MAPPING AND UNDERSTANDING DECOMMISSIONING AND REPOWERING OF LARGE-SCALE SOLAR PLANTS IN AUSTRALIA

SMART ENERGY COUNCIL

TABLE OF CONTENTS

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REPORT HIGHLIGHTS

Australia needs to **urgently develop solar panel recycling infrastructure and stewardship schemes** to prepare for a substantial increase in decommissioned solar panels.	Queensland has the highest number of installed solar panels, resulting in the **largest projected volume of solar panel waste** and a need for focused waste management strategies.	Repowering solar farms increases energy output and extends operational life, but **generates waste that must be recycled.**
This report demonstrates the need for a **national stewardship scheme** to manage solar panel waste responsibly.	Each state and territory has unique decommissioning timelines. This requires **tailored waste management plans**.	**Recycling solar panels is essential** for the economy and sustainability, as it recovers valuable materials, reduces waste, and minimises environmental impact.
Remote solar farms face **logistical challenges** (transportation, storage), and financial constraints are a **significant barrier to participation in recycling programs**.	**Building strong relationships with solar farm operators** is crucial for developing effective and sustainable waste management solutions.	The report provides **crucial insights for policymakers** to develop informed strategies for **solar panel waste management and recycling infrastructure**.

DEFINITIONS

- **End of Life:** It is when a solar panel ceases to efficiently generate power, usually after 25-35 years, but not necessarily, becoming due for replacement or disposal.
- **Decommissioning:** The process of dismantling and removing a solar farm at the end of its operational life, due to several reasons (not necessarily at the end of its warranty). This includes clearing panels, wiring, and other equipment, with components ideally recycled or responsibly disposed of.
- **Large-scale:** Refers to significant solar power plants, typically generating electricity in megawatts (MW), which can be connected to the national grid or not. These are distinct from smaller domestic or commercial installations.

INTRODUCTION

This project aimed to create a comprehensive database of Australia's large-scale solar plants, estimate decommissioning timelines and waste volumes, and assess repowering potential. Furthermore, the project sought to understand industry perspectives on solar panel decommissioning, including contractual obligations, recycling awareness, willingness to sell modules, cost expectations, and opinions on the proposed national stewardship scheme. This information will be crucial for developing effective strategies for the sustainable management of solar panel waste and the transition to a circular economy for solar energy in Australia.

This document is part of the Queensland Stewardship pilot project that has been conducted by the Smart Energy Council (SEC), which illustrates practical challenges, early insights, and foundational data that inform the broader themes of repowering and obsolescence.

Pilot Projects

This project is an extension of the Small-Scale Stewardship pilot. The primary objective of the Large-Scale photovoltaic (PV) Recycling Pilot is to complete the overall view of the entire ecosystem for the management of decommissioned solar modules. By testing and evaluating various pathways for the collection, processing (including reuse), and recycling of large-scale solar panels, SEC aims to provide the Queensland Government with a comprehensive understanding of the costs, benefits, and implications associated with the implementation of a stewardship scheme in the State.

Through this pilot, SEC will gain insights into the large-scale solar market, including how it operates and what is required to address the collection, processing, testing, and reuse options for high volumes of solar panels. This understanding will inform the development of a state-based framework and contribute to a national solution, facilitating more accurate recommendations and strategies for effective stewardship and recycling of solar panels.

Decommissioning

The decommissioning of large-scale solar plants in Australia is a growing concern as older installations reach the end of their lifespan. While the recycling of solar panels is a relatively new industry, significant challenges persist. The complex composition of solar panels necessitates specialised recycling processes. Currently, there is a lack of dedicated recycling facilities in Australia, leading to the disposal of many solar panels in landfill. This practice not only wastes valuable resources but also poses potential environmental risks.

To address these challenges, Australia needs to invest in developing robust recycling infrastructure and supporting research and development into advanced recycling technologies. This includes establishing dedicated recycling facilities, implementing clear guidelines for the collection and transportation of end-of-life solar panels, and incentivising the recycling industry. By prioritising sustainable end-of-life management, Australia can ensure that the growth of solar energy does not come at the expense of the environment and can contribute to a circular economy.

Repowering

Repowering solar farms involves upgrading older solar PV modules and other components with newer, more efficient technologies. This process can significantly boost energy output, reduce maintenance costs, and extend the operational life of the solar farm. As solar technology continues to advance, repowering offers a cost-effective way to maximise the value of existing solar installations.

In Australia, repowering solar farms presents a compelling opportunity to further leverage renewable energy. With many early-generation solar farms approaching the end of their initial operational life, repowering can revitalise these facilities and enhance their contribution to Australia's clean energy mix. By upgrading to cutting-edge PV modules and inverters, these solar farms can increase their energy output and reduce their carbon footprint.

However, repowering also presents challenges related to the disposal of decommissioned components. Solar panels, in particular, contain valuable materials like silicon, aluminium, and glass, but their complex structure and the possible presence of hazardous substances (depending on their technology) can complicate recycling efforts. To address this issue, the development of efficient recycling technologies and robust recycling infrastructure is crucial. By investing in research and development, policymakers and industry stakeholders can encourage the development of innovative solutions that enable the recovery and reuse of valuable materials from end-of-life solar panels, minimising waste and promoting a circular economy.

The typical lifespan of a solar farm in Australia is around 25-30 years. However, repowering can occur earlier, often around the 5-10 year mark, depending on factors like technological advancements, degradation rates, and economic viability. It's important to note that while solar panels can last longer, other components like inverters and wiring might need replacement earlier, prompting a partial repowering.

Many regional solar farms in Australia, particularly those developed in the early stages of the solar boom, could be prime candidates for repowering. By upgrading their technology, these farms can increase their power output and reduce their levelized cost of energy (LCOE). Larger large-scale solar plants may also benefit from repowering. By replacing older components with more efficient ones, these plants can increase their energy generation capacity and reduce their operational costs.

Large-scale Solar Plants in Australia

Australia has experienced significant growth in large-scale solar farms in recent years. This growth has been driven by falling technology costs, supportive government policies, and increasing demand for renewable energy. Large-scale solar farms have become a major contributor to Australia's renewable energy mix, providing clean and reliable electricity to the national grid.

