



Introduction

Photovoltaic (PV) systems were placed on the Environment Minister's Product Stewardship Priority List in 2016. The List identifies the products most in need of a product stewardship approach. The current Minister's Priority List includes PV systems with the following actions:

- An industry agreed nationwide scheme design must be finalised by June 2022
- The nationwide scheme must be operational by June 2023 and include an approach to deal with legacy panels.

The Australian, State and Territory Governments have acknowledged the need for a product stewardship scheme for photovoltaic systems over many years:

- During 2018, Sustainability Victoria, with other jurisdictions, investigated and assessed various options to progress a national approach for PV systems in Australia. The resulting report – PV Systems Stewardship Options Assessment (May 2018), found that key stakeholders (including PV manufacturers, importers and industry associations) supported a nationally coordinated approach for managing PV system waste.
- The National Waste Policy Action Plan (2019) Action 3.5 is that a preferred stewardship scheme for photovoltaic system be (a) identified by 2021 and (b) in place by 2023. However, progress has been limited and piecemeal. No industry-led, national product stewardship scheme has been developed. End-of-life solar panels remain a future environmental problem.

This Paper outlines the key issues in relation to End of Life (EOL) PV management and recommendations for Product Stewardship.

Background

International EOL management of Photovoltaic (PV)

In 2012, the EU became the first jurisdiction worldwide to adopt a comprehensive regulatory framework to address PV waste under the Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU¹. Under the WEEE Directive's extended producer responsibility principle, responsibility during the post-consumer stage of a PV product's life cycle is shifted (physically and/or economically; fully or partially) upstream towards the producers (manufacturers) and away from governments². The collection, transport and recycling of retired PV modules has been regulated in every EU country since February 2014. Notably, within Europe the export of waste is prohibited, which has served to promote research and development in ways in which solar PV components can be recovered and recycled.

Outside Europe, other nations (including those with expanding PV markets such as Japan, China, India, Australia and the United States³) treat PV waste within a general regulatory framework for hazardous and non-hazardous solid waste or WEEE and classify PV panels as general or industrial waste. In 2017, Japan published voluntary guidelines on how to properly

¹ European Union. Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on Waste Electrical and Electronic Equipment (WEEE). *Official Journal of the European Union*. 2012

² Chowdhury R, Apul D, Fry T. A life cycle based environmental impacts assessment of construction materials used in road construction. *Resources, Conservation and Recycling*. 2010

³ End-of-life management: Solar Photovoltaic Panels (irena.org)

dispose of EOL PV modules and invited producers, importers and distributors of PV modules to inform waste disposal companies about substances within their composition⁴ In the United States, California has developed legislation for classifying EOL PV waste as hazardous that extends beyond the Federal Resource Conservation and Recovery Act that regulates hazardous and non-hazardous waste management⁵.

Worldwide as the number of PV installations has increased, so too has the number of PVs that have reached EOL. At the end of 2016, cumulative PV waste reached 250,000 t worldwide. As more PV panels reach the EOL span, PV waste streams are expected to rise by 2030, with the highest volumes projected for Asia (3.5 Mt), followed by Europe (3 Mt) and the United States (1 Mt). A further waste volume surge is predicted between 2030 and 2050, with global PV waste estimated to increase to over 60-78 Mt by 2050⁶.

Australian EOL management of PV

There are several key pieces of Policy and Legislation relevant in Australia, including the National Waste Policy, 2009 (revised in 2018), the Product Stewardship Act 2011, the Product Stewardship (Televisions and Computers) Regulations 2011 which are the co-regulatory instrument for the National Television and Computer Recycling Scheme 2011. Together these pieces of legislation constitute Australia's WEEE management. The Product Stewardship Act 2011 is designed to reduce the amount of hazardous waste going to landfill as well as increase recycling and recovery of valuable materials. Under the Act, the Minister for the Environment publishes a list of additional product classes to be considered every year.

For 2016-17 the product list included a class covering PV cells, inverter equipment and system accessories, such as batteries, for domestic, commercial and industrial applications in recognition that "the volume of photovoltaic system equipment reaching end-of-life is expected to sharply increase in coming years to become Australia's largest electronic waste growth stream". However, despite this listing, Australia has yet to develop a PV Product Stewardship Scheme.

At a state level, in 2012 South Australia was the first government to ban e-waste from landfill, alongside investing in recycling infrastructure. However, their definitions of e-waste are designed to support the National Television and Computer Recycling Scheme (NCRS), so PV components are exempted from the ban to date; this may change if the Commonwealth legislation is updated.

