Waste Plastics Export Regulation Phase 2 – Processing Requirements

A Submission to the Department of Agriculture, Water and the Environment

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Acronyms

Terminology	Definition
4NP	Nonylphenol
ABS	Acrylonitrile Butadiene Styrene
ACOR	Australian Council of Recycling
APCO	Australian Packaging Covenant Organisation
ASA	Acrylonitrile Styrene Acrylate
Basel Convention	The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
BBP	Benzyl butyl phthalate
BFR	Brominated flame retardant
BPA	Bisphenol A
CDS	Container Deposit Scheme
COAG	Council of Australian Governments
DBP	Dibutyl phthalate
decaBDE	Decabromodiphenyl ether
DEHP	Diethylhexyl phthalate.
DIBP	Diisobutyl phthalate
ELV	End-of-life vehicle
EPS	Expanded Polystyrene
FTIR	Fourier transform infrared spectroscopy - used to identify plastics containing BFRs.
GPPS	General purpose polystyrene
HBCD	Hexabromocyclododecane1
HDPE	High-Density Polyethylene
HW Act	Hazardous Waste (Regulation of Exports and Imports) Act 1989
ISRI	Institute of Scrap Recycling Industries, Inc.
LDPE	Low-Density Polyethylene

¹ HBCD is also used as an acronym for Hexachlorobutadiene (also listed in the Stockholm Convention).



Terminology	Definition
LLDPE	Linear Low-Density Polyethylene
МССР	Medium-chain chlorinated paraffins
MRA	MRA Consulting Group
MRF	Materials Recycling Facility
NP	Nonylphenol
NWRIC	National Waste and Recycling Industry Council
PBBs	Polybrominated biphenyls including commercial PBBs: hexaBB, octaBB and decaBB
PBDEs	Polybrominated diphenyl ethers including pentaBDE & octaBDE.
PCB	Polychlorinated biphenyls
PET	Polyethylene Terephthalate
Plastic Rules	The Recycling and Waste Reduction (Export-Waste Plastic) Rules 2021
PMMA	Poly(methyl methacrylate) - also known as Acrylic
POPs	Persistent organic pollutant
PP	Polypropylene
PS	Polystyrene
PU	Polyurethanes
PVC	Poly-vinyl Chloride
RaWR Act	Recycling and Waste Reduction Act 2020
RMF	The Recycling Modernisation Fund
SAN	Styrene Acrylonitrile
SCCP	Short-chain chlorinated paraffins
SPI	Society of Plastics Industry
The Department	Department of Agriculture, Water and the Environment
TTS	Tetralead trioxide sulphate
WEEE	Waste electrical and electronic equipment
XRF	Handheld x-ray fluorescence devices used to identify bromine in plastics containing BFRs.



Glossary

Terminology	Definition
Closed-loop recycling	When the recycled material is manufactured into a product with the same or similar purpose to the source product. For example, PET bottles being recycled to make PET bottles.
Commercial and industrial (C&I) waste	Waste from commercial and industrial sources – also commonly referred to as Commercial & Industrial (C&I). This includes institutions and businesses, schools, restaurants, offices, retail and wholesale businesses, and industries including manufacturing.
Construction and Demolition (C&D) waste	Material from the construction, refurbishment and building demolition industries.
Flexible plastics	Soft (flexible) plastics are generally defined as plastics that can be scrunched into a ball (e.g. pallet wrap and plastic bags), unlike 'rigid' plastics such as bottles and tubs, which are moulded and hold their shape.
Household	Waste from domestic household sources – also commonly referred to as Municipal Solid Waste (MSW).
Jazz	Mixed colour flake.
Listed specification	Listed specifications meet the objects of the <i>Recycling and Waste Reduction Act</i> 2020 and the <i>Recycling and Waste Reduction (Export – Waste Plastic) Rules 2021.</i> Waste processed to listed specifications is likely to be almost free from contamination and other types of waste and be ready for recycling or re-use in a way that reduces harmful impacts to human and environmental health.
Open-loop recycling	When the recycled material is manufactured into a product with a different purpose to the source product. For example, PET bottles recycled to make clothing.
Plastic flake	Small flat shaped matter with regular or irregular form that serves as feedstock in plastic product manufacturing operations. Typically, plastic shred pieces are 6-20mm in diameter.
Plastic pellet	Mass of pre-formed moulding material having relatively uniform dimensions used as feedstock in plastic product manufacturing/remanufacturing operations. Pellets are also known as granules or nurdles. Plastic pellets range from 1-5mm in diameter.
Plastic shred	Small flat shaped matter with irregular form from shredding primary input material (e.g. plastic bottles). Plastic shred pieces are typically 20-100mm in diameter.
Polyolefin	A polyolefin is a type of polymer produced from an alkene monomer. Polyethylenes (HDPE and LDPE) and PP are polyolefins.
Post-consumer	Plastic collected from households and non-household sources after being consumed by the public. Considered a dirty stream of waste and may require more thorough washing in the recycling process compared to pre-consumer.



Terminology	Definition
Pre-consumer (previously referred to as post-industrial)	Plastic collected during the manufacturing stage of life of a product, generally from C&I and C&D streams. 'Pre-consumer' and 'post-industrial' are often used interchangeably. Considered a clean stream of waste.
Recyclate	Recyclate is any recovered scrap material from both pre-consumer and post- consumer sources, either before or after reprocessing. It includes scrap plastics (before reprocessing), pellets, fines, and flakes (after reprocessing), but excludes material sent to energy recovery.
Remanufacture	The process of manufacturing using recycled content – usually as a replacement of virgin material.
Reprocess / reprocessing	Processing of recovered waste materials to change its physical structure and properties so it can be used as raw materials when making new products or for direct use.
Resin	Raw polymer material (from both virgin and recycled sources) – also referred to as a pellet.
Rigid plastics	Rigid or "hard" plastic such as bottles and tubs, which are (generally) moulded and hold their shape.
Sorting	A process typically between collection and reprocessing in which collected materials are sorted (or disassembled) into more usable and economically valuable material fractions, such as separating plastics from other commingled materials and sorting by polymer and colour. Secondary sorting can also be undertaken on some material flows. A MRF is an example of a primary sorting facilities.
Technical Guidelines	Technical Guidelines on the Environmentally Sound Management of Plastic Wastes (draft, October 2021)
Thermoplastic	A plastic polymer material that becomes mouldable at a certain elevated temperature and solidifies upon cooling.
Thermoset plastic	A thermosetting plastic is a polymer that irreversibly becomes rigid when heated.
Virgin material	Material that has been sourced through primary resource extraction (e.g., petroleum extraction). Virgin materials are not sourced from recycled materials.
Waste	Any discarded, rejected, unwanted, surplus or abandoned matter, including where intended for recycling, reprocessing, recovery, purification or sale.



Executive Summary

In preparation for phase 2 of the waste plastics export regulation, the Department of Agriculture, Water and the Environment ('the Department') engaged MRA Consulting Group ('MRA') to provide a report to support the assessment of licence applications for Phase 2 of the waste export regulation for plastic under the *Recycling and Waste Reduction Act 2020* and the Plastic Rules. Phase 2 commences on 1 July 2022 and requires waste plastic exports to be sorted to a single polymer and processed ready for remanufacture before export.

This report outlines the processing required for common plastic polymers to meet Phase 2 requirements, the processing required to no longer be considered a waste using end-of-waste criteria and identifies any gaps in the capacity of industry in Australia to process waste plastics at a high level.

Desktop research and industry consultation was undertaken to identify the common process flows and physical forms for each of the major plastic polymer types, including:

- Polyethylene Terephthalate (PET)
- High-Density Polyethylene (HDPE)
- Poly-vinyl Chloride (PVC)
- Low-Density Polyethylene (LDPE) /Linear LDPE (LLDPE)
- Polypropylene (PP)
- Polystyrene (PS)/ Expanded PS (EPS)
- Acrylonitrile butadiene styrene (ABS)
- Polyurethane (PU)
- Polycarbonate (PC)
- High Impact Polystyrene (HIPs)
- Acrylic (acrylonitrile) / Poly(methyl methacrylate (PMMA)

It was found that the level of processing required to meet Phase 2 requirements is highly dependent on the source of the waste, the downstream remanufacturing processes and the intended application. Specific circumstances were identified where additional or lesser processing was required for each polymer. Stakeholders emphasised that there are an immense number of circumstances where different processing may be required and that these must be assessed on a case-by-case basis to determine if processing is 'fit-for-purpose'.

To assist in this assessment, the most common application areas for each polymer were listed to infer the sources of waste plastic as well as the likely streams these may come through, such as preconsumer or post-consumer. This information can be used to estimate the potential contamination and processing required. End uses, such as for remanufacturing into food grade products, also determine the processing required.

Management of potentially hazardous additives was explored for applications areas where their use is likely, such as brominated flame retardants in waste electrical and electronic equipment. Generally, methods and processes to remove these additives from the polymer structure were not performed. Alternatively, methods to identify, separate and remove these hazardous plastics from the non-hazardous plastics allow the non-hazardous plastics to be recycled.

An assessment of information available on Australia's current plastics recovery, reprocessing capacity and projects being funded by the Recycling Modernisation Fund suggests that current gaps in reprocessing capacity could be met by new projects coming online. However, this assessment is provisional as the domestic reprocessing capacity does not:

- Provide information on the compatibility of the reprocessing capacity with the form of plastic being recovered;
- Differentiate between high value and low value remanufactured plastic products; and
- Account for the geographical distribution of facilities.

