RAPPORT

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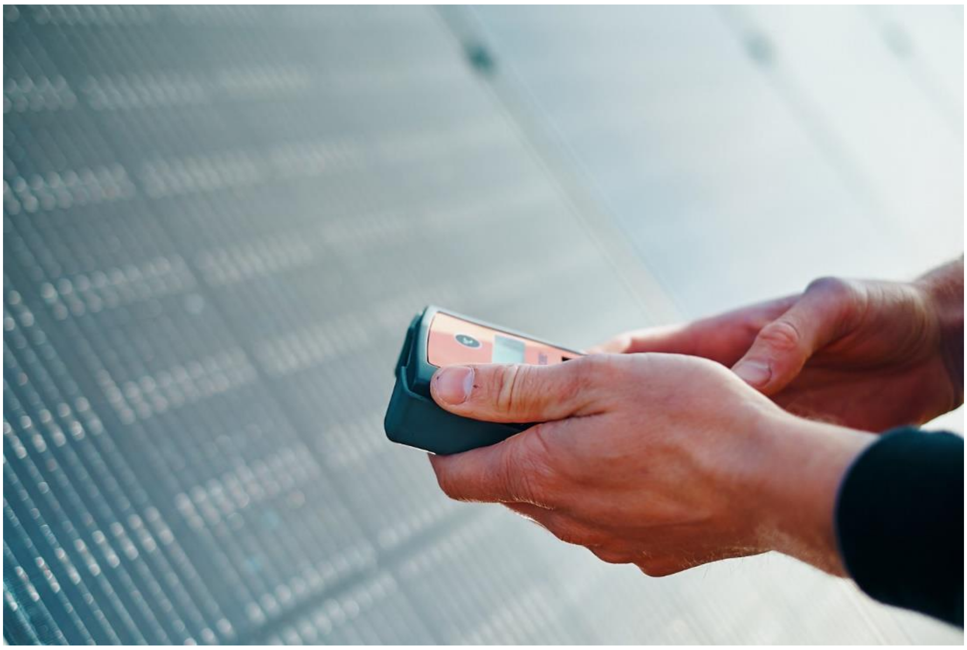
2023-01-11

Beteckning

Kunskapssammanställning om förvaltning och drift av solcellsanläggningar i ett internationellt perspektiv



RISE Research Institutes of Sweden AB
Energi och resurser - Lokala energisystem, solenergi och männi

Utfört av

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Förord

Denna kunskapssammanställning har tagits fram av RISE Research Institutes of Sweden inom ramen för projektet Klimateffektiv Solenergi som ett underlag till en vägledning för en klimateffektiv förvaltning av solcellsanläggningar. Projektet i sin helhet syftar till att bidra till ökad kunskap om och hänsyn till solcellers klimatprestanda hos marknadsaktörer.

Projektet Klimateffektiv Solenergi leds av Energikontoret Storsthlm och utförs i ett samarbete med Energikontor Syd, RISE Research Institutes of Sweden och allmännyttans inköpscentral HBV. Finansiering av projektet kommer från Energimyndigheten (programmet El från Solen) och HBV.

Innehåll

Inledning

Denna kunskapssammanställning tillsammans med resultat från intervjuer ger underlag till en vägledning med råd för en klimateffektiv förvaltning av solcellsanläggningar. Vägledningen kommer i första hand rikta sig till beställare eller ägare av större solcellsanläggningar (ej villa-anläggningar).

Kortfattat ska vägledningen innehålla:

- Optimerad drift för att uppnå hög klimatprestanda i ett livscykelperspektiv
- Råd för en klimateffektiv förvaltning av solcellsanläggningar
- Bedömningar av olika åtgärders relevans för att minska klimatpåverkan per producerad kWh

Utifrån dessa punkter bedöms följande övergripande avsnitt ingå i vägledningen:

1. Solcellsanläggningens klimatpåverkan
2. Förutsättningar för en klimateffektiv förvaltning
3. Förvaltningserfarenheter i Sverige
4. Förvaltningsstrategier på internationella marknader
5. Råd för en klimateffektiv förvaltning

Definitionen av innehållet är vägledande för vilka områden och ämnen som kunskapsinsamlingen omfattar. Primärt blir vägledningen en sammanställning av rekommendationer och aktuell forskning i syfte att beskriva vanliga förvaltningsstrategier som förekommer på andra marknader än den svenska, och förekomsten och betydelsen av driftstopp.

Metod för kunskapssammanställning

Kunskapsinsamlingen påbörjades genom en sökning efter rekommendationer, forskningsrapporter och artiklar hos några av RISE välkända instanser:

- IEA PVPS Task 12 och Task 13
- EU H2020 TRUST- PV
- SolarPower Europe
- NREL, National Renewable Energy Laboratory

Därefter utfördes sökning på termer och nyckelord på plattformarna Google Scholar och Scopus. Angivna träffar från sökningarna anses ha relevant koppling till vägledningens innehåll efter genomläsning av ”abstract” och slutsatser. Sökning utfördes först på Google Scholar och därefter adderades endast träffar från Scopus som ej redan kommit upp i Google Scholar. Sökning utfördes även på termer i de populärvetenskapliga digitala tidskrifterna PV Magazine och PV Tech. Angiven relevant litteratur refereras i denna sammanställning enbart med referensuppgifter samt några med Abstract eller Highlights. Sammanfattning av innehåll eller specifik information refereras separat i vägledningen med tillhörande hänvisning. Samtliga sökningar utfördes under perioden oktober - december 2022.

