity.

Analyzing these components’ historical performance will help your team identify the system’s primary operational challenges and develop a detailed project plan that outlines the scope, timeline, budget, and resource requirements for the repowering process.

■ **Minimize Disruption with Modular Repowering Strategies**

Phased, or modular, repowering strategies break down the repowering project into manageable phases of upgrading specific sections or subsystems. This approach allows flexibility in implementation and reduces the overall impact on energy production during the repowering process. It also enables developers to optimize the use of time and budget resources while maintaining a more consistent energy output throughout the project.

The repowering process should generally address critical components first to enhance overall system efficiency while minimizing downtime. Developing a company-wide strategy that minimizes operational disruptions should include:

- Establish a detailed project schedule with contingency plans to address unforeseen issues and ensure a smooth transition.
- Conduct a thorough compatibility analysis between new and existing components to prevent issues during integration.
- Implement upgrades during low-demand periods where possible, like midday.
- Provide advanced notice for any downtime and communicate real-time updates throughout the project.
- Implement temporary backup systems or alternative power sources to ensure uninterrupted electricity supply during critical phases of the repowering process.
- Collaborate with local authorities and emergency services to coordinate response plans, emphasizing safety measures and minimizing disruptions to the community.

Best Practices for Repowering a Utility-Scale System

Consider Holistic Site Factors

While comprehensive site assessments are the cornerstone of any repowering strategy, more than the system itself needs to be analyzed: its surroundings should also be examined. Consider the impact of any environmental changes since the system was first designed, such as increased shading from new structures or tree growth. Alternately, new areas that previously weren't suitable for panels might now be, due to the loss of a shade factor like a tree or building.

Some solar farms may be in areas where the risk of damage has increased due to the growing frequency and severity of extreme weather events like floods, mudslides, blizzards, hurricanes, and storms. Analyzing the site's climate risks will help identify the need to repower with more resilient components and systems.

Embrace Technological Advances

Don't get bogged down trying to find one-to-one component replacements that may not even be on the market. Many specific models of products that need repowering are no longer being produced, creating the opportunity for better, smarter, more efficient models instead. Take advantage of this opportunity and have your team research which newer components and technologies will best suit your goals.

For instance, current remote monitoring capabilities and predictive maintenance algorithms can identify potential issues before they lead to system failures, reducing downtime and improving overall reliability. Aim to integrate advanced monitoring and control systems that utilize real-time data analytics and artificial intelligence to optimize system performance.



Define Stakeholder, Contractor, and Supply Roles to Streamline the Process

Clearly define roles and responsibilities for all stakeholders, contractors, suppliers, regulators, and other parties involved in the repowering process — especially if there are multiple parties involved. Contracts should include clear outlines of responsibilities, timelines, and performance expectations to minimize potential disputes and uncertainties. Establishing effective communication channels will minimize miscommunication and ensure a cohesive approach.

In addition, consider where centralized decision-making can make sense for your project. Limiting the number of decision-makers involved in critical aspects of the repowering project can expedite the decision process and prevent delays caused by conflicting opinions or bureaucracy.

Similarly, consolidating suppliers can help resolve supply chain issues by improving coordination and decreasing the risk of delays or complications. Find reliable and experienced vendors that can access a range of technologies and are experienced in installing multi-asset installations.



Save on repowering costs by timing hardware purchases with year-end discounts, while transparent stakeholder communication ensures smooth operations and investor confidence.

Capitalize on Discounts and Residual Value

Sometimes, it pays to align repowering product procurement with end-of-year hardware discounts, which can yield considerable savings. Replacing hardware with newer components from the secondary market – or reselling the old equipment you’re replacing – can recover residual value and further optimize the ROI of repowering. Overall, include financial aspects in your repowering strategy, such as taking advantage of tax benefits, incentives, and rebates tied to equipment replacement.

Collaborate with Stakeholders

Communicate transparently and regularly about the planned repowering activities with relevant stakeholders, including utility companies, grid operators, and consumers. Define channels for communication, including email, official notices, and community meetings, to ensure that information reaches all relevant stakeholders promptly.

Provide advanced notice to stakeholders about potential service interruptions due to repowering activities. Transparency about the timing and duration of any disruptions allows for better planning and mitigates any unexpected inconveniences for consumers, utility companies, and grid operators. Provide advance notice of potential service interruptions, and establish clear communication channels for real-time updates during the project.

In addition, actively involve any local communities that the repowering project may impact. For instance, hosting community engagement sessions, surveys, or online forums helps build a positive relationship by addressing concerns, clarifying expectations, sharing project details, and gathering feedback.

Keep investors informed about the progress of the repowering project, providing regular updates on the rationale, progress, and expected outcomes. Regularly share milestones, achievements, and any deviations from the plan. This helps ensure that the project remains aligned with investor expectations and demonstrates the financial benefits of repowering activities, ensuring that investors are confident in the project’s direction.

Communicate with Regulators

Work closely with regulatory authorities to obtain necessary permits well in advance. Stay informed about local regulations, and proactively address any potential compliance issues to avoid delays or complications during repowering.

Use tools that make the project more time- and cost-effective

Taking advantage of advanced technology isn't limited to the components themselves. For instance, each PV module should be tested for efficiency to identify the need for repowering and ensure ROI. For residential solar systems, this doesn't take long. However, efficiency testing is time and labor-intensive for utility-scale solar arrays, which contain thousands of modules. Ultimately, this impacts the cost-efficiency of repowering.

Tools like the Fluke Solmetric PVA-1500HE2 I-V Curve Tracer speed up the repowering process by rapidly measuring current-voltage and power-voltage curves for each string with a single click, enabling fast assessment of individual module performance. Designed for 1500-volts (utility-scale voltage), Copernicus boosts operational efficiency and safety by allowing faster testing across the solar array. Automated data analysis and real-time performance assessment helps technicians immediately identify underperforming modules and strings, which reduces manual data processing time. This ability to quickly identify underperforming modules minimizes downtime and makes the repowering process faster, more efficient, and more cost-effective.

Repowering, the Key to Solar's Future

As the lynchpin of the clean energy transition, many utility-scale solar and storage systems have the potential to provide value far beyond their initial specifications and lifespan. Cost-effective repowering unlocks this massive potential, ensuring PV systems meet the evolving demands of clean energy production. This strategic investment both extends the operational life of solar projects and maximizes their efficiency and economic return. By embracing repowering, solar professionals can lead the charge toward a sustainable, profitable future in clean energy for many decades to come.

Advance your solar project's performance and reliability with Fluke's specialized solar training and precision tools. Start optimizing your operations today by exploring our dedicated solar solutions.



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