Feedback from stakeholder consultation is that there will be a significant gap in Australia's capacity to reprocess LDPE/LLDPE and other flexible plastics such as PP bulka bags. This is confirmed by the Department's 2019-20 data showing exports of 22,000 tonnes of LDPE/LLDPE compared with funded additional capacity of just 9,000 tonnes.



1

1 Introduction

In March 2020, members of the former Council of Australian Governments (COAG) agreed that the export of waste glass, plastic, tyres and paper be regulated by the Australian government. COAG chose to regulate the export of these materials for their potential to cause harm to human health and the environment in less regulated importing countries.

The legislation enforcing this decision, the *Recycling and Waste Reduction Act 2020* (RaWR Act), came into force 15 December 2020. The *Recycling and Waste Reduction (Export-Waste Plastic) Rules 2021* (the Plastic Rules) outline the rules for exporting waste plastic and these sit underneath the RaWR Act.

In preparation for Phase 2 of the waste plastics export regulation, the Department of Agriculture, Water and the Environment ('the Department') engaged MRA Consulting Group ('MRA') to provide a report to support:

- implementation of Phase 2 of the waste export regulation for plastic; and
- determine the level of processing required for waste plastic to no longer be considered a waste under the *Hazardous Waste (Regulation of Exports and Imports) Act 1989* (HW Act).

1.1 Objective

This document is intended to serve as a technical guideline in helping Department staff assess waste export licence applications under Phase 2 of the Plastic Rules and export permits under the HW Act.

1.2 Scope

MRA performed a desktop review and stakeholder consultation to provide information on the following:

- The level of processing required for common plastic polymers to meet the Phase 2 requirements as detailed in the Plastic Rules;
- Advise on the level of processing required for plastic to no longer be considered a waste (under the HW Act and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal ('the Basel Convention')); and
- Identify any gaps in the capacity of industry in Australia to process waste plastics ready for remanufacture by 1 July 2022.

The following types of stakeholders, as listed in Appendix A, were consulted: industry bodies, reprocessors, universities, remanufacturers, equipment supplier and trader/exporter.

The plastic types (and their Plastics Identification Code) included in the scope of this project include:

- 1 Polyethylene Terephthalate (PET)
- 2 High-Density Polyethylene (HDPÉ)
- 3 Poly-vinyl Chloride (PVC)
- 4 Low-Density Polyethylene (LDPE) /Linear LDPE (LLDPE)
- 5 Polypropylene (PP)
- 6 Polystyrene (PS)/ Expanded PS (EPS)
- 7 Other:
 - i. Acrylonitrile butadiene styrene (ABS)
 - ii. Polyurethane (PU)
 - iii. Polycarbonate (PC)
 - iv. High Impact Polystyrene (HIPs)
 - v. Poly(methyl methacrylate) (PMMA)
 - vi. Acrylic (acrylonitrile)
 - vii. Nylon



1.3 Phase 2 Requirements

The RaWR Act provides the legislative framework for regulating the export of waste material from Australia and requires exporters to apply and hold a waste export licence or exemption to export regulated waste material and declare consignments before export in the Waste Export Licensing and Declaration (WELD) portal and in Australian Border Forces Integrated Cargo System (ICS). Only the Minister may or may not grant exemptions. For parties applying for a waste export licence under the RaWR Act, they must also meet the requirements of the HW Act².

The Plastic Rules are made under subsection 188(1) of the RaWR Act and they outline the conditions, or 'requirements', that exporters of waste plastic must meet to be granted a waste export licence. Section 10(2)(a) of the Plastic Rules state that the plastic must be 'sorted, prior to export, into a single polymer plastic or single resin plastic'. Other Phase 2 requirements, regarding the form of plastic and evidence required are summarised in Table 1.

Table 1 Plastics Rules - Phase 2 requirements relating to the plastic form for export

Plastic Rules	Waste plastic export licence application requirements	
Section 7(2)&(3)	Nominate a waste plastic specification for the plastic intended for export on or after 1 July 2022	
Section 7(4)	If the nominated specification is not a listed waste plastic specification*, include a copy of the nominated specification	
Section 7(5)	Include information demonstrating that the regulated waste plastic intended for export will be processed prior to export to comply with the nominated specification	
Section 8(2)(a)	The intended use of the plastic in the place to which it is exported	
Section 8(2)(b)	Whether the specification is appropriate for the intended use of the plastic in the place to which the plastic is intended to be exported	
For nominated specifications that are not listed, applicants must provide the following for consideration by the Minister:		
Section 8(2)(c)(i)	The plastic polymer or resin type covered by the specification	
Section 8(2)(c)(ii)	The threshold for contaminants in the specification, including whether the specification includes any requirements for the plastic to be almost free of contamination and other types of wastes 'Almost free of contamination and other types of wastes' has the same meaning as in Annex II to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal ³	
Section 8(2)(c)(iii)	Any packaging requirements in the specification	
Section 8(2)(c)(iv)	Any colour requirements in the specification	
Section 8(2)(d)(i)	The physical form of the processed plastic required by the specification	

² The Department Hazardous waste permits website: https://www.awe.gov.au/environment/protection/hazardouswaste/permits

³ The Basel Convention states: "In relation to "almost free from contamination and other types of waste", international and national specifications may offer a point of reference".



Plastic Rules	Waste plastic export licence application requirements
Section 8(2)(d)(ii)	Whether that physical form is appropriate for the intended use of the plastic in the place to which the plastic is intended to be exported
Section 8(2)(d)(iii)	Whether the plastic processed in accordance with the specification is capable of remanufacture without further processing

*See the Department website for listed specifications:

https://www.awe.gov.au/environment/protection/waste/exports/specifications-and-documents/plastic-specifications

Phase 2 requirements do not outline the level of processing required for export, rather they allow the Minister (or delegate) and assessors to determine if the waste plastics for export meets the objects of the RaWR Act and the former COAG's commitment to only allow materials to be exported if they have been cleaned and processed into a value-added material likely to be re-manufactured overseas⁴. As outlined in Section 3 of the RaWR Act:

- (1) The objects of this Act are as follows:
 - (a) to reduce the impact on human and environmental health of products, waste from products and waste material, including by reducing the amount of greenhouse gases emitted, energy and resources used and water consumed in connection with products, waste from products and waste material;
 - (b) to realise the community and economic benefits of taking responsibility for products, waste from products and waste material;
 - (c) to develop a circular economy that maximises the continued use of products and waste material
 - (d) to contribute to Australia meeting its international obligations concerning the impact referred to in paragraph (a).
- (2) These objects are to be achieved by:
 - (a) regulating the export of waste material to promote its management in an environmentally sound way; and
 - (b) encouraging and regulating the reuse, remanufacture, recycling and recovery of products, waste from products and waste material in an environmentally sound way; and
 - (c) encouraging and regulating manufacturers, importers, distributors, designers and other persons to take responsibility for products, including by taking action that relates to:
 - (i) reducing or avoiding generating waste through improvements in product design; and
 - (ii) improving the durability, reparability and reusability of products; and
 - (iii) managing products throughout their life cycle.



2 Plastic Processing

This section outlines the common sorting and processing requirements for waste plastics and provides information on the degree of sorting and processing required based on the application area of the original product, source of the plastic waste and the intended end use of the reprocessed plastic. Generally, sorting is comprised of physical separation and material sorting while processing is comprised of size reduction, washing/cleaning, drying, thermal melt-extrusion and/or pelletising⁵.

The process outlined is for mechanical recycling, i.e. processing of plastic waste by physical means, preserving the molecular structure of the polymer⁵. Chemical recycling, i.e. where the polymer molecules are broken down into the chemical constituents, is not included in this report as this is not commonly performed in Australia and does not relate to Phase 2 requirements.

Further considerations for each polymer type are provided in Section 3 to 14.

2.1 Standard plastic sorting

Rigid plastic waste in commingled recycling streams, such as from households and commercial and industry, is typically sorted at a primary sorting facility, such as a materials recycling facility (MRF) or a container deposit scheme (CDS) facility. Mechanical or automated equipment is used to remove non-plastic materials and separate individual polymers.

Equipment and machinery at a sorting facility may consist of:

- Trommel and star screens to separate paper and cardboard;
- Disc screens to break and separate glass;
- Magnets to separate ferrous and magnetic metals;
- Eddy currents to separate non-ferrous metal (aluminium, copper, brass, zinc etc.)⁶; and
- Manual sorting or optical sorters⁷ to sort plastic waste into single polymer or mixed polymer streams⁸.

An example of plastic separation machinery and flow at a MRF is shown in Figure 1 and further information about sorting technologies can be found in Table 15 of the draft Technical Guidelines on the Environmentally Sound Management of Plastic Wastes⁵ (the 'Technical Guidelines').

⁵ Technical guidelines on the environmentally sound management of plastic wastes (draft, October 2021) author unknown.

⁶ Induction sensors may also be used to separate stainless steel and composites however this technology was not reported to be commonly used.

⁷ Optical sorters use infrared lasers and sensors to identify the colour and type of material (polymer) based on absorption of light. A jet of compressed air separates the material. MRFs may use several optical sorters (between 1 and 6) or manually sorting may be performed. The number of optical sorters is generally dependent on the number of plastic categories being sorted and throughput, e.g. sorting natural and coloured PET and HDPE from mixed plastics may require five optical sorters: one machine to separate clear PET, one machine to separate coloured PET, and so on. These separated products are then baled for transport.