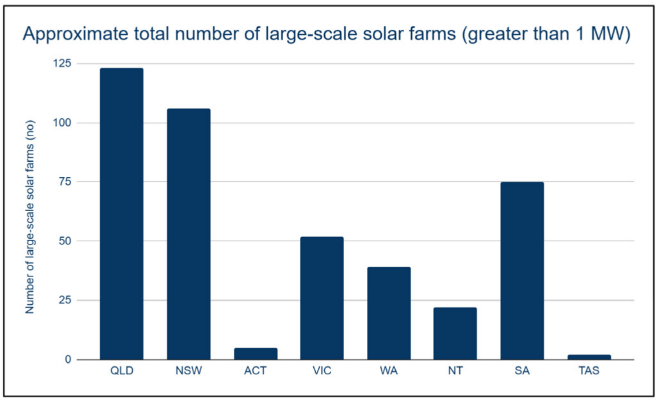
The decommissioning of large-scale solar farms in Australia presents a unique opportunity to recover valuable materials and create new economic opportunities, reducing reliance on primary mining and refining processes. One promising avenue is the recovery of high-purity silicon, a critical component in the semiconductor industry. Additionally, the recovered aluminium and glass can be recycled into new products, such as construction materials or packaging. Furthermore, the recovery of precious metals such as silver from solar panels offers exciting possibilities, as it is widely used in various industries, including electronics, photography, and medicine. By extracting silver from decommissioned solar panels, Australia can contribute to the local and global supply of this valuable metal.

SOLAR WASTE ESTIMATIONS FOR AUSTRALIA

Overview

Australia's booming solar industry needs a plan for managing end-of-life solar panels to avoid environmental and economic risks. Establishing a domestic recycling industry can create jobs, stimulate growth, and reduce reliance on international markets. Recycling solar panels also safeguards the environment by minimising possible hazardous material leakage (depending on the technology). Embracing circular economy principles further enhances economic and environmental outcomes by reducing raw material extraction and greenhouse gases emissions. Australia can become a global leader in sustainable energy by proactively managing the entire solar panel lifecycle.

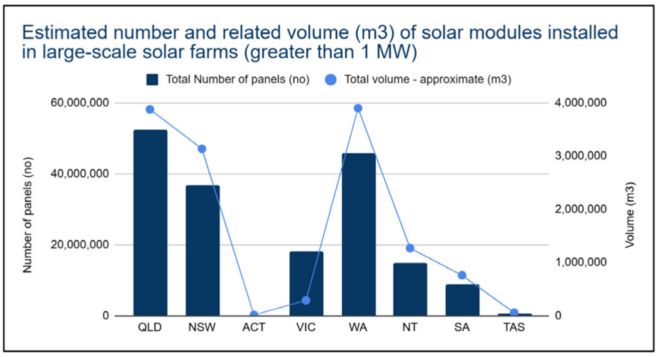
This study provides a detailed estimation of the number of large-scale solar farms across each Australian state and territory, offering crucial insights into the evolving landscape of renewable energy generation.



This report provides critical insights into future waste management challenges associated with the rapid expansion of large-scale solar farms (those exceeding 1 MW) in Australia. By forecasting the number of solar panels installed across various states and territories, and estimating the cumulative waste volume (measured in cubic metres) they will generate as they reach their end-of-life, this report aims to inform and guide waste management strategies and policies.

The included graph visually represents the projected growth of installed solar capacity across each Australian state and territory, offering a clear picture of the varying scales of waste generation anticipated in different regions. This high-level overview serves as a springboard for a more granular analysis in subsequent sections, where waste generation trends and challenges specific to each state and territory will be explored in detail.

The insights presented in this report are intended to support stakeholders across the solar energy sector, the waste management industry, and government bodies, in proactively addressing the waste implications of large-scale solar development and ensuring sustainable practices are embedded in the renewable energy transition.

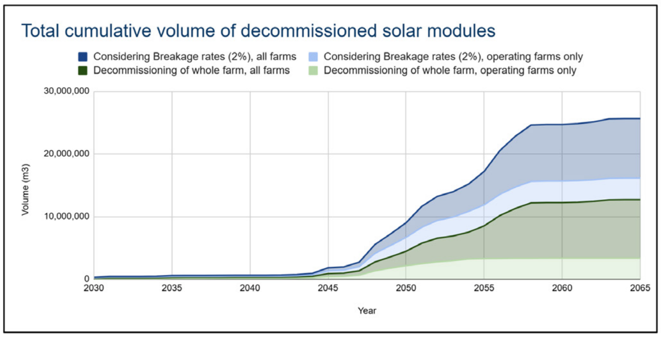


Key Insights

- **Queensland (QLD):** Boasting the highest number of installed solar panels, QLD is the undisputed leader in solar energy adoption among Australian states.
- **New South Wales (NSW):** While having fewer solar panels than QLD, NSW still holds a significant number of installations, demonstrating its substantial contribution to Australia's solar energy landscape. The state's solar capacity is a testament to its growing focus on clean energy sources.
- **Australian Capital Territory (ACT):** Although the ACT has low figures for both the number and volume of solar modules, it's crucial to consider the territory's considerably smaller total area compared to other states and territories. This size disparity contextualises the ACT's solar capacity and underscores the need for nuanced analysis when comparing installation figures across different regions.
- **Victoria (VIC):** Despite having fewer panels than NSW, VIC boasts a significant volume of installed solar modules. This observation suggests that VIC might have a higher proportion of projects utilising larger panels, potentially leading to greater energy generation capacity.
- **Western Australia (WA):** While QLD has the most panels, WA exhibits the largest total volume occupied by solar installations. This finding implies that WA could have a larger share of projects employing larger or differently configured panels, contributing to the increased volume.
- **Northern Territory (NT):** Compared to leading states like QLD and NSW, the NT has a moderate number of solar panels installed in large-scale solar farms. This moderate installation base reflects the territory's ongoing efforts to expand its renewable energy capacity.
- **South Australia (SA):** In comparison to other states, SA demonstrates a relatively low number of solar modules installed in large-scale solar farms. Similarly, SA also presents a comparatively low total volume occupied by these installed modules. The research revealed a substantial number of large rooftop solar installations, indicating that the approach to solar energy in this state or territory differs from others.
- **Tasmania (TAS):** Similar to the ACT, TAS has the smallest number of solar panels and the lowest volume, indicating a smaller presence of large-scale solar farms. This limited large-scale solar development could be attributed to various factors, including Tasmania's energy mix and geographical considerations.

