PV Systems Stewardship Options Assessment Second Phase

Stage Eight – Final Report

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29 March 2019

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1 Introduction

Equilibrium, in partnership with Ernst and Young (EY), was engaged by Sustainability Victoria (SV) and the national photovoltaics stewardship working group, in June 2018 to assess options to progress a national product stewardship approach, through stakeholder identification, consultation and a feasibility assessment for photovoltaic (PV) systems, including panels, associated inverter equipment and energy storage systems (ESS) reaching end-of-life in Australia.

The assessment was informed by stakeholder mapping and stakeholder consultation specifically conducted for this project. It was also informed by a multi-criteria analysis based on the consultation as well as research into existing stewardship studies and data on PV systems and ESS. The research included a review of existing publications relating to PV panels, system inverter equipment and ESS with respect to the current market conditions and capacity as well as lifecycle impacts to the environment and human health and the type of materials expected to be generated at end-of-life systems.

The purpose of this report is to summarise the finding and outcomes of the options assessment for any preferred product scope and stewardship pathway, as well as present the stakeholder engagement and risk management plans that accompanied the analysis for the purpose of implementing a national system of shared responsibility for end-of-life PV products.

1.1 Scope of the assessment and analysis

The assessment considered a number of products being:

- PV panels
- PV system inverter equipment
- PV-connected ESS
- Non-PV grid connected ESS
- Non-PV ESS (vehicles)
- Non-PV ESS other

In analysing the potential options, a number of classes of products, both individually and collectively were considered as well as products that could be grouped as follows:

- All PV system components connected (PV panels, PV inverter equipment and PV ESS equipment);
- PV panels and PV ESS equipment that are connected;
- PV panels and PV inverter equipment connected systems and standalone ESS (regardless of application);
- Standalone PV panels, standalone PV inverter equipment and standalone ESS (regardless of application) components.

In assessing potential implications to product stewardship, voluntary (with or without ACCC accreditation), co-regulatory or mandatory approaches consistent with the Product Stewardship Act 2011 (the Act), were assessed alongside a business as usual (BAU) approach to managing end-of-life waste materials.

It should be noted that in assessing the options, consideration was given to the activities of the Queensland State Government and the appointed independent body, the Battery Stewardship Council (BSC) in proposing either the establishment of an industry led scheme authorised by the Australian Competition & Consumer Commission or a co-regulated or mandatory scheme under the National Television and Computer Recycling Scheme which could potentially include ESS.

2 Background

SV commissioned a Victorian-based e-waste market flow and technology trends analysis in 2015, to inform an effective approach to manage e-waste ahead of the forthcoming e-waste landfill ban. The analysis identified PV panels as the most rapidly growing e-waste stream in future years, largely due to the recent boom in the installation of PV systems over the last 10 years.

With PV panels identified as an emerging e-waste stream with a lack of local reprocessing options, and as a result of the priority product listing for PV systems, on 25 November 2016 the Victorian Government sought and received endorsement through the Meeting of Environment Ministers to convene a multi-jurisdictional working group to work with the PV sector and develop a national product stewardship approach for PV systems. Currently, low volumes of PV system components entering Australia's waste stream present minimal impacts to jurisdictions and Local Governments. However, as this waste stream grows there is a concern from industry and Government that there are insufficient management options to safely dispose of end-of-life PV system components across Australia and a lack of established reprocessors and recyclers capable of recovering valuable resources.

The purpose of the project was to inform the PV working group, led by SV (on behalf of the Victorian Government), consisting of multi-jurisdictional representation from all state and territories in Australia to enable consideration of options for any preferred product scope and stewardship pathway.

A copy of the project plan has been included as Appendix A.

2.1 Approach and methodology

The project was undertaken in eight stages as follows:

- Stage One – Preparation of a project plan
- Stage Two – Stakeholder mapping & consultation
- Stage Three (A) and (B) Options feasibility study - Draft and final reports
- Stage Five – Stakeholder engagement plan development
- Stage Six – Risk management plan development
- Stage Seven and Eight - Draft and final project reports (this report)

Following the completion of Stage One Equilibrium undertook a stakeholder mapping exercise based on research into a number of various industry groups as well as industry players (stakeholders) and other cohorts. Initially Equilibrium identified 500 organisations across the 23 stakeholder groups identified by SV.

This was further developed into a summary of stakeholder group / cohort and specific contact details for each individual stakeholder / organisation for further analysis and review including presentation of the identified contacts to SV and the PV Working group for input and refinement.

Each stakeholder group was mapped according to their industry/sector or main areas of interest/business in order to engage and understand specific stakeholder opinions and views as well as gain industry knowledge to assist with identifying a preferred product scope and stewardship pathway.

Key industry groups including the Clean Energy Council (CEC) and Australian Photovoltaic Institute (APVI) were contacted to test the coverage of identified stakeholders and provide feedback into the engagement program.

In order to inform the program SV and Equilibrium developed several tailored and grouped questionnaires' relevant to the stakeholders and their industry/sector or main areas of interest/business and used this to conduct direct on-on-one interviews with key stakeholders.

In addition to the interviews Equilibrium/SV also presented to and participated in a number of industry stakeholder meetings including the CEC's Energy Storage Systems Directorate meeting and the Utility PV Directorate meeting both held in June and July 2018, respectively and the Australian Battery Recycling Initiative, Energy Storage Working Group meeting held in August 2018.

In addition to the stakeholder consultation program, Equilibrium also undertook desktop research including a review of existing publications relating to PV panels, system inverter equipment and energy storage systems with respect to the current market conditions and capacity as well as lifecycle impacts to the environment and human health and the type of materials expected to be generated at end-of-life systems.

The findings of the stakeholder engagement program and research was used to inform a multicriteria analysis of potential options with respect to most feasible scope of materials for further consideration under a product stewardship approach

The model was developed using a number of product aspects and impacts based on a series of activities relating to opportunities that would result from coordinated management of end-of-life to PV panels, system inverter equipment and energy storage systems.

Aspects are the activities related to product stewardship approaches that can change environmental or human health outcomes. Impacts are the likely level of change to the aspect that may happen or result from a product stewardship approach.

Each aspect was allocated a ranking from negligible/not applicable (1) through to high (4) and extreme (5) with respect to the potential impacts relating to the following opportunities / activities:

- Volume of material,
- Source of material,
- Removal process,
- End-of-life management, and
- Recovery and recycling impacts.

The opportunities identified through the research and engagement phase were assessed against the following categories:

- Materials and waste,
- Community,

- Health and safety,
- Environment,
- Economic and financial, and
- Legal and regulatory opportunities

3 Options feasibility study findings

A copy of the Options Feasibility Study report is presented in Appendix B.

In summary, it was found through the consultation and existing research that all of the products assessed are experiencing increased market uptake, albeit at different rates. Therefore, enhanced approaches to the end-of-life management of all of the products assessed will, at some point, have a potential benefit to the entire industry, Government and the community.

The current volumes, location, life span, composition and disposal pathways of the different products and product applications are also different. The level of detailed knowledge by product on these factors also varies. These factors also influence the current potential strengths and weaknesses for product stewardship approaches to be beneficial.

The multi-criteria analysis tested and identified a set of opportunities against each PV system component category selected for this study and ranked in accordance of the likely potential for product stewardship approaches to have an impact on that product. The results showed overall that PV panels, followed by PV inverter equipment calculated the highest scores as a result of favorable volumes likely to be generated at end-of-life and are therefore amenable to intervention.

With respect to the generation of PV panels and PV inverter equipment waste, community expectations along with economic and financial benefits received the next highest score. Overall, PV panels were assessed to benefit the most from a product stewardship approach, given they will be generated in large amounts, with currently little to no recycling. The opportunity to achieve overall high resource recovery rates was seen as being beneficial to any product stewardship scheme with respect to dealing with end-of-life products.

With respect to PV inverter equipment there is generally existing capacity and capability to recycle these materials. Therefore, these may not be presented in large volumes through a scheme. E-waste recyclers report that they currently can and do receive and process such equipment, because the equipment is made up of materials that are largely consistent with and very common to that found in a wide range of other electronic and electrical products and equipment that currently goes to e-waste recyclers. Given that the current recycling markets are incentivised to recover these products due to the high value and demand of inverter componentry, Government intervention for these products is unlikely to be required.

PV inverter equipment received a lower health and safety and environmental scores as there was less concern due to current collection and processing capacity in Australia. The economic and financial implications were also ranked lower as the value of the materials is currently covered by existing approaches mentioned above.

PV ESS and Non-PV ESS – grid where relatively similar to Non-PV ESS – vehicle receiving the lowest overall score due to lower concern with the opportunities for the current recovery and recycling of non-PV ESS given the relatively new introduction of these systems into Australia. However, it was identified that there would be more regulatory concerns given the size of the

systems and without a scheme the potential for illegal stockpiling, dismantling or disposal of the relatively large systems when compared with PV-ESS.

ESS in vehicles are being managed through manufacturer and repair organisations. Therefore, non-PV ESS – vehicle equipment currently has an established network of end-of-life collection. Although, the consultation revealed that most of the products are being exported for processing, recovery and recycling by individual manufacturers.

Although it was originally stated in the Stage Three (B) – Options Feasibility Study Final Report that PV-connected ESS will be included and accounted for in the next phase of the plan it is recommended that it be removed at this stage as PV-connected ESS is being considered for stewardship action under the Battery Stewardship Council (BSC) proposal, together with handheld batteries.

However, PV-connected ESS may potentially be included as part of future assessments should the BSC-led model not proceed or have its scope reduced.

4 Outcomes of the options assessment

In summary, product stewardship can have significant benefits with respect to end-of-life management of PV products and may achieve a number of outcomes, including:

- Increased resource recovery and recycling of end-of-life materials due to increased industry research and development and greater processing capacities under a scheme
- Increased valuable and critical material recovery (particularly for the rare and more valuable materials currently present in end-of-life PV panels and PV system inverter equipment)
- Reduced uncontrolled disposal of PV products
- Support for Australians to responsibly manage end-of-life products banned from landfill disposal

The options feasibility study found that a voluntary or co-regulatory approach for PV panels, system equipment and PV-connected ESS is feasible. Either a voluntary or co-regulatory approach is likely to achieve the objectives of the Product Stewardship Act 2011 and improve management of materials and enhance resource recovery.

With respect to a voluntary approach, the current absence of natural or obvious industry leaders to drive development suggests that a voluntary approach may be problematic, but if possible, would nonetheless be likely to achieve the objectives of the Act.

Government stakeholders consulted for the feasibility study expect that a co-regulatory approach is more likely to be achievable in the short-to-medium term and to deliver outcomes more consistent with the objectives of the Act, it is considered more feasible to actively consider development of a co-regulatory product stewardship approach. Please note, the Queensland State Government and Australian Government Department of Environment and Energy did not provide a view on which management approach would be most suited for PV systems at the time of this consultation.

There is no indication that a mandatory approach in accordance with the Act is feasible.

While the options feasibility study found that a voluntary or co-regulatory approach for PV panels, system equipment and PV-connected ESS is feasible, for completeness of the stakeholder

engagement and risk management plan it is noted that for reasons outside of these current considerations there may be contemplation of a mandatory scheme for product stewardship.

If that were the case it is assumed that stakeholder engagement and risk management activities would become the domain of the regulatory body, being the Australian Government Department of Environment and Energy under the Product Stewardship Act.

5 Stakeholder engagement plan

A copy of the Stakeholder Engagement Plan is provided in Appendix C.

The stakeholder engagement plan was developed as part of the overall project to guide continued engagement with key stakeholders for the on-going progress of potential product stewardship options for end-of-life management of PV panels and PV system inverter equipment.