IEA PVPS, International Energy Agency Photovoltaic Power Systems Programme - Task 12 PV Sustainability Activities

https://iea-pvps.org/research-tasks/pv-sustainability/

Environmental life cycle assessment of electricity from PV systems (2022 update)

R. Frischknecht, (Ed.) (2022) ”*Fact sheet: Environmental life cycle assessment of electricity from PV systems 2021 Data Update*”, International Energy Agency (IEA) PVPS Task 12

https://iea-pvps.org/fact-sheets/fact-sheet-environmental-life-cycle-assessment-of-electricity-from-pv-systems-2022-update/

Resource Use Footprints of Residential PV Systems

R. Frischknecht, L. Krebs. (2022). ”*Resource Use Footprints of Residential PV Systems*”, International Energy Agency (IEA) PVPS Task 12, Report T12-22:2022. ISBN 978-3-907281-25-3.

https://iea-pvps.org/key-topics/mineral-resource-use-footprints-of-residential-pv-systems/

Status of PV Module Recycling in Selected IEA PVPS Task 12 Countries

K. Komoto, M. Held, C. Agraffeil, C. AlonsoGarcia, A. Danelli, J. Lee, F. Lyu, J. Bilbao, R. Deng, G. Heath, D. Ravikumar, P. Sinha. (2022) ”*Status of PV Module Recycling in Selected IEA PVPS Task 12 Countries*”, International Energy Agency (IEA) PVPS Task 12, Report T12-24:2022. ISBN 978-3-907281-32-1.

https://iea-pvps.org/key-topics/status-of-pv-module-recycling-in-selected-iea-pvps-task12-countries/

Preliminary Environmental and Financial Viability Analysis of Circular Economy Scenarios for Satisfying PV System Service Lifetime

N. Rajagopalan, A. Smeets, K. Peeters, S. De Regel, T. Rommens, K. Wang, P. Stolz, R. Frischknecht, G. Heath, D. Ravikumar. (2021). *“Preliminary Environmental and Financial Viability Analysis of Circular Economy Scenarios for Satisfying PV System Service Lifetime”* International Energy Agency (IEA) PVPS Task 12, Report T12-21:2021. ISBN 978-3-907281-23-9.

https://iea-pvps.org/key-topics/preliminary-environmental-financial-viability-analysis-of-circular-economy-scenarios-for-satisfying-pv-system-service-lifetime/

IEA PVPS, International Energy Agency Photovoltaic Power Systems Programme - Task 13 Reliability and Performance of Photovoltaic Systems

https://iea-pvps.org/research-tasks/performance-operation-and-reliability-of-photovoltaic-systems/

Guidelines for Operation and Maintenance of Photovoltaic Power Plants in Different Climates

Ulrike Jahn et al. (2022).”*Guidelines for Operation and Maintenance of Photovoltaic Power Plants in Different Climates*”, International Energy Agency (IEA) PVPS Task 12, Report T13-25:2022. ISBN 978-3-907281-13-0

https://iea-pvps.org/key-topics/guidelines-for-operation-and-maintenance-of-photovoltaic-power-plants-in-different-climates/

“Abstract
The increasing adoption of PV systems in different climate zones and conditions worldwide has indicated that stress factors such as temperature, humidity, exposure to UV light, rain, and wind could contribute to the occurrence of module failures. Knowing this fact, operation & maintenance (O&M) operators have looked to customize O&M services to the climate zone where particular plants are located.

At present, comprehensive guidelines for climate-specific O&M programs have yet to be developed. With this gap in mind, this report aims to provide comprehensive guidance for customized O&M service in seven different climate zones. The first four are for conditions which broadly prevail in large parts of the world (moderate, hot and dry, hot and humid, desert at high elevation), while the latter three are for extreme conditions (flood-prone regions, cyclonic regions, snowy regions). These guidelines can assist PV plant engineers and de-signers, financing parties, and investors in designing and maintaining PV plants, as well as in determining operational risk related to investment decisions.

The report presents these guidelines according to the following topics: O&M performance indicators and standard O&M operator services, guidelines for monitoring, forecasting, and analysis of PV plant performance and safety, the different types of maintenance services and advanced inspections, and finally the recommendations for climate-specific O&M along with field experiences encountered that affected reliability, performance and safety.”