⁸ Waste Plastics Industry Standards (2021) MRA Consulting.





Seven Steps of Sorting at a Visy Material Recovery Facility (MRF)

1. Pre-Sort

 MRF staff manually remove contamination (eg. plastic bags).

2. Star Screen Sorting

- fans and a series of shafts fitted with rotating star shaped discs propel paper and cardboard forward, while bottles, cans and containers fall backwards.

3. Glass

- sent for further sorting by colour.

4. Magnets

rotating magnets
 pick up steel cans.

5. Eddy Currents

- an electromagnet field repels aluminium cans off the conveyor belt.

6. Optical Sorting

 infrared sensors and air jets sort plastic types 1 and 2 (PET and HDPE respectively).

7. Manual Sorting – MRF staff manually sort the other plastic types (3 to 7).



Source: Visy Australia



Once separated, the plastic streams are baled and sent to a plastics re-processing facility or processed on site if the facility has the appropriate equipment.

Source-separated rigid plastic waste from other sources, such as manufacturing and industrial operations, is often sent directly to a plastics re-processing facility or may undergo reprocessing at the same manufacturing site to be fed directly back into the manufacturing process.

Flexible plastic waste is generally source-separated and often sent directly to a plastics re-processing facility.

2.2 Standard plastic processing

A general overview of recycling rigid plastic and processing it into flake and pellet is shown in Figure 2. Note: this process flow is for food grade plastic recycling.

Figure 2 Example of plastic recycling process flow into pellet



Source: Visy Australia

Plastic is reprocessed into a flake, with the most basic equipment and machinery flow consisting of:

- A shredder for initial size reduction to pieces between 20 and 100mm ('shredded plastic').
- A granulator to further reduce the shredded plastic into flake between 6 and 20mm, according to customer specifications. Different shredders and granulators should be used according to the application, e.g. rigid or flexible plastic.

Other processes may also be performed for flake reprocessing, including:

- A bale breaker to break bales of plastics;
- A pre-sorting stage (manual or optical sorting) to remove contamination and/or sort by polymer type or colour (however this may be performed after size reduction);
- Cold or hot washing of the flake: washing may consist of mixing, stirring, scrubbing, surface friction, abrasion and high-pressure liquid jets to remove surface residues such as labels, glue,



drink and food residues, odour ⁹. This may be done with cold water or with hot water (and/or chemical detergents such as sodium hydroxide) for plastic waste requiring a more thorough wash, e.g. when oils or glues are present or for food grade applications;

- Drying in a mechanical or thermal dryer to achieve a specified moisture content;
- Further sorting (manual or optical sorting) and separation processes (such as density separation¹⁰) to remove other colours, polymer types or other contamination material; and
- Decontamination.

An example process line for separation, size reduction and washing of bottles into flake is provided in Appendix B. It is suitable for food grade PET as well as non-food grade plastics: PET, HDPE, LDPE and PP. An example of an optical sorter suitable for flake is provided in Appendix C. Note: some processing may stop at the flake stage.

For processing flake into a pellet, an extrusion line is required to melt, extrude and pelletise the flake. This may also include sterilisation, filtration and/or degassing before pelletisation. The flake is fed into an extruder and heated to melt the flake. The different polymer types have different melting temperatures and these will determine the extrusion temperature. The molten resin forms a continuous polymer strand and can be passed through screens to filter out any remaining contaminants. Technically, the same extrusion line can be used to process different plastic polymers however purging will need to be performed between polymer types. An example of an extrusion processing line suitable for HDPE, PP and LDPE/LLDPE flake is provided in Appendix D.

A pelletiser is used to cut the polymer strand into pellets. After pelletising, a bagging station may be used to load product into bags.

Further description of processing and equipment/machinery can be found in the Technical Guidelines.

2.3 Sorting and processing considerations

At a re-processing facility, the degree of sorting and processing required is less determined by the polymer type and more by the application area of the original product, source of the plastic waste and the intended end use of the reprocessed plastic. It may also differ largely by the facility and the machinery available.

2.3.1 Application area of the plastics

Certain polymer characteristics make them suitable for certain applications. The majority of polymers in the scope of this project are thermoplastics (able to be re-melted and re-moulded) and can be divided into two primary groups of plastics:

- 1. General purpose commodity plastics: PET, HDPE, LDPE, LLDPE, PP, PVC, ABS.
- 2. Engineering plastics: PMMA, PC, nylon and various polymer blends, e.g. PC/ABS.

Commodity plastics are highly consumed, have a low price and relatively low performance characteristics. They are often used in packaging applications, such as bottles and containers, and mass-produced items, such as children's toys and electronic products.

Engineering plastics are used in applications requiring certain mechanical and thermal properties. They are therefore high performance, have a higher price and a lower consumption compared to commodity plastics.

Under each polymer section (Section 3 to 14), data is included where available regarding the four most common application areas (and a summation of the remaining application areas) and the proportion of

⁹ Technical guidelines on the environmentally sound management of plastic wastes (draft, October 2021) author unknown.

¹⁰ A floatation/sink washing step separates materials by density: PET and PVC sinks while polyolefins (HDPE/LDPE/PP including plastic film and bottle caps) float. Separation of plastics with close density values, such as PVC and PET, can be achieved by modifying the density/salt content of the separation liquid.



plastic consumed in each, sourced from the Plastic Infrastructure Analysis Update Report¹¹ (the Plastic Infrastructure Report). This is included to demonstrate the proportion of the polymer allocated to different applications or industries, which could infer potential sources of waste plastic. Common product types are also provided for most application areas however these do not correlate to the application data and are simply provided as examples.

The categories for application areas are based on those included in the Plastic Infrastructure Report:

- Agriculture;
- Automotive;
- Built environment;
- Electrical & electronic;
- Household (or municipal solid waste) packaging;
- Commercial and industrial packaging;
- Other application area; and
- Unidentified applications.

The Plastic Infrastructure Report does not include a definition for the category 'Other application' area.

Depending on the application area, plastic waste may contain additives related to product function.

2.3.2 Hazardous additives

Additives are chemical compounds added to plastic to provide specific functionalities and improve performance. Some common types of additives are described in Table 2.

Additives	Functions
Plasticisers	Provide softness and flexibility
Flame retardants	Prevent ignition of the material and reduce flammability risks
Antioxidants & stabilisers	Suppress degradation from UV light, oxidation and other impacts
Colourants	Provide colour
Fillers	Improve performance or reduce production costs

Table 2 Common plastic additives and their functions

Most additives are incorporated into the plastic during the melt phase (post polymerisation) and are not chemically bound to the plastic polymer. Other additives are reactive and become part of the polymer chain¹².

Persistent organic pollutants (POPs) are chemicals that can stay in the environment for a long time, accumulate in living organisms and are toxic to living organisms. POPs can cause harmful effects to human health, such as endocrine disruption, and the environment. There is a risk for some additives to be leach from the plastic during the use or recycling phase as well as the risk of transferring potentially hazardous additives into new recycled products with more sensitive application areas, e.g. brominated

¹¹ Plastic infrastructure analysis update (2019) prepared by Envisage Works for the Department of the Environment and Energy.

¹² An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling (2018) Hahladakis et al., Journal of Hazardous Materials.



flame retardants (BFRs) and phthalates in children toys, creating potential adverse human health effects¹³.

Some of these chemicals have been banned or voluntarily phased out, however some may still be in used in manufacturing or exist in older products still in use.

Appendix A outlines a number of resources which list plastic additives that may be considered hazardous. Appendix F provides a list of examples of chemicals of concern in plastic and the polymer and products they may be found in. The most common application areas for potentially hazardous additives are automotive and electronic products.

The processes to identify, remove or manage potentially hazardous additives in waste streams where they are likely, i.e. waste electrical and electronic equipment (WEEE) and end-of-life vehicles (ELV), are discussed in Section 15.

2.3.3 Source of the plastic

Generally, pre-consumer waste sourced from manufacturing processes is considered the 'cleanest': i.e. it has minimal contaminants and is often source separated. Post-consumer plastic waste has higher levels of contamination due to exposure to materials during its use phase. This may include food and liquid residues for food packaging products, dirt and chemicals for agricultural plastics and contamination from other polymers and materials.

Table 3 provides a general overview of the standard processing steps and machinery for both rigid and flexible plastics based on the source of the waste plastic. Additional steps included may or may not be done by the processor (generally based on the source application of the material and the intended end use or remanufacturing requirements).

Source	Processing steps and machinery
Pre-consumer	 A pre-sorting step, to remove physical contaminants from other wastes and polymer types, via manual or optical sorting; Shredding into smaller sized pieces; Granulation to form a flake; and Melting and extrusion of the flake into a pellet (noting that some processing may stop at the flake stage). Additional: Colour sorting may be done at the pre-sorting step or by restriction of input material colours. It could also be done at the flake stage via optical sorting equipment. Washing may also be undertaken (hot or cold) if there are signs of dirt or other contamination¹⁴.

Table 3 Standard plastics processing steps and machinery based on source

¹³ Technical guidelines on the environmentally sound management of plastic wastes (draft, October 2021) author unknown.

¹⁴ For example, post-industrial PVC piping from the ground contaminated with dirt.



