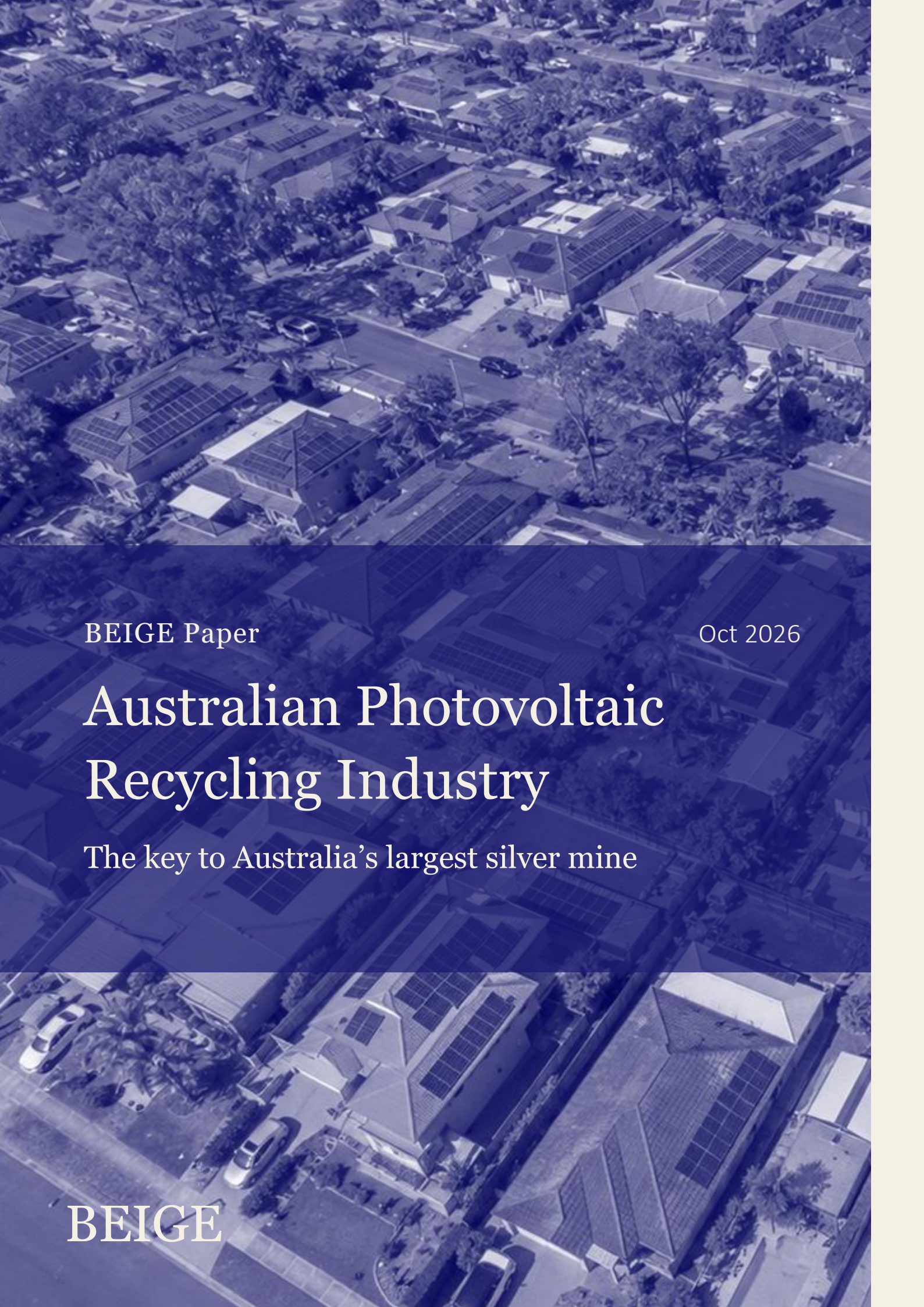




BEIGE Paper

Oct 2026

Australian Photovoltaic Recycling Industry

The key to Australia's largest silver mine

BEIGE



About Beige Advisory

Beige Advisory helps Australian organisations identify and assess technologies and suppliers in China to address sustainability challenges.

Our approach begins with understanding the problem, market context and practical requirements before assessing potential solutions. From there, we research relevant technologies, equipment providers and manufacturers, review stated capabilities and help determine which options warrant closer attention.

The process is intended to support more informed supplier screening, preliminary comparisons and commercial discussions — rather than beginning with a generic supplier list.

Beige Papers apply this same approach to emerging sustainability challenges, combining market analysis with practical investigation of relevant technologies and solution providers.

Executive Summary

Australia is approaching a major wave of end-of-life (EOL) photovoltaic (PV) panels. This emerging waste stream contains significant quantities of glass, aluminium, silicon, copper, and silver, creating a multi-billion-dollar resource recovery opportunity. The market is early stage; the challenge is to create a commercially viable system that can aggregate sufficient feedstock, process it at an appropriate cost and quality, and connect recovered materials with viable downstream markets.

~100 million	200,000–300,000 t	5,000–7,000 t/year	~1,000 t/year
PV panels installed in Australia	potential annual EOL volumes	current processing capacity	apparent utilisation

Key Findings:

1. Feedstock is the immediate bottleneck, not installed recycling capacity.

Australia has an estimated 5,000–7,000 tonnes per year of current processing capacity, but utilisation appears closer to 1,000 tonnes per year. Better collection, aggregation and logistics could unlock existing capacity and support future investment.

2. Higher value recovery is not automatically better economics.

The strongest technologies for Australia are likely to balance recovery value with automation, throughput, energy use, environmental compliance and capital efficiency.

3. Downstream markets are part of the technology decisions.

Recovered material only creates value where buyers, refiners or processors exist for the resulting outputs.

4. China is a relevant source of technology, partners, and potential capital.

Its market offers a broad equipment base and growing international interest, but like Australia, the industry is still nascent with recyclers testing methods, and suppliers requiring capability and performance claim verification.

Implications for Australian Recyclers and Technology Buyers

Understanding the full PV recycling ecosystem and value chain is key.

Near-term advantage is likely to come from solutions that match realistic volumes, control capital and operating costs. International technology can broaden the available solutions, potentially at lower cost.

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Introduction

One of Australia’s greatest critical mineral deposits lies not in the ground, but on the roofs of 1 in 3 Australian households – photovoltaic panels.

Since the early 2000s, Australia has been building one of the world’s largest PV markets. As systems age, technologies improve and panels are replaced, a growing end-of-life (EOL) waste stream is beginning to emerge. Approximately 3.4 million panels, or 68,000 tonnes, were estimated to have been decommissioned in 2025 [13]. Within 10 years, Australia could be decommissioning 200,000–300,000 tonnes of panels each year [14].

These panels represent more than a waste-management challenge – they are a business opportunity.

Australia’s EOL PV fleet contains significant quantities of glass, aluminium, silicon, copper, and silver. Recoverable material value has been estimated at more than AUD 1 billion based on mid-2030s decommissioning volumes [1, 16]. By the mid-2040s the cumulative opportunity will potentially exceed AUD 7.3 billion, including AUD 4 billion of silver [14].

As competition for critical minerals increases globally, Australia should look laterally to recover minerals already contained within its installed infrastructure. The opportunity, however, is not simply to recover as much as technically possible.

Three interrelated challenges currently shape the industry:

- Collecting and transporting sufficient feedstock
- Identifying economically appropriate recycling technologies
- Developing viable markets for recovered materials

The value chain can be simplified as:



Technology cannot be evaluated independently. Successful solutions need to balance industrial material recovery with CAPEX, labour, energy consumption, throughput requirements, material purity, and Australia’s environmental regulations. Technologies capable of reducing processing costs or improving the value of recovered outputs are wanted by the industry.



Photovoltaic Recycling in Australia

Resource Value Embedded in Australia's End-of-Life Panels

There is already an estimated 2,700–4,500 tonnes of silver in Australia's current PV infrastructure [14]. By the mid-2030s Australia's EOL PV panels could contain more than AUD 1 billion of recoverable material value [1, 16]. By the mid-2040s the opportunity could exceed AUD 7.3 billion, including around AUD 4 billion of silver [14].

Photovoltaics Forecasts & Future Waste Streams

Australia has built one of the world's largest PV markets, with roughly 1 in 3 households having rooftop PV panels [2]. By the end of 2023, the country had approximately 34 GW of installed capacity [1], equivalent to around 100 million panels, made up of 3388 different models of PV panel modules from 139 different manufacturers [1]. Despite this variability, roughly 90–95% of the market consists of crystalline-silicon (c-Si) modules [1, 8].

Installed capacity in Australia is forecast to continue growing and reach approximately 50GW by 2030 and 138 GW by 2050 [1]. To put that number in perspective, by 2050 Australia will have the equivalent of 400 million PV panels installed, 11 panels per capita.

The first wave of feedstock coming into Australia's recycling infrastructure will consist of more than 80% decommissioned rooftop PV panels [1, 16]. It is then anticipated that large-scale, commercial PV systems will begin to be meaningfully decommissioned and grow as a waste stream after 2030 [10].

Photovoltaic Lifespan – An Assumption

PV panels typically have around a 25-year service life after which they can be decommissioned and recycled [6, 8]. However, many panels do not reach their 25-year lifespan before being decommissioned.

Damage can occur to panels during installation and during operation from severe weather events. Panels are also decommissioned early due to technology upgrades with homeowners wanting to upgrade their panels for efficiency gains [14]. Australia's national PV panel standards have also rapidly developed over the past 20 years, causing pre-2016 panel arrays to be decommissioned if a single panel breaks since the array cannot be updated to the national standard. Due to these reasons and more, 50–70% of decommissioned panels may be viable for re-use instead of recycling.



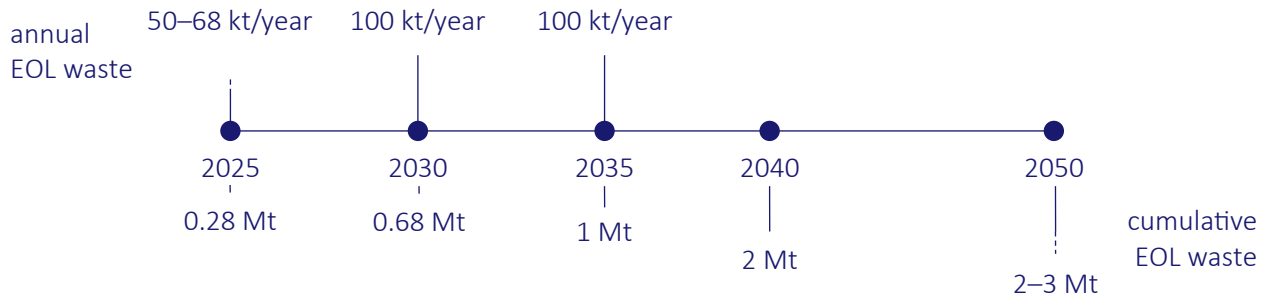
Key Insight

Due to early PV panel decommissioning, the assumption of a 25-year service life may be an overestimate when evaluating forecasted EOL PV panel volumes.

End-of-Life Panel Volumes

In 2025 there were an estimated 3.4 million PV panels decommissioned [14], representing 68,000 tonnes of resources to be extracted.