Quantification of Technical Risks in PV Power Systems

Magnus Herz , Gabi Friesen , Ulrike Jahn , Marc Köntges , Sascha Lindig , David Moser (2021). ”*Quantification of Technical Risks in PV Power Systems*”, International Energy Agency (IEA) PVPS Task 12, Report T13-23:2021. ISBN 978-3-907281-11-6

https://iea-pvps.org/key-topics/quantification-of-technical-risks-in-pv-power-systems/

EU H2020 TRUST-PV - Increase Friendly Integration of Reliable PV plants considering different market segments

https://www.eurac.edu/en/institutes-centers/institute-for-renewable-energy/projects/trust-pv
https://trust-pv.eu/outputs/

Trends and innovations in photovoltaic operations and maintenance

G Oviedo Hernandez et al (2022) "*Trends and innovations in photovoltaic operations and maintenance*" Progress in Energy 4 042002

https://doi.org/10.1088/2516-1083/ac7c4f

Abstract
This review work presents an overview of the innovations shaping today's photovoltaic (PV) operations and maintenance sector by summarising literature and current research. After a brief introduction to the market dynamics and state-of-the-art best practices, relevant insights are provided into emerging fields and key research directions are identified, such as the adaptation and application of the building information modelling concept and digital twins, which are topics already proven to help other industries to render processes more efficient, reduce costs and risks throughout the entire lifecycle of a project. Moreover, it explores new approaches on Supervisory Control and Data Acquisition architectures for remote monitoring of PV assets, highlighting the promising role of 5G wireless technologies such as Narrow Band Internet of things. Finally, concerned about the growing amount of PV waste due to the exponential growth of installed capacity on a global scale, this article covers relevant Circular Economy approaches being adapted to PV, pointing out the most significant research and development efforts that are pushing towards a more sustainable, environmentally friendly and economically viable end of life management for modules and balance of system.

Review of photovoltaic module degradation, field inspection techniques and techno-economic assessment

L. Koester, S. Lindig, A. Louwen, A. Astigarraga, G. Manzolini, D. Moser (2022) "*Review of photovoltaic module degradation, field inspection techniques and techno-economic assessment*" Renewable and Sustainable Energy Reviews, Volume 165, 112616, ISSN 1364-0321

https://doi.org/10.1016/j.rser.2022.112616

Abstract
Considering the relevance of photovoltaic technology in the power generation system, degradation and failure of photovoltaic modules are becoming particularly relevant. To adopt and coordinate preventive measures or actions, defects must be understood, detected and their economic impact evaluated. The variety of different degrading effects are categorized and the most significant ones as well as in-field characterization methods are described in detail. This information is summarized in a matrix showing signatures of important defects using different inspection methods and stating related power losses. The development of economic assessments is shown, resulting in a cost-based failure modes and effects analysis with the recently developed cost priority number. How the economic impact of a defect is estimated by the cost priority number is shown in three use cases, namely cell cracks, short circuit bypass diode and potential induced degradation. For each case, the fixing costs are evaluated in comparison to defect related downtime costs. Ultimately, to rank the usefulness of the calculations, influences beyond the financial factor are discussed.

SolarPower Europe

Operations and Maintenance, Best Practice Guidelines, Version 5.0

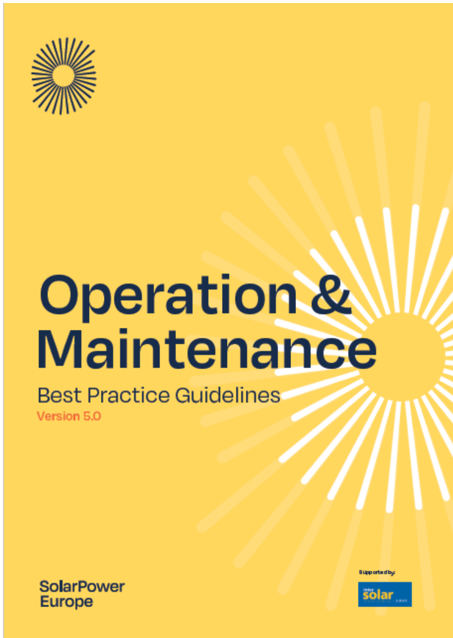
Adele Ara et. al. (2021) ”*Operations and Maintenance, Best Practice Guidelines, Version 5.0”, SolarPower Europe*”, ISBN: 9789464444247

https://www.solarpowereurope.org/insights/thematic-reports/o-and-m-best-practice-guidelines-version-5-0

Lifecycle Quality Workstream
This document is the first O&M Best Practice Guidelines produced by the newly rebranded Lifecycle Quality Workstream. It builds on 2019’s fourth edition and is the result of a year of intensive work by 29 leading solar experts, from 20 companies. The contributors work across the solar PV industry and include O&M service providers, Asset Managers, Asset Owners, renewable energy consultants, legal experts, digital solutions providers, and technical advisors.