Source	Processing steps and machinery
Post-consumer	 A pre-sorting step, to remove physical contaminants from other wastes and polymer types, via manual or optical sorting;
	 Shredding into smaller sized pieces;
	Granulation to form a flake;
	 Cold or hot washing of the flake (may involve multiple washing steps) may include;
	 Friction wash: high speed washing and scrubbing
	 Density separation: washing and separation of materials of different densities
	Drying of the flake may include;
	 Centrifugal drying: dries flake by high speed rotation
	\circ Thermal drying: dries flake with hot air
	 Melting and extrusion of the flake into a pellet.
	Additional:
	 Colour sorting may be done at the pre-sorting step or by restriction of input material colours. It could also be done at the flake stage via optical sorting equipment.
	 A pre-wash step may be required for post-consumer flexible plastics with large amounts of contamination, such as agricultural film.
	 Soluting of the liake may be done for streams likely to be containinated with other polymers or wastes. Density separation (also used for washing).
	Optical sorting. Desentamination/starilisation and filtration before polletisation may be
	 Decontamination/stemisation and initiation before penetisation may be required for material destined for food-grade material.
Notes	 Processors who recycle both pre- and post-consumer waste may use the post-consumer processing steps and machinery for both waste sources.
	• Different extrusion equipment is required for rigid and flexible plastics. The same pre-processing lines (shredding, granulating, washing, etc) could be used however different speeds and temperature are required and some processors will prefer to keep them separate.
	 Machinery may consist of individual units arranged together or a specialised unit completing multiple steps, such as a flexible plastics recycling machine performing all steps from shredding to pelletising.

2.3.4 Remanufacturing process

The remanufacturing process and equipment will determine the input specifications for the product material required by the remanufacturer. After flaking, the flake product may be suitable for direct use in a manufacturing (extrusion) process (i.e. without pelletisation). It should be noted that recycling extruders (used for pelletising waste plastics) and manufacturing extruders (used moulding new plastic products) are different equipment.

Reputable recycling extruders homogenise, vent and filter the polymer to remove solid non-plastic contaminants before pelletising for extrusion in the remanufacturing process. Some manufacturing extruders are robust and are not sensitive to the variable morphology and contamination present in flake



however some manufacturing extruders are more sensitive and may require pellet as the input material. If flake is used directly in the manufacturing process, it must meet the input specifications for the extruder/s used. This would be determined in the nominated specification provided by the export licence applicant.

Further processing of the flake into pellet may be performed by the reprocessor or by the remanufacturer. Where further processing and pelletisation is part of the remanufacturer's process line, the flake input may be considered "capable of remanufacture" (despite requiring pelletisation prior to remanufacture) as it meets the remanufacturers input specifications, i.e. meeting end-of-waste criteria and Section 8(2)(d)(ii) of the Plastic Rules "that physical form is appropriate for the intended use of the plastic in the place to which the plastic is intended to be exported". This is opposed to flake exported for further processing and pelletisation at one facility before being transported to a different facility/country for remanufacture. Evidence is required outlining the manufacturing process line (including pelletisation equipment) and input specification and critical analysis is required based on the evidence provided.

2.3.5 End use application

The type of end use application influences the degree of processing required.

Closed-loop recycling refers to when the recycled material is manufactured into a product with the same or similar purpose to the source product. For example, PET bottles being recycled to make PET bottles.

Open-loop recycling refers to when the recycled material is manufactured into a product with a different purpose to the source product. For example, PET bottles recycled to make clothing.

Generally, closed-loop recycling requires more processing than open-loop recycling, especially for food contact or 'food-grade' applications. In addition to the standard plastic processing outlined in Section 2.1 above, food-grade processing also involves colour sorting, hot washing of the flake, sterilisation and filtration.

To ensure the remanufactured end product performs its intended function, the plastic input material (i.e. flake or pellet) must meet the customer's specification which may require testing to demonstrate that the material contains the appropriate mechanical or thermal properties, or does not contain contaminants or additives of concern.

Some of the laboratory techniques that may be used to identify the polymer type and the additives present include:

- Fourier Transform Infrared Spectroscopy (FTIR);
- Differential Scanning Calorimetry (DSC);
- Thermo-Gravimetric Analysis (TGA);
- Gas Chromatography with Mass Spectrometry (GC/MS);
- Liquid Chromatography with Mass Spectrometry (LC/MC);
- High Performance Liquid Chromatography (HPLC);
- Ion Chromatography (IC);
- X-ray Fluorescence (XRF);
- X-ray Transmission (XRT); and
- Ash content analysis.

Relevant domestic or international standards, such as the American Society for Testing and Materials (ASTM) or the International Organisation for Standardisation (ISO), for performing these tests should be followed.

Further description of these techniques including their purpose, procedure and examples of relevant methodology standards are provided in Appendix G.



2.4 End-of-waste assessment

The Basel Convention is an international treaty controlling the transboundary movements of hazardous waste between countries. Recent amendments have enhanced the controls on plastic waste. Only plastic wastes listed in B3011 (Annex IX) destined for recycling¹⁵ are exempt from this requirement.

In Australia, the HW Act was amended to give effect to the amendments relating to plastic waste in the Basel Convention. Further information regarding waste plastic and the Basel Convention and HW Act is provided in Appendix G.

To determine when a material is no longer considered a waste (and no longer requires regulation under the Basel Convention and HW Act), an end-of-waste assessment may be performed based on the processing the plastic material has undergone¹⁶.

The Basel Convention defines waste as:

Substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law.

Disposal is defined as:

Any operation specified in Annex IV to this Convention;

In the context of plastic recycling, the relevant disposal operations in Annex IV include:

R3: Recycling/reclamation of organic substances which are not used as solvents.

Based on these definitions, any substances or objects that have undergone a recycling operation and are can be used as an input into a manufacturing process without further processing, are not waste. Material at this stage should meet end-of-waste criteria.

The end-of-waste criteria included in the Technical Guidelines accompanying the Basel Convention require material to comply with the following:

- a) The substance or object is commonly used for specific purposes;
- b) A market or demand exists for such a substance or object;
- c) The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products;
- d) The use of the substance or object will not lead to overall adverse environmental or human health impacts.

For plastics, this end-of-waste point is commonly thought to be post pelletisation¹⁶. However, it is largely dependent on the source of the waste and the downstream manufacturing processes required to convert the material into a product. For example, a flake material may meet the technical requirements for the remanufacture of a product and does not require pelletisation in some circumstances. Furthermore, as stated in Section 2.3.4, pelletisation of the flake may be embedded in the remanufacturing process. In this case, flake may meet the manufacturer's specification and may be considered end-of-waste.

Some polymers may never fully satisfy end-of-waste criteria. For example, market is unlikely to exist for a recycled product if it does not meet technical requirements for remanufacture.

Under each polymer section, the forms identified as being consistent with Phase 2 requirements will be assessed as per the end-of-waste criteria included in the Technical Guidelines above. This information provides an indication of the known considerations for the polymer type to meet end-of-waste criteria. The symbols in Table 4 are used to demonstrate the likelihood of the material to meet the criteria.

¹⁵ Recycling is defined as 'recycling/reclamation of organic substances that are not used as solvents' (in Annex IV Section B R3).

¹⁶ Technical guidelines on the environmentally sound management of plastic wastes (draft, October 2021) author unknown.



Table 4 End-of-waste assessment symbols

Symbol	Meaning
\checkmark	Likely to meet this criterion if evidence is supplied.
ŀ	Likelihood of meeting the criterion is unknown and unable to be assessed in this report.
×	Unlikely to meet this criterion due to the nature of the polymer, material or other.



3 PET

Polyethylene terephthalate (PET) is a thermoplastic polymer commonly used for rigid consumer packaging. The most common applications areas and the proportion of PET consumed in each, as well as some common product examples are included in Table 5.

Table 5 PET common application areas and product examples

Common application areas	Product examples
Other application area (40.8%)	Clothing, textiles, strapping
Household packaging (32.9%)	Bottles, food packaging, soft-drink bottles, sport drink bottles, strawberry punnets, condiment container, cosmetic packaging, cooking oil containers
Unidentified applications (13.7%)	Unknown
Built environment (7.4%)	Carpet, rope, fibrefill
Agriculture, automotive & commercial and industrial packaging (5.3%)	Industrial packaging

Source: Plastic infrastructure analysis update (2019) prepared by Envisage Works for the Department of the Environment and Energy. Note: percentages taken from report did not add to 100.0%.

3.1 Process flows

3.1.1 Source

PET waste plastic most often includes post-consumer material, collected from households and commercial and industrial sources, e.g. shopping centres.

Post-consumer PET material is likely to have contaminants in the form of food and beverage residues, labels, caps and glues or adhesives. PET material sourced from MRFs is considered less clean than material sourced from CDS facilities.

Pre-consumer PET material may also be collected and is likely to contain less contamination than postconsumer PET material.

3.1.2 Reprocessing

PET plastic waste is commonly recycled into non-food grade and food grade consumer packaging. Only food grade packaging can be recycled into new food grade plastic.

PET is reprocessed into a flake using the standard mechanical recycling process and machinery:

- Manual sorting or optical sorting machinery to pre-sort and remove physical contaminants;
- Shredders and/or granulators to form a flake;
- One or multiple washing tanks;
- A mechanical or thermal dryer;

After flaking, the flake product may be suitable for:

- Direct use in a manufacturing (extrusion) process (i.e. without pelletisation);
- An extrusion line for melting, extruding and pelletisation of the flake into a pellet;



- Further processing to remove contaminants before extrusion, for example:
 - Optical sorting;
 - Density separation, e.g. floatation/sink washing (this may also be used as a washing step); and
 - Sterilisation (primarily for food-grade processing).

It should be noted that further processing to remove contaminants and/or pelletisation may be performed by the reprocessor or by the remanufacturer.