It is intended to support on-going engagement with key affected stakeholders prior to any detailed economic and regulatory analysis in mid-2020, and once the final product scope has been agreed and endorsed through the Meeting of Environment Ministers process in late 2019.

The plan contains key engagement messages, as well as an expanded review of the stakeholder mapping undertaken during Stage Two of the project, to include an assessment, by stakeholder considering the following aspects:

- Influence the stakeholder potentially has on any scheme
- How the stakeholder may be affected by any scheme
- Potential incentives for participation

As part of the plan a stakeholder register was developed to:

- Identify stakeholders at the individual organisation level
- Identify current contacts at each organisation (and their contact details)
- Map/track the organisations' interaction with SV and the PV Working Group

5.1 Stakeholder matrix

Stakeholders were assessed using a matrix to determine what the best strategic approach to engage with each stakeholder would be.

For SV and the PV Working Group it is appropriate to consider stakeholders in terms of the involvement they may have and the influence they may exert in respect to any scheme that may eventuate. This will enable SV and the PV Working Group to determine where each stakeholder currently sits and what strategy needs to be employed.

Based the strategic approach to engagement an activity register and evaluation and reporting program incorporating indicators, metrics and measurements was developed to support the engagement activities.

6 Risk management plan

A copy of the Risk Management Plan is provided in Appendix D

The purpose of the risk management plan is to provide a framework for identifying, managing, monitoring, reviewing, reporting and communicating project risks (i.e. during the assessment of options).

The risk management plan covers the activities relating to the development of a scheme, whether it is a voluntary or voluntary with ACCC authorisation, a co-regulatory approach or mandatory approach to manage PV panels and system equipment.

When considering the risks, a business as usual approach (where there is no scheme in place and any recovered materials may or may not be managed through existing recycling networks) was used as the basis to identify scheme risks.

For the purpose of the risk management plan, project risks were defined as uncertainties, liabilities or problems that may cause the project to deviate unacceptably from the preferred approach or defined plan.

Activities that were covered and grouped into risk categories were as follows:

1. Management - The overall management and support for the project including leadership, capacity, capability and product stewardship experience.
2. Participation -The participation of key decision makers including the PV Working Group members and other interested parties, including the ability to form consensus on the options assessment.
3. Stakeholder involvement - The involvement of other key stakeholders including their interest, views on scheme design, adequate representation and contribution to the next phase of the approach (i.e. design of the scheme).
4. Industry - PV and PV system industries (manufacturing, suppliers etc.) and the resource recovery sector and factors and influences outside of the influence of the PV Working Group.
5. Regulatory environment - Changes in rules, and laws or regulations that could directly impact on options assessment.
6. Technology environment - Technological changes in components and materials proposed to be covered under the scheme.
7. Situational - Other competing factors outside of the influence of the PV Working Group.
8. Financial - Funding relating to financing the next stages of scheme design.
9. Environmental - Options assessment to consider all environmental impacts.
10. Health and safety - Options assessment to consider all health and safety impacts.

The assessment of the project risks was undertaken based on Sustainability Victoria's internally adopted risk assessment framework as well as considering the approach undertaken within the

voluntary product stewardship financial viability assessment guide (Department of the Environment and Energy, 2018) [1].

6.1 Risk register

A risk register was developed based on an assessment of project risks (i.e. uncertainties, liabilities or problems that may cause the project to deviate unacceptably from the preferred approach or defined plan) against each of the risk categories. The risks were further broken to assess business as usual, voluntary or voluntary with ACCC authorisation, a co-regulatory or mandatory approach to managing:

- all product categories,
- panels and inverters,
- panels and ESS and,
- panels only.

A copy of the risk register has been included as part of the risk management plan.

[1] https://www.environment.gov.au/system/files/resources/e121805f-1d1e-435d-b98f-45e789e2f354/files/vps-financial-viability-assessment-guide.pdf

PV Systems Stewardship Options Assessment First Phase

Stage Three (B) – Options Feasibility Study Final Report

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November 2018

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Tables and Figures

Executive Summary

This report documents an assessment of the feasibility of options to potentially progress product stewardship approaches for photovoltaic panels, associated equipment and energy storage systems.

For this study and report the products assessed are:

- Photovoltaic (PV) panels
- PV system inverter equipment
- PV-connected energy storage systems (ESS)
- Non-PV grid connected ESS
- Non-PV ESS (vehicles)
- Non-PV ESS other

The study assesses the feasibility of product stewardship options for the above class of products both individually and collectively. In accordance with the project scope consideration was also given to the products grouped by:

- All PV system components connected (PV panels, PV inverter equipment and PV ESS equipment);
- PV panels and PV ESS equipment that are connected;
- PV panels and PV inverter equipment connected systems and standalone ESS (regardless of application);
- Standalone PV panels, standalone PV inverter equipment and standalone ESS (regardless of application) components.

The last two bullet points are consistent with whole-of-system approaches being contemplated under some State policies and regulations. In particular, the Queensland State Government and the appointed independent body, the Battery Stewardship Council (BSC) is proposing either the establishment of an industry led scheme authorised by the Australian Competition & Consumer Commission or a co-regulated or mandatory scheme under the National Television and Computer Recycling Scheme. BSC has expressed interest in including ESS under the scheme umbrella, where there are potential linkages and/or leverage points relating to scheme design or scope, collection channels, marketing and reporting and other tools such as tracking and auditing programs The BSC has also expressed interest in including all batteries under the scope which could include ESS within large storage or Bulk Energy Storage Systems (BESS).

The assessment is informed by stakeholder mapping and stakeholder consultation specifically conducted for this project. It is also informed by a multi-criteria analysis that is based on the consultation as well as existing stewardship studies and data on PV systems and ESS.

Product stewardship

For the purposes of this study and report, product stewardship is considered in a manner consistent with the Product Stewardship Act 2011 (the Act).

It is noted that the objects of the Act include to reduce the impacts products have on the environment throughout the product lives. The Act seeks to achieve this through eliminating, avoiding and managing products and waste from products and ensuring re-use, recycling, recovery and safe disposal.[2]

Observations

Consultation and existing research indicate that all of the products assessed are experiencing increased market uptake, albeit at different rates. Therefore, enhanced approaches to the end-of-life management of all of the products assessed will, at some point, have a potential benefit to the entire industry, Government and the community

However, the current volumes, location, life span, composition and disposal pathways of the different products and product applications are of course also different. The level of detailed knowledge by product on these factors also varies. These factors also influence the current potential strengths and weaknesses for product stewardship approaches to be beneficial.

PV panels and associated PV system inverter equipment has experienced and continues to experience greater market uptake than the other products assessed. PV panels have been subject to recent studies and likely waste arising is well understood.

Uptake of ESS, whether PV-connected or not, is currently at a lower rate to PV panels and system equipment. Industry groups, such as the Clean Energy Council (CEC) and the Australian Photovoltaic Institute (APVI) reported that in the current financial year about 20% of domestic PV installations are expected to include an installed ESS.

While ESS has a higher risk profile with respect to potential environmental and health related impacts at the point of disposal due to the different chemistry profiles (particularly with respect to the inclusion of heavy metals) and current lack of processing/recovery practices in Australia, in some streams ESS are already managed by brand owners or manufacturers at end-of-life (particularly with respect to vehicle ESS in order to protect the technology) and a product stewardship approach to potentially manage all ESS is under active development.

With respect to batteries more broadly, the Queensland State Government and their appointed independent body, the BSC, are progressing a proposed stewardship scheme for batteries and the proposed scope is to cover all battery types, including what they term large storage or Bulk Energy Storage Systems (BESS).

The BSC has a current timeline for commencement of a battery scheme in mid-2019, either as a standalone scheme or in conjunction with other existing product stewardship schemes. The BSC notes in the Proposed Stewardship Scheme for Batteries members consultation draft that any final battery scheme will need to be mindful of and coordinated with other product stewardship approaches.

Lead acid batteries and Used Lead Acid batteries (ULABs) are currently generally well managed. This form of ESS is still commonly used as a PV-connected ESS as well as in large volumes in other applications. ULABs generally experience high recovery and recycling rates due to the inherent value in the constituent materials and mature take-back pathways exist in Australia.

[2] Product Stewardship Act 2011 Division 3 Part 4 (1). (2) and (3).

Government and industry stakeholders expressed a desire for a coordinated approach to managing PV panels and associated system equipment at end-of-life. They also reported that experience indicates domestic consumers are desirous for an easy to use and inexpensive environmentally-sound disposal pathway.

The same stakeholders expressed less uniform and clear support for product stewardship with the other classes of products assessed, namely non-PV grid connected ESS and non-PV ESS (vehicles) as these are currently generated at lower volumes and could potentially be incorporated into existing or standalone schemes.

Given the intention for BSC to establish of a national scheme for battery stewardship, there may other avenues to include ESS (regardless of application) into this scheme avoiding duplication, scope contamination and competing messages with respect to community communication and engagement programs.

With respect to the product class of non-PV ESS – other, this was examined however insufficient information was able to be gathered to make an assessment at this time.

Overall it was found that PV panels and inverter equipment present the most feasible scope of materials for further consideration under a product stewardship approach.

Summary of findings

The multi-criteria analysis tested an identified set of opportunities against each PV system component category selected for this study and ranked in accordance of the likely potential for product stewardship approaches to have an impact on that product.

The overall score that was used considered a normalised set of data as a result of a series of consistent questions relating to:

- Volume of material,
- Source of material,
- Removal process,
- End-of-life management, and
- Recovery and recycling impacts.

The multi-criteria analysis showed overall that PV panels, followed by PV inverter equipment calculated the highest scores as a result of favorable volumes likely to be generated, sources are likely to realised and removal process amenable to intervention.

With respect to PV panels and PV inverter equipment material and waste and community expectations were received the highest scores along with economic and financial benefits likely to be realised through a product stewardship scheme as there will be significant panels and associated equipment reaching end of life. The opportunity to achieve high resource recovery rates were also seen as beneficial to any product stewardship scheme as well ass community expectations with respect to dealing with end-of-life products.

PV inverter equipment scored the highest with respect to the volume of material, however, there is generally existing capacity and capability to recycle these materials. E-waste recyclers report that they currently can and do receive and process such equipment, because the equipment is made up of materials that are largely consistent with and very common to that found in a wide range of

other electronic and electrical products and equipment that currently goes to e-waste recyclers. PV inverter equipment received a lower health and safety and environmental scores as there was less concern due to current collection and processing capacity in Australia. The economic and financial implications were also ranked lower as the value of the materials is currently covered by existing approaches mentioned above.

PV ESS and Non-PV ESS – grid where relatively similar to Non-PV ESS – vehicle receiving the lowest overall score due to lower concern with the opportunities for the current recovery and recycling of non-PV ESS given the relatively new introduction of these systems into Australia. However, it was identified that there would be more regulatory concerns given the size of the systems and without a scheme the potential for illegal stockpiling, dismantling or disposal of the relatively large systems when compared with PV-ESS.

ESS in vehicles are being managed through manufacturer and repair organisations. Therefore, non-PV ESS – vehicle equipment currently has an established network of end-of-life collection. Although, the consultation revealed that most of the products are being exported for processing, recovery and recycling by individual manufacturers.

These overall findings indicate that product stewardship can have significant benefits with respect to end-of-life management of PV panels and PV system inverter equipment.