Chapters:

- Health, Safety, Security, and Environment
- Personnel & training
- Technical Asset Management
- Power Plant Operation
- Power Plant Maintenance
- Revamping and Repowering
- Spare parts management
- Data and monitoring requirements
- Key Performance Indicators
- Contractual framework
- Innovations and trends
- O&M for Rooftop Solar



NREL, National Renewable Energy Laboratory

Best Practices for Operation and Maintenance of Photovoltaic and Energy Storage Systems; 3rd Edition

Walker, H. A. et al. (2018). ”*Best Practices for Operation and Maintenance of Photovoltaic and Energy Storage Systems; 3rd Edition*”, United States: NREL

https://doi.org/10.2172/1489002

Abstract
The goal of this guide is to reduce the cost and improve the effectiveness of operations and maintenance (O&M) for photovoltaic (PV) systems and combined PV and energy storage systems. Reported O&M costs vary widely based on the requirements of the system and the nature of the O&M contract, but a more standardized approach to planning and delivering O&M has the potential to both decrease costs and make those costs more predictable over time. This guide encourages adoption of best practices to reduce the cost of O&M and improve the performance of fielded systems, but it also enhances financing of new projects by making cost more predictable and mitigating performance risk. This guide also includes technical improvement opportunities in the design of systems and in specification of equipment because high-quality system deployment improves lifetime project performance and energy production while reducing, or at least optimizing, costs to deliver an O&M program. This guide provides recommendations that increase the effectiveness of O&M services; reduce O&M costs, improve solar asset transparency for investors and rating agencies; provide an industry framework for quality management; and reduce transaction costs.

Best Practices at the End of Photovoltaic System Performance Period – February 2021

Curtis, Taylor, Heath, Garvin, Walker, Andy, Desai, Jal, Settle, Edward, and Barbosa, Cesar. (2021). ”*Best Practices at the End of Photovoltaic System Performance Period*” United States: NREL

https://doi.org/10.2172/1765595

Abstract
Responsible and cost-effective dissolution of photovoltaic (PV) system hardware at the end of the performance period has emerged as an important business and environmental consideration. Alternatives include extending the performance period and existing contracts for power purchase, lease, and utility interconnect; refurbishing the plant by correcting any deficiencies; repowering the plant with new PV modules and inverters; or decommissioning the plant and removing all the hardware from the site. Often key decisions are made very early in the project development and might require decommissioning by some certain date after the end of a power purchase agreement. To “abandon in place” is not an alternative acceptable to landowners and regulators, so any financial prospectus should include costs associated with decommissioning, even if those costs are deferred by extending operations, refurbishment, or repowering. Decommissioning costs are driven by regulations regarding the handling and disposal of waste, with reuse and recycling of PV modules and other components preferred as a way to reduce both costs and environmental impact. Each alternative is discussed with order-of-magnitude costs, and recommendations are provided considering site-specific details of that situation, such as estimated costs to refurbish or repower, projected revenue from continued operations, and tax considerations.

Klimateffektiv Solenergi – rapport inom projektet

Jämförelse av klimatpåverkan från tillverkning av olika solcellsmoduler

Askemar, H., & van Noord, M. (2021). *”Klimateffektiv solenergi : Jämförelse av klimatpåverkan från tillverkning av olika solcellsmoduler”* (Nr 978-91-89385-68-9 (ISBN); RISE Rapport, Vol. 1–2021:78, s. 34). DiVA.

http://urn.kb.se/resolve?urn=urn:nbn:se:ri:diva-56642

Abstract
Denna första rapport från projektet Klimateffektiv solenergi sammanställer kunskapsläget om klimatpåverkan från solcellsmoduler och lägger grunden för vidare projektarbete med utformning av upphandlingskriterier. Litteraturgenomgången täcker både en marknadsöversikt över dagens solcellsmarknad samt en genomgång av klimatpåverkan från olika teknologier och konstruktioner för solcellsmoduler. Litteraturgenomgången avgränsas genom att projektet fokuserar på miljöpåverkanskategorin klimatpåverkan. Vidare har tillverkningsskedet varit centralt i arbetet då tidiga resultat från analyser av klimatpåverkan över solcellers hela livscykel påvisar att övervägande klimatpåverkan sker under tillverkningen av solceller. Centrala utmaningar vid bedömning av klimatpåverkan från solceller är brist på aktuella data, att olika studier redovisar resultat i olika enheter (koldioxidekvivalenter per kWh, per modul eller per kWp) samt hur årlig instrålning, prestanda, degradering och livslängd hanteras i de olika studierna. Resultatet påvisar att dagens dominerande solcellsteknik, kristallina kiselsolceller, har större klimatpåverkan jämfört med tunnfilmstekniker. Vidare har monokristallina kiselsolceller större klimatpåverkan från produktion än multikristallina kiselsolceller, men vilken kiselteknik som producerar el med lägst klimatpåverkan beror på verkningsgradsförhållandena. Nyare cellteknologier såsom PERC- och dubbelsidiga solceller kan minska klimatpåverkan från solel genom att elproduktionen per solcell ökar utan att utsläppen vid tillverkning ökar markant. Slutligen finns andra teknologier och modulkonstruktioner (exempelvis flexibla moduler) med potential att minska klimatpåverkan från solceller, både genom lägre klimatpåverkan från tillverkningen och genom att öka solcellernas effektivitet. Klimatpåverkan från tillverkning orsakas huvudsakligen av energianvändning i olika processer och därmed blir elmixen vid tillverkning avgörande för klimatpåverkan. Elmixen är starkt kopplad till det lokala elsystemet, vilket innebär att tillverkningsland för kiselråvaran, solceller, solcellsmoduler med mera kan bli en nyckelfaktor för att åstadkomma klimateffektiva solcellsmoduler. Eftersom tillverkningen idag sker främst i Kina och övriga asiatiska länder, som har en betydande andel kolkraft i elmixen, orsakas en stor del av klimatpåverkan från dagens solceller av den fossilbaserade elen i dessa länder.