Annual & Cumulative EOL PV Panel Forecast

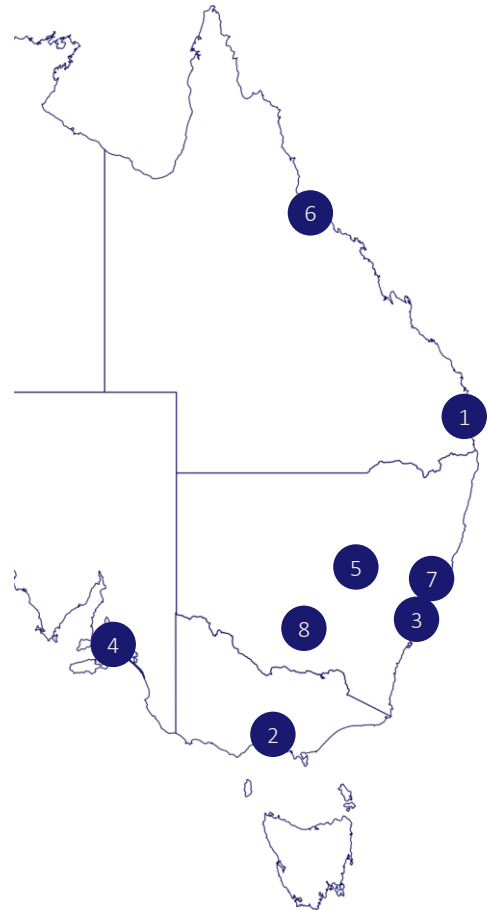


Source: adapted from data in [1, 2, 6, 10, 16]

The above timeline represents a potentially more conservative forecast against one early-decommissioning estimate that projects 2.9 million tonnes (145 million panels) will have cumulatively been decommissioned nationally by 2043 [14]. And that by the mid-2030s additional waste volumes will increase by 200,000–300,000 tonnes each year [14].

Future forecasts expect that a majority of initial waste volumes are likely to come from rooftop PV installations in Queensland, New South Wales, and Victoria [1]. Based on these forecasts, developing recycling facilities near major cities appears to be best to take advantage of expected waste volumes.

		Expected waste volumes (t/year)	
		2029	2035
1	Brisbane, QLD	20,000	→ 20,000
2	Melbourne, VIC	14,000	→ 14,000
3	Sydney / Penrith, NSW	10,000	→ 11,000
4	Adelaide / Adelaide Hills, SA	9,000	→ 9,000
5	Dubbo / Wellington, NSW	7,000	→ 9,000
6	Townsville, QLD	5,000	→ 5,000
7	Newcastle, NSW	4,000	→ 5,000
8	Murrumbidgee, NSW	4,000	→ 4,000



Source: adapted from [1]

Industry Characteristics

An average Australian residential system will comprise 16 panels (less than 30% of the European average) [14]. However, more than 70% of PV installations are centralised near metro regions [1]. This supports a unique opportunity for starting new PV EOL industries as supporting infrastructure such as aluminium and glass recycling, and metal refineries may be in close enough proximity [1] to create a cost-effective downstream supply chain.

**7–10
years**

majority lifespan of decommissioned
panels collected during Queensland pilot

The attractiveness of this opportunity was evident during the Smart Energy Council's solar panel recycling pilot in Queensland. 3 new PV recyclers emerged, and an additional 5 new market operators signalled entry into the industry because the pilot was able to remove the feedstock constraint [14]. During the pilot 62% of panels were between 7–10 years old [14] which fortifies the market trend that technological upgrades are a major factor in a panel's decommissioning.

Offshoring EOL PV panels represented a profitable opportunity for organisations, rather than paying to dispose of panels, organisations could be paid by overseas reuse groups [10]. Up to an estimated 80% of EOL PV panels pre-2024 were shipped overseas [14], however the global surge of PV panels has brought the cost per kW of a new panel down substantially. Combined with the 2025 Basel Convention amendment, which effectively makes the export of PV waste illegal [1], the market incentives for offshoring EOL PV panels have been erased.

Current Photovoltaic Recycling Operations in Australia

Australia's PV recycling industry remains nascent, with a small number of specialist operators (< 20 individual companies) pursuing different methods and business models. In the absence of national recycling requirements or national PV recycling infrastructure, the industry is still developing the ability to recover the material value contained within EOL PV panels.

However, the *big waves* of PV waste are looming, early leaders are fortifying their operations to prepare for the rising demand before significantly larger EOL volumes glut the waste system.

Australia's current annual PV recycling capacity sits between 5,000 tonnes [14] and 7,000 tonnes (250,000–350,000 panels). Actual utilisation, however, appears to sit closer to 1,000 tonnes (50,000 panels).

The industry's current roadblock is not recycling capacity but scale and volume of feedstock.

Operators are trying to optimise logistics across large areas to have sufficient feedstock to be viable, therefore operations cannot scale until a steady stream of feedstock can be secured [13]. This challenge is also encouraging operators to experiment with different collection and circular business models, although these remain at the periphery of the industry.

Feedstock Collection Models

To try optimising the collection of EOL PV panels across large areas a few models have been observed:

1. Panel manufacturers establishing their own recycling pathways.
2. Organisations offering complete full lifecycle solar services.
3. Dedicated recyclers targeting PV panel installers who decommission installed panels.
4. Recyclers working with local councils as part of their waste management systems either as a specialist route for PV waste or using existing waste management infrastructure as a collection point for EOL PV panels. The latter may prove a useful partnership for regional areas where local waste facilities have the excess space to store panels.

Machinery & Processing

Mechanical separation remains the benchmark for commercial-scale c-Si PV modules with most recyclers focussed on aluminium, copper, and glass recovery [14]. That said, some recyclers are invested and optimistic about developing suitable technologies to commercialise silver and silicon recovery.

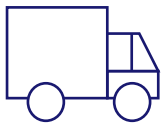
As remains the case across Australian industries – labour is a key cost-driver. Therefore, innovations and improvements to make the recycling process automated are wanted, some recyclers are looking into overseas technologies to streamline sorting, recycling, and refining processes



Challenges Faced by Australian Industry

Australia's PV recycling industry: a billion-dollar opportunity stuck at the unit economics.

The economic challenge in PV recycling stems from three main drivers:



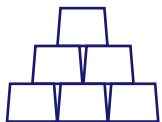
Logistics

The coordination and cost of collecting and transporting EOL PV panels to a recycling site.



Labour Cost

The labour costs involved in the decommissioning of panels as well as in the recycling process. Labour costs have been analysed to account for approximately 45–60% of operating expenditure.



Downstream Markets

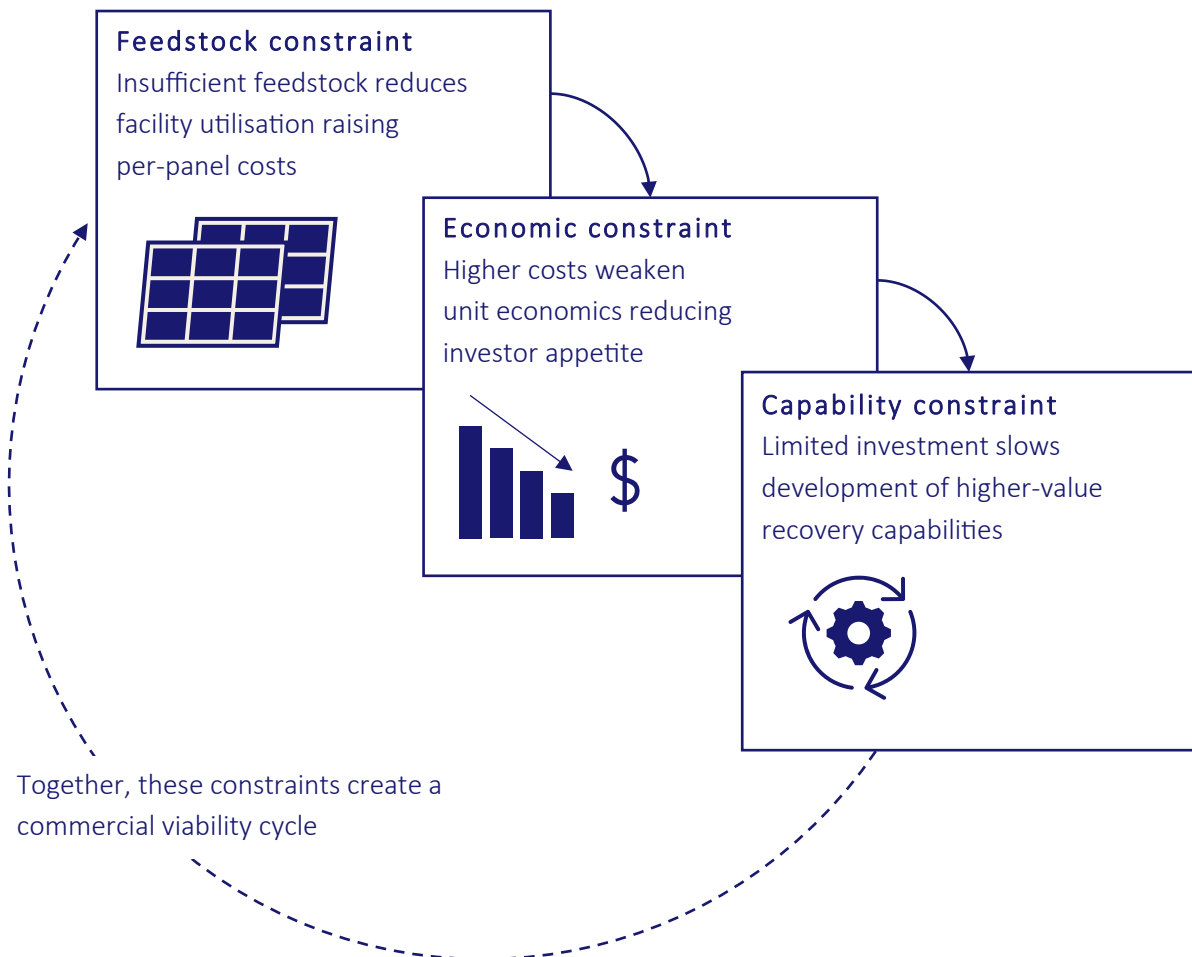
Scrap aluminium recycling is already an established industry in Australia. However, local markets for recycled glass, silicon, and silver remain limited.

The need for cost-effective solutions throughout recycling operations outweighs the want for novel innovation.



Challenge: Logistics & Feedstock

From both research and practical perspectives, feedstock is the industry's primary constraint. While innovative solutions for resource recovery are wanted and needed, they would be built on a system not yet suited to maximise the potential. Recyclers need volume certainty to achieve economies of scale [1, 12, 13, 14], but current feedstock can be irregular, with peaks and troughs.



Source: adapted from [14]

This is particularly evident for the Australian market as current feedstock volumes are fed by rooftop PV panel decommissioning. Currently large-scale systems like solar farms are generally only decommissioning panels in small tranches (e.g. 10% of total panel quantity) each year as they are upgraded. Therefore, these larger commercial systems may not yet have sufficient business rationale to use a recycling pathway when landfill and storage remain cheaper options. Future policy or economic forces may change this choice in future.

Recyclers may test new regions as collection points first to test whether sufficient feedstock volumes exist in that region before investing and scaling operations. While scale is part of the puzzle, it misrepresents the core of the issue for individual recyclers. Scaling the number of recycling operations or locations also scales the same feedstock problem just over a greater area if each individual facility still lacks sufficient local volumes.

Transport is a major contributor to the logistics and feedstock problem [2]. One estimate suggests transport can account for around 60% of total recycling system costs [13]. Regional Australia presents a particular challenge as the long distances make centralised recycling less economical.

Industry participants note that moving panels from regional locations to recycling facilities can cost more than the recoverable materials are currently worth [3]. One proposed model is to undertake delamination in regional locations to then transport a more condensed load of higher-value materials to metropolitan facilities [1].

transportation

60%

of total recycling system costs

Current panel recycling fees for decommissioners are approximately AUD 5–15 per panel [10, 14]. However, once the cost of collection and logistics are added, the total system cost rises sharply to AUD 40–80 per panel, with regional and remote areas potentially higher [14].