In 2014, the Victorian Government committed to a ban on e-waste going to landfill, with regulatory measures in place by June 2019. At the Meeting of Environment Ministers, it was agreed that the state of Victoria would lead innovative programs that seek to reduce the environmental impacts caused throughout the life cycle of photovoltaic systems. In 2018, the Victorian Government provided \$15M of e-waste infrastructure grants to increase Local Governments' capacity to collect and store the increasing volumes of e-waste safely in Victoria. These grants aimed to establish a significant e-waste collection network.

The WA Waste Avoidance and Resource Recovery Strategy and Action Plan 2030 aims to avoid waste, recover more value and resources from waste, and protect the environment from the impacts of wastes. The State Government is implementing a ban on e-waste disposal to landfill by 2024.

⁴ Lunardi MM, Alvarez-Gaitan JP, Bilbao JI, Corkish R. A review of recycling processes for photovoltaic modules. *Solar Panels and Photovoltaic Materials*. 2018b.

⁵ Conservation and Recovery Act 1976, Senate Bill No. 489 - Hazardous Waste: Photovoltaic Modules, (2015).

⁶ End-of-life management: Solar Photovoltaic Panels (irena.org)

According to the Clean Energy Council as of 31 December 2019, there have been 323,000 PV installations representing 30% of homes in Western Australia. Rooftop PV installations were the highest since 2012⁷. The latest PVs on the market have an expected lifespan of 40-50 years⁸, however PVs installed in 2006 may only have an average lifespan of 25 years.

Role of Local Government

Local Governments are responsible for the collection and management of the majority of waste including electronic waste (from households) and, importantly, are the first point of contact for residents with waste management queries. They also play a central role in the implementation of national Product Stewardship schemes such as the National Television and Computer Recycling Scheme (NTCRS). There are 139 Local Governments in Western Australia. Some Local Governments have formed Regional Councils or collaborations which represent collaborative efforts to address common waste management issues across their communities including through resource sharing. Underpinning these groups is the notion that collaboration across wider regions helps to create economies of scale for waste management. Western Australia's geography poses challenges for service delivery and regional development. This is combined with the extremely long distances between settlements, smaller dispersed industries (apart from mining) that find it difficult to achieve economies of scale, lack of essential services, limited infrastructure, extreme climatic variations in weather and seasonal constraints and high transport costs. The predominant means of freight transport are by road and rail and transport costs are high.

Current management of PV

Currently, the options available for EOL management of PV waste include landfill disposal, incineration, reuse and recycling (mechanical, thermal and chemical processes). Currently there are only two commercially available treatments that recycle PV modules. First Solar (operational in the US, Germany and Malaysia) applies both mechanical and chemical treatments to thin film CdTe solar panels; and Deutsche Solar, who recycle crystalline silicon (c-Si) modules. It should be noted that in 2018 Veolia and PV Cycle opened what they claimed to be Europe's first dedicated c-Si PV recycling facility in France⁹. If the cost to landfill disposal remains a legal and affordable option recycling activities will become economically unfavourable. The methods of processing PVs involve either: component repair – repair of components within the junction box; module separation – mechanical separation of panel materials, or the removal and recycling of silicon and other rare metal elements from components, using mechanical, thermal and/or chemical recycling processes.

The costs of recycling, and who bears responsibility for these costs, are important considerations when considering the economic feasibility of recycling. There are many points in the recycling process which may incur costs: removal of the panels, fixing the roof, transporting the panels to an aggregation point, extraction of salvageable parts, transport of reclaimed parts and transport of the remains to landfill. Current low waste volumes present economical obstacles for the development of recycling processes, but if more recycling of PV waste occurs, the volume of recoverable material and precious minerals will also increase.

Barriers to managing solar PV waste include

- costs associated with collecting and transporting removed panels
- not knowing what to do with removed PV panels
- lack of policy direction by the Government for PV panel collection or disposal
- lack of information on PV panel recycling
- lack of PV panel tracking

⁷ Solar Energy Facts | Technology | Clean Energy Council

⁸ How long do Solar Panels last | The Renewable Energy Hub

⁹ Salim HK, Stewart RA, Sahin O, Dudley M. End-of-life management of solar photovoltaic and battery energy storage systems: A stakeholder survey in Australia. Resources, Conservation and Recycling

- small volumes of waste in remote regions
- lack of repair and reuse options
- limited recycling options for the product
- warranty of products.