Google scholar

Sökfraser: "sustainable operation and maintenance pv"/ "sustainable O&M photovoltaics"

A review of photovoltaic systems: Design, operation and maintenance

Luis Hernández-Callejo, Sara Gallardo-Saavedra, Víctor Alonso-Gómez. (2019). "*A review of photovoltaic systems: Design, operation and maintenance*", Solar Energy, Volume 188, Pages 426-440, ISSN 0038-092X

https://doi.org/10.1016/j.solener.2019.06.017

Abstract
Nowadays renewable energies are becoming more important in the generation of electricity. Fossil resources do not present a sustainable option for the future since they are non-renewable sources of energy that contribute to environmental pollution.

Within the sources of renewable generation, photovoltaic energy is the most used, and this is due to a large number of solar resources existing throughout the planet. At present, the greatest advances in photovoltaic systems (regardless of the efficiency of different technologies) are focused on improved designs of photovoltaic systems, as well as optimal operation and maintenance. This work intends to make a review of the photovoltaic systems, where the design, operation and maintenance are the key points of these systems. Within the design, the critical components of the system and their own design are revised. Regarding the operation, it is reviewed the general operation and the operation of hybrid systems, as well as the power quality. Finally, in relation to the maintenance of PV systems, it has been studied their performance, thermography and electroluminescence, dirt, risks and failure modes.

Investigation into the impacts of design, installation, operation and maintenance issues on performance and degradation of installed solar photovoltaic (PV) system

B. Aboagye, S. Gyamfi, E. Antwi Ofosu, S. Djordjevic. (2022). "*Investigation into the impacts of design, installation, operation and maintenance issues on performance and degradation of installed solar photovoltaic (PV) systems*", Energy for Sustainable Development, 66, Pages 165-176, ISSN 0973-0826

https://doi.org/10.1016/j.esd.2021.12.003

Highlights
- Impacts of design, installation, operation and maintenance issues on performance and degradation of PV systems are studied
- Disregard of proper design and installation procedures led to improper sizing of 69% of the systems
- More than 70% of the systems were installed without easy access to the panels for inspection and cleaning
- Improper operation and maintenance practices led to low power output, high degradation rates and components breakdown
- Dissatisfaction with the systems performance, led to abandonment of some of the systems

Survey of maintenance management for photovoltaic power systems

Alfredo Peinado Gonzalo, Alberto Pliego Marugán, Fausto Pedro García Márquez (2020) ”Survey of maintenance management for photovoltaic power systems”,Renewable and Sustainable Energy Reviews, Volume 134, 110347, ISSN 1364-0321

https://doi.org/10.1016/j.rser.2020.110347

Highlights
- Exhaustive literature review and updated survey on maintenance of photovoltaic (PV) plants.
- Novel analysis of the current state and a discussion of the future trends and challenges in PV.
- Analysis of the main faults and degradation mechanisms.
- Study the causes, effects, and the main techniques to detect, prevent and mitigate PV faults.
- Improvement of maintenance management systems in PV plants.

Solar photovoltaics is ready to power a sustainable future

Marta Victoria, Nancy Haegel, Ian Marius Peters, Ron Sinton, Arnulf Jäger-Waldau, Carlos del Cañizo, Christian Breyer, Matthew Stocks, Andrew Blakers, Izumi Kaizuka, Keiichi Komoto, Arno Smets (2021), “*Solar photovoltaics is ready to power a sustainable future*”, Joule, Volume 5, Issue 5, Pages 1041-1056, ISSN 2542-4351

https://doi.org/10.1016/j.joule.2021.03.005

Highlights
- Limiting assumptions on cost and grid integration explains low PV shares in IAMs
- Developments in the pipeline could maintain a high learning rate for solar PV-
- Materials and land availability are not expected to limit solar PV deployment
- Sector coupling could allow large shares of solar PV- in primary energy

Sökfraser: ”repowering PV”/ ”sustainable repowering PV”

Accelerating Photovoltaic Market Entry with Module Replacement

Joel Jean, Michael Woodhouse, Vladimir Bulović (2019) “*Accelerating Photovoltaic Market Entry with Module Replacement*”, Joule, Volume 3, Issue 11, Pages 2824-2841, ISSN 2542-4351

https://doi.org/10.1016/j.joule.2019.08.012

Highlights
- Periodic module replacement reduces initial lifetime requirements for PV modules
- Emerging PV technologies with <15-year initial life can reach a competitive LCOE
- Module replacement is most valuable when non-module costs dominate the system cost
- Continued technology improvement is critical for realizing replacement benefits

Projection of the photovoltaic waste in Spain until 2050

J.D. Santos, M.C. Alonso-García (2018), "*Projection of the photovoltaic waste in Spain until 2050*", Journal of Cleaner Production, Volume 196, Pages 1613-1628, ISSN 0959-6526

https://doi.org/10.1016/j.jclepro.2018.05.252

Highlights

- Repowering of Spanish PV plants could mean 40–50% of the PV power installed in 2050.
- A cumulative PV waste mass of the order of 700,000 tonnes would be expected in 2050.
- Large amounts of PV waste could arise in Spain earlier than other EU countries.
- Irregular evolution of Spanish PV capacity could lead to a period of waste scarcity.
- Minimum recycling targets in WEEE regulation could be oversized for PV waste.