Recycling's number one competitor – landfill – can cost between AUD 2–30 per panel [13], with AUD 10 per panel observed in some council waste systems.

At the point of disposal, recycling is not necessarily dramatically more expensive than landfill. The cost gap emerges primarily when the full collection and logistics system is included.

AUD 355

total ESG cost of dumping a PV panel
into landfill

Looking at the disposal problem from a purely monetary lens does not account for the environmental and social costs associated with landfill, which Smart Energy Council estimates the total cost of landfill (including social and environmental costs) to be AUD 355 per panel [14]. While this figure exemplifies that these decisions have greater ESG considerations, in Australia's current market, it may not shift the needle for private investment.

PV panel installer (or uninstaller) behaviour may therefore be key to the recycling system.

Potential collection models:



Accessible collection networks would require the support of councils, installers, and/or a stewardship framework.

Many installers reportedly want a solution for PV waste, but that solution needs to be low-friction and cost-effective for both installers and recyclers. Existing habits such as taking panels to waste management facilities or stockpiling, can be difficult to change if recycling introduces additional time or cost.

Long-term PV recycling systems will need to balance scale against the proximity to EOL PV panel sources. One report proposes that optimal locations to establish large-scale PV recycling facilities (> 5,000 tonnes per year) are in Australia's major capital cities: Sydney, Melbourne, Brisbane, Perth, and Adelaide [1], followed by expansion into regional areas [1]. However, the challenge is not simply building more recycling capacity in these cities but creating a cost-effective collection and logistics system that can aggregate dispersed panels into predictable, commercially viable feedstock volumes.



Challenge: Technology

The industry recognises the need for more advanced solutions to recover all materials from PV panels [1]. Future technologies need to improve the recovery and value of economically important materials without introducing disproportionate processing costs [1, 15, 16].

Research papers suggest that many advanced processes aimed at advanced silver and silicon recovery remain difficult to commercialise economically. Key constraints stem from process design, low energy efficiency, and the high cost of hazardous chemicals in the recovery process [8, 12, 15]. Commercially viable solutions for recovering minerals contained within PV cells also remain limited [16]. Smart Energy Council suggests that there is yet to be a commercially viable technology to recover high-value silver and silicon [14].

PV cells within a PV panel are estimated to contain 40–50% of the total value of a panel [1], as they contain the silver and silicon, making silver and silicon attractive recovery targets. However, higher-value recovery does not automatically translate into stronger economics.

Economic sustainability requires a market-fit solution.

Current technologies for high-purity silver extraction and refining rely heavily on hazardous chemicals which create an environmental dilemma for an environmentally conscious industry and increased regulatory requirements that extend lead times to operationalisation.

The technology challenge is ultimately one of market fit. Australian recyclers require solutions that balance recovery performance with CAPEX, labour, throughput, energy consumption, environmental requirements and the quality of recovered outputs. This may create opportunities not only for improved silver and silicon recovery, but also for automation, cleaner material separation and technologies that reduce overall processing costs.

Challenge: Markets & Downstream Processing

Australia has established markets for aluminium and copper [4, 10], but weaker markets for other PV-derived materials [1, 10, 16], creating a need for downstream markets for glass, silicon, and silver.

Glass presents one type of downstream-market challenge. Although it represents the largest material fraction recovered from PV panels [4, 16], its relatively low value means transport costs can quickly undermine its economics. Contamination and small particle size (< 1 mm) can also restrict recovered glass to lower-value applications [1] such as concrete, roads, and construction. Australian recyclers are actively exploring higher-value reuse applications, but a commercially established higher-value market has yet to emerge.

Silver and silicon present a different downstream challenge. While these materials represent a higher-value opportunity, domestic demand for recovered silicon and silver remains limited, reducing the incentive for Australian PV recyclers to invest in high-cost recovery facilities. Current practice generally involves on-selling a mixed silicon and silver fraction to downstream recycling facilities or smelters. Although there is some domestic demand for this mix, recyclers have also engaged with international markets to fill the domestic gap. Given the strategic importance of critical minerals, exporting these locally *mined* materials may be less desirable for Australia over the long term.

Australia lacks commercial-scale advanced refining capacity for recovering high-purity silver and silicon [10, 14]. This means recyclers may be able to produce suitable intermediate materials for refining, but the downstream domestic industry currently lacks the capacity to convert those materials into higher-value products.

However, Australia's downstream silicon industry may be beginning to develop. A new project was announced in August 2026 for an integrated quartz-to-silicon manufacturing complex in Townsville, Queensland. The project is intended to support higher-value silicon production and potentially downstream manufacturing for PV wafers, semiconductors, and other advanced technologies [5]. The project has received Australian Government Major Project Status and is expected to involve approximately AUD 4.5 billion of investment in its first stage [5]. This signals a significant investment in the domestic silicon value chain while Australia's EOL PV volumes are expected to accelerate. If recovered silicon can meet suitable purity and specification requirements, development of this downstream industry could create future domestic refining, offtake, and partnership opportunities for PV recyclers.

Notably, Townsville has been mentioned in this report as a potential regional feedstock centre of approximately 5,000 tonnes per year. While no connection currently exists between these developments, the co-location of future PV EOL volumes and emerging silicon-processing capability

could advance North Queensland as a particular area of interest for future PV recycling and downstream partnerships.

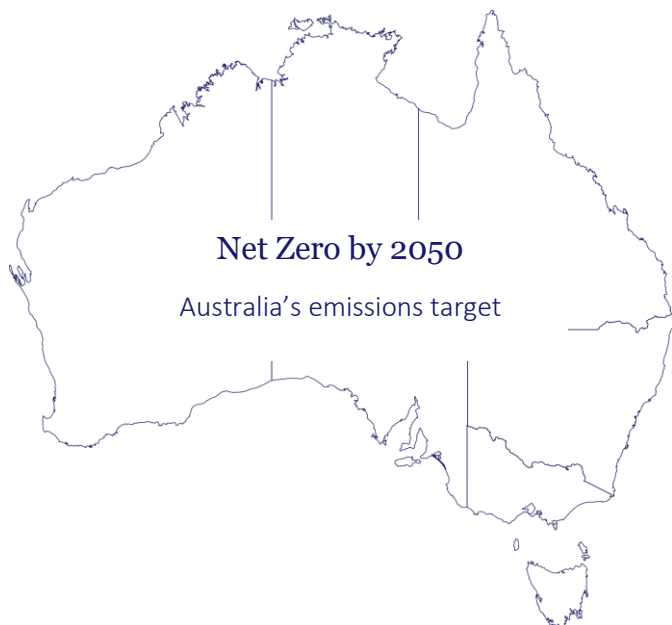
These developments could begin to address one of the structural constraints facing Australian PV recycling. Stronger domestic silicon processing and advanced manufacturing would create additional potential markets for recovered materials [10], while improving the commercial case for investing in higher-value recovery technologies. Similar opportunities may emerge for silver and other recovered materials as Australia expands its critical-minerals and advanced-manufacturing supply chains.



Government Response

Australia's policy framework for EOL PV panels remains relatively underdeveloped, with limited national regulation governing panel collection and recycling. Industry participants suggest that clearer government policy, particularly at the federal level, could provide greater certainty around how the industry should operate and thereby accelerate investment and infrastructure development.

It is in the Australian government's interest to align policy to develop the PV recycling market alongside Australia's broader environmental targets that will boost PV deployment and the looming volume of panels requiring end-of-life management. Australia has committed to reducing carbon emissions by 43% from 2005 levels by 2030 and reaching net-zero by 2050 [1]. The National Waste Policy Action Plan targets an 80% average resource recovery rate across waste streams by 2030 [1] – a government plan that should be supporting EOL PV panels as a resource stream.



State governments are also developing their own collection, funding and regulatory responses, although approaches remain inconsistent across jurisdictions.

National Stewardship

A national product stewardship scheme is emerging as one of the most significant potential policy changes for the industry. The Productivity Commission has recommended a stewardship model in which manufacturers, importers, and retailers share responsibility for panels at end-of-life [3]. Australia's DCCEEW has also considered product stewardship regulation [1].

Industry feedback suggests a national stewardship scheme could address one of the industry's largest barriers: the cost of collecting and transporting geographically dispersed panels – the keystone potentially blocking rapid scale of operators. Current operators suggest that greater government involvement would provide the industry with a clearer understanding of how the system will operate and help existing recycling operations gain momentum.

Federal Government Funding

In lieu of a national stewardship scheme, the Australian government has begun funding the infrastructure, data, and technologies required to support a future national recycling system.

- **Solar Sunshot Program (AUD 1 billion)** – primarily focussed on expanding Australia’s domestic PV manufacturing and broader supply chain capabilities, including recycling, in round 2 [10].
- **Recycling Modernisation Fund (AUD 200 million)** – aimed at renewing and updating recycling infrastructure across Australia [18].
- **Solar Panel Recycling pilot (AUD 24.7 million)** – designed to gather national data on panel collection, recycling, and transportation costs [2].

These programs indicate increasing recognition of PV panel end-of-life management as a challenge worth government investment before policy and regulation.

What Government Intervention Could Unlock

EOL PV panels are recognised as both a waste and an opportunity however, policy still is needed to dictate who pays, who collects, and how panels reach recyclers economically – as industry suggests a panel collection levy, fee, or payment may drastically change the economics plaguing the feedstock issue.

A national stewardship framework could potentially provide the mechanism connecting these parts of the system – allocating responsibility across the supply chain while helping fund collection and transport thereby making individual recycling operations more economically viable.



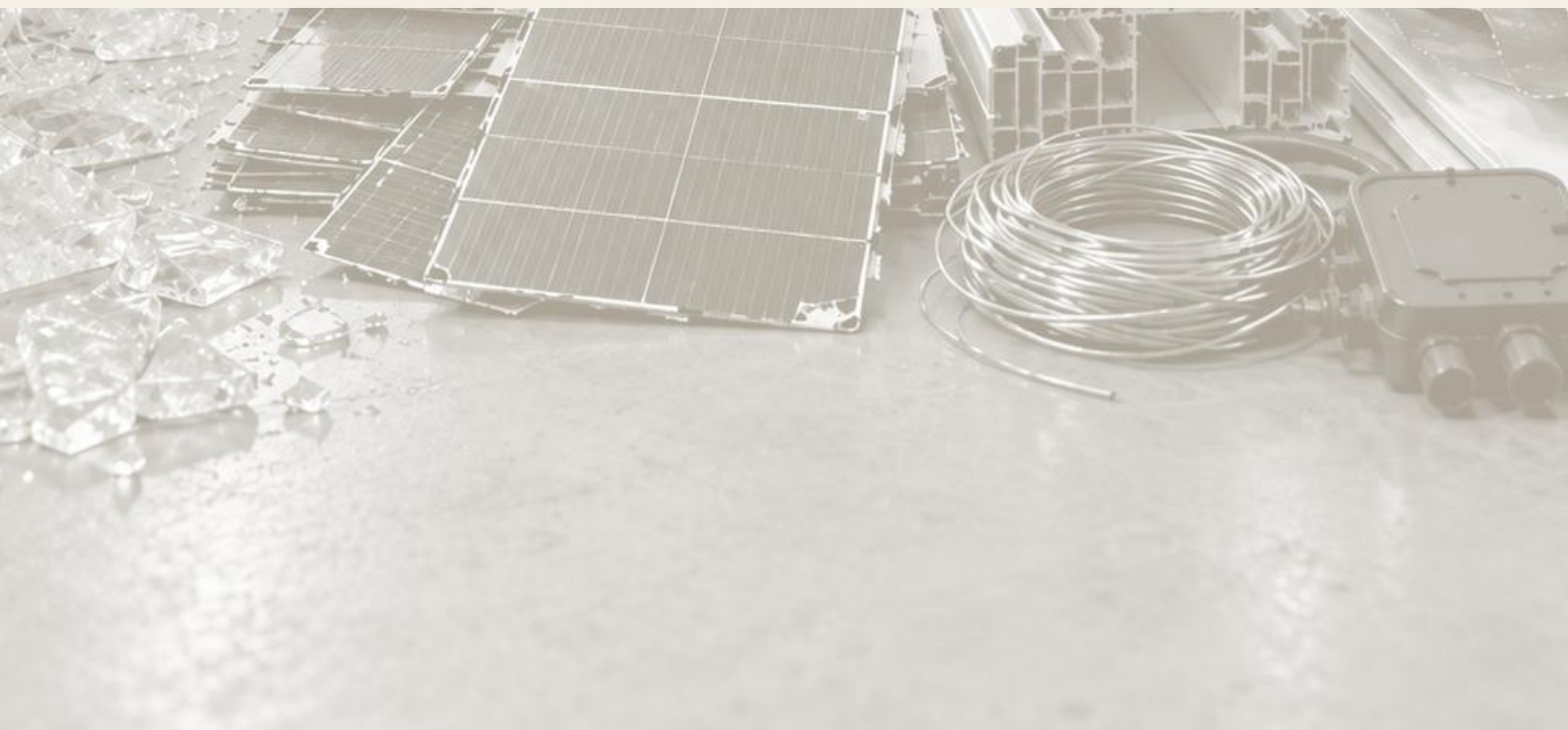
Business Case for Photovoltaic Recycling in Australia



