

A close-up photograph of a person's hands, wearing a blue long-sleeved shirt and bright yellow safety gloves, using a red and black power drill to secure a solar panel. The solar panels are dark blue with a grid of silver lines, and they are being installed on a metal frame. The background is slightly blurred, showing more solar panels and the structure of the installation.

REPOWERING AND OBSOLESCENCE OF SOLAR FARMS: A COMPREHENSIVE OVERVIEW

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INTRODUCTION

This document explores the concept of repowering solar farms, examining its definition, typical timeframes, case studies and relevant references. It also addresses the critical issue of obsolescence in solar farms, covering its definition, contributing factors, impacts, and the development of an effective obsolescence plan for a large-scale solar farm.

REPOWERING

Repowering a solar farm involves upgrading or replacing its existing components to boost performance, extend its lifespan, or both. This can include swapping out older, less efficient modules for newer, higher-efficiency ones, upgrading inverters, or even reconfiguring the farm's layout. Repowering is more than just maintenance or repairs; it aims to significantly improve the plant's overall capacity and efficiency, often bringing it up to current technological standards. It can also include expanding the site's capacity.

The timeframe for repowering a solar farm can vary significantly depending on several factors, including:

- **Scale of the project:** Repowering a small farm will obviously take less time than a large utility-scale project.
- **Complexity of the upgrade:** Replacing just the modules is a simpler process than reconfiguring the entire site and upgrading all components.
- **Regulatory approvals:** Obtaining necessary permits and approvals can be a time-consuming process.

- **Grid connection:** Upgrading the grid connection to accommodate increased capacity might be required and can impact the overall timeline.
- **Supply chain and logistics:** Availability of new equipment and the logistics of replacing old components can influence the project duration.

A typical repowering project could take anywhere from 6 months to 2 years from initial planning to commissioning. This includes feasibility studies, design, permitting, procurement, construction, and testing.

Repowering processes

There are several ways of repowering a solar farm. Some of the most common are listed below:

- **End-of-Life Replacement:** Solar farms have a design lifespan (often 25-30 years). When they reach it, or components fail significantly, you replace a large number of panels, maybe even the whole farm.
- **Module Upgrades:** This is often the most cost-effective, as modules improve a lot over time and the costs are getting increasingly lower. This process consists in swapping out the solar panels that are not producing the expected output for more efficient ones. This process may or may not require changing the whole infrastructure, depending on the difference in power and size of the new solar modules.
- **"Deep Repowering":** This is a phased approach, where components are systematically upgraded over time, rather than one massive overhaul, mainly with the objective of spreading out the costs. An advantage of this method is that it minimises downtime, as you're not rebuilding the whole farm at once.



Main challenges of repowering

- **Logistics:** Managing ongoing upgrades at a solar farm presents a significantly more intricate logistical challenge compared to a single, large-scale project. This happens because instead of a single construction phase, you're looking at multiple, smaller phases spread over time. This requires meticulous scheduling and coordination to minimise disruption to energy generation. Each stage needs its own project management, procurement, and installation plan. Besides, working on an operational solar farm adds another layer of complexity, since you're integrating new equipment into an existing system. This demands careful coordination between different teams and contractors to ensure safety and avoid damage to existing infrastructure, making sure that the right components are delivered at the right time for each stage of the upgrade. Reverse logistics, dealing with the removal and disposal of old components, also needs careful consideration.
- **Cost:** The cost of continuous upgrades needs careful scrutiny to ensure it makes financial sense. While the idea of spreading costs over time is attractive, it's essential to conduct a thorough cost-benefit analysis. For example, while smaller than a full replacement, each upgrade phase still requires a significant upfront investment. These costs need to be factored into the overall financial model. The key is to demonstrate a clear return on investment over the long term. This requires accurate projections of energy generation increases, maintenance cost reductions, and the lifespan of new components. Additionally, securing financing for ongoing upgrades can be more complex than for a single project. Lenders need to be convinced of the long-term viability and profitability of the continuous upgrade strategy. However, there's an opportunity cost associated with each upgrade phase. While the new components are being installed, the old components are still generating some electricity. This should be factored into the cost-benefit analysis.
- **Standardisation:** Standardisation is crucial for making continuous solar farm upgrades more efficient and cost-effective. The industry needs to focus on developing modular components, such as inverters and racking systems, which would make it much easier to swap out old equipment and integrate new technologies. Ensuring that different components from different manufacturers can easily communicate and work together is essential. This requires open standards and protocols for data exchange. That goes for modules, mounting

systems, installation procedures, monitoring software, etc.

