Circular photovoltaics

Circular business models for Australia's solar photovoltaics industry

ARUP

About Arup

Arup is the creative force at the heart of many of the world's most prominent projects in the built environment. From 87 offices in 34 countries, more than 14,000 planners, designers, engineers and consultants deliver innovative projects across the world with creativity and passion. As the Ellen MacArthur Foundation's knowledge partner for the built environment, we are sharing knowledge and collaborating with our CE100 partners to accelerate the shift to a circular economy.

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Contents

Summary

Australia reached 10,000 MW of installed solar photovoltaic capacity in 2018[1] with the vast majority coming from small rooftop systems. This represents a significant step towards a more sustainable energy generation mix in Australia. While this will create benefits for Australia now and in the years to come, the impacts of the growth of the solar PV industry need to be considered in full. One such impact is the production of panel waste which is expected to be between 300,000 and 450,000 tonnes by 2040[2].

Waste from all sectors needs to be reduced if the world is to develop sustainably, run efficiently and find new sources of value, including the photovoltaic industry. Achieving this contributes to Sustainable Development Goal 12, which focuses on **“doing more and better with less”**, but more generally has the potential to provide improved social and environmental outcomes globally.

The circular economy concept is key in achieving many of the UN’s Sustainable Development Goals. It focuses on reducing externalities and retaining value throughout the supply chain, which will be essential for addressing current and future panel waste in the photovoltaic industry. At its core, the circular economy is decoupling resource use and economic growth. It does so through its three core principles:

- Designing out waste and pollution
- Keeping products and materials in use
- Regenerating natural systems

This report explores the opportunities presented by the circular economy for the photovoltaic industry in Australia by analysing the current state of play of the industry and the circular economy, outlining how circular business models could apply to the lifecycle of a photovoltaic panel, and recommending ways forward for industry stakeholders.

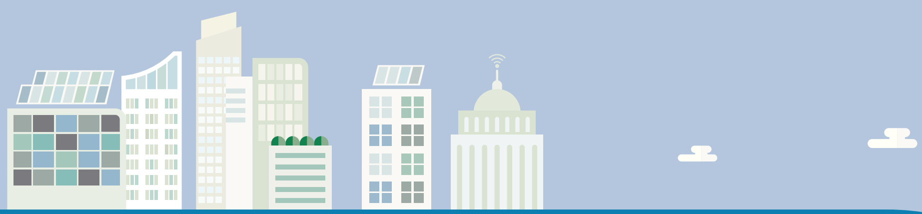
In doing so, this report aims to stimulate leadership and collaboration in the industry on its inevitable transition towards a circular economy.

1 Australian PV Institute, 2018, Press Release: Australia hits 10GW solar
2 International Renewable Energy Agency, 2016, End-of-Life Management: Solar Photovoltaic Panels.

Key recommendations

Together, the whole industry will need to work to enable standardisation, coordination and collaboration for the business models.

- Establish an Extended Producer Responsibility scheme
- Create and expand partnerships between players along the value chain, especially public-private partnerships
- Standardise panel design and data management processes, including labelling and materials passports

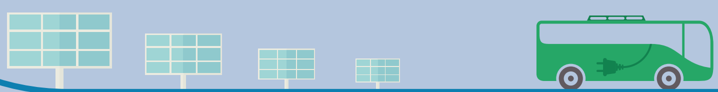


Policymakers should foster a supportive regulatory, research and business environment for circular business models across all States and Territories.

- Use policy levers, including public procurement, to support and spur demand for circular solutions
- Convene and facilitate public-private partnerships to develop scalable projects
- Work with industry and governments to develop a supportive and cohesive national circular economy strategy in Australia

Business should demonstrate leadership in the space through feasibility studies and pilot projects, especially through collaborations.

- Lead private-private and public-private partnerships to develop scalable projects
- Develop an evidence base of data and case studies demonstrating the value of a circular PV industry
- Adapt current business practices and models to reduce waste and increase utilisation



Investors should develop their understanding of the circular economy, and increase their support of CBMs and related R&D.

- Engage in private-private and public-private partnerships to develop scalable projects
- Support research into end-of-life technologies and possible value creation through CBMs
- Consider longer returns on investment, for added social and environmental value

Introduction

Solar photovoltaics (PV) have been instrumental in increasing the volume of electricity generated from renewable sources in Australia.

This is helping to reduce the footprint of electricity generation on the already warming and resource-constrained Earth. In 2018, Australia reached 10 Gigawatts of installed PV capacity driven largely by small-scale installations.

While this should be encouraged and continued, it is important to consider both the positive and the negative impacts of this industry. When panels fail, wear out in their natural life time or fall below desirable performance thresholds, they are retired from operation and will enter waste or recycling streams.

By 2040, it is estimated that 300,000 to 450,000 tonnes of PV waste will have been generated in Australia. This represents not only a significant amount of glass, silicon, aluminium and other metal waste, but also the potential for significant value to the industry and the community.

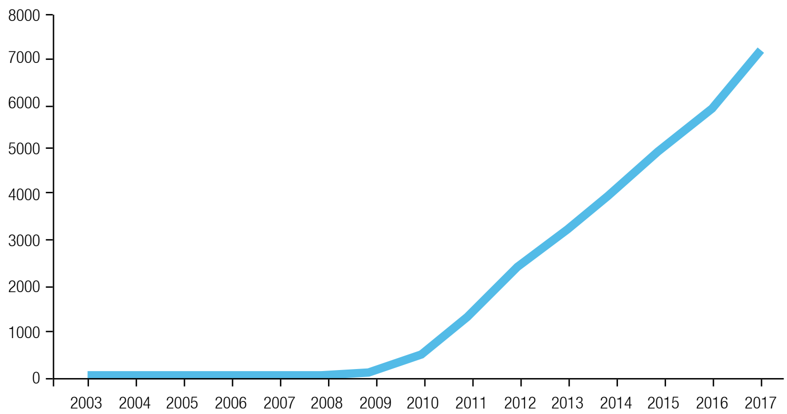
The circular economy concept provides principles, tools and business models that will enable Australia to harness this value. It presents an opportunity not only for existing players in the solar PV industry in Australia to create more value, but also for new services, jobs and programs to be created as new sources of value.

The main principles of the circular economy are:

- Designing out waste and pollution
- Keeping products and materials in use
- Regenerating natural systems

Designing business models around these principles is the key to circular business models.

Australia cumulative installed capacity (MW)[3]



3 Australian PV Institute, 2017, National Survey Report of Photovoltaic Applications in Australia 2017

300,000 – 450,000 tonnes of PV waste are expected in Australia by 2040[4]

To implement these circular models, a shift in mindset is required by the industry and investors. In research for Arup's *First Steps Towards a Circular Built Environment* report, interviewed investors identified twice as many barriers as opportunities to the transition to a circular built environment. More leadership is required to demonstrate and communicate the benefits of the circular economy and how circular business models work.

Circular PV aims to stimulate such leadership in the context of the solar PV industry in Australia by:

- Analysing the current state of play of the industry
- Outlining how circular business models could apply to the lifecycle of a PV panel
- Recommending ways forward for industry stakeholders

Through research, interviews and application of circular ideas, this report demonstrates the significant opportunities for value capture that are present and ready to be explored by industry participants.

Photo: ©iStock

4 International Renewable Energy Agency, 2016, End-of-Life Management: Solar Photovoltaic Panels

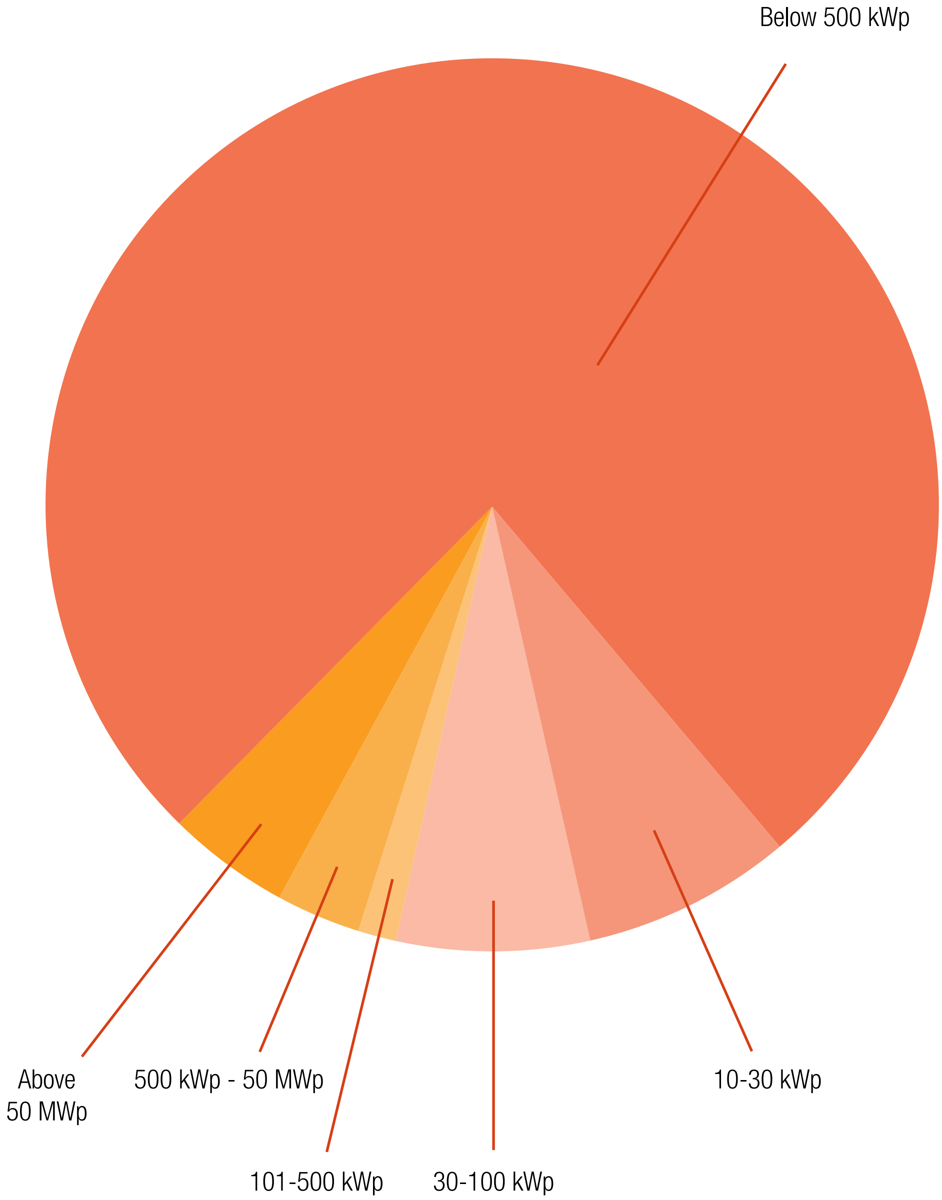
PV in Australia

Solar PV technology is playing a pivotal role in Australia's necessary transition to a renewable and sustainable economy.

This has been largely driven by price in recent years. PV, along with wind power, is already cheaper than new utility-scale coal and gas plants, making it an attractive economic investment[5].