AUD 1,000

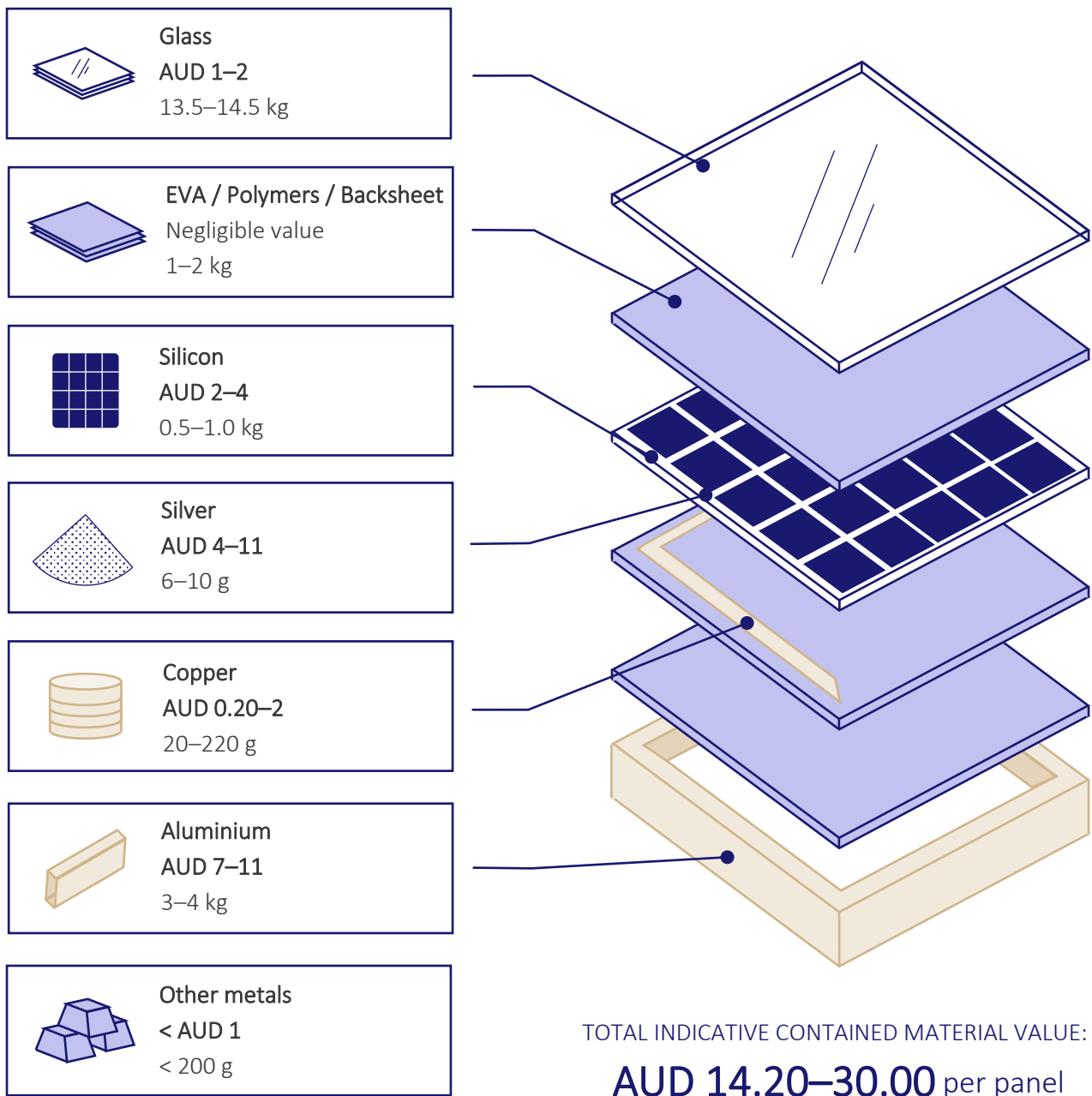
gross recoverable material value
for 1 tonne of c-Si PV panels

The gross recoverable material value for a tonne of c-Si PV panels is estimated at more than AUD 1,000 under relatively favourable recovery and commodity-price assumptions [1]. The value realised by recyclers may be substantially lower depending on material purity, recovery efficiency, and available end markets.



Material Breakdown of a Photovoltaic Panel

Studies suggest 95% of a panel's contents may be recoverable [13], although the economic value of each material varies considerably. Glass is 70% of the panel weight [1, 4, 16] but only 6% of its material value [1]. Silver is around 0.04% of the panel weight [1, 9, 15] but approximately 34–47% [1, 4] of the material value.



Ranges represent indicative values across different module types and sources and should not be summed as the composition of a single panel. Source: adapted from [1, 4, 11, 12, 15].

In total a 20 kg panel has an indicative material value of between AUD 14–30, the *Scoping Study: Solar Panel End-of-Life Management in Australia* has an average indicative value of AUD 22.60 per panel, or around AUD 1,100 per tonne.

Important notes to consider when observing these values:

Material composition is changing over time. Newer PV modules are using decreasing amounts of silver and silicon. The business case that uses the amount of silver and silicon in Australia's initial waves of EOL PV panels may not be suited for later waves over the next 20 years.

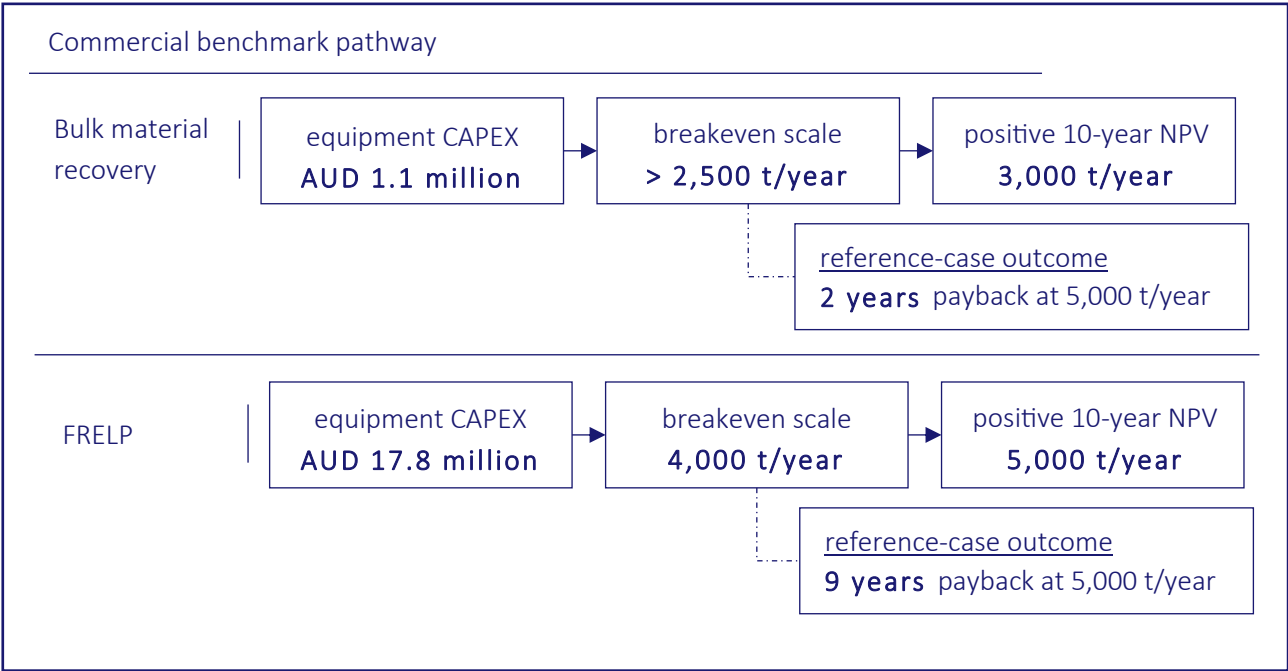
Contained material value is not the same as recovered value. Glass demonstrates this particularly clearly. Clean, separated solar glass may have a useful recycling market, but crushing or milling can contaminate it with metals such as silver and copper. Embedding a high-purity glass system can provide more than double the value for the glass output when compared to contaminated glass [4]. This difference can be highly important for operational profits.

PV Recycling Business Case & Unit Economics

Key Business Case Numbers

indicative

Unit recycling cost	AUD 500–1,000/t	AUD 10–20/panel
---------------------	-----------------	-----------------



Feedstock availability is a key limiting factor

Source: adapted from [1].

The economic levers of PV recycling are maximising the volume and value of outputs while minimising the costs to do so. More advanced recycling technologies may be able to increase the value of outputs but usually require larger upfront capital investment thereby relying on a more consistent supply of panels.

Maximising throughput and recovery:

- Feedstock availability
- Facility utilisation
- Recovery efficiency

Maximising value of outputs:

- Material purity and recovery depth
- Downstream demand and commodity prices
- Feedstock composition

Minimising cost:

- Equipment and facility CAPEX
- Labour
- Feedstock collection and transport
- Energy, utilities and waste treatment
- Technology/process complexity

One cited study suggests a facility recovering glass sheets, silver, copper, and silicon powder could become financially attractive if processing costs can be achieved at AUD 450 per tonne, a process additionally recovering high-purity silicon could become more investable if processing costs are achieved at AUD 650 per tonne [8].

Recent Australian sources generally estimate recycling processing costs are around AUD 500–1,000 per tonne, equivalent to roughly AUD 10–20 per 20 kg panel [1, 13, 16]. These costs can fall as throughput increases. This indicatively suggests that some recycling pathways are already approaching potentially attractive processing-cost levels, while higher-cost operations remain dependent on improvements in facility utilisation, technology and capital efficiency.

Recycling Process Economics Comparison

The *Scoping Study: Solar Panel End-of-Life Management in Australia* provides a useful comparison between bulk material recovery (electrostatic recycling) and Full Recovery End-of-Life Photovoltaic (FRELP) recovery processes.