Considerations when repowering

- **Modules:**
 - Power output: New modules will likely have a higher wattage. This impacts the overall system capacity and might require changes downstream.
 - Voltage and current: The electrical characteristics of the new modules (voltage, current) must be compatible with the existing inverters or require new inverters.
 - Physical dimensions and mounting: New modules may be a different size or require different mounting hardware. This could involve modifying racking systems.
 - Weight: Heavier modules may require structural reinforcement of the racking.
- **Inverters**
 - Capacity: If the overall power output of the farm increases significantly, the inverters may need to be upgraded to handle the extra load.
 - Voltage and current compatibility: Inverters must be compatible with the voltage and current output of the new modules. Sometimes, even if the power increase isn't huge, the electrical characteristics of the modules necessitate new inverters.
 - Technology: Older inverters might be less efficient or lack advanced grid connection features. Repowering provides an opportunity to upgrade to newer inverter technology.
 - String vs. Central Inverters: The type of inverter setup (string or central) might be re-evaluated during repowering.
 - Number of Inverters: With higher wattage modules, fewer inverters might be required.
- **Cabling**
 - Current carrying capacity: Cables must be able to handle the increased current from the higher-power modules. Undersized cables can overheat and become a fire hazard.
 - Voltage rating: Cables need to be rated for the voltage of the system.
 - Connectors: Connectors might need to be replaced to ensure compatibility with the new modules and to maintain weatherproofing.
 - Cable management: The layout and organization of cables might need to be adjusted to accommodate the new modules and inverters.

• Racking and Structure

- Module dimensions and mounting: As mentioned earlier, new modules may require different mounting hardware or spacing.
- Structural integrity: The racking must be able to support the weight of the new modules, especially if they are heavier.
- Corrosion and age: Older racking might be corroded or weakened. Repowering provides an opportunity to upgrade the structure and ensure its long-term reliability.
- Grounding: Might need to be checked and upgraded.

• Transformers and Grid Connection

- Capacity: The transformer must be able to handle the increased power output.
- Grid connection studies: Significant increases in capacity will definitely require new grid connection studies and approvals from the relevant authorities. The grid itself may also need to be upgraded in some cases.

• Monitoring and Control Systems

- Data acquisition: New modules and inverters might have different communication protocols.
- Remote monitoring: Modern systems allow for remote monitoring and control of the solar farm.
- Supervisory Control and Data Acquisition (SCADA) integration: Integrating the solar farm's monitoring system with a SCADA system can improve overall management.

• Sizing and Output Power Considerations:

- Small-scale systems (e.g., <1 MW): Repowering might be simpler, potentially involving just module and inverter replacements. Cabling and racking are less likely to need major overhauls unless there are significant changes in the system's electrical characteristics.
- Mid-sized systems (e.g., 1-10 MW): These systems may require more extensive upgrades, including inverters, cabling, and potentially some modifications to the racking system.
- Large-scale systems (e.g., >10 MW): Repowering large solar farms is a complex undertaking. It often involves replacing modules, inverters, cabling, racking, and possibly even the transformer and grid connection infrastructure. Careful planning and engineering are essential.

Case Studies

Case Study 1: A solar farm located in the UK is a community-owned solar project on social housing. This case study highlights the social and economic aspects of repowering, in addition to the technical upgrades. It demonstrates how repowering can empower communities and contribute to local sustainability goals.

- **Module Upgrades:** Older modules were replaced with newer, more efficient ones, increasing the overall capacity of the solar installations.
- **Community Engagement:** Repowering London emphasizes community involvement in the projects, providing training and employment opportunities for residents.
- **Financial Model:** The projects use a cooperative model, where residents can invest in the solar installations and receive a return on their investment.
- **Outcomes:**
 - Increased energy generation
 - Reduced carbon emissions
 - Community benefits through local investment and job creation
 - Improved energy efficiency in social housing

Case Study 2: A utility-scale solar farm located in the US. This example showcases the technical and economic drivers behind repowering utility-scale solar farms. It demonstrates how repowering can make existing solar assets more efficient and profitable, contributing to the growth of renewable energy.

- **Module Replacements:** Older modules are replaced with newer, high-efficiency modules, often increasing the farm's capacity.
- **Inverter Upgrades:** Inverters are replaced to handle the increased power output and improve grid integration.
- **Racking Modifications:** In some cases, the racking system may need to be modified to accommodate the new modules.
- **Grid Connection Upgrades:** Depending on the scale of the repowering, the connection to the electricity grid may need to be upgraded.
- **Outcomes:**
 - Significant increase in energy production
 - Extended lifespan of the solar farm
 - Reduced levelized cost of electricity (LCOE)
 - Improved performance and reliability

OBSOLESCENCE

Obsolescence in a solar farm refers to the point at which the technology, components, or the entire system becomes outdated, inefficient, or no longer economically viable compared to newer alternatives. It encompasses physical specifications, technological advancements, changing market conditions, and evolving regulatory requirements. Several factors contribute to the obsolescence of solar farms:

- **Technological Advancements:** Rapid improvements in solar technology, such as higher efficiency modules, advanced inverters, and sophisticated monitoring systems, can make older equipment less competitive.
- **Component Degradation:** Solar farm components, including modules, inverters, and racking, degrade over time due to environmental factors like UV exposure, temperature fluctuations, and humidity. This leads to reduced performance and increased maintenance costs.
- **Supply Chain Issues:** Manufacturers may discontinue older product lines, making it difficult or impossible to obtain replacement parts. This can lead to extended downtime and increased costs.
- **Changing Regulations and Standards:** New regulations or industry standards may require upgrades or modifications to older solar farms, making them functionally obsolete if not addressed.
- **Economic Factors:** Declining electricity prices or changes in government incentives can impact the economic viability of older solar farms, making them less profitable and potentially obsolete.
- **Cybersecurity Risks:** Older systems might lack modern cybersecurity features, making them vulnerable to attacks.