Cumulative volume of decommissioned solar modules

The graph below illustrates the projected cumulative volume of decommissioned solar modules in Australia from 2030 to 2065, considering various scenarios including breakage rates and whether all planned and announced or only currently operating solar farms are decommissioned.



Notably, there's a significant uptick in waste volume expected from the mid-2040s onwards, highlighting the critical need for a robust recycling infrastructure to manage the surge in end-of-life solar panels. Besides, the cumulative decommissioned volume plateaus after

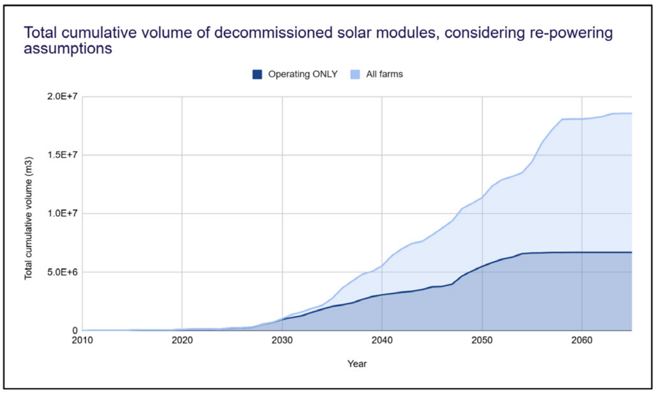
2060 due to the assumption that all existing utility-scale solar farms, as captured in the baseline dataset, will have reached end-of-life. The model does not factor in future installations beyond what is currently operational or committed. As such, unless additional capacity is added to the national network, the volume of modules entering the waste stream stabilizes. This highlights the importance of continuous infrastructure mapping and dynamic forecasting to account for future project developments.

Key Insights

- The graph clearly shows a **substantial rise in decommissioned modules after 2045**, indicating the urgency to establish recycling capabilities well in advance.
- Even a 2% breakage rate **significantly contributes** to the overall waste volume.
- The scenarios considering the planned and announced solar farms show a consistently higher waste volume, suggesting that future solar farm operations will be a **major source of decommissioned modules**.
- With projections extending to 2065, the graph underscores the necessity for **long-term strategic planning** in developing and scaling up solar panel recycling infrastructure.
- The sheer volume of projected waste highlights the need for **proactive measures like extended producer responsibility schemes** and investment in advanced recycling technologies to mitigate environmental impact.

Re-powering assumptions

The graph below provides a projection of the cumulative volume of decommissioned solar modules in Australia, for both operating and planned farms, considering that all farms would replace one-third of their solar modules every five years starting on the 10th year of operation of the solar farm (for example: if the solar farm started operation in 2010, the assumption is that they would replace one-third of their panels in 2020,one-third in 2025 and one-third in 2030). This graph also assumes that at the end of the farm's lifetime all panels would be decommissioned.



Key Insights

- Both scenarios show a substantial increase in the volume of decommissioned solar modules over time, particularly after 2030. This highlights the **growing need for end-of-life management strategies for solar panels**.
- The scenario including planned and announced solar farms shows a **significantly higher volume of decommissioned modules** compared to "Operating ONLY." This shows the substantial impact of solar farm expansion on the volume that will need to be managed.
- The curves in both scenarios steepen considerably after 2030, **indicating a rapid increase in decommissioning**. This suggests that the first wave of large-scale solar installations is reaching its end-of-life around this period.

QUEENSLAND (QLD)

Queensland has seen a significant surge in large-scale solar farm development, positioning the state as a major player in Australia's renewable energy landscape. This growth, while beneficial for clean energy transition, presents a looming challenge: the eventual decommissioning of these solar farms. As these facilities reach their operational lifespan, a substantial volume of solar panels and other components will require proper disposal and recycling.

This study assessed the available data on the large-scale solar farms in Queensland, as well as contacted the solar farms for further information and questions.

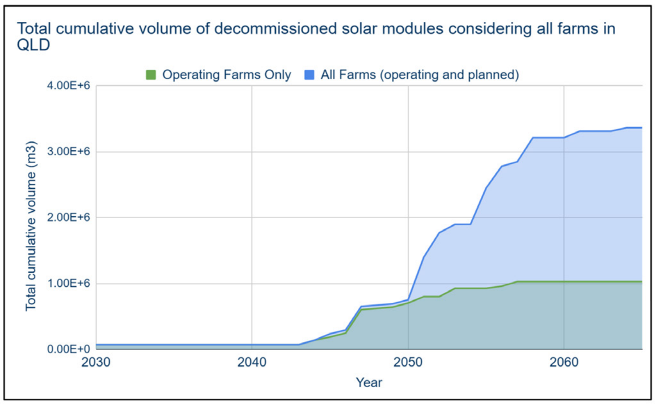
Key Insights

- More than **120 solar farms** in total, being **51 in operation**, and the others in different status, such as pre-construction, construction, decommissioned, announced and proposed.

- It is expected that **more than 12 GW** will be available in the next few years (analysis until 2065).
- Most solar farms use or will use **silicon-based solar modules**, while a few use or will use thin-film technologies (particularly CdTe solar modules).
- The earliest operating farms in **QLD date back to 2015**. This suggests that some of these facilities may soon be due for **repowering** to maintain optimal performance and extend their lifespan.
- Approximately **2 GW** of solar energy capacity is currently **under construction**.
- Approximately **10 GW** of solar energy capacity is anticipated to be added **over the next decade**. This projection includes projects currently in pre-construction, announced, and proposed phases.
- **Reasonable assumptions** were made when the information was not publicly available and/or not provided by the farm responsible person or company.

Cumulative Volume of Decommissioned Solar Modules

The graph below provides a projection of the cumulative volume of decommissioned solar modules in Queensland, considering both operating farms and all planned farms.