	Bulk Material Recovery	FRELP
Equipment CAPEX	AUD 1.1 million	AUD 17.8 million
Annual maintenance	12% of equipment cost	12% of equipment cost
Utilities, materials & waste treatment	AUD 118/t	AUD 91/t
Labour	30 employees at 10,000 t/year	25 employees at 4,000 t/year
Material sales revenue	AUD 655/t	AUD 1,168/t
Breakeven scale	> 2,500 t/year	4,000 t/year
Tested scale with positive 10-year NPV	3,000 t/year	5,000 t/year
Unit cost at 5,000 tonnes per year	AUD 503/t	AUD 978/t

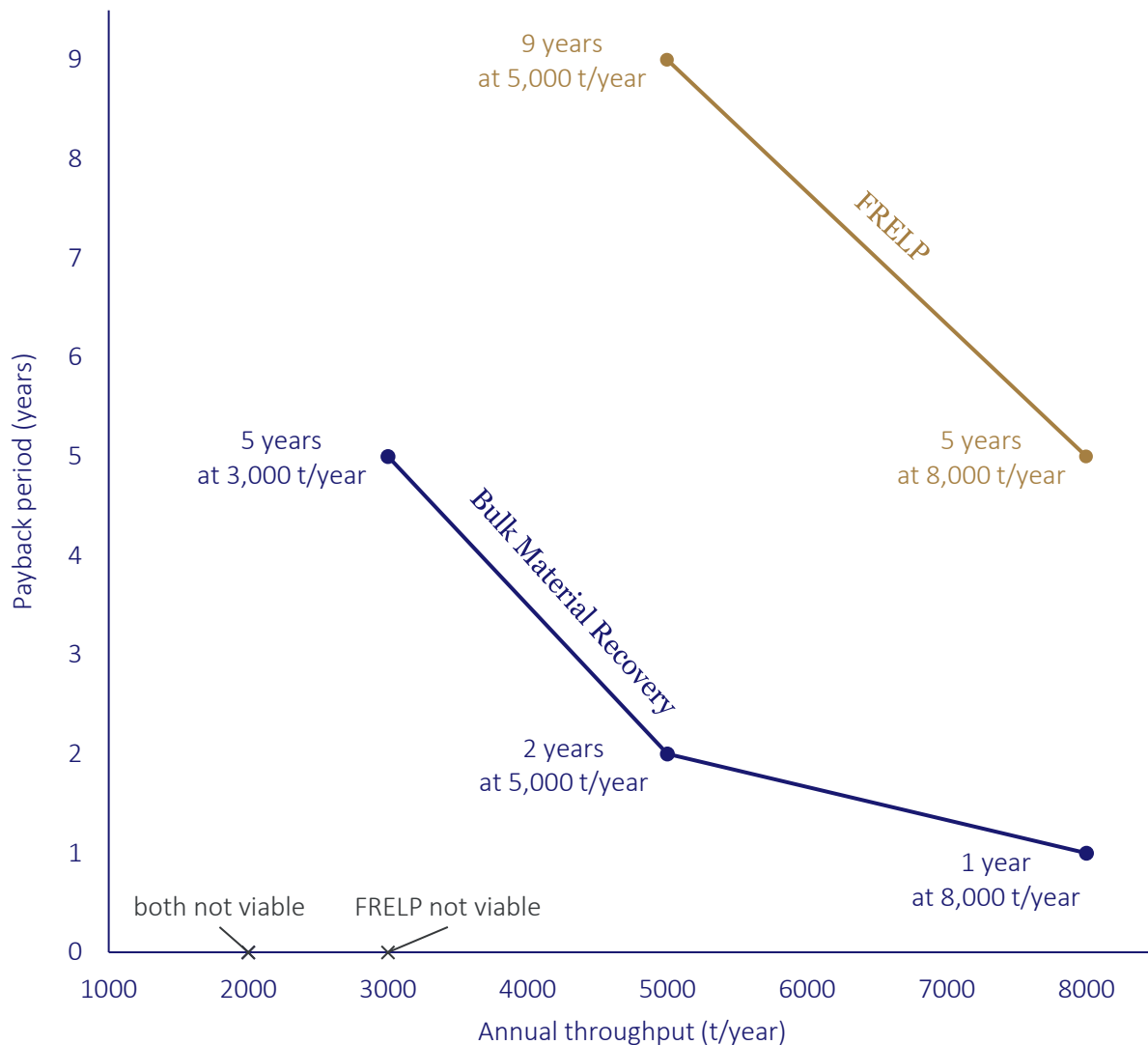
Note: Unit costs include equipment costs depreciated on a straight-line basis over a 10-year facility life. Source: adapted from [1].

The above table illustrates a core decision in PV recycling. Maximising for material sales revenue or output value requires substantially greater capital investment. The commercial advantage of recovering silver, silicon, and other higher-value materials therefore depends on whether the additional revenue outweighs the higher CAPEX and processing requirements.

Effect of Feedstock Availability

As previously mentioned in this paper, optimising panel collection to increase feedstock availability is crucial to the investability of PV recycling facilities and processing lines.

Modelled Payback Periods at Varying Throughputs



Note: Payback estimates are based on a discounted cash-flow analysis using a 7% discount rate and therefore cannot be calculated directly as CAPEX divided by material sales revenue less the stated unit cost from figures within this report. Source: adapted from [1].

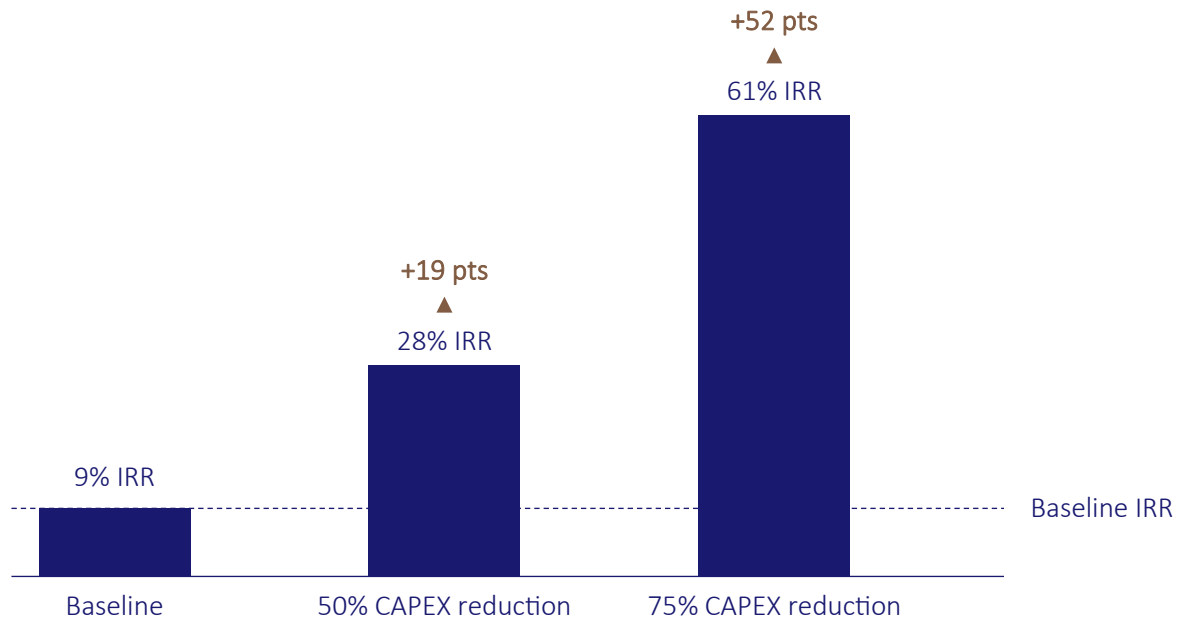
As suggested by the above graph, fixed costs make both pathways difficult to justify at lower volumes, particularly full recovery – 5,000 tonnes a year would roughly require 4,800 panels collected each week.

CAPEX Sensitivity

CAPEX appears to be one of the most important determinants of project viability.

10-Year IRR Sensitivity to CAPEX Reduction

5,000 t/year FRELP facility



Source: adapted from [1].

This demonstrates that reducing equipment and facility costs can have a very large impact on the attractiveness of PV recycling facility investment. However, Australian equipment buyers may be cautious about machinery that competes primarily on price, particularly where earlier low-cost market entrants have developed a reputation for reliability issues, and frequent breakdowns.

Considerations for the Business Case

Declining material content over time. There is a clear trend that newer models continue to use less silver and silicon [3, 7, 12, 13], which may reduce the value recoverable per tonne in the future. This will likely become highly evident in advanced recycling operations, whose economics depend on recovering silver and silicon, once models from the 2020s dominate recycling feedstock.

Long investment payback periods. High-CAPEX recycling facilities, particularly those operating below optimal throughput, may face discounted payback periods exceeding 10 years [7].

High fixed and operating costs. Major economic cost drivers include facility CAPEX, labour, and feedstock collection and transport. Facility utilisation therefore matters heavily, as expensive equipment and fixed operating costs become difficult to justify when feedstock volumes remain inconsistent.

Recovery depth versus processing costs. Recycling operations can take advantage of more advanced equipment to recover higher-value outputs, but that additional cost needs to be balanced with the actual additional recovery revenue.



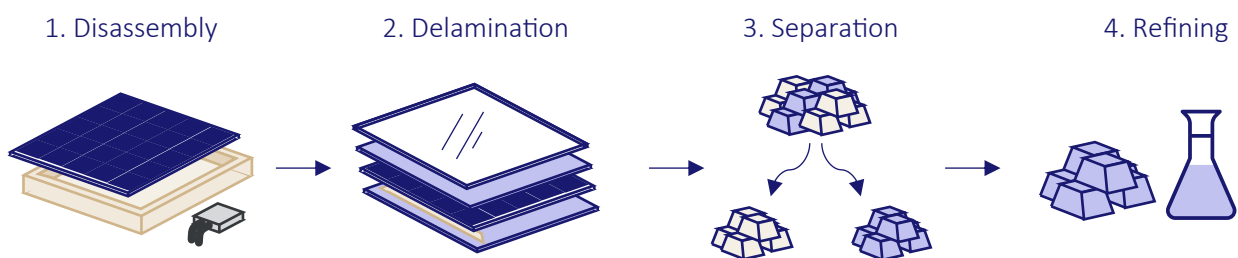
Photovoltaic Recycling Technology

The overall technology challenge for Australian recyclers is not simply achieving the highest possible recovery percentage. The challenge requires a solution that can provide sufficient throughput, high enough material quality and recovery of valuable materials without making the processing line too capital-, energy-, or labour-intensive to operate economically.

Australia has not yet settled on a dominant technology pathway for end-of-life PV recycling. While the industry is still developing, the trade-off between cost, energy consumption, material purity, and recycling depth are being investigated.

Recovery rates above 95% by weight are technically achievable, as demonstrated by overseas commercial operations [1]. However, achieving a high overall recovery rate does not necessarily equate to economically optimal, high-purity materials.

Simplified PV Recycling Process

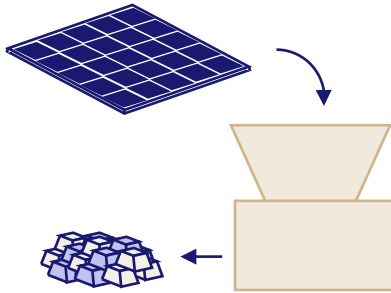


1. Disassembly

Most recycling pathways begin by mechanically removing the aluminium frame, junction box, and cabling. This initial step immediately separates some of the easiest materials to recycle. Despite the relative straightforwardness of initial disassembly, equipment still needs to be sophisticated enough to accommodate different panel dimensions, constructions, and levels of damage. Once these components are removed, the remaining PV laminate contains the glass, EVA/polymer layers, PV cells and embedded metals.