3.2 Physical form/s

Physical forms and considerations required for remanufacture are outlined in Table 6.

Table 6 PET remanufacture considerations

Remanufacture considerations	PET
Physical forms capable of remanufacture	Flake (for direct use in remanufacturing or for further processing within a remanufacturing process ¹⁷) Pellet
Polymers for which processing/ machinery can be used interchangeably	 <u>For food grade processing:</u> Other food grade polymers which currently includes HDPE. <u>For non-food grade processing:</u> Other rigid polymers, such as HDPE, PVC, LDPE, PP, PS, ABS, PC, HIPS, Acrylic and Nylon, which have a low risk of hazardous additives (refer to Appendix F). Stakeholders advised that 'flushing' of the processing line and machinery is performed between polymers to reduce the risk of contamination and remove residual plastic waste.
Circumstances where colour sorting is required	 Food-grade PET processing typically requires a clear colour feedstock. Sorting for black PET for food-grade applications may occur however there is an increased risk in using black PET as contamination is difficult to detect. For non-food grade material, remanufacturers may request clear, green (transparent) or jazz (mixed colour) material for certain applications.

¹⁷ As stated in Section 2.3.4: Where further processing and pelletisation is part of the remanufacturer's manufacturing process line, the flake input may be considered "capable of remanufacture" (despite requiring pelletisation prior to remanufacture) as it meets the remanufacturers input specifications. This is opposed to flake exported for further processing and pelletisation at one facility before being transported to a different facility/country for remanufacture. Evidence is required outlining the manufacturing process line (including pelletisation equipment) and input specification.



Remanufacture considerations	PET
Additional requirements for processed waste plastic intended for food grade uses	 Feedstock to be sourced from food-grade material only Colour-sorted for clear PET Sterilisation of the flake before extrusion Output and processing to receive a letter of no objection (LNO) from the relevant food grade material regulatory body, e.g. United States Food and Drug Administration (FDA) or the European Directive. One stakeholder advised that only two companies manufacture the extrusion equipment suitable for food-grade pellet: Erema Group (Austria) Starlinger Group (Austria) FDA approval can also be obtained for other variations of equipment used and is dependent on the entire production process (not simply the processing equipment used), including the source of the material.
Circumstances where lower levels of processing may be applicable	 Flake is the minimum requirement for re-manufacturing however its suitability is dependent on the waste source, re-manufacturing machinery and intended application. Examples of where it may be suitable include: Feedstock is sourced from "clean" pre-consumer sources, such as PET plastic from manufacturing processes. In this instance, washing (and drying) and/or pelletising may not be required. The manufacturing extruders are robust and can accept the variable morphology and contamination present in flake. PET not intended for food-grade application. In this instance, sterilisation and/or pelletisation may not be required. Material undergoes re-manufacturing into lower "commercial grade" or "off-grade" applications or where the end-product is more forgiving, i.e. requiring less stringent mechanical properties. In these instances, washing, sterilisation and pelletisation may not be required.
The forms not consistent with Phase 2 requirements	 Baled PET Shredded PET (unless it has been flaked to a uniform dimension)
Commonly used industry specifications that could be "listed specifications" consistent with the Phase 2 export ban	 The department has published the following specifications as <i>listed specifications</i> for PET: APCO – PET hot washed flake APCO – Coloured PET cold washed flake No new commonly used industry specifications were identified.
Common co-polymers/ polymer blends	PET is a copolymer made up of two monomers, ethylene glycol and terephthalic acid. No common polymer blends were identified for PET.

3.3 Hazardous waste processing

No potentially hazardous additives of concern were identified to be used in PET products.



3.4 End-of-waste criteria

For the forms identified as being consistent with Phase 2 requirements, an assessment against end-ofwaste criteria is provided in Table 7. As mentioned previously, there are multiple considerations (i.e. the waste source, re-manufacturing machinery and intended application) that require critical analysis, based on evidence provided, for a material to meet the Phase 2 requirements and/or end-of-waste criteria. The table below provides an indication of the known considerations for the polymer forms to meet end-ofwaste criteria and should be used in conjunction with the remanufacture considerations tabled above.

Meeting a legitimate technical specification is an important aspect of the end-of-waste assessment as it demonstrates that the recycled material will go into manufacturing and is not a waste. This criterion is not able to be assessed in this report as the nominated specification and legislation requirements in the importing country are not known however it is likely that analysis and testing of the polymer performance will support this.

Table 7 PET end-of-waste assessment

End-of-waste criteria	Likely to meet	Assessment
The substance or object is commonly used for specific purposes	~	 Re-processed PET flake and pellet is likely to meet this criterion if destined for common applications for remanufacturing. Examples of major and minor applications for re-processed PET include¹⁸: Major uses: beverage bottles. Minor uses: timber substitutes, geo-textiles, pallets and fence posts.
A market or demand exists for such a substance or object	~	Based on known market pricing information, there is likely to be demand for clear recycled PET (rPET) flake and pellet. The demand for food-grade rPET is likely to increase worldwide due to recycled content targets. Market demand for coloured rPET flake and pellet is unknown.
The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products	ļ	Dependent on the nominated specification and legislation in the importing country.
The use of the substance or object will not lead to overall adverse environmental or human health impacts	~	Potentially hazardous additives were not identified to be common for PET therefore the risk of adverse impacts is low.

¹⁸ Australian Plastic Flows and Fates Study 2019-20 (2021) prepared by Envisage Works for the Department of Agriculture, Water and the Environment.



4 HDPE

High Density Polyethylene (HDPE) is a thermoplastic polymer commonly used for rigid consumer packaging. The most common applications areas and the proportion of HDPE consumed in each, as well as some common product examples are included in Table 8.

Table 8 HDPE common application areas and product examples

Common application areas	Product types / examples
Household packaging (35.0%)	Milk bottles, packaging film, tubs/containers shampoo bottles, household cleaning products, motor oil container, ice-cream container, pot plants
Commercial and industrial packaging (20.5%)	Industrial film, gasoline tanks
Other application area (19.0%)	Toys, mobile garbage bins
Built environment (13.1%)	Seating, pipes, crates
Agriculture, automotive, electrical, unidentified applications (12.4%)	Cable insultation

Source: Plastic infrastructure analysis update (2019) prepared by Envisage Works for the Department of the Environment and Energy.

4.1 Process flows

4.1.1 Source

HDPE waste plastic most often includes post-consumer material, collected from households and commercial and industrial sources, e.g. shopping centres.

Post-consumer HDPE material is likely to have contaminants in the form of food and beverage residues, labels, caps and glues or adhesives. HDPE material sourced from MRFs is considered less clean than material sourced from CDS facilities.

Pre-consumer HDPE material may also be collected and is likely to contain less contamination than post-consumer HDPE material.

4.1.2 Reprocessing

HDPE waste plastic is commonly recycled into non-food grade and food grade consumer packaging. Only food grade packaging can be recycled into new food grade plastic.

HDPE is reprocessed into a flake using the standard mechanical recycling process and machinery:

- Manual sorting or optical sorting machinery to pre-sort and remove physical contaminants;
- Shredders and/or granulators to form a flake;
- One or multiple washing tanks;
- A mechanical or thermal dryer;

After flaking, the flake product may be suitable for:

- Direct use in a manufacturing (extrusion) process (i.e. without pelletisation);
- An extrusion line for melting, extruding and pelletisation of the flake into a pellet;



- Further processing to remove contaminants before extrusion, for example:
 - Optical sorting;
 - Density separation, e.g. floatation/sink washing (this may also be used as a washing step); and
 - Sterilisation (primarily for food-grade processing).

It should be noted that further processing to remove contaminants and/or pelletisation may be performed by the reprocessor or by the remanufacturer.

4.2 Physical form/s

Physical forms and considerations required for remanufacture are outlined in Table 9.

Table 9 HDPE remanufacture considerations

Remanufacture considerations	HDPE
Physical forms capable of remanufacture	Flake (for direct use in remanufacturing or for further processing within a remanufacturing process ¹⁹) Pellet
Polymers for which processing/ machinery can be used interchangeably	 For food grade processing: Other food grade polymers which currently includes PET. For non-food grade processing: Other rigid polymers, such as PET, PVC, LDPE, PP, PS, ABS, PC, HIPS, Acrylic and Nylon, which have a low risk of hazardous additives (refer to Appendix F). Stakeholders advised that 'flushing' of the processing line and machinery is performed between polymers to reduce the risk of contamination and remove residual plastic waste.
Circumstances where colour sorting is required	 Food-grade HDPE processing typically requires a 'natural' colour feedstock (e.g. milk bottles). For non-food grade material, remanufacturers may request natural or single colour material for certain applications however the majority is mixed colour.

¹⁹ As stated in Section 2.3.4: Where further processing and pelletisation is part of the remanufacturer's manufacturing process line, the flake input may be considered "capable of remanufacture" (despite requiring pelletisation prior to remanufacture) as it meets the remanufacturers input specifications. This is opposed to flake exported for further processing and pelletisation at one facility before being transported to a different facility/country for remanufacture. Evidence is required outlining the manufacturing process line (including pelletisation equipment) and input specification.