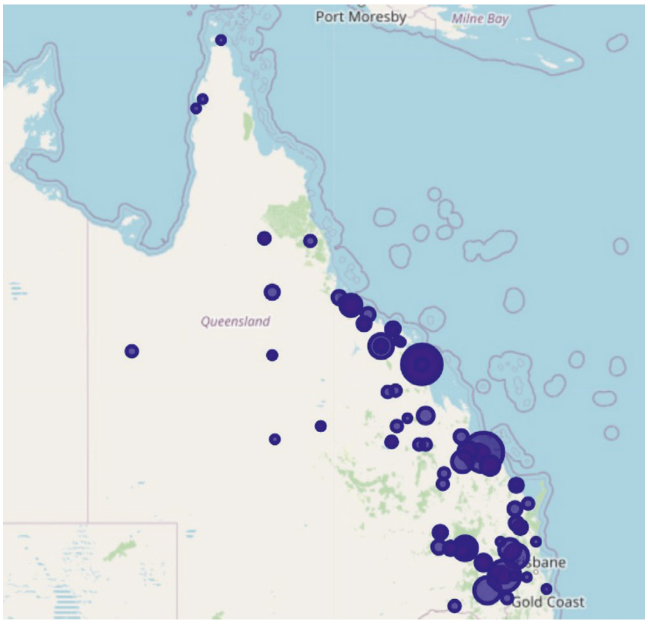


Key Insights

- **Significant Decommissioning Ahead:** The graph clearly shows a substantial increase in decommissioned solar modules over the coming decades, particularly after 2050. This indicates a need for effective recycling and disposal strategies.
- **Impact of Planned Farms:** The graph suggests that the projected volume of decommissioned modules will be significantly higher due to the addition of planned solar farms, if they go ahead on their implementation.
- **Policy and Planning:** The graph highlights the need for proactive planning and policy development to address recycling. This includes creating incentives, investing infrastructure, and establishing clear guidelines for the disposal of solar waste.

Location of Current and Planned Solar Farms

The map below provides a projection of the location of current and planned solar farms in Queensland, considering the projected amount of solar modules to be decommissioned in the future (no specific date). The unit for the map below is volume in cubic metres (m³).

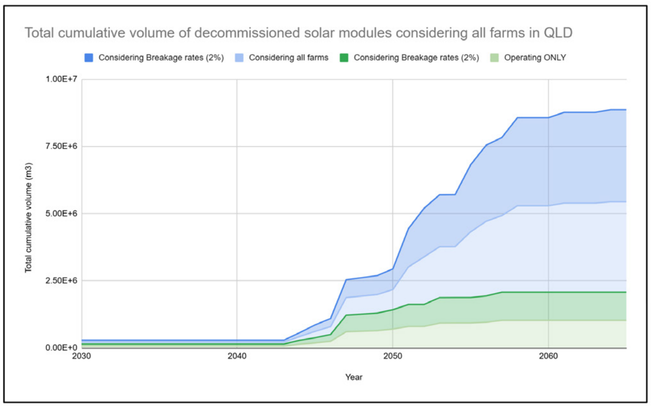


Key Insights

- **Regional Concentration:** The majority of solar farms are clustered in the south-eastern region of Queensland. This concentration is likely due to factors such as higher population density, existing infrastructure, and favorable solar irradiation conditions.
- **Decommissioning Potential:** The larger circles indicate a higher projected volume of solar modules to be decommissioned in those areas. This suggests that these regions may require more attention in terms of planning for recycling and disposal of solar waste.
- **Future Growth:** The inclusion of planned solar farms suggests that the solar industry in Queensland is poised for further expansion. This, in turn, will increase the volume of decommissioned modules in the future.

Cumulative Volume Considering Breakage

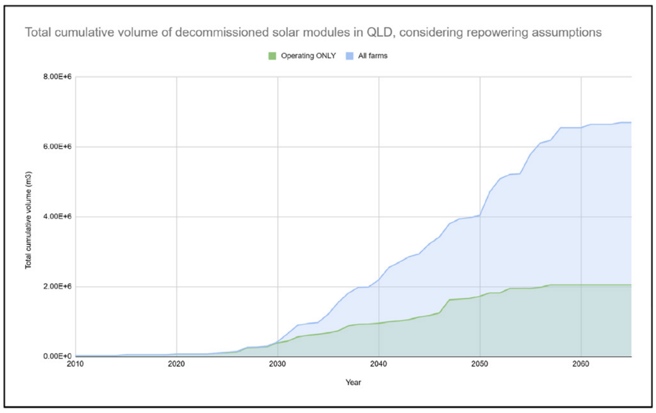
The graph below provides a projection of the cumulative volume of decommissioned solar modules in Queensland, considering breakage rates or 2% (for both operating and planned farms).



It is important to notice that even a seemingly low breakage rate of 2% during the construction of solar farms can have a big impact. Besides the numbers shown on the graph below, it is important to highlight that breakage/damage during construction of solar farms directly impacts solar farms financially due to the necessity of replacing damaged panels, potentially delaying the project and changes on the budget. Besides, breakage can be a hazard for workers and the environment.

Cumulative Volume Re-powering

The projected cumulative volume of decommissioned solar modules in Queensland is shown in the graph below. This projection includes both operating and planned solar farms, and assumes that 1/3 of a solar farm's modules will be replaced every 5 years, beginning in the 10th year of the farm's operation. The model also assumes that all panels will be decommissioned at the end of a farm's lifetime.



As it can be seen on the graph above, re-powering solar farms adds to the growing mountain of electronic waste, meaning we need robust and sustainable recycling systems to minimise environmental damage. It is important to notice that disposing of these panels can be a real cost, adding extra to the re-powering bill, therefore there is a need for proper planning when re-powering. Recycling and reusing these decommissioned panels efficiently is crucial for the long-term sustainability of the solar energy industry, minimising waste and making the most of resources.

Case studies (from the pilot program)

The primary objective of our pilot program is to establish a sustainable recycling pathway for solar modules and encourage responsible end-of-life management within the Australian solar industry. To facilitate this, we developed a comprehensive database of solar farms across all states and territories.

We have conducted outreach to all solar farms within Queensland, resulting in a diverse range of responses. To facilitate learning and knowledge sharing, we have compiled the following case studies.

Sustainable Solar Farm Operations in Remote Australia: Manager shared challenges of some remote solar farms and wants sustainable end-of-life practices for its solar panels but faces logistical challenges due to location and sporadic panel replacements, such as: high transportation costs and complex logistics, irregular panel replacement makes planning difficult, stockpiled panels risk environmental damage during severe weather and vegetation management practices damage panels.