This is primarily because:

- It is highly unlikely a coordinated and widespread approach to end-of-life management will happen in the absence of a product stewardship approach (whether it be a mandatory, co-regulatory or voluntary approach)
- The volume and composition of the products at end-of-life are of sufficient scale that the absence of more recovery and recycling will lead to a significant loss of resources
- There is wide spread desire and support for a nationally coordinated approach
- There is support for a co-regulatory approach rather than voluntary
- Capability and capacity for greater recovery and recycling is emerging
- State-based product landfill bans (e.g. Victoria) will have an impact on end-of-life management
- Some degree of regulatory certainty will underpin resource recovery investment and infrastructure thereby expanding local capacity and capability
- A mandatory stewardship option is unlikely to be pursued as the materials do not inherently present environmental or human health risks, nor present a resource recovery imperative, that may warrant mandatory intervention

The assessment has determined that at this time product stewardship may achieve a number of outcomes, including:

- Increased resource recovery and recycling of end-of-life materials due to increased industry research and development and greater processing capacities under a scheme
- Increased valuable and critical material recovery (particularly for the rare and more valuable materials currently present in end-of-life PV panels and PV system inverter equipment)
- Reduced uncontrolled disposal of PV panels and associated PV system equipment
- Support for Australians to responsibly manage end-of-life products banned from landfill disposal

Government stakeholders emphasised that, in their view, regulators and consumers do not differentiate expectations for the recovery and recycling outcomes of the various components of a PV system. Some expressed that consumers buy a whole system and therefore expect to be able to appropriately dispose of the whole system when needed and therefore expressed an expectation to see a product stewardship approach encompass PV panels, system equipment and PV-connected ESS.

Government stakeholders also emphasised that a voluntary product stewardship approach may have limitations due to the fragmented nature of the industry, fluctuating industry participants and wide spread domestic uptake. On this last point, Government stakeholders noted that there are reportedly high levels of penetration of PV systems and PV-connected ESS in rural and regional areas, and that a product stewardship approach should ensure equity of access across all geographical areas.

Government stakeholders expressed the view that circumstances suggest a co-regulatory product stewardship approach is needed to achieve the desired outcomes. These views included factors such as the diverse nature of the industry, the rapid turnover of companies in the industry potentially undermining voluntary approaches, the time that may be taken to develop a voluntary scheme and the experience to date of voluntary schemes with respect to ensuring wide-spread and equitable access.

There is no indication that a mandatory approach in accordance with the Act is feasible. Although the nature and composition of the products varies, and some may contain materials requiring appropriate handling to manage any environmental or human health risks, overall evidence and advice is that the products pose only a low environmental or human health risk and as such do not require mandated product stewardship.

Overall the study indicates a voluntary or co-regulatory approach for PV panels, system equipment and PV-connected ESS is feasible. Either approach is likely to achieve the objectives of the Act and improve any uncontrolled release of materials and enhance resource recovery.

Given this overall finding and that Government stakeholders in particular expect that a co-regulatory approach is more likely to be achievable in the short-to-medium term and to deliver outcomes more consistent with the objectives of the Act, it is more feasible to actively consider development of a co-regulatory product stewardship approach.

With respect to voluntary approach, the current absence of natural or obvious industry leaders to drive development suggests that a voluntary approach may not be achievable in a timely manner. Nonetheless, as stated, a voluntary or co-regulatory approach for PV panels, system equipment and PV-connected ESS is feasible and likely to achieve the objectives of the Act.

1 Introduction

PV panels, inverter equipment and energy storage systems are increasingly being purchased and deployed as an alternative to traditional means for energy generation.

PV is intended to be an environmentally beneficial technology through its life-cycle and in comparison, to other means for energy and electricity generation.

The life-cycle impacts of PV panels and associated systems includes the end-of-life management of the materials. That is, as PV equipment reaches the end of its useful life span the level of recovery, recycling, re-use and safe disposal is an important part of PV's environmentally beneficial performance.

End-of-life management is also important to protect the environment and human health from any negative impacts from the uncontrolled release of the materials that comprise PV systems and equipment (uncontrolled release may include disposal to landfill, stockpiling, inappropriate recycling and / or illegal dumping).

The amount of PV end-of-life material, or waste, is growing.

Globally the International Renewable Energy Agency estimates PV panels and associated equipment generated 6 – 7 million tonnes of waste in 2016, and that cumulatively that will rise to 55 – 70 million tonnes by 2050 [3].

In Australia, it has been identified that the increasing volumes of end-of-life PV system components and the lack of dedicated recycling capacity and capability warrants examination for potential intervention and management through product stewardship approaches. The Act establishes the Minister's Product List, which identifies products being considered for possible accreditation or regulation under the Act, and in 2016 the Minister for the Environment and Energy listed PV systems to be considered for stewardship arrangements under the Act.

PV panels and system components have an estimated average life span of approximately 7 to 35 years and end-of-life are expected to enter Australia's waste stream in significant volumes from around 2023, largely due to the recent boom in solar installations over the last 10 years.

In Victoria alone, it is estimated that by 2035 there will be 22,000 tonnes of PV panel waste requiring disposal [4]. On this basis, current estimates are that across Australia during 2018 approximately 6,000 tonnes of PV panels will require disposal, rising to about 100,000 tonnes in 2035.

With respect to PV system inverter equipment and ESS, these are also expected to increase significantly to 2035 driven by the increase in the amount of PV panel installations from about 2010

[3] INTERNATIONAL ENERGY AGENCY PHOTOVOLTAIC POWER SYSTEMS PROGRAM, End-of-Life Management of Photovoltaic Panels: Trends in PV Module Recycling Technologies, January 2018

[4] Randell Environmental Consulting, Victoria e-waste MFA: PV Panels and Systems, Part 1, 2015.

and also the amount of PV installations installed with ESS from about 2015. PV panels consumption grew strongly around 2010, reflecting the rapid uptake of rooftop solar panels under a previous federal government installation subsidy. ESS systems were assessed from the baseline year of 2015 when the Material Flow Analysis Report was prepared.

From approximately 2025 waste ESS tonnages increase more rapidly as the increasing battery installations that began around 2015 begin to enter the waste stream. This more rapid growth is driven by significant increases in the amount lithium-ion batteries entering the waste stream. Both lead acid batteries (LAB) and lithium-ion ESS are expected to dominate waste generation.

With respect to lithium-ion ESS, whether PV-connected or not, estimates are that at 2035 there could be over 4,000 tonnes of product reaching end-of-life in Victoria alone[5].

NiCd ESS are projected to be phased out of all PV ESS. The relatively small amount of NiCd tonnages is expected to peak around 2022 before NiCd battery tonnages begin to fall.

Current management

The current end-of-life management of PV panels, systems and ESS is ad hoc. That is, there are no coordinated programs on a significant geographical or national basis providing a dedicated pathway for the take-back, collection, consolidation and / or end-of-life management of the products.

Reports from stakeholders with respect to current management of the end-of-life materials are that:

- PV panel disposal to a recycler is considered expensive and cost-prohibitive
- A small amount of end-of-life PV panels is being disposed to recyclers and refurbishers (locally or domestically)
- PV panels and system equipment is being stockpiled and landfilled as there is limited processing and recycling capacity within Australia.
- PV system inverter equipment is being disposed of along with and in similar ways to the PV panels
- A small amount of PV system inverter equipment is being refurbished and redeployed
- Some companies are providing take-back of product, whether for refurbishment, recycling or disposal (and including PV system equipment going to general e-waste recyclers and PV panels going to metal recyclers for recovery of materials such as aluminium from frames)
- Current and changing policy and regulatory environments (such as the state-wide ban of e-waste from landfill in Victoria and the existing ban in South Australia) are generating industry activity / positioning for future scenarios

While current end-of-life management is ad hoc, government stakeholders did not report current concerns or urgent issues with respect to matters such as illegal dumping or stockpiling. However, it is noted that some jurisdictions are implementing new regulatory guidelines for the receival, storage and management of waste, including e-wastes, that will establish more stringent general standards and subsequent operator requirements.

[5] Randell, P. (2017) 'E-waste MFA: PV panels and systems, Randell Environmental Consulting.

Industry and government stakeholders indicated a growing expectation from consumers and the general community for more resource recovery and recycling of end-of-life product.

1.1 Background

Sustainability Victoria commissioned a Victorian-based e-waste market flow and technology trends analysis in 2015, to inform an effective approach to manage e-waste ahead of the forthcoming e-waste landfill ban. The analysis identified PV panels as the most rapidly growing e-waste stream in future years, largely due to the recent boom in the installation of PV systems over the last 10 years.

With PV panels identified as an emerging e-waste stream with a lack of local reprocessing options, and as a result of the priority product listing for PV systems, on 25 November 2016 the Victorian Government sought and received endorsement through the Meeting of Environment Ministers to convene a multi-jurisdictional working group to work with the PV sector and develop a national product stewardship approach for PV systems. Currently, low volumes of PV system components entering Australia's waste stream present minimal impacts to jurisdictions and Local Governments. However, as this waste stream grows there is a concern from industry and Government that there are insufficient management options to safely dispose of end-of-life PV system components across Australia and a lack of established reprocessors and recyclers capable of recovering valuable resources.

In order to further inform consideration of product stewardship approaches for end-of-life PV systems, Sustainability Victoria engaged Equilibrium (supported by EY) to complete this stakeholder identification, consultation and feasibility assessment.

The PV working group, led by SV, consists of multi-jurisdictional representation from all state and territories in Australia.

Endorsed on 25 November 2016, through the Meeting of Environment Ministers, the role of the working group is to work with the Australian PV sector to develop a national product stewardship approach for PV systems.

This study and report will inform the PV Working Group and consideration of options for any preferred product scope and stewardship pathway.

2 Scope

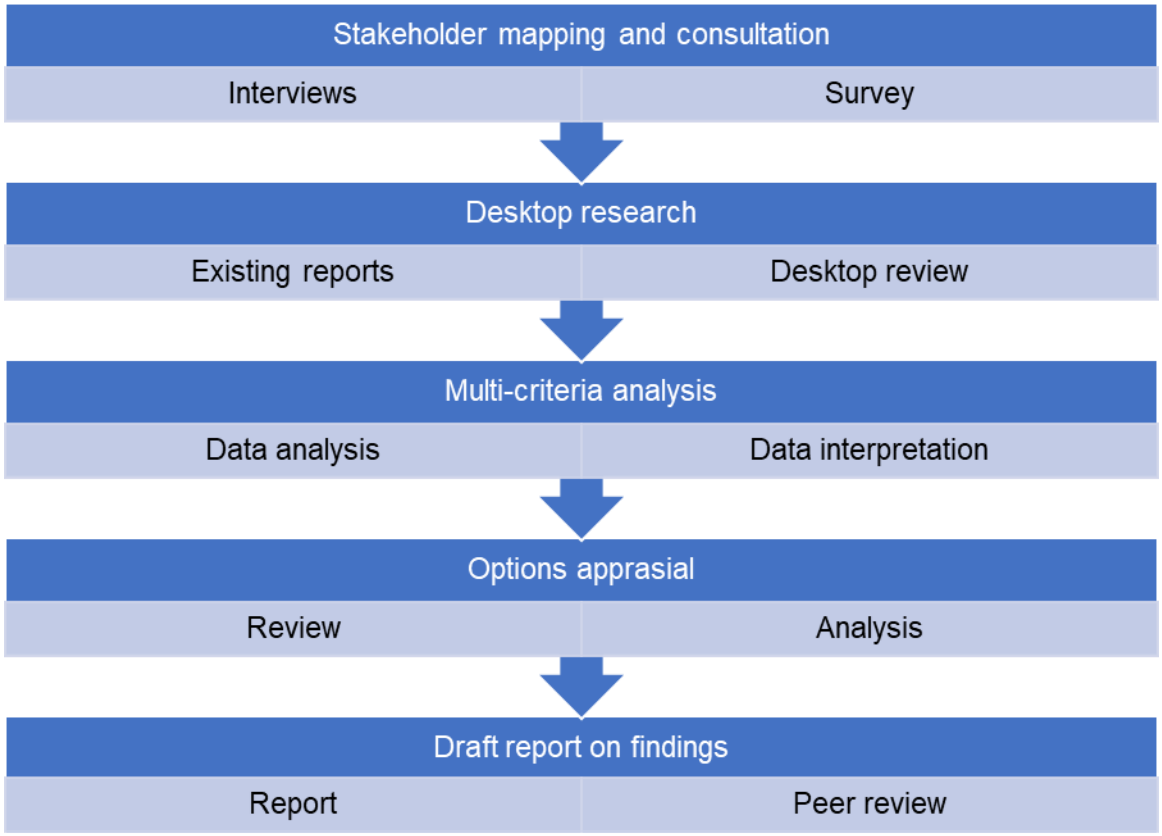
The modelling and assessment to inform this study document elements including, but not limited to, the following:

- Total amount of PV panels in Australian market
- Total amount of PV system components by type in the Australian market
- State and Territory breakdown of PV panels and PV system components in the market
- PV and PV systems market analysis and forecast
- Key developments in the type and content of PV panels and components and likely impact on waste arising
- International experience and approaches to PV systems product stewardship end-of-life management

- State and Territory legislative and regulatory issues for consideration
- State and Territory resource recovery sector capacity and capability across PV system components

3 Methodology

In summary the following flow chart shows the series of activities undertaken to inform the assessment:



3.1 Stage Two - Stakeholder mapping and consultation

Equilibrium undertook a stakeholder mapping exercise based on research into a number of various industry groups as well as industry players (stakeholders) and other cohorts. Initially Equilibrium identified 500 organisations across the 23 stakeholder groups identified in the RFQ by SV.

This was further developed into a summary of stakeholder group / cohort and specific contact details for each individual stakeholder / organisation for further analysis and review including presentation of the identified contacts to SV and the PV Working group for input and refinement.

Each stakeholder group was mapped according to their industry/sector or main areas of interest/business in accordance with the RFQ issued by SV as follows:

- Group A: PV Panels (suppliers, manufacturers and brand owners)
- Group B: PV Inverter Equipment (suppliers, manufacturers and brand owners)

- Group C: PV ESS Equipment (suppliers, manufacturers and brand owners)
- Group D: Non-PV ESS - Electric Vehicles / Electro-mechanical (suppliers, manufacturers and brand owners)
- Group E: Non-PV ESS - Grid Storage ESS (suppliers, manufacturers and brand owners)
- Group F: Non-PV ESS – Other (suppliers, manufacturers and brand owners)
- Group G: PV System Installation & Decommission
- Group H: End-of-Life PV System Component Recovery
- Group I: End-of-Life PV System Component Recycling
- Group J: End-of-Life PV System Component Refurbishment
- Group K: PV System Component Industry Groups & Associations
- Group L: Energy Sector - Energy Regulators
- Group M: Energy Sector - Distribution Network Service Providers
- Group N: Energy Sector - Electricity Retailers
- Group O: Government Agencies - Local, State, Federal
- Group P: Insurance Providers
- Group Q: Australian Industry Standards
- Group R: International Standards
- Group S: Local Accreditation Programs
- Group T: Emerging PV Equipment & Accessories
- Group U: Project Developers
- Group V: Construction Companies
- Group W: Other

Following this initial stakeholder research, several key industry groups including the Clean Energy Council (CEC) and Australian Photovoltaic Institute (APVI) were contacted to test the coverage of identified stakeholders and provide feedback into the list if it was felt that there more organisations should be added to the engagement program.

In order to gain industry knowledge and understand specific stakeholder opinions and views Equilibrium undertook to conduct direct on-on-one interviews with key stakeholders to guarantee coverage, capture granular information and, ultimately, build solid foundation to inform feasibility and on-going considerations.

In addition to the interviews Equilibrium/SV also presented to and participated in a number of industry stakeholder meetings including the CEC’s Energy Storage Systems Directorate meeting and the Utility PV Directorate meeting both held in June and July 2018, respectively and the Australian Battery Recycling Initiative, Energy Storage Working Group meeting held in August 2018.

In order to interview the stakeholders/cohorts Equilibrium developed several tailored questionnaires' relevant to the stakeholders and their industry/sector or main areas of interest/business.

Each targeted stakeholder was grouped as follows:

- Group 1 (Groups A to F above - suppliers, manufacturers and brand owners)
- Group 2 (Group G - PV System installation & decommission)
- Group 2a (Groups H to J above – System and component recovery, recycling and refurbishment)
- Group 4 (Groups K to N above - Energy regulators, distribution network service providers, electricity retailers)
- Group 5 (Group O - Government Agencies - Local, State, Federal)
- Group 6 (Groups P to V - Insurance providers, Australian and International standards, local accreditation programs, emerging PV equipment & accessories, project developers, construction companies)
- Group 7 (Group W – Other)

3.2 Research

The assessments made for this study were informed by desktop research combined with the stakeholder consultation and associated multi-criteria analysis.

Section 5 and Appendix 2 of this report contain detail of the multi-criteria analysis.

Together this has informed the feasibility and options assessment contained in Section 6.

With respect to the research, in order to supplement the findings from the stakeholder engagement program as well as inform the multicriteria analysis, Equilibrium completed desktop research including a review of existing publications relating to PV panels, system inverter equipment and energy storage systems with respect to the current market conditions and capacity as well as lifecycle impacts to the environment and human health and the type of materials expected to be generated at end-of-life systems.

A couple of data sources in particular are notable; the Victorian E-Waste Market Flow Analysis and the Clean Energy Regulator small-scale renewable energy installation data files. These reports provide detailed insights into uptake, use and potential lifecycle of PV panels and systems.

The Clean Energy Regulator data files provides detail of every registered small-scale installation across Australia by post code and installed capacity. The data, while of course not including large-scale installations, will be highly valuable in future consideration of potential product stewardship approaches.

A copy of the research and references used to inform the options analysis have been included in Appendix 1.

3.3 Multi-criteria analysis

The multi-criteria analysis model was developed to support the research and findings from the stakeholder engagement program.

The model was developed using a number of product aspects and impacts based on a number of activities relating to opportunities that would result from coordinated management of end-of-life to PV panels, system inverter equipment and energy storage systems.

Aspects are the activities related to product stewardship approaches that can change environmental or human health outcomes. Impacts are the likely level of change to the aspect that may happen or result from a product stewardship approach.

Each aspect was allocated a ranking from negligible/not applicable (1) through to high (4) and extreme (5) with respect to the potential impacts relating to the following opportunities / activities:

- Volume of material,
- Source of material,
- Removal process,
- End-of-life management, and
- Recovery and recycling impacts.

The analysis was aligned to the Department of the Environment and Energy Assessment Action and Escalation (AAE) Process (Draft for Consultation, 2018) with particular focus on the requirement that the issue must be confirmed as a product impact issue.

The opportunities identified through the research and engagement phase were assessed against the following categories:

- Materials and waste,
- Community,
- Health and safety,
- Environment,
- Economic and financial, and
- Legal and regulatory opportunities

The questionnaire also enabled stakeholders to provide input into a market preference, level of interest and general level of support for a product stewardship approach. This included elements such as whether the stakeholder had a preference for either an industry or Government (from voluntary through to co-regulatory and mandatory) managed approach.

Where there were gaps in the evidence then the scoring was determined on a case-by-case basis based on research and other industry intelligence.

The multi-criteria analysis model was used to determine an activity score based on a weighting (relative importance or priority) using the average score from the rankings applied to each category.

A copy of the impacts and aspects used to inform the model have been presented in Appendix 2 and the results of the analysis summarised in Section 5 below.

4 Option assessment results and findings

4.1 Consultation

Of the 23 stakeholder cohorts initially identified, Equilibrium prioritised the list by applying a number of principals including completeness, accuracy and reasonableness to ensure that sufficient data is gathered to be highly representative/provide sufficient coverage of the industry and ensure gathering of industry product data as well as the views/experience/context from key industry players.

This prioritised list was used to start the initial engagement process contacting organisations to organise a time to walk through the pre-developed questionnaires' relevant to each stakeholder group.

Each stakeholder was provided with a letter describing the program as well as a copy of the relevant questionnaire prior to the interview and a confidentiality agreement to protect the identity of the information if the organisation required this to be in place before the interview.

In summary the following number of organisations were identified and contacted from the initial representative list developed for the project.

Group	Number of contacts made	Number of interviews conducted
Group 1 (A-F)	55	22
Group 2 (G)	9	3
Group 2a (H - J)	6	2
Group 4 (K - N)	22	10
Group 5 (O)	12	11
Group 6 (P-V)	21	12
Group 7 (W)	2	2
Total	**127**	**62**

It is noted that for all stakeholder groups a number of representatives contacted declined to respond at all, in any detail or failed to deliver responses.

As the above table shows, it was common across all stakeholder groups that of those representatives contacted a number were unavailable or declined to participate. While some groups displayed a higher participation rate, there was no discernable pattern or underlying reason with respect to the participation rates per group.

The stakeholders that have been identified in the stakeholder mapping exercise nonetheless form a comprehensive snap shot across the 23 groups.

Pending consideration of options for a product stewardship approach, the next phase of the project will provide an opportunity to further leverage the stakeholder mapping and opportunities for further engagement with stakeholders.

In addition to the questionnaires developed for the one-on-one interviews Equilibrium also developed two surveys to both engage stakeholders into the program by expressing interest and

nominating a time to conduct the interview based on the type of information they could share to assist with the product stewardship options assessment as well as provide a more detailed response and feedback on product stewardship options in more detail.

Five expression of interest responses were collected from the on-line survey. Three detailed responses were collected from the more detailed survey, which were used to inform the options assessment.

4.2 Attitudes and Expectations

The stakeholder identification and consultation included capturing and assessing current attitudes and expectations towards product stewardship approaches for PV systems. This included questioning and discussing product stewardship approaches broadly as well as for each of the class of products and groupings of products being assessed.

This informs the feasibility assessment as up-to-date insight of key stakeholder thinking that may therefore influence the way a potential product stewardship approach may or may not be developed and may or may not achieve the outcomes and objectives product stewardship intend to achieve.

The consultation found that there are attitudes and expectations when it comes to PV panels, inverter equipment and ESS and what a product stewardship scheme should do.

A summary of these are presented as follows:

Stakeholder group	Finding	Issues for feasibility assessment
PV panel and / or equipment suppliers (Group A, B, C, D, E, F)	• End-of-life management increasingly expected by customers and for corporate responsibility • Just want a scheme – mixed views on whether voluntary or co-regulatory is preferred	• Supportive of increased coordination of collection and recycling • Supportive in general of a product stewardship approach • Indicated support for participation in a product stewardship approach • Need on-going engagement

Stakeholder group	Finding	Issues for feasibility assessment
PV installers (Group G)	• End-of-life management increasingly expected by customers and for corporate responsibility • Not familiar with detail of the Product Stewardship Act or detailed design and implementation of a product stewardship working • Just want a scheme in place • Look to brands / manufacturers and Government to manage, lean towards co-regulatory approach	• Supportive of a product stewardship approach • Supportive of an approach that covers free-riders and is no cost to installers • Need on-going engagement to understand design and implementation issues
PV-related industry group (Group K)	• Support intervention and a product stewardship approach • Mixed views on whether voluntary or co-regulatory a preferred approach • Want to ensure no free-riders and equity of access and participation • Industry-wide management	• Interested in input into design and implementation of a product stewardship approach
PV and e-waste recyclers (Group H, I, J)	• PV panel dismantling and recovery costs • Somebody must pay	• Input into scheme design

Stakeholder group	Finding	Issues for feasibility assessment
Government (Group O)	• Scheme needs to be mindful of consumer / household expectations • Whole of system management / disposal at end-of-life preferred • ESS part of whole system from consumer perspective, needs to be addressed by any approach • Regulatory options generally preferred over voluntary • Equity of access to product stewardship collection and support paramount • Funding via industry and users preferred	• Expressed preference that regulatory and co-regulatory options be fully investigated • Industry funded scheme

4.3 Capacity and capability

The current capacity and capability for the take-back and recovery of PV panels, system inverter equipment and ESS was assessed to explore how a future product stewardship scheme may be able to manage material arising; especially as end-of-life volumes start to significantly increase.