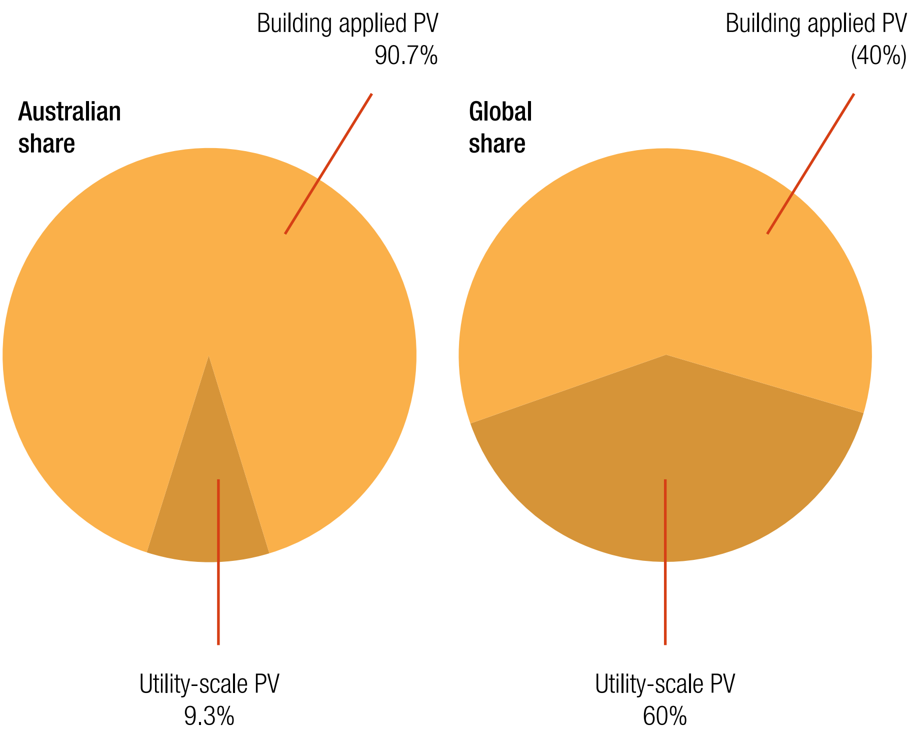
In Australia, systems tend to be small and decentralised. A result of this is that of the MWp installed capacity in Australia, the clear majority comes from small systems, represented in orange in the diagram to the right.

Cumulative installed PV capacity by size range – 2017



5 Bloomberg NEF, 2018, New Energy Outlook 2018

Australia and Global PV breakdown
Building applied PV v. Utility-scale PV

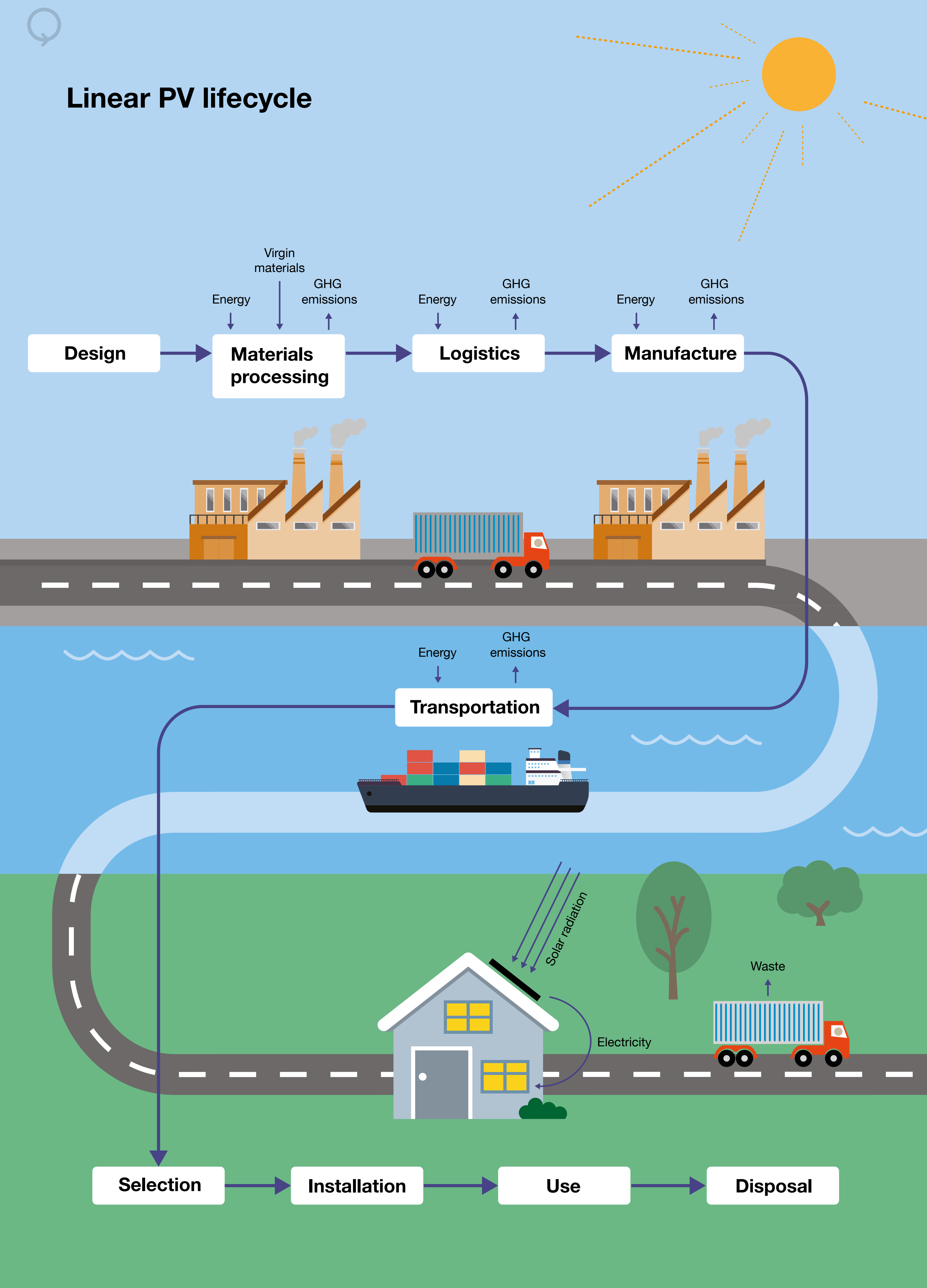


Systems also tend to be applied to buildings at a much greater volume than the global average.

While the increase in the use of solar PV is important, the current lifecycle of the technology poses challenges to achieving a sufficiently sustainable industry and economy in Australia.

Energy requirements, virgin material consumption, greenhouse gas emissions and waste levels are high and cause many externalities. This is made even more challenging by the small, distributed nature of PV in Australia. This traditional model needs to be re-examined to ensure better outcomes are achieved for more stakeholders.

Linear PV lifecycle



92%

The market share of silicon-based panels in 2015[6]

1st Generation panels	2nd Generation panels	3rd Generation panels
Solar panels made from traditional or wafer-based cells made of crystalline silicon.	Panels made up of thin film solar cells, that include amorphous silicon, Cadmium Telluride or Copper Indium Gallium Sellenide.	Panels that are made up of organic materials, often organometallic compounds, as well as inorganic substances.

The current lifecycle of solar PV in Australia generally follows the traditional take-make-dispose model. At the end of this lifecycle, PV panels are generally destined for disposal. It is estimated that 300,000 to 450,000 tonnes of PV waste will hit Australian waste streams by 2040[7].

When panels fail, wear out in their natural life time or fall below desirable performance thresholds, they are retired from operation and will enter waste or recycling streams. Given the current dominance of silicon-based panels in the market, these will be the first to enter waste streams in large volumes globally and in Australia. Therefore, these should be the preliminary focus of recovery efforts to address the growing PV waste stream.

However, focus should also be placed on the early lifecycle stages (i.e. design) of second and third generation panels to consider how waste can be firstly designed out, and secondly whether they have been manufactured for maximum reparability, reusability and recyclability.

Diagram developed based on: Carra & Magdani, 2017, Circular Business Models for the Built Environment

System inputs/outputs taken from: Kannan, Leong, Osman, Ho, and Tso, 2006, Lifecycle assessment study of solar PV systems

6 Sica, Malandrino, Supino, Testa and Lucchetti, 2018, Management of end-of-life photovoltaic panels as a step towards a circular economy
7 International Renewable Energy Agency, 2016, End-of-Life Management: Solar Photovoltaic Panels

Projected waste volumes

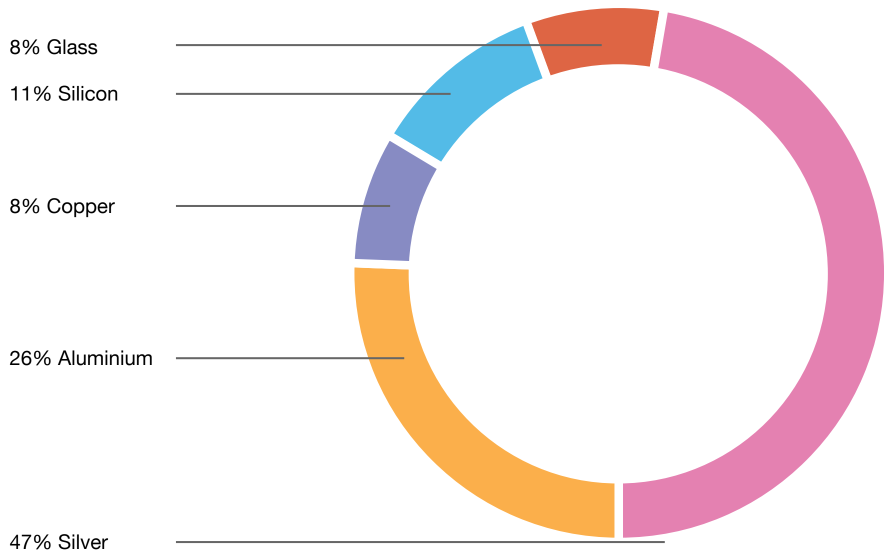
The following cumulative waste projections in Australia show the potential volume of materials Australia can expect under IRENA's regular and early loss scenarios[8].

	Mass composition of 1000 kg of c-Si waste as recycling input		Mass composition of c-Si waste as recycling input					
			2020		2030		2040	
Component	Quantity (kg)	Percentage (%)	Regular Loss Quantity (t)	Early Loss Quantity (t)	Regular Loss Quantity (t)	Early Loss Quantity (t)	Regular Loss Quantity (t)	Early Loss Quantity (t)
Glass	700	70	1400	11900	21000	101500	210000	315000
PV Frame (Aluminium)	180	18	360	3060	5400	26100	54000	81000
EVA	51	5.1	102	867	1530	7395	15300	22950
Solar Cell (silicon metal)	36.5	3.65	73	620.5	1095	5292.5	10950	16425
Back-sheet Layer (PVF)	15	1.5	30	255	450	2175	4500	6750
Silver	0.6	0.06	1.2	10.2	18	87	180	270
Internal (Cu, polymers)	11.1	1.11	22.2	188.7	333	1609.5	3330	4995
Other Metals (Sn, Pb, Al, etc)	5.9	0.59	11.8	100.3	177	855.5	1770	2655
Total	**1000**	**100**	**2000**	**17000**	**30000**	**145000**	**30000**	**450000**

The global economy is spending 30% more natural resources than it can afford[9]

Relative value of materials in solar panels[10]

While silver is present in small volumes in the cells, it represents a significant share of global silver consumption and the highest value material in a typical silicon panel. The precious metal represents almost half of the material value of these panels, followed by aluminium which holds a quarter of the overall value.



8 Based on projections from International Renewable Energy Agency, 2016 and compositions from Sica, Malandrino, Supino, Testa and Lucchetti, 2018. Assumes the waste is from silicon-based panels.
9 Goncalves, 2008, The WWF Pocket Guide to a One Planet Lifestyle

Photo: ©iStock

Sustainable Development Goal 12: Responsible Consumption and Production

If the world is to develop sustainably, run efficiently and find new sources of value, we need to reduce the waste produced from all sectors, including solar PV. Achieving this contributes to SDG 12, which focuses on “doing more and better with less” in order to provide better social and environmental outcomes globally.

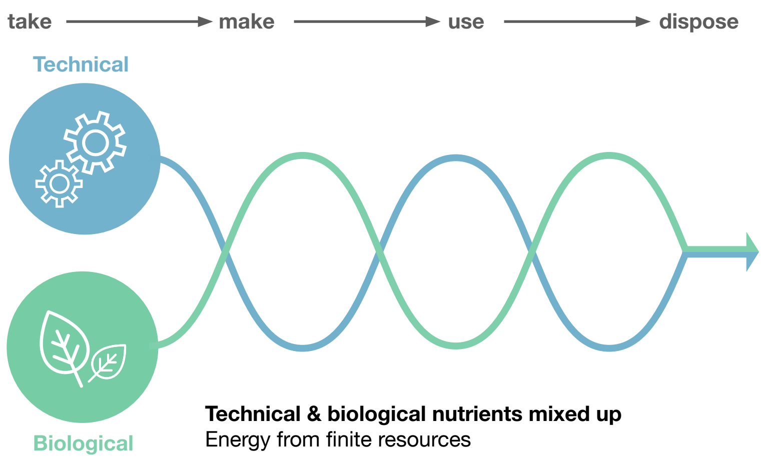
The solar PV industry has implications beyond this Goal as well. It influences Goal 7 (Affordable and Clean Energy), Goal 9 (Industry, Innovation and Infrastructure) and, of course, Goal 17 (Partnerships for the Goals).