Opportunities & Strategic Solutions:

- Optimised Stockpile Management: Implement modular storage, real-time tracking, and explore partnerships
- Regional Recycling Hub Feasibility: Investigate creating hubs with other operators
- Transportation Optimisation: Pursue backloading and drone transport
- Enhanced Operational Procedures: Develop guidelines for vegetation management
- Strategic Planning & Obsolescence Management: Assist with repowering strategy, obsolescence analysis, and database creation.

Solar Panel Recycling Initiative facing logistical and financial challenges: This solar farm has adopted a proactive approach to managing end-of-life solar panels by implementing on-site assessment and segregation protocols, initiating early engagement with recyclers, and integrating circular economy principles into its asset management strategy. Rather than waiting for regulatory requirements or system failures, the farm has invested in planning for the responsible handling of decommissioned panels well ahead of their expected end-of-life.

Key Challenges Faced:

- Manufacturers must take responsibility for embedding the logistical costs of transporting large volumes of panels into the product's price
- Innovate and develop cost-effective recycling technologies, including testing and repurposing reusable panels
- Reuse is more sustainable but requires rigorous testing, standardisation, certification and new warranties
- Government's role is vital in developing a sustainable solar panel recycling framework

Key Learning: Collaboration, government support, and a circular economy approach are essential to enable effective solar panel reuse and recycling. Early planning, data collection, and cost-effective transportation are also vital to this process.

Solar farm is interested in helping, however it doesn't have any panels for recycling at the moment: Some solar farms expressed strong interest in supporting the solar panel pilot recycling program. However, they currently have no panels ready for recycling (for different reasons). Despite not having immediate recycling needs, most of them offered valuable support to the program, including responding to our short questionnaire. Some also agreed to participate in interviews to provide valuable insights into industry perspectives on recycling challenges, potential solutions, and future recycling needs.

- **Main Action:** Engage industry stakeholders beyond immediate recycling needs. This involves actively seeking input and collaboration from solar farms, even when they don't have panels ready for recycling.
- **Key Learning:** The value of proactive stakeholder engagement. Building strong relationships with industry stakeholders is crucial for the long-term success of any recycling program. Even without immediate material flow, their insights and support are invaluable.

Solar farm is interested in the pilot program and already has a small amount of solar panels to be collected: Some solar farm managers enthusiastically embraced the pilot program and have a small number of older, decommissioned panels resulting from breakages/damage during construction and/or recent re-powering, making them an ideal candidate for early program participation. We already have engaged them with our logistics partner for pick-up and recycling.

- **Main Action:** Leverage early adopters to streamline logistics and refine procedures. By working with solar farms that have small volumes of decommissioned panels, the pilot program can test and refine its collection and recycling processes in a controlled environment.
- **Key Learning:** Data collection is essential for program improvement. Collecting data on the types, conditions, and quantities of panels collected from early adopters provides valuable insights for program planning, resource allocation, and future program improvements.

Solar farm is interested in the pilot program and already has some decommissioned solar panels, but only wants to get 200 collected: Some solar farm managers are interested in our pilot program and have some decommissioned panels to be collected. However, they only want 200 to be collected, as they are not interested in paying for the collection of the other panels. We already have engaged them with our logistics partner for pick-up and recycling.

- **Main Action:** Address financial barriers to participation. The pilot program needs to explore flexible funding models or alternative incentives to encourage participation from solar farms with larger volumes of decommissioned panels.
- **Key Learning:** Financial constraints are a significant barrier to participation. Many solar farms may be willing to participate in recycling programs but may be hesitant to incur additional costs. Exploring alternative funding models is crucial. The pilot program should investigate options such as subsidies, rebates, or pay-per-service models to make recycling more accessible and cost-effective for solar farms.

OTHER STATES AND TERRITORIES

The Large-Scale Photovoltaic (PV) Recycling Pilot, having commenced in Queensland, has naturally yielded a greater volume of data pertaining to that state. Nonetheless, the mapping and analysis of solar farm decommissioning across all other Australian states and territories has been meticulously conducted and is presented in subsequent sections of this report.

NEW SOUTH WALES (NSW)

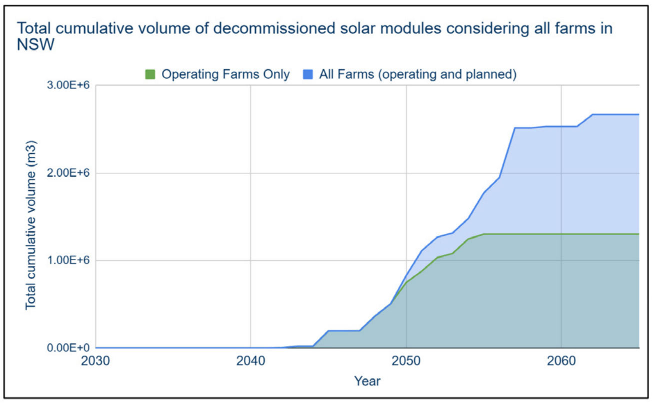
New South Wales has experienced a substantial expansion in large-scale solar farm development, solidifying the state's role in Australia's renewable energy sector. While this expansion is crucial for the national clean energy transition, it brings forth a significant long-term consideration: the eventual decommissioning of these facilities. As these solar farms approach their end-of-life, a considerable volume of solar modules and associated components will necessitate responsible disposal and recycling.

Key Insights

- More than **100 solar farms** in total, being **44 in operation**, and the others in different status, such as pre-construction, construction, decommissioned, announced and proposed.
- It is expected that **more than 11 GW** will be available in the next few years (analysis until 2065).
- Most solar farms use or will use **silicon-based solar modules**, while a few use or will use thin-film technologies (particularly CdTe solar modules).
- The earliest operating farms in **NSW date back to 2015**. This suggests that some of these facilities may soon be due for **repowering**.
- Approximately **1 GW** of solar energy capacity is currently **under construction**.
- Approximately **10 GW** of solar energy capacity is anticipated to be added **over the next decade**. This projection includes projects currently in pre-construction, announced, and proposed phases.

Cumulative Volume of Decommissioned Solar Modules

The graph below provides a projection of the cumulative volume of decommissioned solar modules in New South Wales, considering both operating farms and all planned farms.