Life cycle assessment of PV module repowering

Sina Herceg, Marie Fischer, Karl-Anders Weiß, Liselotte Schebek (2022), "*Life cycle assessment of PV module repowering*", Energy Strategy Reviews, Volume 43, 100928, ISSN 2211-467X

https://doi.org/10.1016/j.esr.2022.100928

Highlights

- Optimum environmental repowering time for PV plants is between 15 and 21 years.
- Dedicated recycling is crucial for sustainable repowering.
- Lowest environmental impacts when the entire available area is used for repowering.
- a new calculation approach for optimum PV repowering is presented.

The role of innovation for economy and sustainability of photovoltaic modules Ian Marius Peters, Jens A. Hauch, Christoph J. Brabec

Peters, Ian Marius & Hauch, Jens & Brabec, Christoph. (2022). "*The Role of Innovation for Economy and Sustainability of Photovoltaic Modules*". iScience. 25. 105208.

https://doi.org/10.1016/j.isci.2022.105208

Highlights

- Innovation influences the economy and sustainability of solar panels significantly
- Innovation has increased the ability of solar panels to displace carbon 4-fold
- Installations should maximize the carbon displacement potential of each panel
- Capacity expansion should be prioritized over system replacements

Economy and Sustainability of PV-Repowering

Peters, Ian Marius and Hauch, Jens and Brabec, Christoph. (2021). "*Economy and Sustainability of PV-Repowering*"

https://dx.doi.org/10.2139/ssrn.3974935

Abstract

PV-Repowering describes the processes of replacing old PV modules with new and better ones. The dynamics of this process are driven by two factors: degradation and innovation.

Faster degradation prepones the ideal moment for module replacement. Innovation has a more complex impact; better technology makes replacements attractive earlier, yet a great rate of progress may make waiting for tomorrow's technology the better choice. While these two factors affect the ideal timing for repowering from an economical as well as from a sustainability point of view, they do so in different ways. Economically, we see advantages for module replacement after 20 to 25 years of operation in the field, yet when considering CO2 reductions, repowering is opportune only within a limited window. In Germany, this window pertains to PV modules installed before 2017. Yet even then repowering only results in minor improvements of the CO2 balance at best. In all cases, whether considering economics or sustainability, repowering is inferior to using new PV modules for additional PV-installations. To achieve carbon neutrality, PV capacity expansion at the earliest possible time has to be prioritized. PV-repowering is a second order effect, yet it has its place wherever capacity expansion is not possible, for example for rooftop installations used for electricity self-consumption. In all cases where repowering is advantageous, we see opportunities for advanced technologies like tandem solar cells.

Sökfraser: " lifetime PV systems"/ "lifetime PV systems statistics"/ "lifetime reliability PV"

A combined model for PV system lifetime energy prediction and annual energy assessment

Tatiani Georgitsioti, Nicola Pearsall, Ian Forbes, Gobind Pillai (2019), "*A combined model for PV system lifetime energy prediction and annual energy assessment*", Solar Energy, Volume 183, Pages 738-744, ISSN 0038-092X

https://doi.org/10.1016/j.solener.2019.03.055

Highlights
- Model development on the lifetime energy prediction and annual energy assessment.
- Expression of domestic PV generation potential in various climatic conditions.
- Demonstration of the importance of the reliability and maintenance of PV systems.
- Demonstration of the energy prediction risks regarding PV systems' economic viability.

Lifetime Evaluation of Grid-Connected PV Inverters Considering Panel Degradation Rates and Installation Sites

A. Sangwongwanich, Y. Yang, D. Sera and F. Blaabjerg. (2018). "*Lifetime Evaluation of Grid-Connected PV Inverters Considering Panel Degradation Rates and Installation Sites*", IEEE Transactions on Power Electronics, vol. 33, no. 2, pp. 1225–1236.

https://doi.org/10.1109/TPEL.2017.2678169

Abstract
Lifetime of Photovoltaic (PV) inverters is affected by the installation sites related to different solar irradiance and ambient temperature profiles (also referred to as mission profiles). In fact, the installation site also affects the degradation rate of the PV panels and, thus, long-term energy production and reliability. Prior-art lifetime analysis in PV inverters has not yet investigated the impact of PV panel degradations. This paper, thus, evaluates the lifetime of PV inverters considering panel degradation rates and mission profiles. Evaluations have been carried out on PV systems installed in Denmark and Arizona. The results reveal that the PV panel degradation rate has a considerable impact on the PV inverter lifetime, especially in the hot climate (e.g., Arizona), where the panel degrades at a faster rate. In that case, the PV

inverter lifetime prediction can be deviated by 54%, if the impact of PV panel degradations is not taken into account.