10 International Renewable Energy Agency, 2016, End-of-Life Management: Solar Photovoltaic Panels based on Raithel, 2014, International Technology Roadmap for Photovoltaic – Results

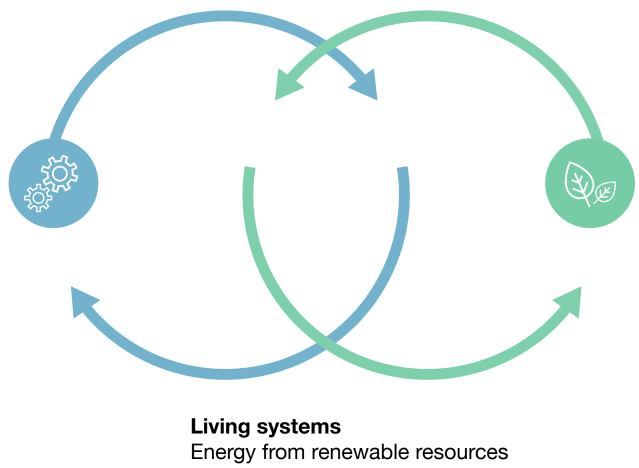
Circular economy

The circular economy presents an opportunity for government, businesses and consumers to rethink the traditional take-make-dispose model of consumption and develop business models that produce better social, environmental and economic outcomes.

Linear economy



Circular economy[11]



The circular economy represents a shift to an economy where loops replace linear processes.

11 Taken from Arup/EMF report, where it was adapted from Ellen MacArthur Foundation 2015

Systems thinking

The 'systems thinking' underlying the circular economy provides a holistic approach to product lifecycles that enables a variety of benefits to be realised. Not only does it work towards a reduction in waste and landfill volumes, but also towards the generation of new markets, greater utilisation rates, resource efficiencies, economic stimulation and better social outcomes.

Business models that are based on the circular economy enable:

- Greater control of resource streams.
- Innovation through the supply chain.
- Enhanced collaboration within the supply chain.
- Creation of services that capture value[12].

Importantly, these benefits are maximised and more likely to be simultaneously achieved when all elements of a business model are circular. Having a model that focuses only on recycling is theoretically not as economically sustainable as one that focuses on a mixture of models, such as sustainable material development, sharing and reusing platforms, and recycling. It is not just about dealing with waste, but about reducing total demand and increasing overall efficiency and impact too.

The circular economy is on the global agenda

A potential boost of €1.8tn to the EU economy by 2030 has been estimated[13].

149 organisations internationally are members of the Circular Economy 100 – a program from the Ellen MacArthur Foundation that facilitates collaboration, innovation and understanding between members looking to develop CBMs[14].

In 2018, China and the EU signed a Memorandum of Understanding on Circular Economy Cooperation[15].

12 Carra and Magdani, 2017, Circular Business Models for the Built Environment
13 Ellen MacArthur Foundation, SUN, McKinsey Center for Business and Environment, 2015, Growth Within: a circular economy vision for a competitive Europe
14 Ellen MacArthur Foundation, 2018, Member Groups
15 http://ec.europa.eu/environment/circular-economy/pdf/circular_economy_MoU_EN.pdf

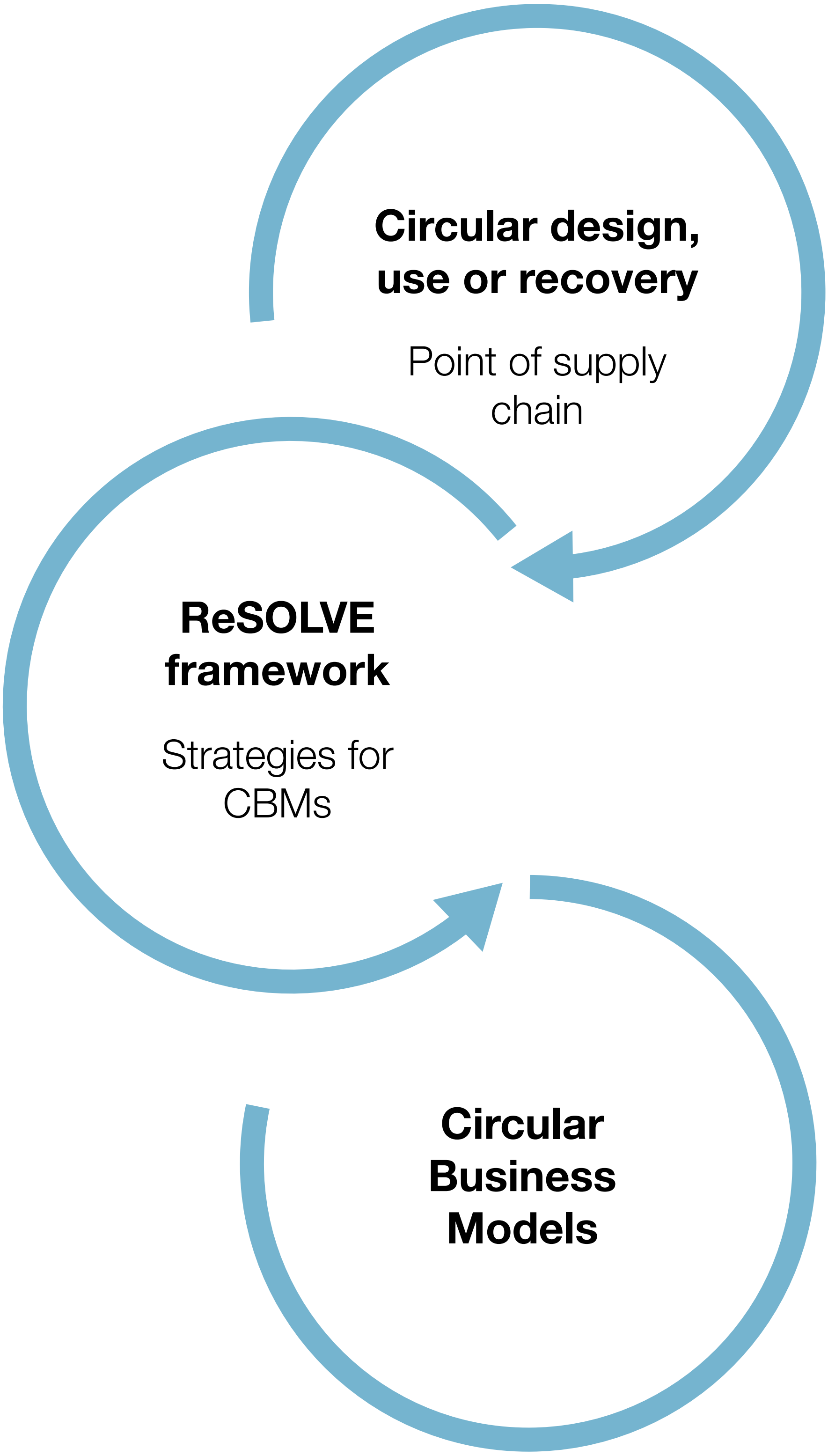
Business models for the circular economy

Several methods of naming and defining Circular Business Models (CBMs) exist. The method utilised in this report places CBMs under three key categories, depending on when in the lifecycle they are implemented[16].

Circular design occurs in the development and planning phase of the asset.

Circular use occurs in the operational phase of an asset.

Circular recovery occurs at the end of the product's service life.



16 Carra and Magdani, 2017, Circular Business Models for the Built Environment
17 Developed by the Ellen MacArthur Foundation, SUN and McKinsey Center for Business and Environment

The ReSOLVE framework presents six strategies that CBMs utilise[17]. These strategies, when used in the context of circular design, circular use and circular recovery, create CBMs.

Regenerate	Regenerating and restoring natural capital
Share	Maximising asset utilisation
Optimise	Optimising system performance
Loop	Keeping products and materials in cycles, prioritising inner loops
Virtualise	Displacing resource use with virtual use
Exchange	Selecting and replacing resources and technology

Key CBMs, their benefits and challenges

This report explores how CBMs across the ReSOLVE Framework and design, use and recovery phases could apply to the solar PV industry in Australia. Key CBMs are listed below along with their high-level benefits and associated challenges. The underlined CBMs are explored in detail in this report.

While there are distinct models within these distinct categories, the business models do not tend to function individually. Rather they co-exist, co-operate and co-evolve to create a circular ecosystem.

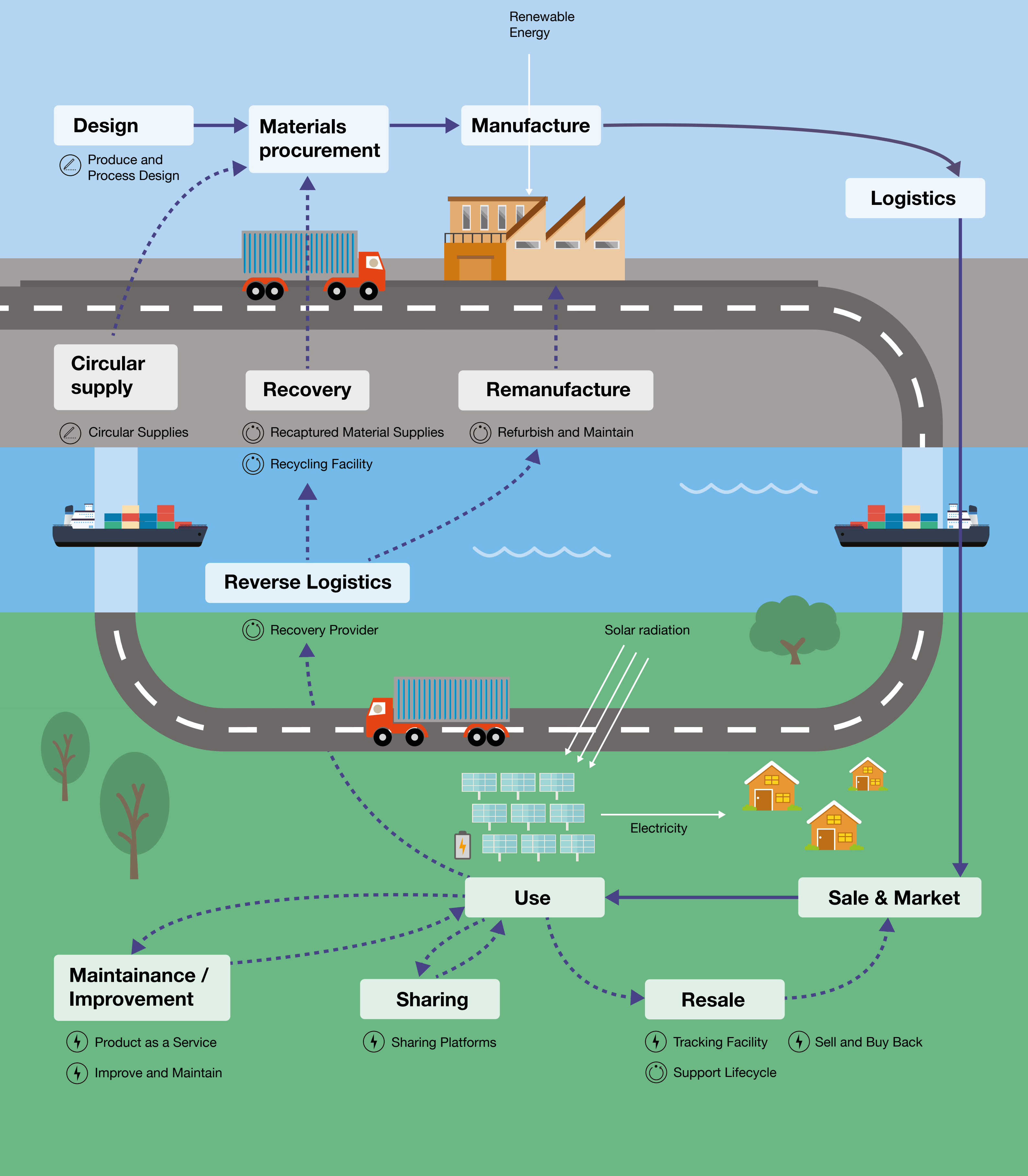
	Circular design	Circular use	Circular recovery
Circular Business Models	Product and process design Circular supplies	Sharing platforms Product as a service Lifetime extension Sell and buy back Tracking facility	Support lifecycle Recovery provider Refurbish and maintain Recycling facility Recapture material suppliers
Benefits	– Reduces effort and waste later in the lifecycle. – Reduction in material, finance, energy and emissions. – Collaboration is facilitated with end of life partners.	– Renewable and affordable energy is made more accessible. – New business models, based on sharing, services or digital platforms, are possible. – New or expanded customer bases are enabled through new business models. – New services increase long term revenues.	– Value is created from waste, enabling new revenue to be generated. – High potential for job creation around the recovery, reuse and recycling of materials.
Challenges	– Generally, requires a level of standardisation and collaboration between companies. – Lower market acceptance or understanding of reused or recycled products. – Significant upfront investment required. – Uncertainty or lack of data around performance, life span and operational costs.	– A shift from upfront investment to ongoing payments has potential implications for operating capital and taxation. – Payback period is often greater, and this influences the kinds of loans required. – Consumer preference for new, individual products, rather than shared or service-based products.	– Lack of regulatory or producer responsibility schemes to drive action if disposal is cheaper than higher order activities. – Investment is required to develop appropriate infrastructure. – Depends on the quality of design and ability to disassemble the panels. – It is not clear who should bear the cost and when for these models. – Recycled materials are often of lower quality than virgin materials (i.e. they are downcycled).