Key Insights

- The graph shows a **substantial increase** in the cumulative volume of decommissioned solar modules from **2030 to 2060**.
- The volume of decommissioned modules starts to **increase more rapidly after 2040**, considering operating and planned farms.
- The increase in decommissioned modules appears to **slow down slightly after 2050**.

AUSTRALIAN CAPITAL TERRITORY (ACT)

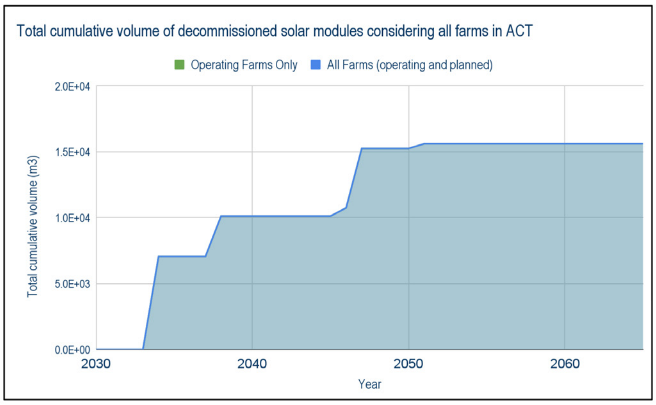
The Australian Capital Territory, while demonstrating a focused approach to renewable energy, presents a unique scenario within Australia's broader solar landscape. While large-scale solar farm development is less extensive than in other states, the ACT's commitment to 100% renewable energy targets necessitates strategic planning for the eventual decommissioning of existing solar infrastructure. As these facilities reach their operational lifespan, the responsible management of solar modules and associated components will become increasingly important.

Key Insights

- Around **5 solar farms** in total, being **all in operation**.
- It is estimated that these solar farms account for **more than 50 MW**.
- All solar farms assessed use **silicon-based solar modules**.
- The earliest operating farms in **ACT date back to 2014**.

Cumulative Volume of Decommissioned Solar Modules

The graph below provides a projection of the cumulative volume of decommissioned solar modules in ACT, considering all farms assessed.



Key Insights

- Compared to other states, the ACT's **projected cumulative volume** of decommissioned solar modules is **significantly lower**.
- There is a **noticeable increase** in decommissioned modules **starting around 2035**, indicating that some of the ACT's solar installations are expected to reach the end of their operational lifespan relatively early.
- The graph shows periods where the **cumulative volume remains relatively constant**, suggesting periods with less decommissioning activity.
- The graph shows that the **volume stabilises after 2050**. This indicates that the ACT's large scale solar farm decommissioning will have mostly concluded by this time.

VICTORIA (VIC)

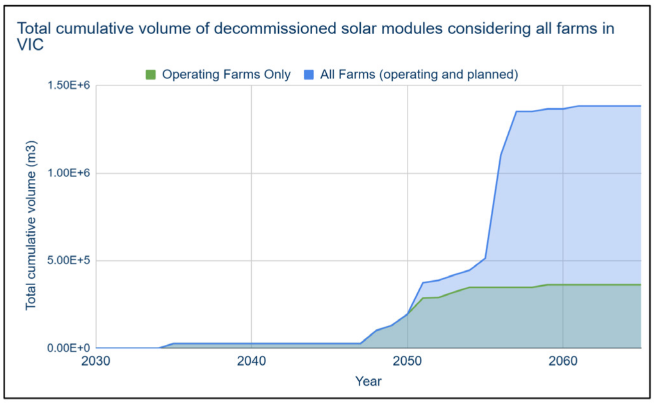
Victoria has witnessed a notable increase in large-scale solar farm development, strengthening the state's contribution to Australia's renewable energy mix. While this development is vital for the national transition to clean energy, it necessitates careful planning for the eventual decommissioning of these assets. As these solar farms reach their operational lifespan, the responsible management of a substantial volume of solar modules and associated components will be essential.

Key Insights

- More than **50 solar farms** in total, being **18 in operation**, and the others in different status, such as pre-construction, construction, decommissioned, announced and proposed.
- It is expected that **more than 3 GW** will be available in the next few years (analysis until 2065).
- Most solar farms use or will use **silicon-based solar modules**, while a few use or will use thin-film technologies (particularly CdTe solar modules).
- The earliest operating farms in **VIC date back to 2018**. This suggests that some of these facilities may soon be due for **repowering** to maintain optimal performance and extend their lifespan.
- Approximately **730 MW** of solar energy capacity is currently **under construction**.
- Approximately **3 GW** of solar energy capacity is anticipated to be added **over the next decade**. This projection includes projects currently in pre-construction, announced, and proposed phases.
- **Reasonable assumptions** were made when the information was not publicly available and/or not provided by the farm responsible person or company.

Cumulative Volume of Decommissioned Solar Modules

The graph below provides a projection of the cumulative volume of decommissioned solar modules in VIC, considering all farms assessed.



Key Insights

- The graph clearly shows a substantial **increase in the cumulative volume** of decommissioned solar modules **occurring after 2050**. This indicates that a large portion of Victoria's solar farm installations are projected to reach their end-of-life around this period.

- There is a clear divergence between the "Operating Farms Only" and "All Farms" scenarios, indicating that **factoring in planned solar developments is crucial** for accurately projecting future decommissioning volumes.
- While the major surge happens post-2050, there's a steady, albeit smaller, increase in **decommissioned modules from around 2045**. This suggests that some earlier installations will also require decommissioning.
- The graph demonstrates that by 2060, the projected cumulative **volume of decommissioned solar modules in Victoria approaches 1.5 million cubic metres**. This signifies a large amount of material that will need to be properly managed.

WESTERN AUSTRALIA (WA)

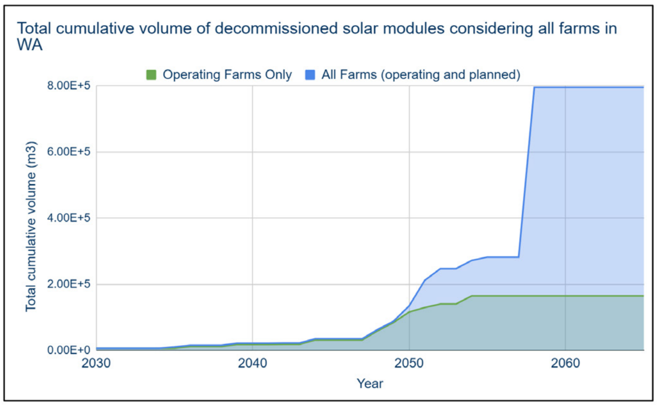
Western Australia has seen a significant uptake in large-scale solar farm development, contributing substantially to the state's renewable energy capacity. While this growth is pivotal for Australia's transition to a clean energy future, it also highlights the need for strategic planning regarding the eventual decommissioning of these assets. As these solar farms reach their operational lifespan, the responsible management of a considerable volume of solar modules and associated components will be critical.