This part of the assessment was intended to identify current capacity and capability at a high-level.

Consultation with respect to capacity and capability generally found that:

- Dedicated PV system component recovery and recycling operations are in development in Australia at present with a number of recyclers undertaking research and development into processes and systems for effective dismantling and recovery of panel materials.
- There is no known dedicated PV panel recovery, dismantling and recycling provider operating on a commercial-scale in Australia at present.
- PV panels remain excluded from some jurisdiction's regulatory actions, such as e-waste bans, partly because there is a lack of domestic recycling capacity.
- Some general e-waste recovery, dismantling and recycling operators have trialed PV panel recovery and indicate that current operations do not enable cost-effective separation and recovery and that further investigations and trials are being considered.
- There is ad hoc refurbishment and redistribution of PV panels domestically and through export.
- Opportunities for consolidating and facilitating increased recovery and re-use or recycling may be linked to installation and removal regulations and industry standards. PV panel providers and installers note they currently are asked to manage end-of-life equipment and are active in seeking cost-effective recycling options.
- The cost and handling requirements for current disposal to recyclers is a barrier.

- Limited availability of and access to recyclers is a barrier.
- General e-waste recovery, dismantling and recycling operators are watching the space for opportunities and exploring options for participation.
- ESS as a whole product class is generally well catered for with respect to end-of-life recovery options as a number of companies across Australia accept end-of-life ESS.
- Companies that accept ESS for recycling include aggregators that may do some limited handling before sending the materials for recycling domestically or overseas.
- ESS recovery capacity is sufficient however blockages in collection, consolidation and transport exist and need to be addressed. Blockages include the diffuse application / location of materials, distances to recyclers and real or perceived limitations due to transport certification requirements.
- Acknowledge different chemistries in products and what different chemistries may mean for processing, particularly with respect to the value that could be extracted from the product and end-of-life.

The implications of the general findings for the feasibility assessment are determined to be:

- Capacity for PV panel recycling in Australia is developing.
- A number of recyclers report they are undertaking research and development into processes and systems for effective dismantling and recovery of panel materials as well as the expected volume of panels that will become available for recycling.
- Some degree of regulatory certainty will underpin resource recovery investment and infrastructure thereby expanding local capacity and capability
- PV panel dismantling is a specialised activity and general e-waste recyclers are generally not equipped to handle end-of-life PV panels.
- Material value in PV panels is low as laminated glass is the bulk of the product by weight and a low value commodity for recovery and recycling (and the value may decline as future design and production changes or reduces the materials in PV panels).
- End-of-life ESS management (whether PV-connected or from other sources) is well covered by general e-waste collections and recycling operators.
- Local dedicated ESS collection and recycling operators are operating and building capacity across all battery chemistries.
- E-waste recyclers can manage PV system inverter equipment as the product is made up of materials that are commonly found in other electronic and electrical equipment.

5 Multi-criteria analysis

The multi-criteria analysis (MCA) is informed by the information gathered in the consultation undertaken for this study and by existing published research and reports.

The MCA is fundamentally testing the key opportunities and the likely impact of product stewardship as an approach to address the “problem” of the different products.

The “problem”, as per the Act, is predominantly concerned with the end-of-life of life impacts of the products. Namely, whether the products have human health or environment impacts that can be mitigated by product stewardship, or whether there are resource recovery opportunities that can be enhanced by product stewardship.

As noted earlier, the MCA examined an identified set of “opportunities”. These are:

- Volume of material,
- Source of material,
- Removal process,
- End-of-life management, and
- Recovery and recycling impacts.

These opportunities were consistently examined for each PV system component category in order to rank the applicability of each product in relation product stewardship approaches.

The ranking determined for each product by each opportunity therefore presents an indication of the likely potential for product stewardship approaches to have an impact on that product in accordance with the identified categories.

Higher ranking indicates greater product stewardship potential

The higher the scoring, the greater the potential positive impact of a product stewardship approach.

Higher scoring indicates that the consultation and research has identified that given the values currently attributed to, involved with or inherent in that product, there is a higher potential for a product stewardship approach to be warranted.

For example, the opportunities related to the volume and source of a product influence whether the category of material and waste designates a potential for product stewardship. In this example, as the known volume of end-of-life materials is higher, a higher ranking is achieved. Likewise, a less concentrated and more diffuse source of the end-of-life materials achieves a higher ranking.

The ranking provides an indication of the potential impact of a product stewardship approach as well as an indication of the comparative impact of a product stewardship approach across the range of products.

Limitations of MCA

The MCA was developed taking into account the impacts and aspects across a number of opportunities for each product category.

The information used to inform the analysis was based on the research of available information as well as the stakeholder consultation phase which was limited to the number of interviews able to be conducted over the consultation period as well as the quality of the information that was received.

In some cases where there were gaps in the questionnaire answers, information from other sources (such as the research) was used to information the analysis. The information and therefore data are limited to what was able to be gathered during the consultation period and found through existing research and reports.

Findings by opportunity by product type

The following sections provide a breakdown of the opportunities identified by the multi-criteria analysis based on the sum of the rankings divided by the total number of questions, used to normalize the data across each of the identified opportunities.

5.1.1 PV panels

PV panels are the assembly of photovoltaic cells or other photovoltaic collector technology and ancillary parts intended to generate electrical power under sunlight. This does not include photovoltaic cells that is part of a consumer device for which it provides electricity to make the device function.

The significant consultation and research findings for PV panels are:

- Multiple key stakeholders operating in Australia noted they currently send PV panels overseas to be recycled, commonly to the country of original manufacturer. Where is it being sent, who is providing these services and what volumes are currently unknown.
- In Victoria alone, it is estimated that by 2035 there will be 22,000 tonnes of PV panel waste will reach end of life [6]. On this basis, current estimates are that across Australia during 2018 approximately 6,000 tonnes of PV panels will reach their end-of-life, rising to about 100,000 tonnes in 2035.
- Recycling modules instead of landfill disposal reduces the risk of health and safety to the community because of the increased control of hazardous materials and enhanced resource recovery[7]
- Stakeholders reported that early generation PV panels contained potentially hazardous materials such as cadmium and lead (with the level of potential hazard dependent on volumes, location and materials handling and management processes). However, it should be noted that these materials are contained in the system (unless damaged) and are therefore not available to be leached unless poor handling and disposal practices are employed.
- Stakeholders reported that subsequent and current generations of panels have very low or no potentially hazardous materials.

It is also noted that thin-film solar technology is under development and emerging. Such technology prints solar cells on PET plastic sheets affixed directly to surfaces and structures. The University of Newcastle was contacted for this study as they are currently conducting trials on end-of-life management of thin-film solar.

Based on the above findings, the MCA finds that PV panels have the highest opportunity. This relates to the volumes and sources of materials that are expected to be generated, with limited

[6] Randell Environmental Consulting, Victoria e-waste MFA: PV Panels and Systems, Part 1, 2015.

[7] Aman, M., Solangi, K., Hossain, M., Badarudin, A., Jamson, G., Mokhils, H., Bakar, A. and Kazi, S. (2015) 'A review of Safety, Health and Environmental (SHE) issues of solar energy system', Renewable and Sustainable Energy Reviews 41, pp. 1190-1204.

recycling (or end-of-life management) and increased stockpiling of panels a common issue with no clear separation and recycling industry present within Australia.

It was also acknowledged that there would be community expectations that PV systems would not be illegal dumped and therefore would not become a cost or more particularly that there could be a community expectation that end-of-life management practices be in place for PV panels.

Economically it was identified that a product stewardship approach is highly unlikely to be viable without significant subsidies or costs paid for by the, OEM's, importers or retailers or under a shared approach between one or more of the supply chains including consumers/community.

Stakeholders reported that the current collection and recycling cost per panel was significant compared to disposal to landfill and also compared to the current wholesale cost of a new panel.

The MCA finds that with respect to PV panels that of the five product types tested, PV panels have the greatest product stewardship potential impact. This does not factor in various panel types but is especially likely due to the overall volumes and diffuse distribution of PV panels in Australia.

As noted, however the value of the separate materials recovered from panels is generally considered to be low. While some high value metals and materials can be recovered, glass is low value and by weight comprises the bulk of recovered materials.

Stakeholders reported that downstream pathways for non-standard PV panels, such as thin film and other emerging technologies, is likely to be entirely different from standard PV panels and will present different management and handling issues that are as yet unidentified.

A summary of the normalised data is presented as follows:

Opportunity	Material and Waste	Community	Health and Safety	Environment	Economic and Financial	Legal and Regulatory	Score
1. Volume of Material	3.60	3.50	2.00	3.00	4.00	3.00	**19.10**
2. Source Material	3.60	3.50	2.00	3.00	4.00	3.00	**19.10**
3. Removal Process	3.30	3.00	3.00	3.00	3.50	2.30	**18.10**
4. Current End of Life Management	3.30	3.50	3.00	3.30	2.00	2.00	**17.10**
5. Current Recovery and Recycling	3.30	3.50	3.00	3.00	3.00	3.00	**18.80**
						Total	**92.20**

The scores were based on the total calculated sum out of a total maximum of 5 (highest score) divided by the number of questions to normalise the dataset.

5.1.2 PV system inverter equipment

PV equipment means the inverter, isolator and associated system accessories needed for domestic, commercial and industrial applications of a PV system.

Through the consultation, it was found that one stakeholder, a large international player whose products include PV equipment, takes back PV system inverter equipment in small- and large-scale installations in Australia, refurbishes it at overseas facilities and then redeploys the equipment up to five times.

The MCA finds that with respect to PV system inverter equipment that health safety concerns and reducing the export of systems provides the greatest opportunity to implement a scheme given the range of different materials, present in the components which differ widely depending on the age of the technology as well and by manufacturer. There is currently very limited tracking of the export of PV system inverter equipment which could lead to poor environmental practices at the import country as well limited environmentally sustainable end-of-life use and recycling of components.

E-waste is defined as a hazardous waste for the purposes of the Basel Convention. However, it should be noted that a country receiving e-waste is not necessarily bound by the definition of hazardous waste and they are free to decide whether it considers a specific waste to be “hazardous” in accordance with its national legislation.

Hazardous and other wastes are required to be managed in an environmentally sound manner or be disposed of in the country in which they were generated. In summary, International movements of wastes are only permitted if they do not endanger human health and the environment; are handled in an environmentally sound way, cannot be disposed of in an environmentally sound and efficient manner with the country who generated the waste; can be used as a raw material for recycling or recovery industries in the country of import; or if the transboundary movements in question are in accordance with other criteria decided by the parties.

Furthermore, there are limited standards and training available for the removal of PV system inverter equipment and currently little to no recycling, particularly with respect to the inverter technologies rather than the connections (such as wires etc.). The MCA finds that with respect to PV equipment that of the five product types tested, PV inverter equipment have the second highest product stewardship potential impact.