[18]

18 Challenges / benefits partially based on Carra and Magdani, 2017, Circular Business Models for the Built Environment

Circular PV lifecycle

By adding loops within the current value chain for solar PV in Australia, the required inputs and generated outputs could be reduced.



Circular design

Model 1: Product and process design

Regenerate
Share
Optimise
Loop
Virtualise
Exchange

This involves rethinking the design to improve the maintenance, repair, upgrade, refurbishment and/or manufacturing process.

This often centres around adapting existing business and technology models, especially through collaboration with the end-of-life stakeholders.

Energy, emissions and material efficiencies can be made through both process and product design.

The energy that goes into making a solar panel is significant. The energy payback time for silicon -based panels is 1.5 to 2.7 years. After this time, the panels have finally generated more energy than was required for their production. The impact of their production is further increased by the volume of greenhouse gases (GHG) emitted that is not considered in the energy payback, which is between 23 and 45 grams of carbon dioxide per kilowatt hour of power produced by the average silicon panel. Designers and manufacturers should investigate ways of reducing both the energy and GHGs in production.

Lifecycle energy requirement:

- 2699-5253 MJ / m^2
- Energy payback time: 1.5-2.7 years
- GHG emission rate: 23-45 g CO_2 eq / kWh[19]

Of all the primary energy used across the life of a typical mounted solar PV system, including energy required for material production, manufacturing, transportation and recycling, 81.4% of the primary energy use comes from the manufacture of the panel modules. With the next largest shares made up by aluminium production (9.7%) and then metal recycling (7.5%). Transportation is only 0.5%[20]. These figures are based on a 2.7 kW system in Singapore, and will vary depending on the size and location of the system, but show a significant demand for energy during the module manufacture stage.

It is important that circular products are designed with the end-of-life in mind, as well as the potential for repair, upgrade and part removal during their life.

Sometimes radical innovation is required, sometimes it is a simple change.

Common strategies to achieve more circular designs include:

- Standardisation – both within a design organisation and between organisations
- Modularisation – to improve separability, reparability and upgradability

19 Sica, Malandrino, Supino, Testa and Lucchetti, 2018, Management of end-of-life photovoltaic panels as a step towards a circular economy
20 Kannan, Leong, Osman, Ho and Tso, 2006, Life cycle assessment study of solar PV systems: An example of a 2.7 kWp distributed solar PV system in Singapore

Standardisation would mean a more consistent method of assembling panels across the PV industry. Potential recyclers would have to use fewer techniques to recycle different panel types. Modularisation for the PV panel industry is probably less applicable as the nature of PV systems – being made of PV panels – means the systems are already in fact modular at least at a high level. Therefore, focusing on ensuring the panels are designed for deconstruction will be key, in order to facilitate an efficient recovery process.

Designers and manufacturers could instead aim to increase the lifespan of their product by increasing durability and designing for higher utilisation rates. Generally, panels are considered to be at the end of their life when their efficiency drops below 80%, however this can vary panel to panel and case by case. The time taken to reach this point is dependent on the panel degradation rates – a 2012 review of which found the median value to be 0.5% power lost per year[21]. A focus on reducing degradation rates and purchasing panels with lower rates, will, all other factors kept equal, increase a panel's efficiency over its life.

It is equally important that designers rethink their material procurement.

Recycled, recyclable, upcycled and non-hazardous substances should be selected where possible. Partnerships, research and development, and pilot programs will enable trust and economies of scale to be achieved for the market for these materials.

Manufacturers of panels used in Australia are mostly based in Asia.

This means that the Australian sales and installation industry will need to work within the Asia-Pacific region to establish goals, design priorities and collaborations required for better product and process design.

70%

Australia imports over 70% of its solar panels from China. Malaysia, Singapore. The Republic of Korea and Hong Kong are other major suppliers[22]

21 National Renewable Energy Laboratory, 2012, Photovoltaic Degradation Rates – An analytical review
22 Australian PV Institute, 2017, National Survey Report of Photovoltaic Applications in Australia 2017

Benefits	Barriers
Addressing the issue upfront makes all later stages of the life cycle easier Targets the most energy-intensive point of the life cycle	Lack of motivation from manufacturers overseas Lack of interaction between designers and recyclers Lack of design standardisation between designers

Future enablers

Target percentages for recycled and non-hazardous materials.

Legislated incentives to encourage manufacturers to close-the-loop on their supply chain. This could include a product stewardship scheme (see page 41).

Design for disassembly principles will provide guidance on how to design for a more efficient deconstruction phase, and will be constantly evolving.

Labelling or materials passports that track and disclose material origin and composition, recyclability and repair process on panel. Global databases on panel contents would accompany this.

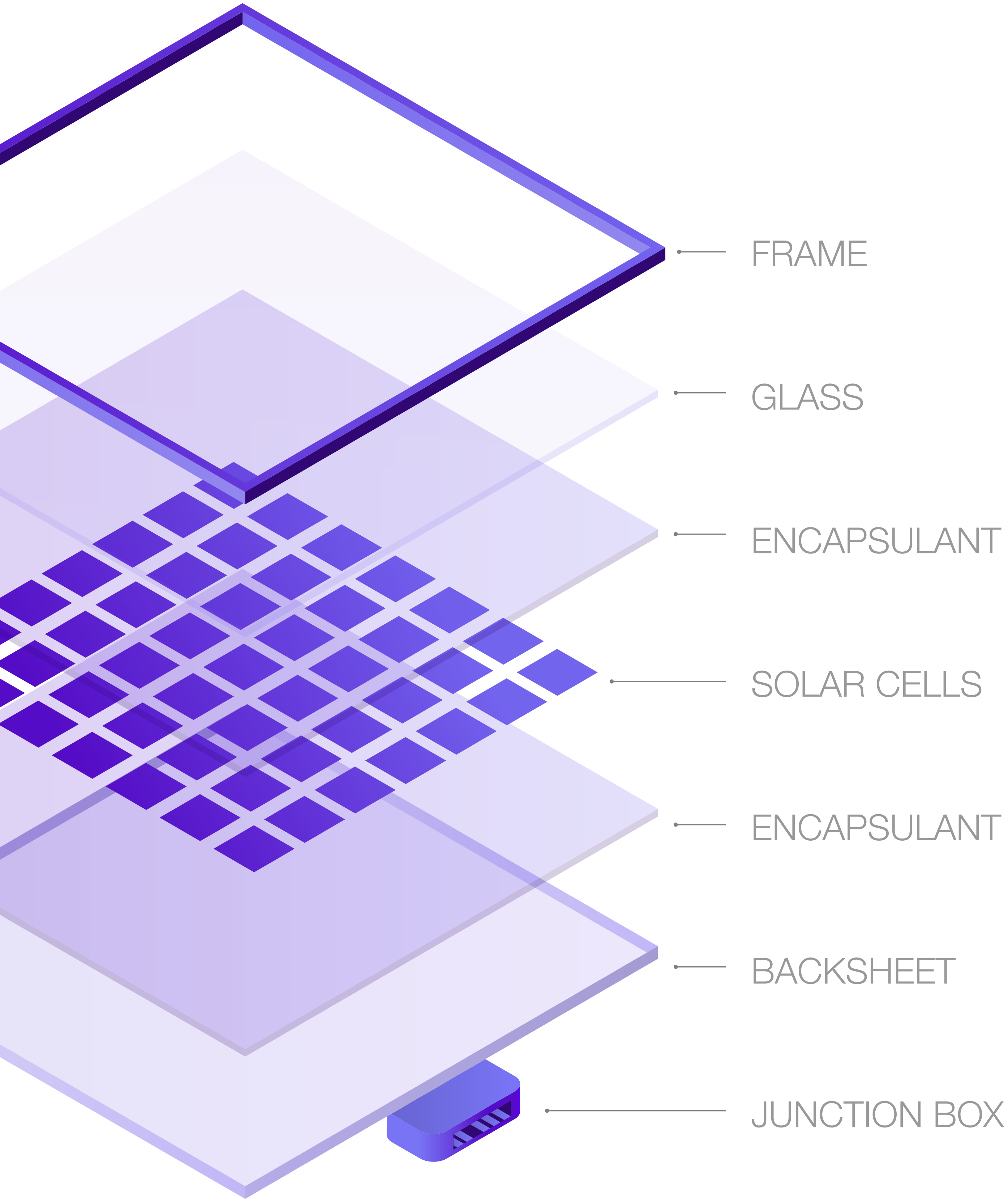
Standardisation of panel design by industry and government to enable more efficient recycling, and to enable the waste industry to plan for future waste streams.

Recycling challenges

The lack of standardisation and level of deconstructability and modularity of panels makes recycling challenging. Techniques, equipment and levels of manual labour required vary and so individual plants are not necessarily able to handle all panel types[23].

More specific technical barriers exist too. A critical element in end-of-life management is the removal of the laminate encapsulant, often made of ethylene vinyl acetate (EVA), a thermosetting plastic. This film is placed on the glass of many panels, and its removal is perceived as a significant technical barrier to efficient and safe recycling. Design of panels needs to take factors like this into consideration. Potential alternatives include thermoplastic films, which are more readily recycled[24], but this should be investigated directly with recyclers.

23 Sica, Malandrino, Supino, Testa and Lucchetti, 2018, Management of end-of-life photovoltaic panels as a step towards a circular economy
24 Oreski, 2014, Encapsulant Materials and Degradation Effects


FRAME
GLASS
ENCAPSULANT
SOLAR CELLS
ENCAPSULANT
BACKSHEET
JUNCTION BOX

Circular use

Model 2: Sharing platforms

Regenerate
Share
Optimise
Loop
Virtualise
Exchange

This model focuses on enabling or offering shared use, access or ownership so more people can benefit from the asset.

The past five years in Australia have seen a growth in energy-based peer-to-peer trading platforms and innovations.

This includes microgrids, virtual power plants (VPPs) and energy market platforms.

Microgrids are small decentralised energy networks with local control. This can range from an individual to many users. Usually a combination of solar and battery technology is utilised allowing the microgrid to disconnect from the traditional electricity network (grid). Within these microgrids, energy can be shared between users.