Key Insights

- More than **30 solar farms** in total, being **15 in operation**, and the others in different status, such as pre-construction, construction, decommissioned, announced and proposed.
- It is expected that **more than 42 GW** will be available in the next few years (analysis until 2065).
- Most solar farms use or will use **silicon-based solar modules**, while a few use or will use thin-film technologies (particularly CdTe solar modules).
- The earliest operating farms in **WA date back to 2014**. This suggests that some of these facilities may soon be due for **repowering** to maintain optimal performance and extend their lifespan.
- Approximately **155 MW** of solar energy capacity is currently **under construction**.
- Approximately **40 GW** of solar energy capacity is anticipated to be added **over the next decade**. This projection includes projects currently in pre-construction, announced, and proposed phases.
- **Reasonable assumptions** were made when the information was not publicly available and/or not provided by the farm responsible person or company.

Cumulative Volume of Decommissioned Solar Modules

The graph below provides a projection of the cumulative volume of decommissioned solar modules in WA, considering all farms assessed.



Key Insights

- The graph shows a **dramatic increase** in the cumulative volume of decommissioned solar modules **occurring after 2055**. This indicates a large wave of solar farm installations in WA are projected to reach their end-of-life around this period.
- As with other states, the **planned and proposed solar farms** are expected to add a significant volume of solar modules in WA.
- The substantial gap between the two scenarios emphasises the **impact of factoring in planned solar developments** when forecasting future decommissioning volumes.
- Prior to the major surge, there's a gradual, steady increase in decommissioned modules, suggesting that some **earlier installations will also require decommissioning**.
- The graph indicates that **by 2060**, the projected cumulative volume of decommissioned solar modules in WA approaches a **significant amount of material** requiring effective management.

NORTHERN TERRITORIES (NT)

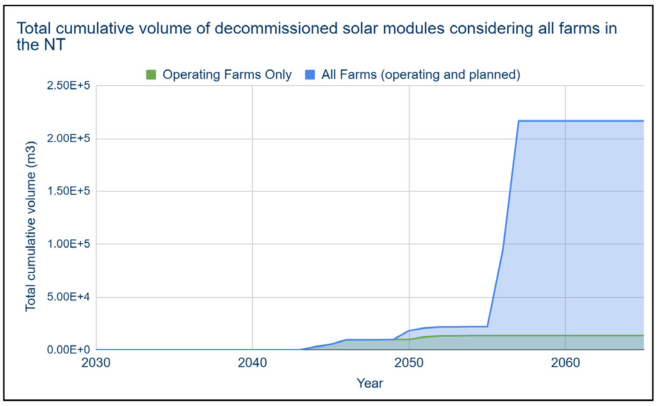
The Northern Territory, while experiencing a more localised and distributed approach to solar energy deployment, nonetheless requires strategic consideration for the lifecycle management of its solar assets. While large-scale solar farm development is less extensive compared to other states, the NT's unique geographical and logistical challenges emphasise the importance of planning for the eventual decommissioning of these installations. As these assets reach their end-of-life, the responsible management of solar modules and associated components will be crucial, especially given the NT's remote locations.

Key Insights

- More than **20 solar farms** in total, being **11 in operation**, and the others in different status, such as pre-construction, construction, decommissioned, announced and proposed.
- It is expected that **more than 11 GW** will be available in the next few years (analysis until 2065).
- Most solar farms use or will use **silicon-based solar modules**, while a few use or will use thin-film technologies (particularly CdTe solar modules).
- The earliest operating farms in the NT **date back to 2016**. This suggests that some of these facilities may soon be due for **repowering** to maintain optimal performance and extend their lifespan.
- Approximately **21 GW** of solar energy capacity is anticipated to be added **over the next decade**. This projection includes projects currently in pre-construction, announced, and proposed phases.
- **Reasonable assumptions** were made when the information was not publicly available and/or not provided by the farm responsible person or company.

Cumulative Volume of Decommissioned Solar Modules

The graph below provides a projection of the cumulative volume of decommissioned solar modules in the NT, considering all farms assessed.



Key Insights

- The graph shows a **very sharp increase** in the cumulative volume of decommissioned solar modules **occurring after 2055**. This indicates a concentrated period of solar farm installations in the NT reaching their end-of-life around this time.
- The graph highlights the importance of considering **announced and planned solar developments** for accurate future decommissioning projections.
- Prior to the major surge, there's **very little decommissioning activity**, suggesting that the NT's solar farms are **relatively new** or have a longer operational lifespan.
- After the sharp increase, the cumulative volume plateaus, indicating a **stabilisation of decommissioning activity in the later years**.

SOUTH AUSTRALIA (SA)

South Australia, a leader in renewable energy integration, has seen a strategic deployment of large-scale solar farms, contributing significantly to the state's diverse energy portfolio. While this deployment is vital for the national transition to a sustainable energy future, it also necessitates planning for the eventual decommissioning of these assets. As these solar farms reach their end-of-life, the responsible management of a substantial volume of solar modules and associated components will be essential.

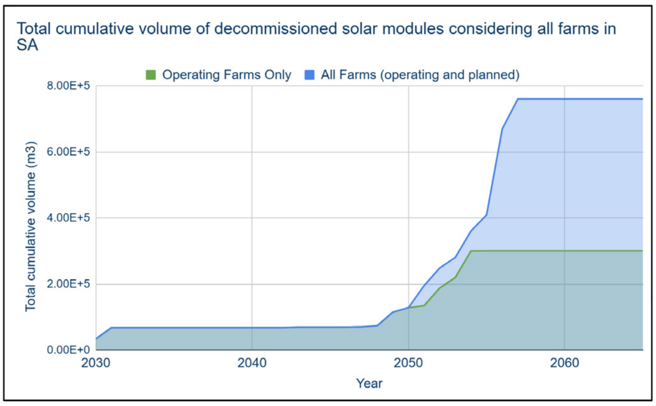
Key Insights

- More than **70 solar farms** in total, being **56 in operation**, and the others in different status, such as pre-construction, construction, decommissioned, announced and proposed.
- It is expected that **more than 2 GW** will be available in the next few years (analysis until 2065).
- Most solar farms use or will use **silicon-based solar modules**, while a few use or will use thin-film technologies (particularly CdTe solar modules).
- The earliest operating farms in the **SA date back to 2017**. This suggests that some of these facilities may soon be due for **repowering** to maintain optimal performance and extend their lifespan.
- Approximately **3.5 GW** of solar energy capacity is anticipated to be added **over the next decade**. This projection includes projects currently in pre-construction, announced, and proposed phases.