Remanufacture considerations	HDPE
Additional requirements for processed waste plastic intended for food grade uses	 Feedstock to be sourced from food-grade material only Colour-sorted for natural HDPE Sterilisation of the flake before extrusion Output and processing to receive a LNO from the relevant food grade regulatory body, e.g. United States FDA or the European Directive. One stakeholder advised that only two companies manufacture the extrusion equipment suitable for food-grade pellet: Erema Group (Austria) Starlinger Group (Austria) FDA approval can also be obtained for other variations of equipment used and is dependent on the entire production process (not simply the processing equipment used), including the source of the material.
Circumstances where lower levels of processing may be applicable	 Flake is the minimum requirement for re-manufacturing however its suitability is dependent on the waste source, re-manufacturing machinery and intended application. Examples of where it may be suitable include: Feedstock is sourced from "clean" pre-consumer sources, such as HDPE plastic from manufacturing processes. In this instance, washing (and drying) and/or pelletising may not be required. The manufacturing extruders are robust and can accept the variable morphology and contamination present in flake. HDPE not intended for food-grade application. In this instance, sterilisation and/or pelletisation may not be required. Material undergoes re-manufacturing into lower "commercial grade" or "off-grade" applications or where the end-product is more forgiving, i.e. requiring less stringent mechanical properties. In these instances, washing, sterilisation and pelletisation may not be required.
The forms are not consistent with Phase 2 requirements	 Baled HDPE Shredded HDPE (unless it has been flaked to a uniform dimension)
Commonly used industry specifications that could be "listed specifications" consistent with the Phase 2 export ban	 The department has published the following specifications as <i>listed specifications</i> for HDPE APCO – Natural HDPE flake for food grade applications APCO – Coloured HDPE flake No new commonly used industry specifications were identified.
Common co-polymers/ polymer blends	HDPE is classified as a homopolymer. No common polymer blends were identified for HDPE.

4.3 Hazardous waste processing

No potentially hazardous additives of concern were identified to be used in HDPE products.

4.4 End-of-waste criteria

For the forms identified as being consistent with Phase 2 requirements, an assessment against end-ofwaste criteria is provided in Table 10. As mentioned previously, there are multiple considerations (i.e. the



waste source, re-manufacturing machinery and intended application) that require critical analysis, based on evidence provided, for a material to meet the Phase 2 requirements and/or end-of-waste criteria. The table below provides an indication of the known considerations for the polymer forms to meet end-ofwaste criteria and should be used in conjunction with the remanufacture considerations tabled above.

Meeting a legitimate technical specification is an important aspect of the end-of-waste assessment as it demonstrates that the recycled material will go into manufacturing and is not a waste. This criterion is not able to be assessed in this report as the nominated specification and legislation requirements in the importing country are not known however it is likely that analysis and testing of the polymer performance will support this.

Table 10 HDPE end-of-waste assessment

End-of-waste criteria	Likely to meet	Assessment
The substance or object is commonly used for specific purposes	~	 Re-processed HDPE flake and pellet is likely to meet this criterion if destined for common applications for remanufacturing. Examples of major and minor applications for re-processed HDPE include²⁰: Major uses: milk bottles, films, pallets, wheelie bins, irrigation hoses and pipes. Minor uses: cable covers, extruded sheet, moulded products, shopping and garbage bags, slip sheets, drip sheets for water, wood substitutes and mixed plastics products (e.g. fence posts, bollards, kerbing, marine structures and outdoor furniture), materials handling and roto-moulded water tanks.
A market or demand exists for such a substance or object	~	Based on known market pricing information, there is likely to be a demand for natural and coloured recycled HDPE (rHDPE) flake and pellet. The demand for food-grade rHDPE is likely to increase worldwide due to recycled content targets.
The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products	ļ	Dependent on the nominated specification and legislation in the importing country.
The use of the substance or object will not lead to overall adverse environmental or human health impacts	~	Potentially hazardous additives were not identified to be common for HDPE therefore the risk of adverse impacts is low.

²⁰ Australian Plastic Flows and Fates Study 2019-20 (2021) prepared by Envisage Works for the Department of Agriculture, Water and the Environment.



5 PVC

Polyvinyl Chloride (PVC) is a thermoplastic polymer commonly used in construction and industrial applications. PVC has a high compatibility with many different types of additives giving it many different mechanical properties and making it suitable for a wide range of applications. Compounding PVC with plasticisers, such as phthalates, creates a flexible PVC product while unplasticized PVC is used for rigid applications. PVC is not inherently heat stable so often contains heat stabilising additives. Some additives used in PVC plastic may be considered hazardous, refer to Appendix F.

The most common application areas and the proportion of PVC consumed in each, as well as some common product examples are included in Table 11.

Table 11 PVC common application areas and product examples

Common application areas	Product types / examples
Built environment (67.6%)	Plumbing pipe, sheeting, flooring, window frames, roofing, fencing
Other application area (9.3%)	Furniture, shower curtains, sporting goods, medical devices such as IV bags, oxygen masks and tubing (flexible PVC)
Electrical & electronic (9.1%)	Wire and cable insultation
Household packaging (5.1%)	Blister packs & containers
Automotive & unidentified applications (8.9%)	Car wrap sheeting

Source: Plastic infrastructure analysis update (2019) prepared by Envisage Works for the Department of the Environment and Energy.

5.1 Process flows

5.1.1 Source

Most rigid PVC for recycling is source-separated scrap from pre-consumer sources, such as manufacturers of PVC pipe and sheeting.

Flexible PVC is often sourced from suppliers of medical, building or packaging products.

Recyclers may reject PVC sourced from applications with a high risk of containing hazardous additives, such as lead stabilisers, or they may request testing, such as a basic lead testing kit, to be performed.

5.1.2 Reprocessing

PVC plastic waste is commonly recycled into non-food applications.

PVC is reprocessed into a flake using the standard mechanical recycling process and machinery:

- Manual sorting or optical sorting machinery to pre-sort and remove physical contaminants;
- Shredders and/or granulators to form a flake;
- One or multiple washing tanks;
- A mechanical or thermal dryer;

After flaking, the flake product may be suitable for:



- Direct use in a manufacturing (extrusion) process (i.e. without pelletisation);
- An extrusion line for melting, extruding and pelletisation of the flake into a pellet;
- Further processing to remove contaminants before extrusion, for example:
 - Optical sorting;
 - Density separation, e.g. floatation/sink washing (this may also be used as a washing step); and
 - Sterilisation (primarily for food-grade processing).
- Functional additives, such as heat and UV stabilisers and antioxidants, are commonly blended in with PVC before pelletisation.

It should be noted that further processing to remove contaminants and/or pelletisation may be performed by the reprocessor or by the remanufacturer.

5.2 Physical form/s

Remanufacture considerations regarding physical forms are outlined in Table 12.

Table 12 PVC Remanufacture considerations

Remanufacture considerations	PVC
Physical forms capable of remanufacture	Flake (for direct use in remanufacturing or for further processing within a remanufacturing process ²¹)
	Pellet (reported to be preferred by the majority of remanufacturers)
Polymers for which processing/ machinery can be used interchangeably	Several stakeholders noted that PVC contamination was an issue for processing other polymers. This means that processors may keep processing separate or avoid PVC processing altogether. However, there were some instances where facilities use the same machinery for PVC as other rigid polymers, such as PET, HDPE, LDPE, PP, PS, ABS, PC, HIPS, Acrylic and Nylon, which have a low risk of hazardous additives (refer to Appendix F). Flexible forms of PVC can be recycled with standard flexible plastic reprocessing machinery used for other flexible plastics such as LDPE and PP. Stakeholders advised that 'flushing' of the processing line and machinery is performed between polymers to reduce the risk of contamination and remove residual plastic waste.
Circumstances where colour sorting is required	PVC may be colour sorted if a customer requests a specific colour for their application. The common colour streams are transparent, white and colour. Stakeholders noted that clear or white colour separated PVC is more valuable than mixed or black material. Processors can be selective with the colours they source and process or may perform manual colour sorting.

²¹ As stated in Section 2.3.4: Where further processing and pelletisation is part of the remanufacturer's manufacturing process line, the flake input may be considered "capable of remanufacture" (despite requiring pelletisation prior to remanufacture) as it meets the remanufacturers input specifications. This is opposed to flake exported for further processing and pelletisation at one facility before being transported to a different facility/country for remanufacture. Evidence is required outlining the manufacturing process line (including pelletisation equipment) and input specification.



Remanufacture considerations	PVC		
Additional requirements for processed waste plastic intended for food grade uses	PVC is not currently recycled into food grade applications.		
Circumstances where lower levels of processing may be applicable	 Flake is the minimum requirement for re-manufacturing however its suitability is dependent on the waste source, re-manufacturing machinery and intended application. Examples of where it may be suitable include: Feedstock is sourced from "clean" pre-consumer sources, such as PVC plastic from manufacturing processes. In this instance, washing (and drying) and/or pelletising may not be required. The manufacturing extruders are robust and can accept the variable morphology and contamination present in flake. Material undergoes re-manufacturing into lower "commercial grade" or "off-grade" applications or where the end-product is more forgiving, i.e. requiring less stringent mechanical properties. In these instances, washing and pelletisation may not be required. 		
The forms are not consistent with Phase 2 requirements	 Baled PVC Shredded PVC (unless it has been flaked to a uniform dimension) PVC recycled from sources of PVC waste with hazardous additives classified as POPs (if the additive is not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.) 		
Commonly used industry specifications that could be "listed specifications" consistent with the Phase 2 export ban	No new commonly used industry specifications were identified.		
Common co- polymers/polymer blends	PVC is a homopolymer composed of the vinyl chloride monomer.		
	PVC may be blended with other polymers such as ABS for use in medical devices and other applications.		
	It would be appropriate for PVC blended polymers to be recycled without separation in circumstances where:		
	 There is a remanufacture process capable of incorporating the blended copolymer without separation. 		
	 Material can be processed from a single product stream (source) of consistent polymer blend material 		

5.3 Hazardous waste processing

PVC contains numerous additives which may be considered hazardous, refer to Appendix C for a list of examples and products they may be found in. The main additives discussed by stakeholders were lead stabilisers and the DEHP plasticiser.