A **virtual power plant (VPP)** can be created if distributed energy resources (such as solar, batteries and demand management technologies) in the community are pooled together and controlled centrally, with energy exported to support the grid. This central control can then coordinate, deploy and monitor the energy export, similar to how a traditional power plant would run.

Market platforms for energy markets play an important role in energy sharing. These virtual markets provide a place for users, who range from consumers to communities to network utilities, to trade locally generated solar and battery-stored power with one another and with the grid.

All of these models help to increase the utilisation rates of solar PV, while sharing its benefits further.

At a local level, more and more communities around Australia are developing, executing and benefiting from solar PV projects independently.

Community Renewable Energy (CORE) provides these communities with ownership over the resource, which increases the accessibility and affordability of solar PV, while also enabling individuals to collectively act against climate change. These sharing projects are of larger scale and provide greater utilisation rates than would be achieved if individuals installed personal PV systems.

Currently, apartment owners or other residents who do not control their roof, find it difficult or impossible to place solar PV on their buildings.

By enabling these groups to more readily negotiate for this, solar PV with high utilisation rates due to sharing between building users could be achieved. This has the added benefit of expanding the accessibility of solar to more of the community. Solar gardens provide the opportunity to share solar PV, especially for renters or people with shaded roofs. Users own shares in a solar garden, the return on which is credited to their energy bill[25]. Models like this also provide efficiencies through economies of scale.

Benefits	Barriers
Increase utilisation rates and decrease unnecessary demand for new panels Encourage collaborative production and off-site generation Depending on the platform, both small and large-scale generators can participate	Preference of consumers to have individual ownership rather than shared or no ownership Restrictive rules that prevent renters, apartment owners or other community members from installing and sharing PV

Future enablers

Pilot projects and investment in scaling these projects up. Many digital- and hardware- based platforms are emerging in Australia, and rapid scale is expected soon. Funding and investment are important for this.

Flexible rules that enable renters, apartment owners or other residents to negotiate for and benefit from shared solar on shared roofs.

Peer-to-peer trading platforms and markets.

Community-focused groups, that bring CORE to more people, including solar gardens. Policy plays an important role in ensuring these projects are viable.

25 Community Power Agency, 2016

Power ledger

Power Ledger is an Australian start-up that provides peer-to-peer renewable energy trading, built using Ethereum distributed ledger technology. They enable this trading to occur directly between consumers using Power Ledger's hardware and application to trade "sparkz". Trials have been completed in Australia and overseas, with the company reporting cheaper outcomes for consumers and a better return for producers of renewable energy.

"No one gets left behind" – Power Ledger, 2018

Reposit power

Reposit Power is another Australian start-up that provides individuals with the ability to buy and sell energy with the market. Its Reposit Box is a smart device that learns your patterns of consumption, and performs marketplace transactions based on your demand and supply levels. The company has also been involved in multiple VPP projects in Australia.

"Reposit puts the control back into consumer hands" – Reposit Power, 2016

deX (Decentralised Energy Exchange)

Consumers, businesses, communities and network utilities can trade battery-stored solar power in an open marketplace through this software platform from Greensync. A pilot marketplace has been successfully implemented and the company is currently adapting and improving their software.

"Consumer choice lies at the heart of deX" – deX, 2018

AGL

Long-established players in the energy industry are also innovating in this space. In 2017, AGL led a virtual trial to simulate peer-to-peer energy trades between 68 customers in Melbourne. This trial identified the value of such trading for customers, and determined that distributed ledger technology can enable this, under particular pricing structures and market reform.

"Customers are driving the development of P2P energy models in Australia" – AGL, 2017

A word of caution

While sharing models can make solar PV more accessible and increase a panel's use, there is also the potential to increase the total amount of waste produced as more panels would be demanded overall.

While all replacement of non-renewable energy forms with renewable ones is to be encouraged, this highlights the importance of the whole value chain transitioning to CBMs. This CBM relies on other parts of the value chain reducing waste and utilising circular materials. It also reflects the importance of ensuring the correct ownership structures and responsibility attributions are in place.

Model 3: Product as a service

Regenerate
Share
Optimise
Loop
Virtualise
Exchange

This involves delivering performance rather than products, where the ownership is retained by the service provider. The service provider is well-placed, and has scale, to more efficiently manage and maintain the asset than the consumer.

Through leasing, consumers commit to paying a certain amount of money for the use of the panels.

Leasing solar PV systems is popular in some specific overseas markets, but not in Australia.

This is largely due to differences in policy, and the relative attractiveness of purchasing rather than leasing. This attractiveness is largely financially driven, given the longer return on investment for leasing, but also driven by the fact that many consumers derive emotional and status benefits from owning rather than leasing[26].

Leasing does, however, provide an opportunity to increase the utilisation of individual panels while making solar PV more accessible. Particularly among renters or low-income households, leasing has the potential to provide a flexible and efficient way to use renewable energy. Additionally, the manufacturer and owner of the panel will be incentivised to ensure a long lifespan and high-quality repairs and maintenance.

Despite this, renters or those involved in strata arrangements may have difficulty in obtaining agreement on solar panel installation with building owners.

Power Purchase Agreements (PPA) offer an alternative to leasing, and ownership, whereby consumers commit to buy a certain number of kWh of energy from a provider.

The provider could be generating the power at the consumers site or transmitted from another location. PPAs could be a useful tool to facilitate solar PV use for renters and apartment owners. PPAs do require longer term time commitments of ten or more years that may be prohibitive for some consumers.

A significant benefit of product as a service models is that there is a centralised owner who is responsible for many panels. This responsibility covers maintenance, repairs and recovery of the panels, which streamlines these processes, and enables other circular business models to work more effectively.

26 Lewandowski, 2015, Review of Designing the Business Models for Circular Economy - Towards the conceptual framework

PPAs and RE100

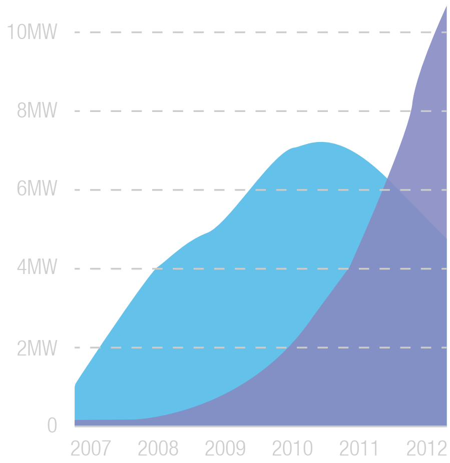
Two-thirds of the end-use of electricity is accounted for by companies in the commercial and industrial sector globally[27].

RE100 is a global initiative bringing together companies committed to using 100% renewable energy, given the significant role they play in the end-use of electricity. Many of these companies are using PPAs to reach the goal. While they are not generating the clean energy themselves, they are outsourcing the generation, and virtually obtaining the PV power.

27 International Renewable Energy Agency, 2016, End-of-Life Management: Solar Photovoltaic Panels
28 Climate Policy Initiative, 2013

Leasing in California

California saw a rapid uptake in leasing arrangements in 2009. This has been attributed to a decrease in incentives for up-front purchasing of panels[28].



Benefits	Barriers
Increase utilisation rates Accessible due to low capital investment for users A centralised provider is responsible for maintenance, repairs and recovery Decreases complexity of investment Likely to increase overall deployment of solar PV	Negative consumer attitudes towards leasing rather than owning Lower return on investment for leasing over time Low awareness of leasing models Long term commitments of leases or PPAs

Future enablers

Providing more *financing methods* for leasing panels.

Raise awareness of leasing options and PPAs.

Renters leasing panels.

More flexible *PPAs* with the private sector.

Circular recovery

Model 4: Refurbish and maintain

Regenerate
Share
Optimise
Loop
Virtualise
Exchange

This model focuses on repairing and refurbishing part or whole of the asset so they can be returned to operations or sold at the typical end-of-life.

In a circular economy, when panels are returned to a manufacturer under a warranty agreement, the preferable course of action would be to attempt to repair the panel, and then failing that use it for parts, and then failing that recycle the materials. The potential for reuse is high, with one study estimating that by recovering components from 1000 used panels, about 422 new PV panels can be produced[29].

Warranties can have notable exclusions to their cover that decrease the adaptability of the system. For example, changing a panel's location may void the warranty[30]. This has important implications for CBMs based on leasing, sharing or selling in a second-hand capacity.

When it comes to the natural end-of-life for panels, installers or solar developers are left with the waste. For rooftop solar, which makes up most of the panels in Australia, the local governments often end up dealing with the waste. Rules and practices for dealing with these panels is dependent on location and varies greatly, with interviewees sighting **dumping and stockpiling of panels as somewhat common practices.**

Second-hand panel markets for the re-use of panels do exist, particularly online.

IRENA research indicates that a typical second-hand price is approximately 70% of the original price[31]. Given that manufacturers frequently guarantee at least 80% output after 20 to 30 years of life[32], there is clearly some value to be derived from these panels.

In Australia, these panels tend to be exported as they are not as attractive to domestic consumers. This is partly because second-hand panels cannot receive small scale technology certificates in Australia, and so they are not as attractive financially as new panels. They also do not come with the same quality assurance that a new panel does. Standards and formalised panel testing provide an opportunity to overcome this.

Monitoring systems can also be used to provide a consumer with more information about their performance and usage patterns, leading them to make more efficient consumption decisions.

29 Sica, Malandrino, Supino, Testa and Lucchetti, 2018, Management of end-of-life photovoltaic panels as a step towards a circular economy
30 Ecogeneration, 2016, Warranties and Insurance
31 International Renewable Energy Agency, 2016, End-of-Life Management: Solar Photovoltaic Panels
32 Vazquez and Rey-Stolle, 2008, Photovoltaic Module Reliability Model Based on Field Degradation Studies

<table>
<tr><th>Benefits</th><th>Barriers</th></tr>
<tr><td>Can sell parts cheaply to other places, where there may be people for whom the technology is less accessible

Extending the useful life of panels, thus reducing demand for new panels</td><td>Distinguishing between working second-hand panels and e-waste

Used panels cannot receive small-scale technology certificates

Determining the condition and performance of used panels</td></tr>
<tr><td colspan="2">Future enablers

Testing and certification of second-hand panels that would enable them to be eligible for financial schemes and insurance schemes. Market research is an obvious first-step to determine the viability of this.

Clear and standardised rules across Australia for collection, repair, resale and recycling of solar PV panels.</td></tr>
</table>

Repair of a solar panel typically includes replacement of frames, junction boxes, diodes, plugs, sockets or even solar cells[33].

Second-hand markets in the EU

In the EU, used panel markets have appeared online through platforms such as Second Sol. Second Sol also engages in module testing, recycling and disposal, and repair of panels. This centralisation will better enable them to distribute these services and their panels and parts. In 2015, around 60 MW of both new and used PV modules were traded among users[34].

pvXchange is another online platform for second-hand solar, which focuses on large-scale systems.

Panel testing and inspection

A hurdle to second-hand sales of panels is uncertainty over their performance and a lack of certification. Panel testing services, such as those developed by PV Lab Australia, could play an important role in providing quality assurance for second-hand panels.

A challenge in achieving this is keeping the cost of testing low, as the cost of comprehensive testing of panels can be in the order of the cost of the panel itself in Australia. Statistical sampling of large batches of panels could reduce the number of tests required.

33 Weckend, Wade, & Heath, 2016
34 Fiedler, 2016

Model 5: Recycling facility

Regenerate
Share
Optimise
Loop
Virtualise
Exchange

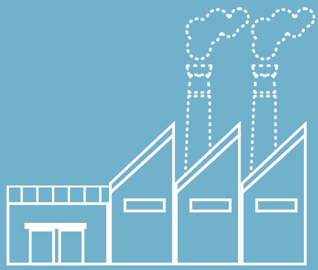
In this model, waste is transformed into raw materials to return to the circular supply chain.