- **Reasonable assumptions** were made when the information was not publicly available and/or not provided by the farm responsible person or company.

Cumulative Volume of Decommissioned Solar Modules

The graph below provides a projection of the cumulative volume of decommissioned solar modules in SA, considering all farms assessed.



Key Insights

- The graph indicates a **substantial increase** in the cumulative volume of decommissioned solar modules occurring **after 2055**.
- Even before 2050, **there's a gradual but noticeable increase in decommissioned modules**.
- The steepness of the curve after **2055 highlights a rapid acceleration** in decommissioning activity. This suggests that a significant wave of solar farms will be simultaneously reaching their end-of-life.
- The projected surge in decommissioned modules has **significant implications for SA's waste management and recycling infrastructure**. It will necessitate the development of robust collection, transportation, and processing systems to handle the large volume of materials.

TASMANIA (TAS)

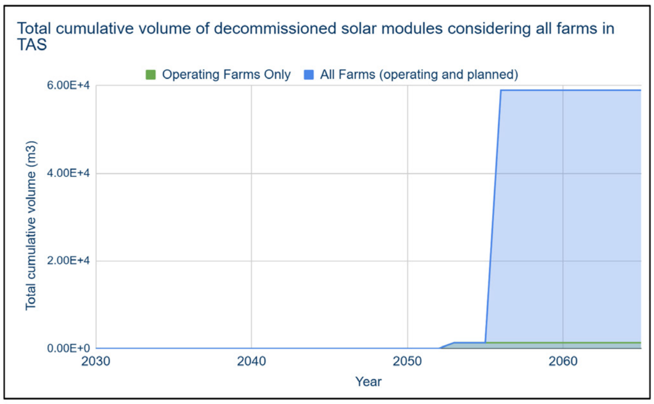
Tasmania, while possessing a distinct renewable energy profile dominated by hydro power, is also seeing a gradual increase in solar farm development. Even with a smaller scale of solar deployment compared to mainland states, strategic planning is essential for the eventual decommissioning of these assets. As these solar farms approach their end-of-life, the responsible management of solar modules and associated components will be necessary, particularly given Tasmania's unique environmental considerations.

Key Insights

- More than **2 solar farms** in total, being **one in operation and one in pre-construction** phase.
- It is assumed that both solar farms have **silicon-based solar modules**, however this information was not found.
- The earliest operating farms in the **SA date back to 2023**. This suggests that these farms are quite new and are expected to have a long lifespan.
- Approximately **288 GW** of solar energy capacity is anticipated **to be added by 2026**. This projection includes a project currently in the pre-construction phase.
- **Reasonable assumptions** were made when the information was not publicly available and/or not provided by the farm responsible person or company.

Cumulative Volume of Decommissioned Solar Modules

The graph below provides a projection of the cumulative volume of decommissioned solar modules in TAS, considering all farms assessed.



Key Insights

- The graph reveals a striking, **near-vertical climb in the cumulative volume** of decommissioned solar modules **after 2055**. This represents a concentrated period where an announced solar farm is expected to reach its end-of-life.
- **Future planned solar projects** will be the primary source of decommissioned modules in Tasmania.
- The graph shows **almost negligible decommissioning activity until the late 2050s**. This

highlights that Tasmania's solar farm infrastructure is relatively new or built to last.

- While the overall **volume of decommissioned modules** is relatively low compared to mainland states, it's still a **significant amount** for Tasmania and requires careful management.

CONCLUSION

This report has provided a comprehensive overview of the decommissioning and repowering landscape for large-scale solar plants in Australia, highlighting the significant opportunities and challenges that lie ahead. Through detailed data analysis, stakeholder engagement, and pilot project initiatives, we have mapped the current state of solar farm development across each state and territory, and projected future decommissioning volumes with unprecedented granularity.

The findings underscore the urgent need for a national, coordinated approach to solar panel waste management. The projected surge in decommissioned modules, particularly from the mid-2050s onwards, necessitates the immediate development of robust recycling infrastructure, clear regulatory frameworks, and effective stewardship schemes. The successful implementation of the Large-Scale PV Recycling Pilot, alongside the insights gained from direct industry engagement, has demonstrated the feasibility and importance of collaborative solutions.

Repowering presents a compelling pathway to maximise the value of existing solar assets, offering significant potential to enhance energy output and extend operational lifespans. However, this also necessitates careful consideration of the associated waste streams. The development of advanced recycling technologies and a circular economy approach are crucial to ensure that repowering contributes to a truly sustainable solar industry.

The state and territory-specific analyses reveal differing patterns in the development and projected decommissioning of large-scale solar farms. Queensland, New South Wales, and Western Australia, which have seen the highest uptake in large-scale solar installations, are expected to generate the largest volumes of decommissioned modules in the coming decades. This correlation between higher deployment and future waste volumes highlights the critical need for early investment in recycling and recovery infrastructure. While the Australian Capital Territory and Tasmania are forecast to produce smaller quantities of waste, strategic planning remains essential due to their specific geographic and environmental contexts.

The case studies presented within this report provide valuable insights into the practical challenges and opportunities faced by solar farm operators. From logistical hurdles in remote areas to the financial considerations of recycling, these examples underscore the need for tailored solutions and collaborative partnerships.

Ultimately, this report serves as a call to action for policymakers, industry stakeholders, and researchers to work together in developing and implementing effective strategies for the sustainable management of solar panel waste. By embracing innovation, investing in infrastructure, and fostering a culture of responsible stewardship, Australia can solidify its position as a global leader in renewable energy and pave the way for a truly circular economy.