From a waste management perspective Local Governments tend to be concerned with aspects of waste disposal such as providing collection services, regulations around collection, sending collected panels for recycling, informing consumers about proper disposal, connecting to product stewardship schemes and extending landfill life by diverting PV panels.

Key Principles for Effective Product Stewardship for Management of Photovoltaic (PV) Stewardship		
Responsibility	Producers and importers should take responsibility for the end-of-life product impacts	Responsibility for managing end of life PV, should be the responsibility of the manufacturer/importer. Product Stewardship requires manufacturers and producers to take responsibility for the whole of lifecycle impacts of their products. This has the potential to create a price signal and provides incentives for up-stream change to reduce waste and improve recycling outcomes.
	Product Stewardship Scheme should cover the entire cost of product recycling	
Access	Leverage Existing Schemes and Collection Locations	Every Scheme does not have to start from scratch regarding collection locations, they may be able to leverage existing schemes and collection locations. For example, PV's could be collected at similar locations as the TV and Computer Product Stewardship Scheme materials and leverage economies of scale transport.
	Make it easy, convenient and consistent for the community	<p>There are several elements which need to be addressed in relation to this criteria:</p> <ul style="list-style-type: none"> • Leveraging existing collection locations, will ensure that the community is aware of where to take material. • Public awareness of the issues surrounding the disposal of PV waste needs to be raised now in order to help reduce the sharp surge expected in PV waste. • Solar PV panels are increasingly viewed as consumer items. Newer models, which are cheaper, more efficient and provide greater wattage, enable customers to upgrade with relative ease and low cost. There needs to be a clear distinction drawn between 'functional obsolescence', whereby new technology makes an older, but functioning, product seem outmoded, and actual end of life whereby the product no longer functions at all. • Engaging consumers and providing information regarding ways to increase longevity, pay for disposal, as well as environmentally responsible ways of disposal could encourage shifts in consumer attitudes and behaviour.
	National coverage and equitable access for all	Any new scheme would need to consider options for regional areas. Currently many Product Stewardship Schemes are developed mainly to service densely populated urban areas, with only limited regional coverage. Transport costs play a significant role in determining the economic feasibility and potential environmental impacts of PV recycling. Australia's large, sparsely populated land

Key Principles for Effective Product Stewardship for Management of Photovoltaic (PV) Stewardship		
		area, high freight costs and vast distances need to be taken into account in any consideration of adapting European modelling to the Australian context.
Scheme Design	Evidence based	There is a need to adopt a systemic approach to managing PV waste that is cognisant of the complexity of this particular waste stream and the varied waste mobility flows/after-lives that occur, whilst understanding the particular behavioural drivers underpinning consumption (installation) of ever-increasing volumes of solar PV panels. In particular, reviewing the locations where PVs are installed and their projected life. This will assist in ensuring the national coverage and equitable access.
	National Product Stewardship legislation should be used	The Federal Government has directed industry that a national Product Stewardship Scheme to manage solar PV and battery storage, to be implemented in the 2022/23 financial year.
	Timely action and industry cooperation	The need for a collaborative approach by industry and government in managing PV waste is paramount. For example, co-funding research into reuse options and effective disposal of PV panels, designing panels for disassembly and recovery whilst also manufacturing panels with less contaminants, are all ways that would contribute towards reducing future PV waste.
	Product Stewardship Schemes should be demand based and aim to recover the maximum amount of material possible, rather than being limited by targets	Targets work to drive recovery rates; however, they can become a problem if they are easily exceeded or only applied nationally (as with the TV and Computer Scheme). Local Government, as a service provider, cannot turn the community away if a national target has been reached: they keep taking the material and pay the costs associated. Schemes need to ensure they are collecting enough funds to cover costs of all products being collected. Budgets can be managed by staged implementation and approaches to communication. For PVs, given they have a relatively long use time an annual target may not be effective to drive recovery, instead in the first instance the Scheme could focus on widespread access to recycling options.
	Product Stewardship Schemes should focus on 'no cost' at end-of-life options for consumers or provide incentives for recovery	The consumer should not be charged to dispose of a product, this price should be built into the purchase price of the product and be enough to ensure legacy products can also be recovered. Implementation of existing Schemes has clearly shown that the community do not, generally, want to pay for recycling costs at end of life.