Material Recovery Facilities (MRFs) are common in Australia. These are essentially sorting plants that receive materials from co-mingled household and commercial recycling collections and then send the separated materials to recycling facilities in Australia or overseas. Separate MRFs operate to process construction and demolition waste. **Solar PV panels are not currently handled by materials recovery and recycling facilities in Australia and will not form part of an efficient logistics chain for PV panel recycling.** Australia does, however, have one specialty in-country recycling service - Reclaim PV Recycling. The costs of utilising this PV recycling service are currently greater than landfill, though are expected to reduce over time.

Due to the specialist nature of solar panel installation and removal services, damaged or end-of-life solar panels are typically obtained as a clean, single-product waste stream. Maintaining this clean, source separated waste stream from the generation site to a dedicated solar panel recycling facility supports more efficient and cost-effective recycling.

This is due to the fact that panels do not have to pass through unnecessary sorting processes to separate them from other types of waste. Solar panels may be aggregated before transport to a recycling facility, for example, at an e-waste drop-off site. However, the panels would typically remain sorted and separated from other types of e-waste at these transfer stations.

Australian businesses and households are most familiar with comingled recycling, which does not accept PV panels. **Education for households and businesses which maintain and remove solar panels is essential to raise awareness about appropriate recycling pathways and the benefits of solar panel recycling instead of landfill disposal.** A dedicated, national product stewardship scheme for PV panels could facilitate a consistent approach to providing education campaigns and access to recycling systems for rooftop PV.



1.2 tonnes of CO_2 emissions saved

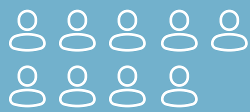
per tonne of silicon-based PV modules recycled[35]

"Thousands of tonnes of e-waste are falsely declared as second-hand goods

and exported from developed to developing countries, including waste batteries falsely described as plastic or mixed metal scrap, and cathode ray tubes and computer monitors declared as metal scrap." UNEP, 2015[38]

6x reduction

Study estimated that the environmental impact of PV end-of-life (EOL) can be reduced by a factor of six by having pre-treatment and recycling of solar panels[36]



9.2 jobs are created per 10,000 tonnes of waste recycled compared to 2.8 jobs per 10,000 tonnes of waste disposed[37]

37,000 Australians

are directly employed in waste collection, treatment and disposal services, a number which has grown over 50% in the past decade[39]

35 Fraunhofer Institute for Building Physics and Department Life Cycle Engineering, 2012
36 Monier and Hestin, 2011, Study on Photovoltaic Panels Supplementing the Impact Assessment for a Recast of the WEEE Directive
37 Deloitte Access Economics, Employment in waste management and recycling, 2009
38 UN Environment Programme, 2015, Illegally Traded and Dumped E-Waste Worth up to $19 Billion Annually Poses Risks to Health
39 Australian Bureau of Statistics, 2018, Labour Force, Australia, Detailed, Quarterly, Aug 2018

A key challenge in the recycling of materials is the disassembly of components and materials. If the disassembly challenge can be overcome, it unlocks the value of the waste stream by converting it into raw materials and enabling its potential re-use. If the solar cell and EVA sheet can be removed efficiently from the glass, these can be sold on separately rather than crushed and used for asphalt or landfilled together.

Standardisation of waste and recycling legislation across Australia can unlock more efficient solar PV recovery and recycling

In Australia, responsibility for waste policy and legislation lies with the States and Territories. Waste classification, management, and legislation is not consistent and results in confusion and barriers to better outcomes. A consistent approach to the management of PV panels across Australia would promote the potential economies of scale and certainty for the industry to invest in local reprocessing infrastructure rather than rely on an export market. Exporting PV panels for recycling results in lost material availability and potential market opportunities in Australia.

Solar PV is not recognised as a unique waste category for waste reporting or regulatory compliance in any Australian jurisdiction. Some states recognise and record e-waste, which would include solar PV systems. However, data remains very limited. Explicit identification and reporting of e-waste is typically driven by resource recovery policy and regulation. For example, **if specific recovery targets are set, or restrictions are placed on the disposal of certain materials, they must be identified and are usually measured.**

E-waste is banned from landfill in South Australia and Victoria. Landfill bans require e-waste to be separated from other materials and delivered to transfer and recycling facilities. **Landfill bans on e-waste eliminate the cheap but unsustainable option of landfill disposal, forcing a viable collection and recovery network to be implemented.** E-waste landfill bans are likely to be highly effective for supporting PV panel recycling, because panels are large, readily identifiable and typically collected in a single waste stream by specialist service providers.

Photo: ©iStock

Consistent landfill ban legislation across Australia would prevent solar panel disposal to landfill and help to obtain economies of scale for domestic PV recycling. It would also mitigate the risk of interstate transport of e-waste for landfill disposal, which could eventuate if a large price differential develops between recycling costs and landfill disposal in neighbouring jurisdictions.

PV panels may contain potentially hazardous materials or components but are not explicitly classified as hazardous waste under the National Environment Protection Measure (Movement of Controlled Waste between States and Territories) or in state or territory legislation. They are not subject to transport and handling licencing and reporting requirements and there is no readily available data on the movement of PV panels for recycling or disposal in Australia.

This is appropriate, as intact PV panels do not present hazardous characteristics and onerous transport licencing requirements can be a potential barrier to efficient aggregation for recycling. The non-hazardous status of PV panels may be strengthened in legislation if additional measures such as landfill bans or product stewardship schemes are introduced to increase recycling.

For example, the Queensland Environmental Protection (Regulated Waste) Regulations explicitly state that various intact or partly disassembled electronic items are not considered regulated waste, in order to support transport for recovery under the existing product stewardship schemes for mobile phones, computers and televisions.

Selection of the right combination of recovery provision and recycling business models should carefully consider the benefits of a decentralised system versus a centralised one.

A centralised recycling system would enable a smaller number of large recycling facilities to efficiently process a large volume of panels, however large transportation costs and impacts would be incurred, and value would be divided amongst fewer stakeholders.

A decentralised system with many more smaller processing facilities would address these distribution issues but would need to be cleverly designed to overcome the challenges around volume and economies of scale to allow for the development into a sustainable business.

Benefits	Barriers
Job creation for waste collectors, pre-treatment companies, waste managers, waste processers and researchers	Allocation of responsibility and cost is unclear
Environmental impact of PV EOL reduced	To produce high purity recycled products, a combination of mechanical, thermal and chemical processing steps is often required
High potential for revenue creation, especially through rare earth metals	Reaching economies of scale in Australia, without waste being sent overseas
Plastic can be used for energy	Cost of logistics
Opportunity for further innovation and development of recycling processes and products	Lack of standardisation for waste collection, regulation, hazardous materials and approvals
	Distributed nature of solar and waste collection
	Insufficient standardisation of panel design

Future enablers

Clear and standardised rules across Australia for collection, repair, resale and recycling of solar PV panels.

Research and development into key topics such as distributed disassembly and film delamination.

Market research to establish the costs and benefits of both centralised and decentralised facilities in Australia.

Labelling or materials passports for product identification.

$100M – Predicted value of module recycling industry in Australia in 2032[40]

One study looking to model the profitability of a PV recycling industry in Australia estimated that the profit would be between $0.036/W to $0.12/W, or $100M in 2032. This assumes all panels are silicon-based and 200 W, with a 20-year life-span. This is heavily dependent on future policy in Australia, as well as the fluctuating costs of processing the panels and the value of key materials such as polysilicon.

More research such as this is required to investigate how newer types of panels may fit into this industry, how creating this industry in Australia compares to shipping these modules overseas, and how technological developments in distributed recycling and disassembly technology may influence these models.

Photo: ©iStock

40 Kang, White and Thomson, 2015, PV Module Recycling: Mining Australian Rooftops
41 International Renewable Energy Agency, 2016, End-of-Life Management: Solar Photovoltaic Panels
42 National Television and Computer Recycling Scheme - myths and facts, 2015

Who bears the cost?

The storage, treatment, disassembly, recovery, recycling, disposal, and management of the process come at a cost. Given the long lifespan of the panels, the matter of who pays these costs and when is critical.

The Government?

This approach ultimately makes the community, who do not necessarily directly cause nor benefit from correcting the externality, indirectly responsible for bearing the costs.

Consumers?

This is a common approach that could be implemented at alternative ends of the life cycle – either at the start as an upfront recycling fee or at the end as a disposal fee.

Producers?

This would fall under an Extended Producer Responsibility (EPR) principle.

...and when?

Funding for recycling could either be before use or after use. In the EU, the pay-as-you-go approach provides a good case study and has proven to be more cost-effective.

"The pre-funding scheme for collecting and recycling high-volume e-waste such as PV panels has not proved cost-effective. Producer pay-as-you-go (PAYG) approaches combined with last-man-standing insurance and joint-and-several liability producer schemes are therefore more commonplace today although the revised 2012 directive still allows the prefunding scheme[41]".

TV and computer waste in Australia

Like solar panels, televisions and computers are a form of e-waste. In Australia, these fall under a co-regulatory product stewardship arrangement (see page 41 for more information). Importers and manufacturers in Australia are responsible for paying a fee. The e-waste recyclers must be certified and have a 90% material recovery target[42].

The EU approach: Extended Producer Responsibility

*"The EPR system has been proven to be an effective approach for the management of many types of waste, especially electronic waste" **

In the EU, the Waste Electrical and Electronic Equipment (WEEE) Directive relies on the EPR principle, whereby producers are responsible for waste regardless of their location. In addition, the Directive outlines:

- Recovery and recycling targets including weight recovery quota, undertaken with a staggered approach over time.
- E-Waste requirements outlining how to handle waste in order to protect the environment and human health.
- Responsibilities allocated for financing, reporting and information.
- List of Wastes including common nomenclature, terminology, coding and classification
- Registration: of modules and specific labelling required

The WEEE Directive focuses on 'high-value recycling' which ensures rare metals and potentially harmful substances are recovered, materials with high embedded energy are recycled and recycling processes are mindful of the quality of recycled materials[43].

For private households, the producer is responsible for collection and recycling of panels. For non-private households, it may either be the customer or the producer, as both could be well placed to do so. Such a system does, however, have the process and financing in place for when a producer goes out of business.