Stakeholders processing PVC pipe reported that lead stabilisers, such as lead distearate, may still be used by some manufacturers in the production of pipes. One processor stated that they require PVC pipe waste generators (manufacturers) to test for the presence of lead in their material before they agree to recycle it. X-ray fluorescence or other basic lead testing kits can be used. Alternatively, there may be certain products that can safely incorporate these lead additives²².

The plasticiser DEHP was reported to still be used in the production of PVC products, such as medical products, in Australia however it is likely to be phased out in the next year due to customers of PVC products demanding its exclusion.

Testing for DEHP or other potentially hazardous plasticisers or additives (other than lead) were not reported by reprocessors or remanufacturers contacted, however laboratory techniques could be employed to identify the presence of phthalates, flame retardants and other hazardous additives, as mentioned in Section 2.3.5.

Further investigation is required regarding the impact of recycling plastic with potentially hazardous additives into suitable applications.

A project is being undertaken at CSIRO, funded by Sustainability Victoria, to develop a tool that can analyse the composition of PVC to increase recycling opportunities²³. It will analyse additives included in PVC waste, such as fillers and heat stabilisers, to determine what additional additives are required to meet end market specifications.

5.4 End-of-waste criteria

For the forms identified as being consistent with Phase 2 requirements, an assessment against end-ofwaste criteria is provided in Table 13. As mentioned previously, there are multiple considerations (i.e. the waste source, re-manufacturing machinery and intended application) that require critical analysis, based on evidence provided, for a material to meet the Phase 2 requirements and/or end-of-waste criteria. The table below provides an indication of the known considerations for the polymer forms to meet end-ofwaste criteria and should be used in conjunction with the remanufacture considerations tabled above.

Meeting a legitimate technical specification is an important aspect of the end-of-waste assessment as it demonstrates that the recycled material will go into manufacturing and is not a waste. This criterion is not able to be assessed in this report as the nominated specification and legislation requirements in the importing country are not known however it is likely that analysis and testing of the polymer performance will support this.

²² Schuyler Q, Walton A, and Farbotko C., PVC recycling in Australia: Current status, barriers, and opportunities (2022) CSIRO.

²³ Article: Saving PVC from landfill (2022), Annabel Boyer. https://ecos.csiro.au/pvc-recycling/



Table 13 PVC end-of-waste assessment

End-of-waste criteria	Likely to meet	Assessment
The substance or object is commonly used for specific purposes	~	 Re-processed PVC flake and pellet is likely to meet this criterion if destined for common applications for remanufacturing. Examples of major and minor applications for re-processed PVC include²⁴: Major uses: industrial and garden hose, profiles, pipes and conduit. Minor uses: gumboots, mats, resilient flooring, mudflaps and coving (decorative building mouldings).
A market or demand exists for such a substance or object	ļ	Market pricing/demand information was not identified for reprocessed PVC however commodity prices for virgin PVC resin have increased steeply ²⁵ . Some stakeholders suggested there is not significant demand for PVC flake.
The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products	ļ	Dependent on the nominated specification and legislation in the importing country.
The use of the substance or object will not lead to overall adverse environmental or human health impacts	ļ	Potentially hazardous additives were identified as a risk in some PVC plastic products. Testing, separation and removal of hazardous PVC material containing POPs is required. If not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.

²⁴ Australian Plastic Flows and Fates Study 2019-20 (2021) prepared by Envisage Works for the Department of Agriculture, Water and the Environment.

²⁵ Article: Saving PVC from landfill (2022), Annabel Boyer. https://ecos.csiro.au/pvc-recycling/



6 LDPE/LLDPE

Low Density Polyethylene (LDPE) is a thermoplastic polymer made up of ethylene monomers commonly used in its flexible form in packaging film applications. Linear Low Density Polyethylene (LLDPE) is a copolymer of ethylene and long chain olefins and this material is also often used in film applications. LLDPE elongates under stress (stretches) and has higher tensile strength and impact resistance than LDPE.

The most common applications areas and the proportion of LDPE consumed in each, as well as some common product examples are included in Table 14. Common applications of LLDPE were not reported in the Plastic Infrastructure Analysis Update Report but may include plastic bags, sheets and agricultural films such as silage wrap.

Table 14 LDPE common uses common application areas and product examples

Common application areas	Product types / examples
Household packaging (36.1%)	Packaging film, lids, flexible containers, cling wrap, plastic bags, bin liners
Commercial and industrial packaging (34.9%)	Packaging film, pallet wrap, flexible film
Agriculture (12.8%)	Irrigation pipes, silage bale wrap
Other application area (6.8%)	Toys, tubing & vehicle dashboards
Built environment, electrical & unidentified applications (9.4%)	

Source: Plastic infrastructure analysis update (2019) prepared by Envisage Works for the Department of the Environment and Energy.

6.1 Process flows

6.1.1 Source

LDPE is commonly sourced from:

- Pre-consumer material from manufacturing processes (factory offcuts, manufacturing scrap) or commercial and industrial sources such as supermarket pallet wrap
- Post-consumer material, including from:
 - Agricultural sources
 - Horticultural sources
 - Households (collected from supermarket front-of-store drop-off or at MRFs through the Curby system)

Pre-consumer material is likely to be very clean. LDPE from commercial and industrial sources is often in the form of clear pallet wrap used in the transport of products and the main contaminants are labels, tape and strapping.

Post-consumer material from agricultural and horticultural applications is often heavily contaminated with soil and other residues from its use, such as silage.

Post-consumer material from households is heavily contaminated with food residues and is generally a mix of other flexible polymer types, including PP, PVC and polyamines.


6.1.2 Reprocessing

Rigid LDPE is reprocessed into a flake using the standard mechanical recycling process and machinery:

- Manual sorting or optical sorting machinery to pre-sort and remove physical contaminants;
- Shredders and/or granulators to form a flake;
- One or multiple washing tanks;
- A mechanical or thermal dryer;

After flaking, the flake product may be suitable for:

- Direct use in a manufacturing (extrusion) process (i.e. without pelletisation);
- An extrusion line for melting, extruding and pelletisation of the flake into a pellet;
- Further processing to remove contaminants before extrusion, for example:
 - Optical sorting;
 - Density separation, e.g. floatation/sink washing (this may also be used as a washing step); and
 - Sterilisation (primarily for food-grade processing).

It should be noted that further processing to remove contaminants and/or pelletisation may be performed by the reprocessor or by the remanufacturer.

The same reprocessing steps apply to flexible LDPE however, generally a processing line specific to flexible plastic will be used.

One stakeholder sourcing flexible LDPE waste from commercial and agricultural sources, utilises magnet separation before shredding to remove metal contaminants and a pre-wash before shredding to remove dirt and other residue. They utilise two washing machines with a friction washer in between and a centrifuge dryer.

There is currently a very limited re-processing capacity for flexible LDPE film in Australia with only a select few re-processing highly contaminated material from the agricultural industry into a LDPE or mixed polymer pellet. Most companies reported that it is being baled and exported due to limited high quality domestic re-processing.



6.2 Physical form/s

Remanufacture considerations regarding physical forms are outlined in Table 15.

Table 15 LDPE remanufacture considerations

Remanufacture considerations	LDPE
Physical forms capable of remanufacture	Rigid LDPE: Flake (for direct use in remanufacturing or for further processing within a remanufacturing process ²⁶) Pellet <u>Flexible LDPE</u> : Pellet
Polymers for which processing/ machinery can be used interchangeably	Other rigid polymers, such as PET, HDPE, PVC, PP, PS, ABS, PC, HIPS, Acrylic and Nylon, which have a low risk of hazardous additives (refer to Appendix F). Stakeholders advised that 'flushing' of the processing line and machinery is performed between polymers to reduce the risk of contamination and remove residual plastic waste. Although the same standard shredding and granulating machinery could technically be used for rigid plastics and flexible LDPE, machinery for flexible LDPE requires different speeds and settings to reduce the size of material. Different extruding lines are required for LDPE. The same processing line could be used for different flexible polymers with limited hazardous additives, such as PVC and HDPE. Stakeholders noted that flexible polymers like LDPE from post-consumer sources require significantly more cleaning than rigid plastics.
Circumstances where colour sorting is required	There are three (3) colour grades for LDPE: natural, black or jazz (mixed colours). Other colours may also be sorted for if requested by the re-manufacturer. Clear LDPE is the most valuable and is able to be re-processed back into clear film. Black LDPE may be used to make a thicker building film.
Additional requirements for processed waste plastic intended for food grade uses	 LDPE is currently not reprocessed for food grade applications. If this were possible in the future: Feedstock to be sourced from food grade material only Colour-sorting for clear Appropriate reprocessing, e.g. hot cash and sterilisation. Output and processing to receive an LNO from the relevant food grade material regulatory body, e.g. United States FDA or the European Directive.

²⁶ As stated in Section 2.3.4: Where further processing and pelletisation is part of the remanufacturer's manufacturing process line, the flake input may be considered "capable of remanufacture" (despite requiring pelletisation prior to remanufacture) as it meets the remanufacturers input specifications. This is opposed to flake exported for further processing and pelletisation at one facility before being transported to a different facility/country for remanufacture. Evidence is required outlining the manufacturing process line (including pelletisation equipment) and input specification.