2. Delamination – the Key Technology Decision

Separating the laminated layers of the panel presents more of a technical challenge and trade-off. The EVA encapsulant bonds the glass, PV cells, and backsheet (or glass in double-glass panels) together, creating a challenge to mechanically, thermally, or chemically break these bonds. However, recycling facilities may require more than one processing pathway to accommodate different panels.



Mechanical / Crushing

Shredding, crushing or milling breaks the PV laminate into smaller fragments before subsequent sorting.

Advantages: relatively simple, scalable, and lower cost; can process heavily damaged panels.

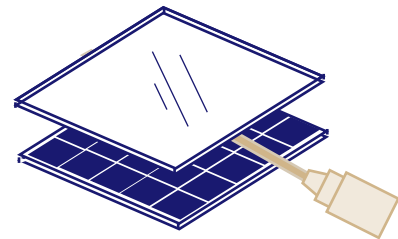
Limitations: can contaminate glass and create mixed, lower-purity material fractions.

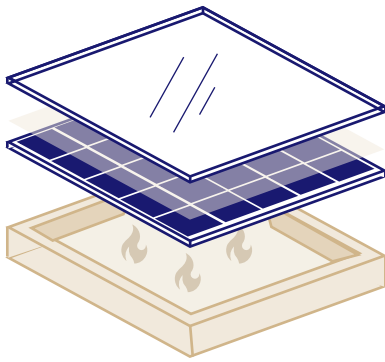
Selective Cutting

Hot-knife, diamond-wire or water-jet systems separate the glass from the PV laminate without extensively crushing it.

Advantages: can preserve cleaner, potentially intact glass; improves material quality and reduces material entering downstream separation.

Limitations: more specialised equipment: generally better suited to intact panels and may require a complementary crushing pathway for heavily damaged PV panels.





Thermal / Pyrolysis

Heat decomposes EVA and other polymers.

Advantages: Can produce relatively clean separation of glass and PV cells; suitable for advanced material recovery.

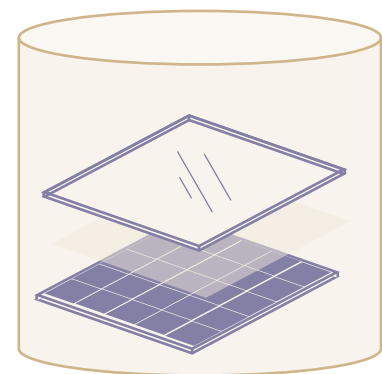
Limitations: Energy-intensive; emissions require treatment; Australian recyclers have raised regulatory and operating-cost concerns.

Chemical

Organic or inorganic solvents dissolve EVA/polymer layers.

Advantages: Can preserve high-quality glass and improve recovery of metals and silicon.

Limitations: Chemical consumption and disposal; potentially expensive; some processes can take several days.



Delamination technology choice appears to be the most important technology consideration in current operations, as the quality of separation may affect every downstream material pathway in particular glass. While silver extraction may be the headline, glass represents around 70–75% [1, 3, 12, 15] of a panel's weight and represents a significant financial decision in choosing delamination technology [3, 5, 14].

The key issue is not simply whether glass can be recovered but in what condition.

Crushing and milling delamination processes can mix silver, copper, silicon, and polymer contaminants into recovered glass, reducing quality and restricting its potential downstream value to only be suitable for low-value secondary applications such as construction aggregate.

Delamination processes that separate the glass sheet before intensive crushing – selective cutting, pyrolysis, and chemical – can potentially produce a cleaner and more valuable glass output that may even be used as feedstock for glass in new PV panels [3, 14] – creating a more circular economy. There is also an added benefit that removing the glass earlier lessens the amount of material to process in latter separation equipment.

Mechanical Processing

Mechanical processing through shredding, crushing, or milling is generally one of the simplest and lowest-cost recycling pathways and is currently most common in Australia. The panel is broken into smaller fragments before subsequent sorting and material separation. This approach is particularly practical for heavily damaged panels that cannot be processed through other methods.

The trade-off is material quality. Crushing can mix glass with silicon, silver, copper, and polymer fragments, producing lower-purity material streams and reducing the potential value of outputs – particularly glass [3].

Selective Cutting

Hot-knife, diamond-wire and water-jet systems separate the glass from the laminated module without extensively crushing the panel. This method can preserve a cleaner and potentially intact glass sheet, improving its quality and value while also reducing the volume of material requiring downstream separation.

However, selective cutting is unlikely to provide a complete standalone solution. Severely damaged or broken panels may not be able to be processed through selective cutting machines, meaning facilities may require a secondary mechanical processing pathway.

Pyrolysis

Pyrolysis, or heat delamination, heats the PV laminate until the polymer layers decompose, allowing a relatively clean separation of the glass and PV cell components.

Pyrolysis is a suggested route for achieving high-quality material recovery [8, 11, 14] but it is also one of the most energy intensive. By essentially burning away bonding chemicals, the high temperatures in the process produce volatile compounds, requiring appropriate gas collection and purification. There are still other advantages as pyrolysis machinery manufacturers suggest these systems could have lower long-term maintenance costs when compared to more mechanically complex alternatives.

Within Australia, pyrolysis processes bring additional regulation to protect and safeguard the environment, communities, and workers, with some regions having complete bans on pyrolytic processes. The environmental, regulatory, and energy intensity concerns have skewed perception away from pyrolysis as a long-term viable method of delamination.

Chemical

Chemical delamination uses solvents to dissolve or weaken the polymer layers bonding the panel together.

Its main advantage is the potential to retain high-quality glass, silicon, and metal fractions, making it an attractive choice for advanced material recovery [11, 14]. The cost for this advanced recovery is the time required and management of dangerous chemicals. Chemical delamination methods require several days to separate the polymer from the PV cell, which may make them difficult to translate into industrial applications [8] which require thousands of panels to be processed weekly. Treatment and disposal of the solvents also need to be incorporated into the recycling system, creating additional layers of environmental and safety regulation for operators.

3. Material Separation

After delaminating or crushing, the resultant glass, PV cell, and metal fragments are separated.

Common separation techniques include:

- Sieving/screening
- Density/gravity
- Electrostatic

Simple mechanical separation is attractive because it can be relatively low-cost and straightforward, but conventional methods can struggle to cleanly separate glass from PV cell and metal fragments.

Research illustrates the effect process design can have on recovery rates. Conventional sieving in one study recovered only around 31.7% of silver, whereas an improved sieving treatment using separation aids recovered approximately 96.3% of the silver [8].

Electrostatic separation separates conductive and non-conductive fractions, with research reporting overall separation efficiencies of around 95% by weight under suitable conditions [6].

These research papers suggest that mechanical delamination itself is not necessarily a low recovery option, the efficacy depends on the design of subsequent systems for separation.

4. Refining – Advanced Recovery of Silver, Silicon and Copper

Physical separation can recover bulk materials, but to extract high-purity silver and silicon requires additional refining.

Chemical leaching is one of the main approaches investigated. Research identifies nitric acid (HNO_3) as particularly effective because of its high silver-leaching efficiency, while sulphuric and hydrochloric acids can also be used [8].

These additional processing stages can substantially increase the value of outputs, but also introduce further chemical consumption, waste-treatment requirements, energy use, and additional capital expenditure.



Technology Selection Framework



Technology selection is unlikely to be determined by any single performance metric. The preceding analysis suggests that suitable PV recycling technology for Australia will depend on a combination of feedstock characteristics, facility utilisation, processing costs, output quality, and available downstream markets.

The following considerations provide a qualitative framework for comparing potential technology pathways.



INPUT & CAPACITY

Feedstock Compatibility & Flexibility

Recyclers receive varied panel constructions with varying levels of damage.

TEST

- Which panel types can it process?
- Can it accept damaged panels?
- How easily can configurations be adapted?

Throughput & Utilisation

Higher nominal capacity is not advantageous if feedstock cannot match capacity.

TEST

- Does capacity meet feedstock volumes?
- What is the minimum operational capacity?

ECONOMICS & OPERATIONS

CAPEX & Labour Intensity

Australian economics are highly sensitive to capital and labour.

TEST

- Total installed CAPEX?
- How many operators required?
- Where can automation reduce labour?

Energy, Chemicals & Environment

Thermal and chemical processes may add utility, treatment, and regulatory requirements.

TEST

- What utilities are needed?
- What chemicals are needed?
- What waste streams are created?
- Is additional treatment required?

Operational Flexibility & Scalability

Processing requirements may change as PV waste volumes and panel types evolve.

TEST

- Can capacity be expanded modularly?
- Can processing stages be added later?
- What is the secondary route for unsuitable panels?

OUTPUT VALUE

Recovery Quality & Depth

Overall recovery rate does not necessarily indicate high-value outputs.

TEST

- What can be recovered, and at what purity?
- Is glass preserved as a single-sheet or contaminated?

Downstream Market Fit

Recovered material only has value where viable downstream buyers or processors exist.

TEST

- Who can purchase each output?
- Is further refining required?
- Does deeper recovery generate enough additional revenue?

Evaluating International Technology Manufacturers

When considering international technology for deployment in Australia, it is suggested to consider several additional factors that may affect the practical suitability and lifecycle value of a solution.

PROJECT & TECHNOLOGY FIT

Define the project before approaching the market. Clear requirements around feedstock, throughput, panel type, desired outputs and operating conditions make supplier engagement more productive and comparisons more meaningful.

Look beyond broad capability claims. Statements such as “all panel types”, “high recovery” or “fully automated” can depend heavily on the actual equipment configuration. Panel dimensions, construction, damage tolerance and pre-processing requirements should be confirmed explicitly.

Check Australian compliance requirements early. Electrical, environmental, safety and other requirements may affect equipment specifications, supporting systems or modifications required.

EVIDENCE & VERIFICATION

Test performance claims against evidence. Distinguish demonstrated operating performance from design specifications, manufacturer marketing and laboratory results.

Look for comparable operating references. Installations using similar feedstock, technology and throughput can provide a stronger indication of commercial maturity than headline specifications alone.

Verify critical specifications rather than relying on documentation alone. Certifications and specification sheets are useful indicators, but important project requirements may warrant additional technical clarification, operating references or testing.

SUPPLIER & DELIVERY CAPABILITY

Treat after-sales support as part of the equipment decision. Installation, commissioning, training, servicing, spare parts and response capability can materially affect the lifecycle value of imported equipment.

Distinguish export experience from export ambition. An international-sales function does not necessarily mean a supplier has successfully commissioned comparable PV-recycling equipment overseas. Previous installations, operating locations and post-delivery support are useful indicators.

Separate PV-recycling experience from broader machinery experience. An established recycling-equipment manufacturer may still be relatively new to PV recycling. PV-specific reference projects and operating lines should therefore be considered alongside the wider company’s history and scale.