43 International Renewable Energy Agency, 2016, End-of-Life Management: Solar Photovoltaic Panels

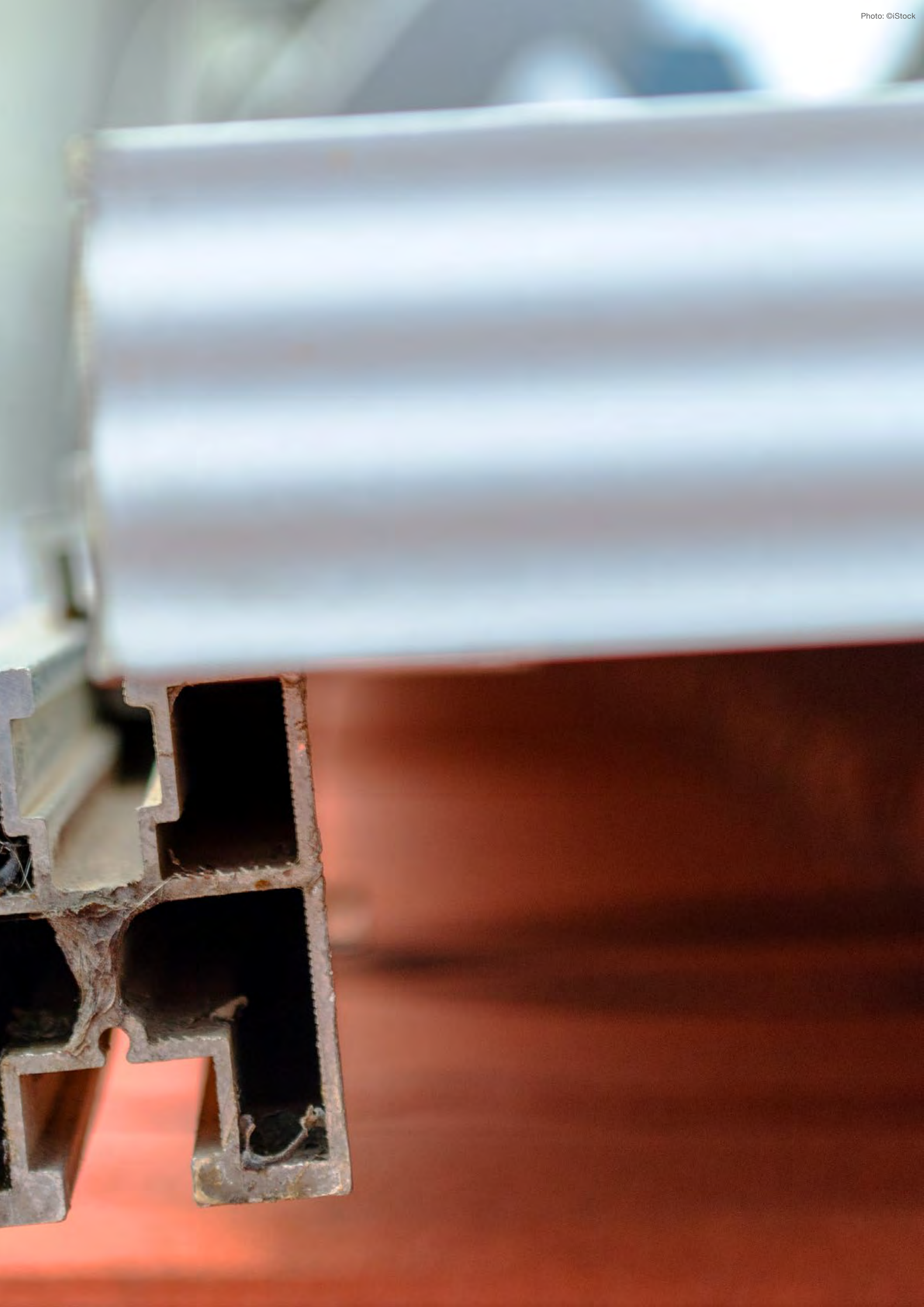


Photo: ©iStock

Photo: ©iStock

Extended Producer Responsibility in Australia

The EPR principle is enacted in Australia through the Product Stewardship Act. Under the Act, stewardship can be:

Voluntary – industry leads and funds these schemes, which are then monitored but not regulated by the Australian Government. E.g. Mobile Muster.

Co-regulatory – both industry and Government collaborate to run this agreement. Minimum outcomes and operational requirements are set by the Government, then industry can determine how to follow these. E.g. National Television and Computer Recycling Scheme (NTCRS).

Mandatory – the Government places a legal obligation on industry to follow requirements, with no or little discretion available to industry.

To date, there are no mandatory schemes in place[44].

In order to maximise the effectiveness of the EPR principle for solar PV, a mandatory scheme would be an attractive choice. This would, however, come with significant challenges, and the benefits of the collaborative approach found in co-regulatory schemes have been documented following a review of the NTCRS[45]. Regardless of which option is selected, these kinds of schemes should be explored with industry in a collaborative forum. PV panels are currently listed as a product that is intended to be considered under the scheme.

Micro-factories with SMaRT@UNSW

The SMaRT Centre at the University of New South Wales investigates and develops innovative methods for waste to raw material conversion. As part of this work they have created "microfactories" that process e-waste to recover valuable materials[46]. This work has covered auto-glass and e-waste glass, and researchers believe there is potential for this to be applied to PV panels.

Given the costs of transportation and logistics in Australia, decentralised technology such as this could make recycling of panels more accessible and affordable, and work to address the current challenges with panel disassembly. Even if panels could only partially be processed in a micro-factory, some costs might be saved.

44 Australian Government, 2018
45 Australian Continuous Improvement Group, 2017, Evaluation of the National Television and Computer Recycling Scheme (NTCRS)
46 Sahajwalla, 2018, Green Processes: Transforming Waste into Valuable Resources

Recommended steps

"At the highest level of engagement, we need to start a multi-stakeholder dialogue about mutual gains. The circular economy model can drive innovation and new ways of working; we see this as a way of rethinking design and redesigning thinking."

– Carol Lemmens, Arup (Global Advisory Services Leader)

It is essential that we identify and address these barriers and leverage the known enablers of CBMs if we are to achieve a circular PV industry in Australia. This section of the report consolidates these key barriers and enablers, and outlines broad recommendations for industry stakeholders to move forward.

Key barriers

These barriers draw the contents of this report as well as general barriers to the circular economy identified by the World Economic Forum[47].

Technical barriers Separation of film and glass Designed to dispose, not to reuse, disassemble or recycle Lack of labelling and tracking of materials	**Social barriers** Lack of awareness and sense of urgency, especially given the long life of a panel Resistance to change and lack of motivation for most industry participants
Financial barriers High transition costs Upfront investment Product pricing and measurement of growth Economic viability of recycling High collection costs due to Australian geography, market size and industry maturity	**Institutional barriers** No restrictions to promote recycling or restrict landfilling of solar PVs Deep rooted linear mindset Inconsistent regulations across States and Territories Lack of standards around the design and manufacture of sustainable panels

47 World Economic Forum, 2018, Circular Economy in Cities: Evolving the model for a sustainable urban future

Key enablers

In Arup's research for the *First Steps Towards a Circular Built Environment* report, key themes were identified among stakeholders as essential to "combatting common barriers and facilitating the transition to a circular built environment". These included:

Collaboration – is required to build trust and increase engagement along the supply chain, which is currently fragmented and lacking a whole-life cycle industry approach.

Knowledge – of how to implement CBMs across the industry will need to be generated and disseminated to provide industry stakeholders with the skills to take steps towards circular business models.

Policy – will incentivise and facilitate circular behaviour.

Leadership – from "first movers" is necessary to act as a beacon for other industry players who are willing to follow.

Finance – is often perceived as a barrier rather than an opportunity or an enabler to circular built environment projects, though investment opportunities that recognise the unique challenges of the built environment are essential to project initiation and success.

These key enablers have informed the development of recommendations for the solar PV industry in Australia.

Photo: ©iStock

Key recommendations

Together, the whole industry will need to work to enable standardisation, coordination and collaboration for the business models.

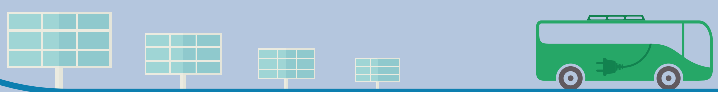
- Establish an Extended Producer Responsibility scheme
- Create and expand partnerships between players along the value chain, especially public-private partnerships
- Standardise panel design and data management processes, including labelling and materials passports

Policymakers should foster a supportive regulatory, research and business environment for circular business models across all States and Territories.

- Use policy levers, including public procurement, to support and spur demand for circular solutions
- Convene and facilitate public-private partnerships to develop scalable projects
- Work with industry and governments to develop a supportive and cohesive national circular economy strategy in Australia

Business should demonstrate leadership in the space through feasibility studies and pilot projects, especially through collaborations.

- Lead private-private and public-private partnerships to develop scalable projects
- Develop an evidence base of data and case studies demonstrating the value of a circular PV industry
- Adapt current business practices and models to reduce waste and increase utilisation



Investors should develop their understanding of the circular economy, and increase their support of CBMs and related R&D.

- Engage in private-private and public-private partnerships to develop scalable projects
- Support research into end-of-life technologies and possible value creation through CBMs
- Consider longer returns on investment, for added social and environmental value

Together

Together, the whole industry will need to work to enable standardisation, coordination and collaboration for the business models

Establish an Extended Producer Responsibility scheme

Who is ultimately responsible for panel waste is a key issue and should be a priority for the industry as a whole. This should be a collaborative process that engages the whole industry and draws lessons from both national and international experience.

Other e-waste industries in Australia, such as that for televisions, provide valuable reference points to initiate dialogue. These industries also provide the potential for collaboration, due to similarities in materials and components between products.

Create and expand partnerships between players along the value chain, especially public-private partnerships

These partnerships have the potential to increase certainty, decrease risk and enhance innovation through the circular economy journey. These should involve pilot projects and be open to collaborators from all points of the panel lifecycle. Early projects will be particularly important to provide an evidence-base for larger collaborations. In Australia, many of these early projects can look to projects already established in the EU and Asian markets.

Standardise panel design and data management processes, including labelling and materials passports

The more panel design can be standardised, the more easily processes can be built to disassemble them. Included in design standards should be processes for data management, that ensure that information on a panel's components, materials and manufacturing methods is readily accessible at the end of its life. The more these can align with international standards and processes, the better.

40%

Just over 40% of policymakers cited the importance of creating real projects in scalable sectors to demonstrate the benefits of a circular economy approach and generate greater political interest and momentum[48]

The Australian Steel Stewardship Forum is an industry body working to improve the performance of the steel industry across the whole product lifecycle, through developing steel stewardship. The Forum aims to: "Develop, improve and advocate the economic, environmental and social credentials of the Australian steel value chain." Their past and future initiatives include a sustainability certification scheme, mapping of the steel value chain footprint, and re-use of steel building components, all while collecting data to inform future projects.

It is an initiative supported by Government and sponsored by industry[49].

48 Arup, 2018, First Steps Towards a Circular Built Environment
49 ASSF, 2018

Policymakers

Policymakers should foster a supportive regulatory, research and business environment for CBMs across all States and Territories

Use policy levers, including public procurement, to spur demand for circular solutions

Government-led change is an important part of the circular economy.

Typical intervention methods include:

- Education, information and awareness
- Collaboration platforms (public-private partnerships, R&D programmes, etc.)
- Business support schemes (incentives/financing, advisory/support)
- Public procurement and infrastructure
- Regulatory frameworks (targets, product regulations, waste regulations, other regulations, reporting regulations)
- Fiscal frameworks (tax changes)

These interventions each have the potential to increase confidence in the sustainability and profitability of CBMs in the future. They reduce risk for investors and provide incentives and support for businesses.

A policy change that should be considered seriously is the formal inclusion of solar PV waste in the Product Stewardship Act, either as a co-regulatory or mandatory product. Given the relative success of the extended producer responsibility scheme under the WEEE Directive in Europe, key lessons can be drawn from there, however recognition of the Australian context and inputs from industry stakeholders should be incorporated. This scheme could go beyond recycling and consider certification for re-use as well.

> "It's important we do this early so it's not an issue." Joyanne Manning, Arup (Australasian Resource and Waste Leader), 2018

Government interventions should focus on all CBMs, not just those centred on waste recovery. Leasing, second-hand markets and sharing-based models should be encouraged to increase panel utilisation before they become waste, through programs like the NSW Government Resource Efficiency Policy (GREP). Through the GREP, Government agencies are requested to investigate and report on solar leasing and PPA opportunities for their site[50].

Convene and facilitate public-private partnerships to develop scalable projects

The Government has an important role in facilitating the networking and collaboration between groups along the value chain, as well as creating knowledge platforms. This is particularly important at the State and Territory level, where local Governments are well placed to bring stakeholders together, both in-person and online.

An important element of this is convening the conversations around policy and the Product Stewardship Act, so that any policy changes are co-developed and endorsed by industry stakeholders.

Programs that connect businesses with circular economy research, initiatives and business models are an important part of this. The NSW Sustainability Advantage Program is an example of a project doing this at a broader level for sustainability initiatives. The Program helps participants (business organisations) to identify and implement projects that increase their efficiency and sustainability, thereby saving them money[51]. The combination of information, support and networking provided to participants in this Program could be emulated in a solar PV-focused initiative.

> "Stimulating investment and innovative financing schemes for PV end-of-life management is necessary to overcome financing barriers and ensure the support of all stakeholders." – IRENA

50 NSW Government, 2017, NSW Government Resource Efficiency Policy: Progress report 2015-16
51 NSW Government, 2018, https://www.environment.nsw.gov.au/sustainabilityadvantage/

Work with industry to develop a supportive and cohesive national circular economy strategy in Australia

The National Waste Policy should be built upon to create an Australian Circular Economy Strategy. As recommended by the Wealth from Waste report, the Federal Government should bring together groups like Sustainability Victoria and Green Industries (SA) to co-create a coordinated policy with industry.

SA is already on their way to having a coordinated circular economy strategy. In SA alone, it is estimated that over 25,000 jobs can be generated by 2030 through a circular economy. At the same time, a 27% reduction in GHG emissions may be achieved[52].