Monitoring, Diagnosis, Prognosis, and Techniques for Increasing the Lifetime/Reliability of Photovoltaic Systems

G. Spagnuolo, W. Xiao and C. Cecati. (2015). "*Monitoring, Diagnosis, Prognosis, and Techniques for Increasing the Lifetime/Reliability of Photovoltaic Systems*", IEEE Transactions on Industrial Electronics, vol. 62, no. 11, pp. 7226–7227.

https://doi.org/10.1109/TIE.2015.2475336

Abstract
The articles in this special section focus on photovoltaic power systems (PVS). The market for photovoltaic power systems has increased exponentially, but the government subsidies have been reduced dramatically in recent years. The return of the investment mainly relies on selling the energy produced during the PV plant lifetime. Thus, the PV system must be designed and controlled properly in order to ensure its lifetime and reliability but also new features are required: 1) real-time monitoring of the energy production; 2) on-site diagnostic functions; and 3) estimation of the residual life. The degradation of electronic components and PV cells can be accelerated by various unpredictable and unavoidable phenomena.

Sökfraser: ” downtime statistics photovoltaics”

Towards the development of an optimized Decision Support System for the PV industry: A comprehensive statistical and economical assessment of over 35,000 O&M tickets

S. Lindig, S. Gallmetzer, M. Herz, A. Louwen, E. Koumpli, P. Paez, D. Moser. (2022). “*Towards the development of an optimized Decision Support System for the PV industry: A comprehensive statistical and economical assessment of over 35,000 O&M tickets*”, Progress in Photovoltaics

https://doi.org/10.1002/pip.3637

Abstract
Due to the overall declining costs of photovoltaic systems, market players in the operation and maintenance sector are under increasing price pressure when offering their services. The automation and standardization of maintenance and failure tickets as well as their statistical and economical evaluation are key to ensure optimal yield and long lifetime. A thorough understanding of typical faults, classified through a standardized taxonomy, can be a pathway of developing location and technology specific decision support, offering cost-time efficient solutions to reduce component downtime and costs in case of failure appearance. A useful method for this approach is the Cost Priority Number, a methodology to assess technical failures and their economic impact in energy systems. In this work, this method is further improved to be applied to individual use cases to make it useful in the actual operation of PV plants. A standardized ticket taxonomy for the operational phase of PV systems has been developed where more than 35,000 PV systems' tickets have been statistically evaluated, and a fully automated methodology to calculate the cost of individual maintenance tickets has been developed.

Sökfraser: ”pv, operation, maintenance, lifetime, downtime”, ”pv, sustainable, operation, maintenance, lifetime, downtime”

Why Can Simple Operation and Maintenance (O&M) Practices in Large-Scale Grid-Connected PV Power Plants Play a Key Role in Improving Its Energy Output?

Iftikhar, Hamid, Eduardo Sarquis, and P. J. Costa Branco. (2021). "*Why Can Simple Operation and Maintenance (O&M) Practices in Large-Scale Grid-Connected PV Power Plants Play a Key Role in Improving Its Energy Output?*" Energies 14, no. 13: 3798.

https://doi.org/10.3390/en14133798

Abstract
Existing megawatt-scale photovoltaic (PV) power plant producers must understand that simple and low-cost Operation and Maintenance (O&M) practices, even executed by their own personal and supported by a comparison of field data with simulated ones, play a key role in improving the energy outputs of the plant. Based on a currently operating 18 MW PV plant located in an under-developing South-Asia country, we show in this paper that comparing real field data collected with simulated results allows a central vision concerning plant underperformance and valuable indications about the most important predictive maintenances actions for the plant in analysis. Simulations using the globally recognized software PVSyst were first performed to attest to the overall power plant performance. Then, its energy output was predicted using existing ground weather data located at the power plant. Compared with the actual plant's annual energy output, it was found that it was underperforming by −4.13%, leading to a potential monetary loss of almost 175,000 (EUR)/year. Besides, an analysis of the O&M power plant reports was performed and compared to the best global practices. It was assessed that the tracker systems' major issues are the forerunner of the most significant PV power plant underperformance. In addition, issues in inverters and combiner boxes were also reported, leading to internal shutdowns. In this case, predictive maintenance and automated plant diagnosis with a bottom-up approach using low-cost data acquisition and processing systems, starting from the strings level, were recommended.

Recent progress towards photovoltaics' circular economy

Malek Kamal Hussien Rabaia, Concetta Semeraro, Abdul-Ghani Olabi. (2022). ”*Recent progress towards photovoltaics' circular economy*”, Journal of Cleaner Production, Volume 373, 133864, ISSN 0959-6526.

https://doi.org/10.1016/j.jclepro.2022.133864

Highlights
- Market states, potentials, and challenges of the three generations of PV were discussed.
- Crystalline silicon- and CdTe- based technologies are the dominating source of PV wastes.
- A circular business model was developed for the PV industry.
- Recent improvements and optimizations towards sustainable PV lifecycle were critically discussed.
- A novel research roadmap is created to assist in future research on PV's circular economy.