With respect to PV system inverter equipment and recycling, there is generally existing capacity and capability. This is evident as general e-waste recyclers report that they currently can and do receive and process such equipment. It is also because the equipment is made up of materials that are largely consistent with and very common to that found in a wide range of other electronic and electrical products and equipment that currently goes to e-waste recyclers.

A summary of the normalised data is presented as follows:

Opportunity	Material and Waste	Community	Health and Safety	Environment	Economic and Financial	Legal and Regulatory	Score
1. Volume of Material	3.3	3.5	4	3	3	3	19.8
2. Source Material	3.4	3.5	4	2	2	2	16.9
3. Removal Process	3	2.5	3	3	2.5	3	17
4. Current End of Life Management	3.1	3	3	3	2.5	2	16.6
5. Current Recovery and Recycling	3.6	4	3	2	2.5	2	17.1
						Total	**87.40**

5.1.3 PV ESS

PV ESS means photovoltaic energy storage systems that can store the energy produced by photovoltaic panels in a controlled manner.

The significant consultation and research findings for PV ESS are:

- The OECD found through a life cycle analysis of PV ESS for stand-alone PV systems, that the PV ESS's are responsible for most of the potential environmental impacts, due to their relatively short life span and their high valuable metal content.
- Consultation found that there are presently low volumes of ESS compared with PV panels in the Australian market.

One stakeholder operating in the Australian market reported an in-house recycling program that achieves a 100% recyclability for PV ESS products. The MCA finds that with respect to PV ESS again there are limited standards and training available for the removal of PV ESS and currently little to no recycling, particularly with respect to the battery technologies on a broad scale currently in Australia. Again, it is also acknowledged that there would be community expectations that PV systems would not be illegal dumped and therefore would not become a cost or more particularly that there could be a community expectation that end-of-life management practices be in place for PV ESS.

In an article published by Forbes [8] it was suggested that there is not the same level of high-value materials in lithium-ion batteries when compared to other ESS battery systems. It was also

[8] McMahon, J (2018) Innovation is making solar panels harder to recycle, Forbes.

observed that through manufacturing innovation, the high value materials such as cobalt are being minimised through redesign. Although a growing market, the level of infrastructure for recycling lithium-ion batteries is not currently available.

It was identified by Randell [9] that the variable and developing chemistry of ESS has impacts on the optimal recycling process to extract materials that can be effectively recovered. It was identified that the most significant is the phasing out of Cobalt and Nickel from lithium-ion batteries, making recycling less economically viable. Newer chemistries such as Lithium Iron Phosphate (LFP) do not contain Cobalt or Nickel and are therefore cheaper to manufacture, however, are also costlier to recycle as the returns on recovered metals are lower

The BSC, with support of the QLD Department of Environment and Science, have put forward a position paper nominating all battery chemistry types be included in the scope of a product stewardship approach, except some battery types which incentivise market driven solutions due to inherent value (such as Used Lead Acid Batteries) that may therefore be exempt from operational contributions, but may be included to contribute to overall program education and awareness.

The voluntary approach supports that there is an emergence of a variety of responses by local and state Government seeking to provide solutions and thus introducing regulatory frameworks that include landfill bans on all battery types (VIC), and collection of all battery types (e.g. WA, NSW, VIC, SA and numerous council collections).

It has also been identified that by leveraging existing Schemes to include battery collection will enable a maximum and immediate action to improve collection and sorting of batteries. These include stewardship arrangements (e.g. MobileMuster, NTCRS), large retail chains, ULAB collections, local Government resource recovery sites and the like which collectively have a national footprint involving thousands of collection points.

It should be noted that the NTCRS is the only co-regulatory scheme currently operating and that there are currently no fully mandatory product stewardship schemes in place under the Act.

A summary of the normalised data is presented as follows:

Opportunity	Material and Waste	Community	Health and Safety	Environment	Economic and Financial	Legal and Regulatory	Score
1. Volume of Material	3.4	3	3	2.3	2	2	15.7
2. Source Material	3.4	3	3	2.3	2	2	15.7
3. Removal Process	3	3.5	2.5	2	2	2	15

[9] Randell, P. Pickin, J. Latimer, G. (2015) 'Victorian E-waste Market Flow Analysis (MFA), Randell Environmental Consulting.

Opportunity	Material and Waste	Community	Health and Safety	Environment	Economic and Financial	Legal and Regulatory	Score
4. Current End of Life Management	2.7	3.5	2	2	3	2.3	15.5
5. Current Recovery and Recycling	2.7	3.5	2	2	2	2	14.2
						Total	**76.1**

5.1.4 Non-PV ESS – grid storage

Non-PV ESS – grid equipment is used to capture electrical energy produced on a large scale within an electrical power grid.

The MCA finds that with respect to non-PV ESS that there is lower concern with the opportunities for the current recovery and recycling of non-PV ESS given the relatively new introduction of these systems into Australia. Although it was identified that there would be more regulatory concerns given the size of the systems and without a scheme the potential for illegal stockpiling, dismantling or disposal of the relatively large systems when compared with PV-ESS.

With respect to investment in repair and maintenance as well as dismantling and recycling for non-PV ESS compared to PV-ESS, it is expected that the larger (non-PV ESS) systems would be more valuable and therefore more amenable to large scale operations. The volume of waste arising is expected to be as the research has suggested however given the size of large-scale systems it would be expected that different scaled industries, at least in the short term, could manage the different sized systems.

Of the five product types tested, that this product type was found to have the second lowest product stewardship potential impact.

A summary of the normalised data is presented as follows:

Opportunity	Material and Waste	Community	Health and Safety	Environment	Economic and Financial	Legal and Regulatory	Score
1. Volume of Material	2.6	2	2	2	3	2	13.6
2. Source Material	2.4	2	3	3	3	2.3	15.7
3. Removal Process	2.6	2	3	3	3	2.3	15.9
4. Current End of Life Management	2.6	2.5	3	3	2	2.3	15.4

Opportunity	Material and Waste	Community	Health and Safety	Environment	Economic and Financial	Legal and Regulatory	Score
5. Current Recovery and Recycling	2.4	3	3	2.7	2	2	15.1
						Total	**75.7**

5.1.5 Non-PV ESS – vehicle

Non-PV ESS vehicle systems are equipment that can store energy in a controlled manner within an electric vehicle.

Through the consultation, stakeholders reported ESS in vehicles are being managed through manufacturer and repair organisations. Therefore, non-PV ESS – vehicle equipment currently has an established network of end-of-life collection. Although, the consultation revealed that most of the products are being exported for processing, recovery and recycling by individual manufacturers

The MCA finds that with respect to non-PV ESS – vehicle systems that the highest opportunity relates to the interpreted capacity, cost, access/awareness and capability of the current arrangements manage end-of-life Non-PV vehicle ESS. However, through a scheme there may be an opportunity to realise localised recycling opportunities.

Of the five product types tested, non-PV ESS - vehicles equipment had the lowest product stewardship potential impact.

A summary of the normalised data is presented as follows:

Opportunity	Material and Waste	Community	Health and Safety	Environment	Economic and Financial	Legal and Regulatory	Score
1. Volume of Material	2.1	2.5	2	2	2	2	**12.6**
2. Source Material	2	2.5	2.5	2.7	2	2.7	**14.4**
3. Removal Process	2.3	2	2	2.3	2	2	**12.6**
4. Current End of Life Management	2	2	2	2	2	2	**12**
5. Current Recovery and Recycling	2.9	2	2	2.7	2	2	**13.6**
						Total	**65.20**

5.1.6 Non-PV ESS – other

For this study, non-PV ESS - other is ESS product that may be used in applications such as hydrogen storage, pumped-hydro storage and thermal storage.

Insufficient information was able to be gathered at this time to complete the MCA with respect to non-PV ESS - other.

5.2 Multi-criteria analysis summary

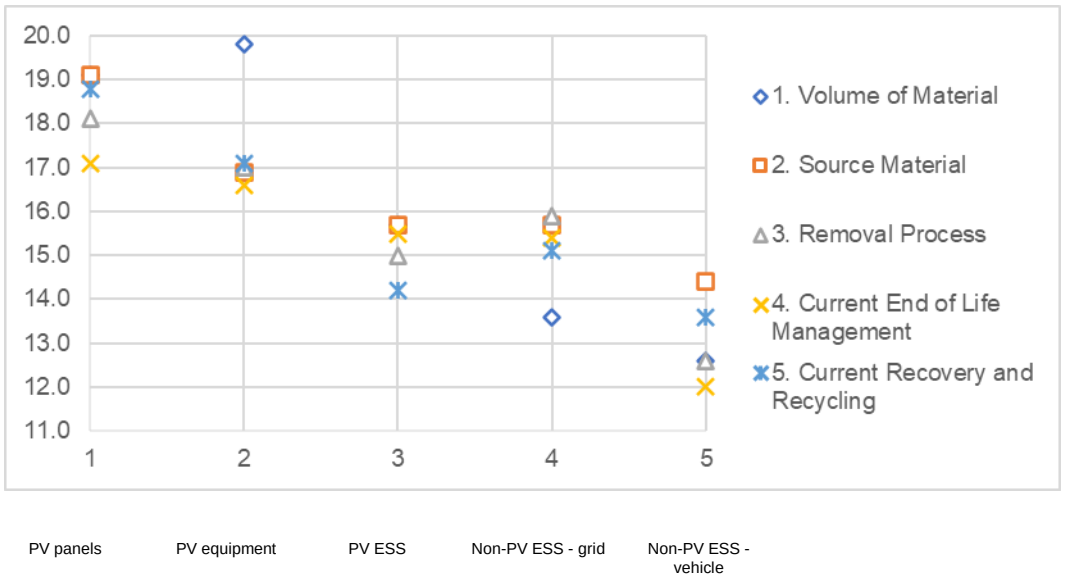
The following table presents the results of the multi-criteria analysis based on the normalised scores.

Table 1 – MCA summary results

Opportunities	PV panels	PV inverter equipment	PV ESS	Non-PV ESS - grid	Non-PV ESS - vehicle
1. Volume of Material	19.1	19.8	15.7	13.6	12.6
2. Source Material	19.1	16.9	15.7	15.7	14.4
3. Removal Process	18.1	17	15	15.9	12.6
4. Current End of Life Management	17.1	16.6	15.5	15.4	12
5. Current Recovery and Recycling	18.8	17.1	14.2	15.1	13.6
Total	**92.20**	**87.40**	**76.10**	**75.70**	**65.20**

The following chart shows graphically the spread of results relating to the multi-criteria analysis based on the ranking above.

Figure 1 – Graphical representation of the multi-criteria analysis



6 Options feasibility assessment

The likely impacts that different product stewardship approaches may have on the class of products are contingent on a number of factors. For this study and report it is considered that whether a proposed product stewardship approach is voluntary, co-regulatory or mandatory will have a different effect on the management of the different classes of products.

This review of likely impacts is also informed by the consultation undertaking for this study and existing research.

With respect to the different types of product stewardship approaches and likely associated impacts, the Act and its objectives are considered as the primary basis for a scheme and to guide the different types of schemes.

6.1 Voluntary approach

A voluntary approach is typified as industry being organized to establish processes for the end-of-life management of a class of products. A voluntary scheme that is aligned with the Act is one which is run by industry and is designed to further the objects of this Act. Voluntary schemes aligned with the Act may also seek to be accredited by the Australian Government which may also include being authorized to use the product stewardship logos in connection with any such schemes.