This could bring together all intervention methods into a consistent approach across states.

Energy and social equity in Australia

With many Australians unable to maintain a basic standard of living[53] and wholesale electricity prices rising 50% over the past decade[54], the accessibility and affordability of electricity in Australia is a key equity issue.

As rooftop solar PV and storage become more widespread and thus demand for the grid decreases, the fixed costs of the grid are redistributed, and those without these technologies pay more. Many of these people are low-income Australians who unable to afford the upfront capital investment for solar PV, despite being the ones who could benefit the most.

Consideration of this inequity should factor heavily in policy decisions, especially given the positive social outcomes that can be achieved through CBMs that focus on sharing panels and increasing utilisation.

Toolkit for Policymakers | Ellen MacArthur Foundation

This toolkit provides insights, a step by step approach and eleven tools for creating policies that promote circular behaviour, alongside a case study of Denmark.

Policy intervention types, methods for identification and prioritisation of ideas, and qualitative and quantitative tools for estimating value, implications and barriers, are just some of the contents of the report designed to enable policy makers to take the first steps towards creating circular industries.

52 Green Industries SA, 2017
53 Saunders and Bedford, 2017, New Minimum Income for Healthy Living Budget Standards for Low-paid and Unemployed Australians
54 Australian Energy Market Commission, 2018, Residential Electricity Prices Trends Review

Business

Business should demonstrate leadership in the space through feasibility studies and pilot projects, especially through collaborations

Lead private-private and public-private partnerships to develop scalable projects

Pilot projects between collaborators will play an important role. These will not only demonstrate leadership, but enable the industry to better understand the value, costs and required scale of PV CBMs.

In Europe, PV Cycle and Veolia teamed up to develop the first dedicated solar panel recycling plant in Europe. PV Cycle is a member-based organisation that offers take-back and recycling of PV panels. This is enabled by their collaboration with waste processors including Veolia. In 2018, they processed 1300 tonnes of waste and are aiming for 4400 tonnes in 2022.

Develop an evidence base of data and case studies demonstrating the value of a circular PV industry

Where possible, projects should share their findings and data. An evidence base of functioning CBMs will be important to provide justification for new investments and up-scaling of initiatives. The EU has a growing evidence-base and can be used as a model, however the population, geographical and policy context in Australia demand Australian-based evidence.

Adapt current business practices and models to reduce waste and increase utilisation

New business models will play an important role in the future of the solar PV industry. However, also important is the innovation and adaptation that will occur within existing models. The diversification of revenue streams, the increase in renewable energy in factories, and the utilisation of current waste streams all present opportunities for improvement.

PV recycling in Japan

Japan is a market with significant PV module installation and a high environmental commitment on the part of consumers and companies. The Japanese government funded the Akita Photovoltaics Recycling Model Project (APV) that is significantly reducing the number of panels going to landfill. PV Cycle supports the project with take-back and recycling expertise, and collection and recycling facilities. Fourteen collection points have been opened to collect small quantities of PV panel waste[55].

55 PV cycle launches take-back and recycling service in Japan, PV Cycle, 2016

Investors

Investors should develop their understanding of the circular economy, and increase their support of CBMs and related R&D

Engage in private-private and public-private partnerships to develop scalable projects

Private investment is essential for many CBMs given the limited Government funding available, and the significant potential for value in the industry. When it comes to Australian start-ups, many digital- and hardware- based platforms are emerging in Australia, and rapid scale is expected soon. Funding and investment are important for this to occur.

$9.3 billion

Additional value to Australian business of using a collaborative economy[56]

Support research into end-of-life technologies and possible value creation through CBMs

Investment through R&D will be important moving forward, given some of the technical and economic barriers in place. Where possible, open research and innovation should be undertaken in order to share knowledge and increase participation in CBMs. Potential areas for investment are included over the page.

"R&D, education and training, are all needed to support PV end-of-life management to design and implement socio-technological systems[57]." – IRENA

Consider longer returns on investment, for added social and environmental value

Currently, CBMs typically involve longer returns on investment. This means that in order to realise the social and environmental benefits they provide, investors should be looking at their investments longer-term. Given the increasing levels of waste and resource scarcity, these CBMs also provide the opportunity for investors to future-proof their investments in the long-term as they await their returns.

These longer term green investments could be bundled up and sold as green investment products in the market. Moody's expect that global green bond issuance will grow by another 20% to reach $200 billion in 2019[58].

Research areas to support

- Market analyses for CBMs
- Distributed and mobile disassembly technology
- Film and glass separation
- Feasibility studies for new technologies
- Reviews of existing infrastructure and gaps

"There has been limited research to understand the role of business models to enable new value opportunities in a circular economy[59]."

56 Deloitte Access Economics, 2014, The Collaborative Economy (report prepared for Google)
57 International Renewable Energy Agency, 2016, End-of-Life Management: Solar Photovoltaic Panels
58 Moodys, 2019, Moody's: Green bond market poised to hit $200 billion in 2019
59 Wealth from Waste, 2017, Australian Opportunities in a Circular Economy for Metals: Findings of the wealth from waste cluster

Consumers

What about consumers?

The Government and PV industry are not the only ones who can take action.
Here is a list of small actions consumers can take towards a more circular PV industry:

- Consider leasing solar panels
- Join a Community Solar or Solar Garden arrangement
- Investigate Power Purchasing Agreement (PPA) for solar power
- Consider opting for second-hand panels when installing or replacing your system

Photo: ©iStock

Conclusion

If Australia is to effectively work towards achieving SDG 7 (Affordable and Clean Energy), solar PV and other forms of renewable energy will be essential to our efforts. However, achieving this SDG should not come at the expense of another. SDG 12 (Responsible Consumption and Production) should be integrated in our approach to all aspects of sustainable development. Similarly, SDG 17 (Partnerships for the Goals) will underpin a number of the actions needed to achieve change.

By doing more with less through a circular approach, we can reduce waste and increase value for stakeholders along the value chain, and work towards achieving both SDGs at once.

This report has explored the opportunities and barriers presented by the circular economy in achieving this.

Together, the whole industry will need to work to enable standardisation, coordination and collaboration for the business models.

Policymakers should foster a supportive regulatory, research and business environment for CBMs across all States and Territories.

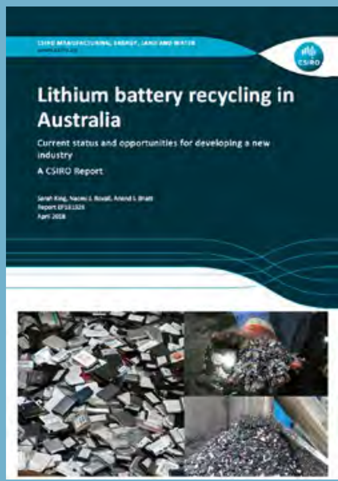
Business should demonstrate leadership in the space through feasibility studies and pilot projects, especially through collaborations.

Investors should develop their understanding of the circular economy, and increase their support of CBMs and related R&D.

While recommendations have been developed for individual industry stakeholders, it is clear that collaboration and open communication will be essential for the implementation of circular business models in the industry.

Further reading

First steps towards a circular built environment, Arup



Lithium battery recyling in Australia, CSIRO

Toolkit for Policymakers, Ellen MacArthur Foundation

End-of-life for solar PV panels, IRENA

Glossary and acronyms

Circular business models (CBMs) are business models that enable the realisation of the circular economy.

Circular economy is a term used to describe an economic system based on the re-use, recycling, recovery and reduction of materials and products. Rather than products and materials being produced, used and then disposed of in a linear fashion, feedback loops and efficiencies are introduced in order to close the system and reduce externalities.

Community owned renewable energy (CORE) refers to renewable energy projects financed by communities.

Distributed energy resources (DER) are small energy generation units located behind the meter (i.e. on the consumer's side of the meter connection). Residential rooftop solar is an example of this.

Distributed ledger technology (DLT) is the digital infrastructure that enables the immutable synchronisation, validation and sharing of data across a network. This decentralised network reduces the need for a centralised authority.

End-of-life in the context of this report is the point at which a product is no longer considered functional and is removed from operation.

Externalities are the consequences of an economic activity that impact an external third party. These can be positive or negative consequences. The traditional take-make-dispose model of production has several common negative externalities, such as pollution.

Materials passports are attributed to materials and products, and provide information on their content, recycling processes, re-use potential and origin. This information is collected in a database and facilitates improved end-of-life practices.

Power Purchase Agreements (PPAs) are contracts between an energy generator and an energy purchaser that determine the terms of the sale.

Product as a service business models involve a company maintaining ownership of a product while consumers pay for use of the product, rather than many consumers owning the product individually. This enables the products to have greater utilisation rates and for fewer products to be required overall.

The ReSOLVE Framework provides six strategies for those wanting to develop CBMs to utilise. They include: regenerate, share, optimise, loop, virtualise and exchange.

Solar photovoltaic (PV) systems convert light into electricity through an arrangement of solar panels (made up of solar cells) and several pieces of electrical equipment. This is a renewable form of energy generation.

Sharing economy is a broad term used to describe economic activity based on connecting people who have a product or service to sell, hire or lease. This is often peer-to-peer and online.

Upcycling is material or product recycling that increases the quality of the item.

Virtual power plant (VPP) is the term used to describe a system of aggregated distributed energy resources, which are centrally controlled.

CBM – circular business model

EPR – extended producer responsibility

EVA – ethylene vinyl acetate

GHG – greenhouse gas

IRENA – International Renewable Energy Agency

PAYG – Pay as you go

PPA – power purchase agreement

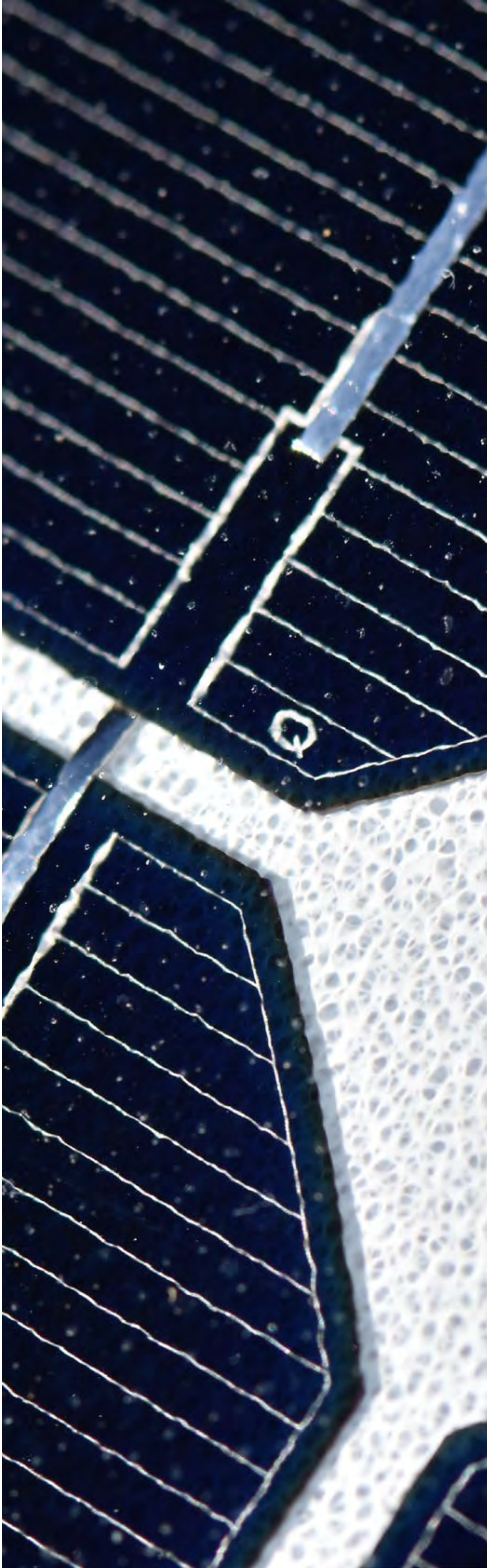
PV – photovoltaic

R&D – research and development

SDG – Sustainable Development Goal

VPP – virtual power plant

WEEE – waste electrical and electronic equipment

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