Scopus

Sökfraser: ”sustainable operation and maintenance pv”/ ”sustainable O&M photovoltaics”

Effects of different environmental and operational factors on the PV performance: A comprehensive review

Hasan, K, Yousuf, SB, Tushar, MSHK, Das, BK, Das, P, Islam, MS. (2022), ”*Effects of different environmental and operational factors on the PV performance: A comprehensive review*”, Energy Sci Eng. 2022; 10: 656– 675.

https://doi.org/10.1002/ese3.1043

Abstract
Conventional fossil fuel-based power generation is one of the main contributors to global environmental pollutions. The rapid depletion of fossil fuel reserves as well as their adverse environmental impact heighten the quest for cleaner and sustainable energy resources to generate electricity. Solar energy is an unlimited and immeasurable source of renewable energy that is used for direct electricity production through the solar PV cell. However, environmental conditions as well as operation and maintenance of the solar PV cell affect the optimum output and substantially impact the energy conversion efficiency, productivity and lifetime, thus affect the economy of power generation. In this study, an investigation about recent works regarding the effect of environmental and operational factors on the performance of solar PV cell is presented. It is found that dust allocation and soiling effect are crucial, along with the humidity and temperature that largely affect the performance of PV module. Additionally, the wind itself carries a significant amount of dust and sand particles, especially in the deserted areas. Deposition of dust in humid conditions forms adhesive, sticky mud on the PV cell and worsens the situation as it reduces the power generation up to 60–70%. This study discusses advanced approaches to mitigate the effects of these factors with their relative merits and challenges. Finally, a guideline is proposed to minimize the effect of different environmental and operational factors to optimize the performance of solar PV cell.

A review on maintenance strategies for PV systems

Khaled Osmani, Ahmad Haddad, Thierry Lemenand, Bruno Castanier, Mohamad Ramadan, (2020), “A review on maintenance strategies for PV systems”, Science of The Total Environment, Volume 746, 141753, ISSN 0048-9697

https://doi.org/10.1016/j.scitotenv.2020.141753

Highlights

- Maintenance strategies aim to avoid the decrease in efficiency that is caused by potential faults.
- Four types of maintenance strategies may be identified, preventive, predictive, corrective and urgent.
- The study presents a review on the main developed techniques under each of the four maintenance categories.

Sökfraser: ”repowering PV”/ ”sustainable repowering PV”

Towards a successful re-use of decommissioned photovoltaic modules

A.S.H. Van der Heide, L. Tous, K. Wambach, J. Poortmans, J. Clyncke, E. Voroshazi. (2021). "*Towards a successful re-use of decommissioned photovoltaic modules*", Progress in Photvoltaics, 30, issue 8.

https://doi.org/10.1002/pip.3490

Abstract
Since massive numbers of photovoltaic (PV) modules are expected to be discarded in the next decades, it is important to think about end-of-life management for those PV modules and to include re-use next to recycling. However, the re-use of decommissioned PV modules is a quite complex subject since there are requirements from technical, economic, environmental and legislative point of view. An evaluation of possible applications for second-hand PV modules showed that currently, the use of these PV modules in high-income countries is only interesting for specific applications. These are the replacement of some defect modules to repair PV systems (that usually still receive feed-in tariff) or the replacement of all PV modules for either a low-cost extension of system lifetime or the repowering of severely underperforming systems. For low-income countries, second-hand PV modules are interesting to build new small to medium size PV systems (often off-grid). The typical decommissioned PV module is a crystalline silicon glass-backsheet module from a utility power plant. Most PV modules originate from plants that have been partly damaged by severe weather or from repowered plants that did not receive feed-in tariff (anymore). Currently, technical requirements to qualify potentially re-usable PV modules for re-use are lacking. In the legislation also, a clear criterion for a PV module to be considered functional is needed, since it is not an easy yes/no situation like for a typical electronic device. In this paper, guidelines for a low-cost quality inspection and cost-effective PV module repair are given. It is proposed to set a clear performance threshold at 70% of the original power for a PV module to be not considered as waste. With this paper, we aim to open the dialogue on a commonly accepted re-certification protocol and threshold values. Currently, the worldwide re-use market size is estimated to be around 1 GWp/year, of which 0.3 GWp/year is originating from Europe (mainly Germany, with Italy rapidly coming up). Many second-hand PV modules are shipped to developing countries without recycling facilities which might create the risk of disposal on the longer term. To create a healthy and sustainable market for second-hand PV modules, it will be important that evaluation standards for potentially re-usable PV modules become available and that the existing electronic waste legislation will be adapted for energy-generating products like PV modules.

Sökfraser: ”pv, operation, maintenance, lifetime, downtime”

Long-term degradation rate of crystalline silicon PV modules at commercial PV plants: An 82-MWp assessment over 10 years

J. Pascual, F. Martinez-Moreno, M. García, J. Marcos, L. Marroyo, E. Lorenzo. (2021). "*Long-term degradation rate of crystalline silicon PV modules at commercial PV plants: An 82-MWp assessment over 10 years*", Progress in Photovoltaics, 29, issue 12

https://doi.org/10.1002/pip.3456

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