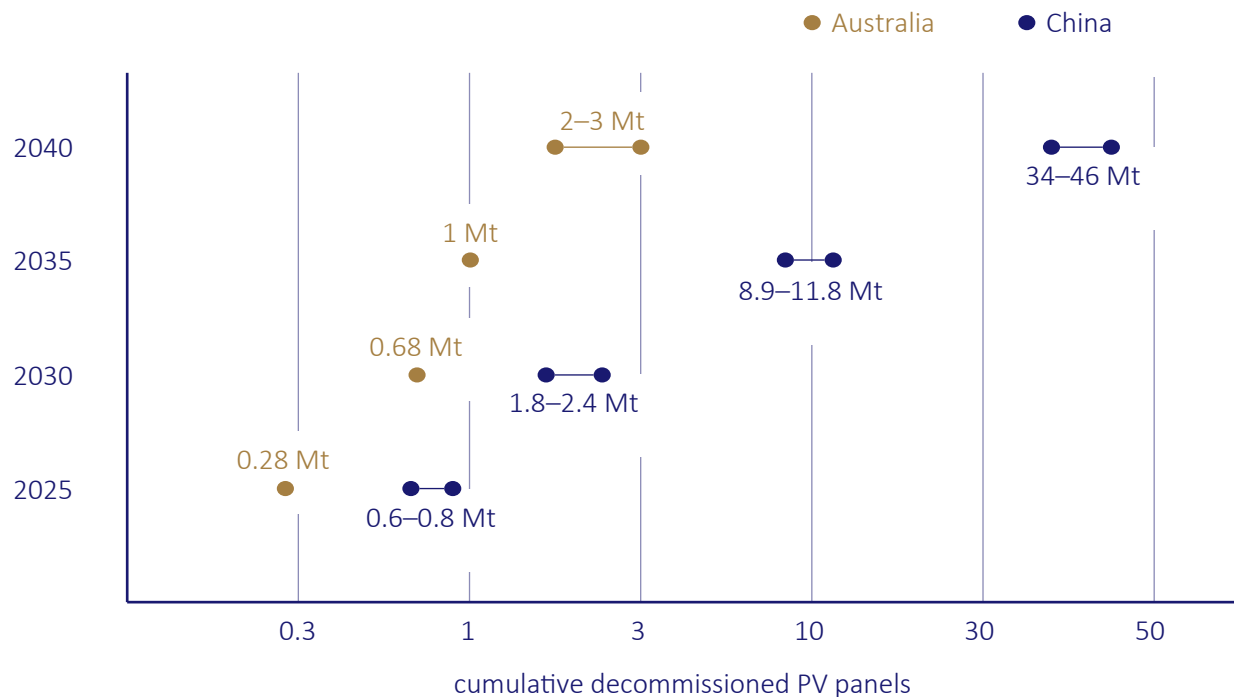
Verify the contact company’s actual role. The sales contact may be an exporter or trading company rather than the manufacturer, with certifications, patents and production held by different entities. Confirm who manufactures, contracts and supports the equipment.



China: Reference Market for Photovoltaic Recycling

China provides a useful reference point for Australia because its PV recycling industry is confronting many of the same commercial constraints at a slightly more advanced stage of market development. Dedicated PV recyclers nevertheless remain relatively limited in number, with the specialist industry still developing alongside broader wind, waste and resource-recovery companies.

Projected Cumulative Decommissioned Panel Volumes in China & Australia



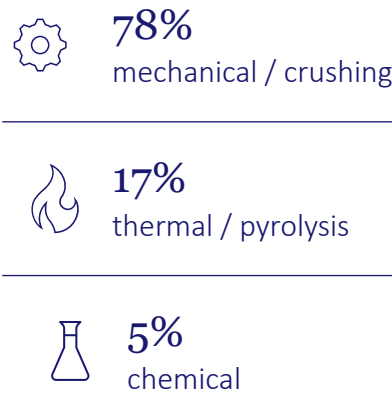
Source: adapted from [1, 20]

The Chinese PV recycling industry continues to face several constraints that closely mirror those in Australia [20]:

- **Feedstock and utilisation** – national decommissioning volumes do not automatically translate into stable feedstock.
- **Collection and logistics** – dispersed rooftop systems and remote utility-scale projects increase transport and aggregation costs.
- **Technology economics** – more advanced recovery must justify higher CAPEX, energy use, and process complexity.
- **High-value recovery** – silver and high-purity silicon remain more difficult to recover economically than bulk materials.

Mechanical processing remains the industry baseline, with thermal/pyrolysis and chemical processing added where they can improve the recovery or purity of higher-value materials [20]. Australia currently shows a similar pattern, with mechanical separation focussed mainly on aluminium, copper, and glass while operators continue to explore better silver and silicon recovery.

Delamination Mix in China



Source: adapted from [21]

The Chinese industry also demonstrates that larger market size does not remove collection constraints. Remote utility-scale projects and dispersed distributed PV systems continue to create a significant logistics challenge. In response, the industry is exploring regional collection hubs, decentralised pre-processing and mobile dismantling or processing systems [20].

Policy support is strengthening to build the industry to handle the coming large-scale decommissioning wave by 2030.

In 2026, six Chinese government departments issued national guidance for PV module end-of-life management, targeting improved recycling technology, clearer standards and responsibilities, better-aligned processing capacity [22].

Chinese Industry Interest in the Australian Market

Engagement undertaken for this report suggests that some Chinese PV recycling equipment manufacturers are actively looking overseas for future growth. As international EOL volumes increase, similar incentives may encourage Chinese PV recyclers to consider overseas operating, investment, or partnership opportunities. Australia may therefore become relevant not only as a technology market, but also as a potential destination for cross-border industry participation.



Chinese PV Recycling Equipment Manufacturers

The manufacturers reviewed cover a range of delamination technologies as the main differentiator with varying capacity ranges from below 1 tonne per hour to multiple tonnes per hour. However, compatibility varies significantly: many recycling machines are designed for a specific panel construction type, so single and double-glass capability should be verified rather than assumed.

While highly dependent on technology, capacity and project scope, simple mechanical recycling lines can come in around the AUD 200,000 mark at the equipment level.

		Manufacturer				
		A	B	C	D	E
Delamination Process	Mechanical / Crushing	●	●	●	●	●
	Selective Cutting	●		●		
	Thermal / Pyrolysis	●	●	●	●	
	Chemical					
	Silver Extraction / Refining					●

- Capability represented in equipment reviewed.

Mechanical processing remains the most established technology. All manufacturers reviewed offer at least one mechanical or crushing-based configuration. This is consistent with the previously mentioned 78% mechanical delamination in China. Selective delamination and pyrolysis are offered by fewer suppliers and appear less mature but, in particular pyrolysis, seems to be where many manufacturers are spending in R&D.

Across the manufacturer set, differentiation is therefore found less in fundamentally different process architectures or novel equipment.

Technology & Equipment Market Observations

Beige Advisory’s review of Chinese PV recycling equipment manufacturers suggests several recurring market characteristics that are relevant when assessing technology for Australian applications.

Mechanical processing remains the market baseline, with pyrolysis a *hot* alternative. Mechanical lines are offered widely across the manufacturers reviewed, while pyrolysis is frequently

promoted as the next major technology pathway. Selective cutting appears less common and more specialised.

Feedstock compatibility should be verified, not assumed. Panel construction, dimensions, single- or double-glass configuration, and the condition of incoming panels can materially affect whether a particular system is suitable.

Modular, mobile and staged processing may be suitable avenues for the Australian market. These configurations may offer greater flexibility where feedstock is geographically dispersed, volumes remain uncertain, or processing requirements are expected to change over time.

Headline performance claims are not always directly comparable. Recovery, purity and throughput may be measured or reported differently between manufacturers, sometimes with limited supporting detail. Claims should therefore be examined carefully and, where material to the project, independently verified.

International capability varies significantly between suppliers. Some manufacturers have established export operations and overseas installation capability, while others have comparatively limited international experience.

Company age does not reflect PV-recycling experience. Many manufacturers reviewed are broader recycling or machinery businesses rather than dedicated PV-recycling specialists. This can bring useful engineering and manufacturing capability, but their PV-specific track record may be considerably shorter than the history of the wider company. The reviewed set ranges from a PV specialist founded in 2024 to older groups active across battery recycling, solid-waste processing and pyrolysis equipment.



Implications for Australian Recyclers & Technology Buyers

Early market engagement may be valuable. Australia has not yet settled on dominant technologies nor downstream market structures, so companies that can optimise operations before larger EOL PV volumes arrive may be better positioned for longevity as the industry develops.

Technology & Processing

Match processing capacity to secured feedstock. Australia already has more installed recycling capacity than current utilisation suggests is required. New investment should therefore be based on realistic collection volumes rather than long-term national waste forecasts alone.

Optimise for economics, not maximum recovery. Higher recovery can increase material revenue and may be a headline, but additional costs and complexity can outweigh the value recovered. Technologies that instead reduce unit processing costs may offer the stronger near-term proposition.

Flexibility may be valuable in a growing market. Modular, staged, or mobile systems can provide greater adaptability where feedstock volumes and collection networks remain uncertain. Processing capability can then expand as volumes, downstream markets, and policy frameworks develop.

Advanced silver and silicon recovery should be approached selectively. These materials contain significant value, but they may not be the *silver bullet* to balancing recycling economics. Recyclers may not need to integrate deep material recovery if downstream processors are available as markets.

Downstream Markets & Partnerships

International offtake may bridge gaps in Australia's current value chain. Where domestic refining capacity is limited, established international buyers or processors may provide a route to market for mixed or partially refined silver and silicon fractions.

Domestic downstream capability could improve recycling economics. Emerging silicon processing and advanced-manufacturing investment may create new markets for recovered materials if recyclers can meet the required purity and specification.

Partnerships may be more practical than full vertical integration. Collection, primary recycling, advanced refining, and material offtake do not necessarily need to occur within one organisation. Partnerships across these stages may allow recyclers to access higher-value recovery without carrying the full capital and operational burden themselves.

MARKET INSIGHT

Feedstock scale may also influence foreign investment interest.

In discussions with a Chinese PV recycler, Beige Advisory was told that joint-venture opportunities become more meaningful once stable feedstock begins to exceed approximately 8,000 tonnes per year. Australia is still considered early, but the threshold provides an indication of the scale at which international strategic interest may begin to translate into investment.

Appendix 1: PV Recycling Equipment Manufacturer Profiles

Manufacturer identities and model designations have been anonymised in this appendix to ensure presentability of key information. The equipment specifications presented are based on details provided by manufacturers directly only.

Manufacturer A

Founded in 2024 and focusses specifically on the development and commercialisation of PV module recycling equipment. Its portfolio is centred on integrated recycling and dismantling solutions, with multiple configurable pathways combining physical separation, selective glass removal and pyrolysis for different module types and recovery objectives.

Containerised On-site Recycling Line

Mobile mechanical recycling line

 mechanical / crushing

 Capacity

Up to 60 panels/hour

 Key Characteristics

Containerised system designed for deployment directly to the decommissioning/project site by truck.
Modules can be fed directly into the line on site, reducing the need to transport intact retired modules to a central recycling facility. Process produces no waste gas or wastewater.

Mechanical + Mechanical Model

Heat-assisted selective-separation recycling line

 mechanical / crushing

 selective cutting

 Feedstock

Single-glass and double-glass

 Rated Power

260 kW

 Key Characteristics

Heat is used to soften the laminate. Mechanical stripping breaks the bonding interfaces between the layers, allowing glass, metals and encapsulation materials to be separated without a pyrolysis stage.

Mechanical + Pyrolysis Model

Selective-separation + pyrolysis
recycling line



thermal / pyrolysis



selective cutting

**Feedstock**

Single-glass and double-glass

**Key Characteristics**

Uses a mechanical/separation process; preheating, glass removal and encapsulant-cell layer separation.

Pyrolysis stage then thermally decomposes remaining organic encapsulation and polymer materials, weakening material bonding and enabling more complete interface separation.

Pyrolysis Model

Low-oxygen tunnel-pyrolysis recycling line



thermal / pyrolysis

**Key Characteristics**

Uses a low-energy regenerative tunnel pyrolysis system.

Organic encapsulation and polymer structures are decomposed under controlled high-temperature, low-oxygen conditions, breaking the bonding between material layers.

Mechanical Model

Mechanical crushing and multi-stage sorting line



mechanical / crushing

**Feedstock**

Single-glass and double-glass
Designed for severely damaged panels

**Rated Power**

160 kW

**Key Characteristics**

Adaptive crushing / structural deconstruction, followed by particle-size classification and multi-stage material separation. Process combines particle-size classification, gravity-based separation and metal separation

Dual-Glass Mechanical Model

Automated mechanical recycling line

 mechanical / crushing



Feedstock

Single and double-glass
990 × 1,650 mm – 1,350 × 2,500 mm



Recovery | Purity

Overall recovery rate 97%
Glass purity 99%



Key Characteristics

Automated mechanical processing system with automatic parameter calculation and a built-in database for switching between module configurations.