Australia currently has a number of voluntary schemes for products such as mobile phones (MobileMuster), mercury-containing lamps (FluoroCycle), paint (Paintback) and tyres (Tyre Stewardship Australia). Mobile Muster and FluoroCycle are currently accredited schemes under the Act.

6.2 Co-regulatory approach

A co-regulatory product stewardship scheme is one where manufacturers, importers, distributors and / or product users develop and manage a scheme but are subject to regulation if certain requirements are not met.

The scheme members (or liable parties) are specified in regulation and the scheme must have outcomes, specified in the regulations, that are designed to further the objects of the Act. The scheme must also take all reasonable steps to ensure the regulated outcomes are achieved.

The National Television and Computer Recycling Scheme is the only fully co-regulatory scheme under the Act.

6.3 Mandatory approach

A mandatory scheme is one where regulations require companies or people to take specified actions in relation to specific products. These requirements might include restricting the manufacture or import of products, prohibiting products from containing particular substances, labelling and packaging requirements and other requirements relating to reusing, recycling, recovering, treating or disposing of products.

6.4 Other regulation

It is noted that there is a range of other State and Territory regulation that may directly impact product stewardship approaches for the products being assessed. There are a range of programs in place around Australia that have the effect of incentivising the uptake of products such as electronic vehicles, PV panels (domestic or industrial) and energy storage systems (PV-connected or not, domestic or industrial).

Such regulation may or may not contemplate the end-of-life management of the product or products addressed or impacted by the regulations.

For this study and report, the real or likely effect of any other such regulations have not been assessed and are not considered in the findings.

6.5 Product stewardship options

The following presents the likely implications of a product stewardship approach by summarising the strengths or weaknesses for each class of product according to each different approach.

The summary is in accordance with the general performance objectives of product stewardship approaches consistent with the voluntary, co-regulatory or mandatory approaches as set out in the Act. Business as usual (BAU) is also presented.

Table 2 – Potential product stewardship implications

Potential Product Stewardship Implications								
Product	**Business and usual (BAU)**		**Voluntary**		**Co-regulatory**		**Mandatory**	
	Strengths	**Weaknesses**	**Strengths**	**Weaknesses**	**Strengths**	**Weaknesses**	**Strengths**	**Weaknesses**
PV panels	• Currently low end-of-life volumes • Potentially hazardous materials declining over time • Product scope banned from landfill disposal in Victoria •	• Increasing end-of-life volumes not managed • No coordinated and consistent approach • Cost-prohibitive recovery and recycling without financial subsidies or contributions • Loss of resources • Potentially hazardous if not controlled	• Growing volumes of materials • Industry engagement and expectation	• No obvious industry leader from product stewardship approach at present • No industry commitment at present • Coverage and access potentially limited • High-level of free-riders likely • Low-level disposal access likely • Companies no longer operating avoid responsibility • Highly fragmented stakeholder group	• Enforceable minimum standards for access • Enforceable minimum standards for participation / limit free-riders • Economy wide coverage • Generally favoured by some Government stakeholders	• Administrative and reporting costs potentially higher for all stakeholders	• Enforceable standards • Accountability and transparency • Economy wide coverage	• Best practice regulation threshold against regulatory impacts may not be met

Potential Product Stewardship Implications								
Product	**Business and usual (BAU)**		**Voluntary**		**Co-regulatory**		**Mandatory**	
	Strengths	**Weaknesses**	**Strengths**	**Weaknesses**	**Strengths**	**Weaknesses**	**Strengths**	**Weaknesses**
PV equipment	• Low risk materials • Potentially hazardous materials declining over time	• Lost resources • Increasing end-of-life volumes not managed • No coordinated and consistent approach	• Components similar to general e-waste • Potentially collected with PV panels • Australian e-waste recycling sector can effectively manage expected EoL volumes • Material component value incentivising recovery	• Industry coordination and leadership • No industry commitment at present • Coverage and access potentially limited • Free-riders • No obvious industry leader from product stewardship approach at present	• Enforceable minimum standards for access • Enforceable minimum standards for participation / limit free-riders • Economy wide coverage • Australian e-waste recycling sector can effectively manage expected EoL volumes • Material component value incentivising recovery • Generally favoured by some Government stakeholders	• Standalone approach may not be beneficial • May take longer to implement • Administrative and reporting costs potentially higher for all stakeholders	• Enforceable standards • Accountability and transparency • Economy wide coverage • Australian e-waste recycling sector can effectively manage expected EoL volumes • Material component value incentivising recovery	• Best practice regulation threshold

Potential Product Stewardship Implications								
Product	**Business and usual (BAU)**		**Voluntary**		**Co-regulatory**		**Mandatory**	
	Strengths	**Weaknesses**	**Strengths**	**Weaknesses**	**Strengths**	**Weaknesses**	**Strengths**	**Weaknesses**
PV connected ESS	• Low EoL volumes of product at present	• Volumes of product make increase rapidly • Product not able to be managed through general e-waste streams • Government interventions and incentives for uptake not support with EoL management programs, schemes or initiatives • Materials may be risk to environment and human health	• Linked to PV installations (especially domestic applications) • Valuable resource recovery	• No obvious industry leader from product stewardship approach at present • No industry commitment at present • Coverage and access potentially limited • Free-riders	• Enforceable minimum standards for access • Enforceable minimum standards for participation / limit free-riders • Economy wide coverage • Generally favoured by some Government stakeholders	• Standalone approach not warranted • May take longer to implement • Administrative and reporting costs potentially higher for all stakeholders	• Enforceable standards • Accountability and transparency • Economy wide coverage	• Best practice regulation threshold
Non-PV ESS - grid	• Low EoL volumes of product at present • Pathways available for some of the materials to be managed • Identifiable point of liability	• Volumes may increase rapidly • Materials may be risk to environment and human health	• Limited liable parties • Industry design and managed approach	• No obvious industry leader from product stewardship approach at present • No industry commitment at present • Coverage and access potentially limited • Free-riders	• Enforceable minimum standards for access • Enforceable minimum standards for participation / limit free-riders • Economy wide coverage	• Standalone approach not warranted • May take longer to implement • Administrative and reporting costs potentially higher for all stakeholders	• Enforceable standards • Accountability and transparency • Economy wide coverage	• Best practice regulation threshold

Potential Product Stewardship Implications								
Product	**Business and usual (BAU)**		**Voluntary**		**Co-regulatory**		**Mandatory**	
	Strengths	**Weaknesses**	**Strengths**	**Weaknesses**	**Strengths**	**Weaknesses**	**Strengths**	**Weaknesses**
Non-PV ESS - vehicle	• Product managed through vehicle manufacturers • Vehicle and general consumer law provisions	• Proprietary Approach • Uptake of electric vehicles	• Industry engagement and expectation • Industry design and managed approach	• Cohesive and coordinated industry • No industry interest or commitment • Coverage and access potentially limited • Cross-over with other battery stewardship approaches	• Enforceable minimum standards for access • Enforceable minimum standards for participation / limit free-riders • Economy wide coverage	• Requires • May take longer to implement • Administrative and reporting costs potentially higher for all stakeholders	• Enforceable standards • Accountability and transparency • Economy wide coverage	• Best practice regulation threshold

7 Findings

This study and report assessed the feasibility of options to potentially progress product stewardship approaches for photovoltaic panels, associated equipment and energy storage systems.

For this study and report the products assessed are:

- Photovoltaic (PV) panels
- PV system inverter equipment
- PV-connected energy storage systems (ESS)
- Non-PV grid connected ESS
- Non-PV ESS (vehicles)
- Non-PV ESS other

The information gathered for this study and that accessed through existing research and reports is generally more detailed and longer-term for PV panels than it is for any of the other products assessed.

The information from stakeholders and existing studies for PV system inverter equipment and PV connected ESS is less detailed than PV panel information, but nonetheless provides some detail about the current use and end-of-life management of these products.

Information regarding non-PV ESS grid connected and non-PV ESS vehicles is largely verbal from stakeholders and less certain in terms of current estimates of end-of-life management volumes and/or potential issues. Access may also be a factor due to the scale of the non-PV ESS grid connected and the current take-back activities that have emerged for non-PV ESS for vehicles.

Product stewardship is under active consideration as a means to improve the life cycle management of PV panels in Australia. Product stewardship is considered in a manner consistent with the Product Stewardship Act 2011 (the Act), and that the objectives of Act are to reduce the impacts products have on the environment throughout the product lives.

In practice the Act and existing product stewardship approaches in Australia, whether under the Act, other regulation or otherwise, are currently weighted towards the improved end-of-life management of products rather than broader lifecycle and upstream objectives. In this regard, product stewardship is currently weighted towards improved take-back, resource recovery and recycling of products in Australia.

The stakeholder input, information gathered, multi-criteria analysis and assessments undertaken for this study indicate that nationally coordinated product stewardship approaches can have a significant benefit on the end-of-life management of PV panels and system inverter equipment in Australia.

In particular the volumes of PV panels and the diffuse installation / use locations suggests resource recovery and disposal pathways will remain ad hoc without any intervention – whether regulatory or voluntary – that establishes a national, easy to access and coordinated approach. An ad hoc

approach will see the continued loss of resources. Given the nature of an installation of PV panels and information from stakeholders, system inverter equipment is assessed to follow a similar recovery pathway and trajectory in that those dismantling or recovery the equipment are often the same operator. The PV panel and system inverter equipment may or may not then follow different paths downstream as PV panels require specialised management materials whereas system equipment can also be managed through general e-waste operations.

It is feasible that PV panels and system equipment can be part of and can benefit from a combined product stewardship approach (i.e. a joint scheme incorporating PV panels and system equipment) primarily because:

- It is highly unlikely a coordinated and widespread approach to end-of-life management will happen in the absence of a product stewardship approach
- The volume and composition of the products at end-of-life are of sufficient scale that the absence of more recovery and recycling will lead to a loss of resources
- There is wide spread desire and support for a nationally coordinated approach
- Capability and capacity for greater recovery and recycling is emerging and pending regulation (i.e. landfill bans) for responsible end-of-life management may fast-track investments

The assessment has determined that at this time product stewardship for PV panels and system equipment may achieve a number of outcomes, including:

- Increased resource recovery and recycling of end-of-life materials due to increased industry research and development and greater processing capacities under a scheme
- Increased valuable and critical material recovery (particularly for the rare and more valuable materials currently present in end-of-life PV panels and PV system inverter equipment)
- Reduced uncontrolled disposal of PV panels and associated PV system equipment
- Support for Australians to responsibly manage end-of-life products banned from landfill disposal

The feasibility of a product stewardship approach for the other products assessed is less clear.

Information with respect to the classes of products non-PV ESS – grid and non-PV ESS vehicles suggest current volumes of end-of-life product are not known with a great deal of certainty, and that there are some existing coordinated pathways for the management of these products at end-of-life.

Information gathered with respect to the class of product non-PV ESS – other was insufficient to make an assessment at this time.

There are grounds to consider inclusion of PV-connected ESS in a product stewardship approach for PV panels and system inverter equipment. State-based approaches already contemplate this approach and inclusion, and stakeholders reported a view that consumers will expect ESS to be managed along with PV panels and system inverter equipment.

Stakeholders reported that they consider all products associated with a PV installation as a group of products.

Government stakeholders emphasised that, in their view, regulators and consumers do not differentiate expectations for the recovery and recycling outcomes of the various components of a PV system. Some stakeholders expressed that consumers buy a whole system and therefore expect to be able to appropriately dispose of the whole system when needed. Some expressed an expectation to see a product stewardship approach encompass PV panels, system equipment and PV-connected ESS.