IMPACTS OF OBSOLESCENCE

- **Reduced Energy Production:** Degraded components and outdated technology lead to lower energy output, impacting revenue and return on investment.
- **Increased Maintenance Costs:** Older equipment requires more frequent maintenance and repairs, increasing operating expenses.
- **Extended Downtime:** Obsolete components can be difficult to replace, leading to prolonged periods of downtime and lost revenue.
- **Safety Risks:** Aging equipment can pose safety hazards, such as electrical faults or structural failures.

- **Environmental Impact:** Inefficient or malfunctioning systems can have a greater environmental footprint.
- **Financial Losses:** Ultimately, obsolescence can lead to significant financial losses for solar farm owners and investors.

OBSOLESCENCE PLAN FOR A LARGE-SCALE SOLAR FARM (EXAMPLE)

A solid obsolescence plan is essential for managing the risks that come with ageing solar farms. This plan should cover these key areas:

Inventory and Assessment

- **Detailed Inventory:** Keep a complete record of all components, including modules, inverters, racking, cabling, transformers, and monitoring systems. Note down manufacturer details, model numbers, installation dates, and expected lifespan.
- **Performance Monitoring:** Set up a reliable performance monitoring system to track energy output, spot any performance decline, and pick up potential problems early.
- **Condition Assessments:** Regularly inspect and assess all components to find any signs of wear, damage, or degradation.

Technology Roadmap

- **Staying Informed:** Maintain awareness of the latest advancements in solar technologies, encompassing module efficiency, inverter technology, energy storage solutions, and monitoring systems.
- **Technology Evaluation:** Conduct regular assessments of emerging technologies to determine their potential to enhance solar farm performance and extend operational lifespan.

Replacement Strategy

- **Component Lifespan:** Determine the anticipated lifespan of all key components, based on manufacturer specifications and industry best practices.
- **Phased Replacement:** Develop a phased replacement strategy for components approaching their end-of-life or exhibiting significant performance degradation. This may involve a rolling replacement schedule, where a designated percentage of components is replaced annually.

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- **Spare Parts Management:** Maintain an inventory of critical spare parts to minimise downtime in the event of component failure. However, consideration must be given to appropriate storage conditions and the potential for obsolescence of the spare parts themselves.
- **End-of-Life Management:** Establish a plan for the responsible disposal or recycling of obsolete components, ensuring compliance with all applicable environmental regulations.

Financial Planning

- **Budgeting:** Allocate appropriate funds within the solar farm's operating budget to accommodate future replacements and upgrades.
- **Lifecycle Cost Analysis:** Conduct comprehensive lifecycle cost analyses to assess the economic viability of various replacement strategies and technology upgrades.
- **Insurance:** Secure adequate insurance coverage to mitigate potential financial losses arising from component failures or other unforeseen circumstances.

Cybersecurity

- **Regular Updates:** Implement a schedule of regular software and firmware updates to address and remediate identified security vulnerabilities.
- **Security Audits:** Conduct periodic security audits to proactively identify and mitigate potential cybersecurity risks.
- **Data Protection:** Implement robust data protection measures to ensure the safeguarding of sensitive information.

Regular Review and Updates

- **Dynamic Plan:** Acknowledge that the obsolescence plan is a dynamic document requiring regular review and updates to reflect evolving technology, regulatory changes, and market conditions.
- **Stakeholder Engagement:** Engage with relevant stakeholders, including operators, maintenance providers, and financial institutions, to ensure alignment of the plan with their respective needs and objectives.

REFERENCES

- <https://www.pfnexus.com/blog/solar-repowering>
- <https://www.baywa-re.com/en/asset-operations/pv-revamping-and-repowering#:~:text=Revamping%20your%20solar%20PV%20plant,and%20to%20increase%20its%20efficiency>
- <https://www.baywa-re.co.uk/en/company/blog/the-importance-of-revamping-and-repowering-your-solar-plant>
- <https://www.business.qld.gov.au/industries/mining-energy-water/energy/renewable/project-development/industry-associations/australian>
- <https://www.aeic.gov.au/observations-and-recommendations/governance-compliance>
- <https://en.blog.milkthesun.com/solar-power-plants-repowering/>