Manufacturer B

Manufacturer established in 2005 with international-facing group company. Its equipment portfolio spans both solar-panel and lithium-battery recycling, giving it the profile of a broader heavy/recycling-equipment manufacturer rather than a dedicated PV-recycling company.

Single-Glass Line Single-glass mechanical recycling line		 mechanical / crushing	
 Feedstock Single-glass Damaged panels accepted		 Capacity 1 tonne/hour	
 Key Characteristics Mechanical recycling route using frame removal and glass removal before downstream size reduction. Remaining material is processed through shredding → crushing → grinding → gravity separation → electrostatic separation.			
 Rated Power 277.6 kW		 Footprint 36 × 6 × 6 m	
 Recovery Purity Overall recovery rate stated at >95% Material purity stated at >95%		Manufacturer did not provide material-by-material recovery or purity figures for this line.	

Double-Glass Series

Double-glass tunnel-kiln pyrolysis line

 thermal / pyrolysis**Feedstock**
Double-glass**Capacity**
#500: 500 kg/hour
#1000: 1 tonne/hour
#2000: 2 tonnes/hour**Key Characteristics**

EVA and backsheet materials are thermally decomposed under oxygen-deficient conditions at approximately 450–550°C. Pyrolysis gas is treated and returned to the combustion system for heat recovery.

**Rated Power**
#500: 116.65 kW
#1000: 126.65 kW
#2000: 136.65 kW**Footprint**
#500: 65 × 13 × 7.5 m
#1000: 72 × 13 × 7.5 m
#2000: 80 × 13 × 7.5 m**Single-Double Glass Series**

Single and double-glass cracking-furnace pyrolysis line

 thermal / pyrolysis**Feedstock**
Single and double-glass**Capacity**
#5: 5 tonnes/day
#16: 16 tonnes/day**Key Characteristics**

EVA, backsheet and other organic materials are thermally decomposed under oxygen-free conditions at approximately 400–500°C. Condensed pyrolysis oil can be recovered as fuel, while non-condensable gas is returned to the combustion system.

**Rated Power**
#5: 140.45 kW
#16: 142.45 kW**Footprint**
#5: 46 × 33 × 7.5 m
#16: 40 × 26 × 7.5 m

Manufacturer C

Industrial group operating through several manufacturing and sales entities focussed primarily on recycling and environmental equipment. PV recycling equipment is marketed under an international brand, while certifications and intellectual property reviewed are held by different companies within the wider group structure. Of the manufacturers reviewed, it presents the most developed international-sales presence, overseas installation support and a substantial self-reported export record.

Single-Glass Line Single-glass physical recycling line			 mechanical / crushing		 selective cutting option													
 Feedstock Single-glass 1,000 x 800 mm – 2,400 x 1,300 mm Damaged or broken panels not accepted			 Capacity 50–60 panels/hour (1.5–2.1 tonnes/hour)															
 Key Characteristics Two glass-removal configurations are available: mechanical milling, or low-temperature selective glass removal at 60°C. Robot feeding and automatic panel-size measurement can be integrated.																		
 Rated Power 291.78 kW		 Footprint 46 × 8.5 × 5.2 m with robot 39 × 8.5 × 5.2 m without robot			 Labour 3–4 operators													
 Recovery Purity <table><tr><td>Aluminium</td><td>≥99% ≥98%</td><td>Glass</td><td>85–95% ≥90%</td><td>Plastic</td><td>≥95% ≥90%</td></tr><tr><td>Silicon</td><td>≥95% 45–60%</td><td>Metals</td><td>≥95% ≥95%</td><td></td><td></td></tr></table>							Aluminium	≥99% ≥98%	Glass	85–95% ≥90%	Plastic	≥95% ≥90%	Silicon	≥95% 45–60%	Metals	≥95% ≥95%		
Aluminium	≥99% ≥98%	Glass	85–95% ≥90%	Plastic	≥95% ≥90%													
Silicon	≥95% 45–60%	Metals	≥95% ≥95%															

Double-Glass Line

Double-glass physical crushing line

 mechanical / crushing

	Feedstock Double-glass (single-glass not recommended) 1,000 x 800 mm – 2,400 x 1,300 mm Damaged or broken panels accepted		Capacity 1–2 tonnes/hour 3–4 tonnes/hour
Key Characteristics  Designed specifically for double-glass modules. Uses automated crushing and downstream physical sorting. Accepts damaged and deformed modules.			
	Rated Power 389.6 kW		Footprint 57.2 × 7.65 × 5.16 m
			Labour 5 operators
	Recovery Purity		
	Aluminium ≥99% ≥98%	Glass 85–95% 90–95%	Plastic 85–95% ≥90%
	Silicon 70–80% 40%	Metals 80–90% ≥95%	

Thermal Line

High-temperature thermal recycling line



thermal / pyrolysis



Feedstock

Single and double-glass
1,000 × 800 mm – 2,400 × 1,300 mm
Damaged and deformed modules accepted



Capacity

50–60 panels/hour



Key Characteristics

Material is heated at approximately 400–700°C, decomposing EVA and other polymer materials. After cooling, the line separates silicon wafers, glass and copper before further air, vibration and photoelectric sorting.



Energy

Electricity: 239.8 kWh
Gas: 80–100 m³/hour



Footprint

67.6 × 25.6 × 5.5 m



Recovery | Purity

Silicon Wafer ≥90%

50% of recovered silicon-wafer
material at 98% purity

Copper Ribbon 80–90%

80% of recovered copper-
ribbon material at >97% purity

Glass

≥95% | ≥99%

Manufacturer D

Operates within the wider machinery manufacturing group. Its business extends beyond PV recycling into broader solid-waste processing, pyrolysis and precious-metal recovery equipment. Within the PV portfolio, covers both complete mechanical and thermal recycling lines as well as downstream silver extraction and refining, giving it a comparatively broad position across both primary material separation and higher-value recovery.

Double-Glass Series Double-glass pyrolysis recycling line		 thermal / pyrolysis	
 Feedstock Double-glass Bifacial		 Capacity #1000: 1 tonne/hour #2000: 2 tonnes/hour	
 Key Characteristics Pyrolysis operates at approximately 400–550°C, decomposing EVA and other polymer materials. Flue gas from the pyrolysis stage is treated through a secondary-combustion / heat-recovery system before exhaust-gas treatment.			
 Rated Power #1000: 410 kW #2000: 480 kW		 Footprint #1000: 25 × 10 × 6 m #2000: 33 × 13 × 6 m	

Physical Line

Configurable physical recycling line with optional pyrolysis route



mechanical / crushing



thermal / pyrolysis



Feedstock

1,000 × 800 mm – 2,400 × 1,300 mm



Capacity

#500: 100–500 kg/hour
#1000: 500–1,000 kg/hour
#2000: 1,000–2,000 kg/hour
#3000: 2,000–3,000 kg/hour



Key Characteristics

An alternative thermal route can process the remaining silicon, metals and cables through pyrolysis after frame and glass removal. The configuration therefore allows conventional mechanical separation while also incorporating thermal treatment where required.



Rated Power

#500: 138 kW
#1000: 285 kW
#2000: 380 kW
#3000: 485 kW



Footprint

#500: 30 × 7 × 5 m
#1000: 45 × 7 × 5 m
#2000: 65 × 20 × 6 m
#3000: 100 × 25 × 6 m



Recovery | Purity

Aluminium ≥99% | ≥98%

Glass

85–95% | ≥90%

Plastic

≥95% | ≥90%

Silicon

≥95% | 45%

Metals

≥95% | ≥95%

Single-Glass Line

Single-glass mechanical crushing and sorting line



mechanical / crushing



Feedstock

Single-glass



Capacity

#500: 1 tonne/hour
#1000: 2 tonnes/hour



Rated Power

#500: 138 kW
#1000: 285 kW



Footprint

#500: 30 × 7 × 6 m
#1000: 45 × 20 × 6 m

Silver Extraction Series

Silver extraction and refining system



silver extraction / refining

**Capacity**

#500: 500 kg/hour

#1000: 100 kg/hour

based on PV-panel input**Emissions / Residual Management**

Waste-liquid storage

Acid-fume treatment

**Key Characteristics**

Supporting equipment includes electrolysis, drying, waste-liquid storage and acid-fume treatment.

**Rated Power**

#500: 30–200 kW

#1000: 50–230 kW

**Footprint**#500: 50–100 m²#1000: 80–150 m²**Manufacturer E**

Machinery manufacturer specialising in crushing, screening and materials-processing equipment. Its PV recycling offering is centred on mechanical dismantling and separation, including complete single-glass recycling lines integrating frame removal, glass removal, shredding, crushing and downstream material separation.

Single-Glass Line

Single-glass mechanical recycling line



mechanical / crushing

**Feedstock**

Single-glass

**Rated Power**

233.35 kW

**Key Characteristics**

Downstream processing is connected to a pulse dust-collection system; the complete line uses PLC-based control with one-button start/stop and automatic feed-rate control.

Appendix 2: Standalone PV Recycling Equipment

Manufacturer identities and model designations have been anonymised in this appendix to ensure presentability of key information. The equipment specifications presented are based on details provided by manufacturers directly only.

Module Pre-Processing

Manufacturer	Equipment	Function	Key Specifications / Characteristics
C	Junction-Box Remover / 3D Vision System	Automated junction-box identification and removal	3D vision-based module inspection and automated junction-box removal
C	Frame Removal Equipment	Aluminium-frame removal	Automatic and semi-automatic configurations available
A	Junction-Box Removal Equipment	Cable and junction-box removal	Dedicated PV-module pre-processing equipment
A	Intelligent Frame-Removal Machine	Automated aluminium-frame removal	Intelligent/automated operation; workbook includes cycle-time and utility specifications
D	Frame-Removal Equipment	Aluminium-frame removal	Multiple configurations with specified panel-processing throughput
E	Frame Dismantling Machine	Aluminium-frame removal	Hydraulic system; semi-automatic/manual operation; 3 kW motor

Glass & Laminate Separation

Manufacturer	Equipment	Function	Key Specifications / Characteristics
C	Milling-Type Glass Removing Machine	Mechanical glass removal	Milling-based removal of front glass with stated glass-separation performance
C	Heating-Type Glass Removal Equipment	Low-temperature selective glass removal	Approximately 60°C heating; integrated and standalone configurations
A	Layer-Removal Equipment	Glass, backsheet and rear-glass separation	Equipment family covering selective removal of different module layers and constructions

A	Encapsulant-Film / Solar-Cell Separation Equipment	Separation of encapsulant and cell layers	Dedicated downstream laminate-separation step
D	Glass-Removal Equipment	Mechanical glass removal	Multiple configurations; approximately 30–70 panels/hour depending on model
E	Glass Removal System	Heat-assisted mechanical glass removal	6 m heated conveyor softens EVA before 44 reciprocating milling cutters remove glass; companion brushing machine removes residual fragments

Downstream Material Separation

Manufacturer	Equipment	Function	Key Specifications / Characteristics
C	Solar Cell Crushing & Separating Machine	Cell-laminate size reduction and material separation	Standalone downstream processing module with stated recovery/purity specifications
A	Eddy-Current & Airflow Separation Equipment	Separation of downstream material fractions	Combines metal separation with density/aerodynamic separation

Specialist & Secondary Processing

Manufacturer	Equipment	Function	Key Specifications / Characteristics
A	Frame Sealant / Adhesive Scraping Machine	Aluminium-frame cleaning	Removes residual sealant/adhesive from recovered aluminium frames before further processing or reuse

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