Government stakeholders expressed the view that circumstances suggest a co-regulatory product stewardship approach is needed to achieve the desired outcomes. These views included factors such as the diverse nature of the industry, the rapid turnover of companies in the industry potentially undermining voluntary approaches, the time that may be taken to develop a voluntary scheme and the experience to date of voluntary schemes with respect to ensuring wide-spread and equitable access.

There is no indication that a mandatory approach in accordance with the Act is feasible. Although the nature and composition of the products varies and some may contain materials requiring appropriate handling to manage any environmental or human health risks, overall evidence and advice is that the products pose only a low environmental or human health risk and as such do not require mandated product stewardship.

Overall the study indicates a voluntary or co-regulatory approach for PV panels, system equipment and PV-connected ESS is feasible. Either approach is likely to achieve the objectives of the Act and improve any uncontrolled release of materials and enhance resource recovery.

Given this overall finding and that Government stakeholders in particular expect that a co-regulatory approach is more likely to be achievable in the short-to-medium term and to deliver outcomes more consistent with the objectives of the Act, it is more feasible to actively consider development of a co-regulatory product stewardship approach.

With respect to voluntary approach, the current absence of natural or obvious industry leaders to drive development suggests that a voluntary approach may not be achievable in a timely manner. Nonetheless, as stated, a voluntary or co-regulatory approach for PV panels, system equipment and PV-connected ESS is feasible and likely to achieve the objectives of the Act.

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Appendix 2– Multi-criteria analysis product impacts and aspects

Product Impacts and Aspects		Material and Waste						
		Material Occurrence of waste material (quantity)	**Hazardous material toxicity**	**Resource recovery / landfill diversion (%)**	**PV Industry practices and management - scale of separation and recycling components**	**Stockpiling of waste materials - scale of issues.**	**Overseas exports - amount exported (%)**	**End use of overseas exports - maturity of tracking system**
Ranking	**Points**	**The extent to which material is being generated.**	**Waste characterisation - level of toxic chemicals that have potential to cause harm to human health and the environment.**	**Waste industry practices and capability to recover/recycle materials. (Issues may include practices or lack of infrastructure in Australia)**	**PV Industry knowledge and systems for managing waste materials for recycling/disposal.**	**Amount of materials being stockpiled by waste industry and potential for environmental and OHS harm (e.g. fire, pollution).**	**Amount of material exported from Australia to other countries for re-use, re-furbishment, final treatment and disposal.**	**Downstream vendor regulations and management to ensure regulated and environmentally sound recycling and disposal of materials.**
Extreme	**5**	Large quantities / volumes across the nation. Will emerge as large and prevalent national issue in the next 2 to 3 years, with a high risk of continuing.	Extremely toxic - death and long term environmental harm	Less than 10% of materials are recovered for re-use.	National and widespread landfilling - no recycling	Stockpiling of materials is a common and widespread problem, with large quantities already stockpiled in jurisdictions across the nation.	Nearly 90% to 100% of materials are exported.	Minimal or no tracking / verification systems in place. High level concerns regarding use of end of life materials. National Issue.
High	**4**	Quantities generated of ongoing concern, or will become of major concern for a number of jurisdictions within the next 3 to 5 years.	Highly toxic - serious illness and long term environmental harm	Resource recovery rate 10% to 40%	Most industry participants do not separate for recycling, landfill all components. Issues are cross-jurisdictional.	Stockpiling an issue with most waste management companies, large stockpiles a known cross-jurisdictional issue.	50% to 90% of materials are exported.	Systems for tracking / verification have been developed, but not implemented. High potential for poor environmental practices.
Medium	**3**	Generation of material on a seasonal basis. May only present as an issue at certain times of the year. Could present in single state or territory. Likely to be an issue in the next 5 to 10 years.	Medium toxicity - illness and environmental harm (recoverable)	Resource recovery rate 40% to 80%	Some (<50%) industry participants do not separate for recycling, landfill all components). Issues are in single state/territory.	Stockpiling is an issue with some waste companies in single state/territory, with potential to become a large problem.	30% - 50% of materials are exported.	Systems for tracking / verification developed, partially implemented. Potential for poor environmental practices.
Low	**2**	Transient, only produced at times. Quantities and volumes not significant issue at this stage. Not likely to grow in size over the next 10 years. May only be a of regional or local concern.	Low toxicity - temporary health impacts (e.g. headache) and low level environment contamination.	Resource recovery rate 80% to 95%	Most industry participants separate and recycling components where possible. Issues of poor recovery may present in some local and regional areas only.	Some minor issues have occurred (eg regionally), however not a significant concern at this stage.	10% to 30% of materials are exported.	Systems for tracking and verification are well developed and fully implemented, low level of concern.
Negligible / Not Applicable	**1**	No significant quantities generated, or likely to be generated.	Negligible or no toxicity impacts.	Resource recovery rate >95%	All industry participants separate and recycling components where possible. No issues identified across the nation.	No known issues, and not expected that this will become a problem. No issues identified across the nation.	<10% of materials are exported.	No issues of concern with tracking and verification, and use of end of life materials.

Product Impacts and Aspects		Community	
		Illegal Dumping - number of cases	**Community Expectations - level of issue**
Ranking	**Points**	**Illegal dumping of materials causing community concerns and impacting amenity.**	**Not meeting Community Expectations for resource recovery and product stewardship.**
Extreme	**5**	Common and widespread issue for many communities around the nation. Impacting rural, regional and cities nationally.	National issue of importance, significant issue in public forums and media.
High	**4**	An issue occurring in most states, has potential to become worse. Cross jurisdictional issue.	High levels of concern in most jurisdictions. National media attention.
Medium	**3**	Isolated high impact cases that are known. In single state/territory.	An issue for some jurisdictions, potential to become a more widespread issue. Local media and community concern.
Low	**2**	Small number of cases known, but not presenting as a concern. Regional or local issues may present.	Minor isolated concerns raised by stakeholders and community.
Negligible / Not Applicable	**1**	No known issues or concerns.	Minimum or no known issues or concerns.

Product Impacts and Aspects		Health and Safety	
		Health and Safety - community	**Health and Safety - industry practices**
Ranking	**Points**	**Direct health and safety issues to communities from removal of systems (e.g. fires, exposure to toxic chemicals)**	**Direct health and safety issues to workers removing or processing materials (e.g. fires, working at heights, handling components, exposure to toxic chemicals)**
Extreme	**5**	Multiple or single Death	Multiple or single Death
High	**4**	Serious health impacts on multiple or single persons or permanent disability.	Serious health impacts on multiple or single persons or permanent disability.
Medium	**3**	More than 10 days rehabilitation required for injured persons	More than 10 days rehabilitation required for injured persons
Low	**2**	Injury to person resulting in claims	Injury to person resulting in lost time and claims
Negligible / Not Applicable	**1**	Persons requiring first aid	Persons requiring first aid

Product Impacts and Aspects		Environment		
		Environmental Harm - extent of direct impacts	**Lifecycle Impacts - resource use**	**Lifecycle Impacts - environment and OHS**
Ranking	**Points**	**Current known industry practices (e.g. landfill, re-use, refurbishment, stockpiling, re-processing) leading to environmental damage to ground water, waterways and water bodies, air, land.**	**Potential to increase the conservation of materials used in the products, or the recovery of resources (including materials and energy) from waste from the products;**	**Potential to reduce the impact that the products have on the environment, or that substances in the products have on the environment, or on the health or safety of human beings.**
Extreme	**5**	Impact extends beyond the site boundary (point of removal, processing site, landfilll, stockpile); and/or long term residual impacts >5yrs	Extremely significant opportunities to improve resource use and resource recovery.	Extremely significant opportunities to reduce environmental and OHS impacts. National benefit.
High	**4**	Impact covers most of the site; and/or longer term residual impact (2-5yrs)	High level of opportunity to improve resource use and resource recovery.	High level opportunities to reduce environmental and OHS impacts. Benefit realised across several jurisdictions.
Medium	**3**	Impacts are within a smaller percentage of the site; and /or medium term residual impact (1-2yrs)	Medium level of opportunity to improve resource use and resource recovery.	Medium level opportunities to reduce environmental and OHS impacts. Benefits may be realised only in a single state or territory.
Low	**2**	Impacts within the immediate vicinity of the site; and short term residual impact <1 year	Low level of opportunity to improve resource use and resource recovery.	Low level opportunities to reduce environmental and OHS impacts. Benefits realised at a regional or local level only.
Negligible / Not Applicable	**1**	Impacts within immediate the vicinity of the site; and no residual impact	Minimal or no opportunity to improve resource use and resource recovery.	Minimal or no opportunity to reduce environmental and OHS impacts.

Product Impacts and Aspects		Economic and Financial	
		Scheme Costs - scheme implementation	**Current Disposal Cost - landfill**
Ranking	**Points**	**Costs associated with Product Stewardship Scheme involving collection infrastructure, materials recycling, waste processing and administration.**	**Cost of landfill and disposal (e.g. prescribed waste costs).**
Extreme	**5**	Scheme not viable without significant subsidies / high consumer cost. Deemed too expensive to operate by both Industry, Government and community/consumers across the Nation.	Cost of disposal exceeds $500 per tonne of material.
High	**4**	Scheme not viable without significant subsidies / high consumer cost. Deemed as too costly by most jurisdictions. Single jurisdictions may implement within 5 years.	Cost of disposal $400 to $500 per tonne of material.
Medium	**3**	Scheme viable with government subsidy consumer pays system in place. Timeframe to implement Nationally within 5 years.	Cost of disposal $200 to $400 per tonne of material.
Low	**2**	Scheme profitable with small user pays / subsidy model. Timeframe to implement Nationally within 3 years.	Cost of disposal $150 to $200 per tonne of material.
Negligible / Not Applicable	**1**	Scheme self funding, and profitable, without added costs to communities/consumers. Timeframe to implement Nationally within 3 years.	Cost of disposal less than $150 per tonne of material.

Product Impacts and Aspects		Legal and Regulatory		
		Legal action and costs (e.g. environmental harm, OHS)	**Jurisdictional Regulations**	**Industry standards**
Ranking	**Points**	**Implications associated with legal action (e.g. illegal stockpiling, dismantling, or disposal)**	**Disposal regulations impacts on resource recovery rates (e.g. prescribed waste regulations, e-waste landfill ban).**	**Materials handling and removal standards (e.g. Clean Energy Council, Australian Standards).**
Extreme	**5**	Resulting in high level litigation and/or penalties	Existing or proposed regulations will have a severe and negative impact to recovery rates under a product stewardship scheme. National issue.	Industry Standards will have a severe and negative impact to recovery rates under a product stewardship scheme. National issue.
High	**4**	Resulting in low level litigation and/or penalties	Existing or proposed regulations will have a severe and negative impact to recovery rates under a product stewardship scheme. Issue in some jurisdictions.	Industry Standards will have a severe and negative impact to recovery rates under a product stewardship scheme. Issue in some jurisdictions.
Medium	**3**	Notification and minor on the spot fine by regulator	Existing or proposed regulations will have negative impacts to recovery rates under a product stewardship scheme. Issue in only in a single state or territory.	Industry Standards will have negative impacts to recovery rates under a product stewardship scheme. Issue in only in a single state or territory.
Low	**2**	Notification and/or negotiations with regulator	Existing or proposed regulations will have negative impacts to recovery rates under a product stewardship scheme. Issue likely to occur at a regional or local level.	Industry Standards will have negative impacts to recovery rates under a product stewardship scheme. Issue likely to occur at a regional or local level.
Negligible / Not Applicable	**1**	No impact	Existing or proposed regulations will have no impact to a product stewardship scheme recovery rates, and may provide positive benefits.	Industry Standards will have no impact to a product stewardship scheme recovery rates, and may provide positive benefits.

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