Remanufacture considerations	LDPE
Circumstances where lower levels of processing may be applicable	 Flake is the minimum requirement for rigid LDPE remanufacturing however its suitability is dependent on the waste source, re-manufacturing machinery and intended application. Examples of where it may be suitable include: Feedstock is sourced from "clean" pre-consumer sources, such as LDPE plastic from manufacturing processes. In this instance, washing (and drying) and/or pelletising may not be required. The manufacturing extruders are robust and can accept the variable morphology and contamination present in flake. Material undergoes re-manufacturing into lower "commercial grade" or "off-grade" applications or where the end-product is more forgiving, i.e. requiring less stringent mechanical properties. In these instances, washing, sterilisation and pelletisation may not be required. Pellet is the minimum requirement for flexible LDPE remanufacturing. Flexible LDPE flake is very fluffy and inefficient to transport therefore densification (pelletisation) is required for downstream manufacturing.
The forms are not consistent with Phase 2 requirements	 Baled flexible LDPE Flexible LDPE shred or flake Unsorted flexible films from households Unwashed material from post-consumer sources
Commonly used industry specifications that could be "listed specifications" consistent with the Phase 2 export ban	No new commonly used industry specifications identified.
Common co-polymers/ polymer blends	LDPE is a homopolymer and LLDPE is a copolymer. No common polymer blends were identified.

No potentially hazardous additives of concern were identified to be used in LDPE products.

6.4 End-of-waste criteria

For the forms identified as being consistent with Phase 2 requirements, an assessment against end-ofwaste criteria is provided in Table 16. As mentioned previously, there are multiple considerations (i.e. the waste source, re-manufacturing machinery and intended application) that require critical analysis, based on evidence provided, for a material to meet the Phase 2 requirements and/or end-of-waste criteria. The table below provides an indication of the known considerations for the polymer forms to meet end-ofwaste criteria and should be used in conjunction with the remanufacture considerations tabled above.

Meeting a legitimate technical specification is an important aspect of the end-of-waste assessment as it demonstrates that the recycled material will go into manufacturing and is not a waste. This criterion is not able to be assessed in this report as the nominated specification and legislation requirements in the importing country are not known however it is likely that analysis and testing of the polymer performance will support this.



Table 16 LDPE end-of-waste assessment

End-of-waste criteria	Likely to meet	Assessment
The substance or object is commonly used for specific purposes	~	 Re-processed LDPE pellet is likely to meet this criterion if destined for common applications for re-manufacturing. Examples of major and minor applications for re-processed LDPE include²⁷: Major uses: film (including builder's and agricultural film, concrete lining, freight packaging, garbage bags, shopping bags), agricultural piping. Minor uses: trickle products, vineyard cover, pallets, shrink wrap, roto-moulding, slip sheets, irrigation tube, timber substitutes, cable covers, builders' film, garbage bags, carry bags and other building industry applications.
A market or demand exists for such a substance or object	~	Based on known market pricing information, there is likely to be a demand for natural, jazz or black recycled LDPE (rLDPE) pellet.
The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products	ļ	Dependent on the nominated specification and legislation in the importing country.
The use of the substance or object will not lead to overall adverse environmental or human health impacts	~	Potentially hazardous additives were not identified to be common for LDPE therefore the risk of adverse impacts is low.

²⁷ Australian Plastic Flows and Fates Study 2019-20 (2021) prepared by Envisage Works for the Department of Agriculture, Water and the Environment.



7 PP

Polypropylene or PP is a common thermoplastic polymer used in rigid and flexible applications, including food and non-food grade consumer packaging. The most common applications areas and the proportion of PP consumed in each, as well as some common product examples are included in Table 17.

 Table 17 PP common application areas and product examples

Common application areas	Product types / examples
Household packaging (34.8%)	Food packaging (chip packets, containers, nut packets), plastic tubs & packaging films
Other application areas (25.1%)	Bags, furniture, clothing, bulka bags
Automotive (16.8%)	Automotive body components
Unidentified applications (10.8%)	Unknown
Agriculture, built environment, electrical & commercial and industrial packaging (12.6%)	Electrical components

Source: Plastic infrastructure analysis update (2019) prepared by Envisage Works for the Department of the Environment and Energy. Note: percentages taken from report did not add to 100.0%.

7.1 Process flows

7.1.1 Source

PP waste plastic most often includes post-consumer packaging material, collected from households and commercial and industrial sources, e.g. shopping centres. This material is sorted from other waste materials and plastic types at MRFs.

Post-consumer rigid PP material is likely to have contaminants in the form of food and beverage residues, labels, and glues or adhesives.

Pre-consumer PP material may also be collected and is likely to contain less contamination than postconsumer PP material.

A key source of flexible PP is bulka bags used in agriculture, food production, mining, construction and other industries.

7.1.2 Reprocessing

PP plastic waste is commonly recycled into non-food grade material. Stakeholders identified that PP is not recycled into food grade material due to the challenge of sorting for large volumes of clear, uniform food grade packaging as applications of PP are very diverse.

PP is reprocessed into a flake using the standard mechanical recycling process and machinery:

- Manual sorting or optical sorting machinery to pre-sort and remove physical contaminants;
- Shredders and/or granulators to form a flake;
- One or multiple washing tanks;
- A mechanical or thermal dryer;

After flaking, the flake product may be suitable for:



- Direct use in a manufacturing (extrusion) process (i.e. without pelletisation);
- An extrusion line for melting, extruding and pelletisation of the flake into a pellet;
- Further processing to remove contaminants before extrusion, for example:
 - Optical sorting;
 - Density separation, e.g. floatation/sink washing (this may also be used as a washing step); and
 - Sterilisation (primarily for food-grade processing).

For re-processing of flexible PP, similar processing machinery to flexible LDPE can be used.

It should be noted that further processing to remove contaminants and/or pelletisation may be performed by the reprocessor or by the remanufacturer.

7.2 Physical form/s

Remanufacture considerations regarding physical forms are outlined in Table 18.

Table 18 PP remanufacture considerations

Remanufacture considerations	РР
Physical forms capable of remanufacture	Flake (for direct use in remanufacturing or for further processing within a remanufacturing process ²⁸) Pellet
Polymers for which processing/ machinery can be used interchangeably	Other rigid polymers, such as PET, HDPE, PVC, LDPE, PS, ABS, PC, HIPS, Acrylic and Nylon, which have a low risk of hazardous additives (refer to Appendix F). Flexible forms of PP can be recycled with standard flexible plastic reprocessing machinery used for other flexible plastics such as LDPE. Flexible PP and rigid PP have different melt flows, therefore two different extrusion lines would be ideal. Stakeholders advised that 'flushing' of the processing line and machinery is performed between polymers to reduce the risk of contamination and remove residual plastic waste.
Circumstances where colour sorting is required	PP may be sorted into clear, mixed and black colour streams which may be used by remanufacturers for certain applications. Some stakeholders noted that because black was so dominant in any mix they chose only to processed to black resins. Other stakeholders noted if material was single sourced and coloured then they might run a "special batch" of 2-5tonnes if demand existed for that colour e.g. blue milks crates. One stakeholder noted that there was only demand for black PP resin and so colour sorting was not required. A common use of black rPP is gardening pots.

²⁸ As stated in Section 2.3.4: Where further processing and pelletisation is part of the remanufacturer's manufacturing process line, the flake input may be considered "capable of remanufacture" (despite requiring pelletisation prior to remanufacture) as it meets the remanufacturers input specifications. This is opposed to flake exported for further processing and pelletisation at one facility before being transported to a different facility/country for remanufacture. Evidence is required outlining the manufacturing process line (including pelletisation equipment) and input specification.



Remanufacture considerations	PP
Additional requirements for processed waste plastic intended for food grade uses	Recycling of PP for food-grade applications is currently not undertaken. Stakeholders advised PP is used in a variety of food grade and non-food grade applications, such as food grade packaging of differing colours and non-food grade items such as black gardening pots, making it difficult to secure a reliable stream of food grade PP material from post-consumer sources. This is unlike HDPE and PET, where the market is dominated by products of identical colour and food-grade quality, i.e. milk bottles and clear beverage bottles, respectively.
Circumstances where lower levels of processing may be applicable	 Flake is the minimum requirement for re-manufacturing however its suitability is dependent on the waste source, re-manufacturing machinery and intended application. Examples of where it may be suitable include: Feedstock is sourced from "clean" pre-consumer sources, such as PP plastic from manufacturing processes. In this instance, washing (and drying) and/or pelletising may not be required. The manufacturing extruders are robust and can accept the variable morphology and contamination present in flake. Material undergoes re-manufacturing into lower "commercial grade" or "off-grade" applications or where the end-product is more forgiving, i.e. requiring less stringent mechanical properties. In these instances, washing and pelletisation may not be required.
The forms not consistent with Phase 2 requirements	 Baled PP Shredded PP PP recycled from sources of PP waste with hazardous additives classified as POPs (if the additive is not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.)
Commonly used industry specifications that could be "listed specifications" consistent with the Phase 2 export ban	 The department has published the following specification as <i>listed specifications</i> for PP: APCO – Cold washed coloured recycled PP flake No new commonly used industry specifications identified.
Common co- polymers/polymer blends	None identified

PP used in automotive and electronic products may contain additives that are potentially hazardous, refer to Appendix C. For example, HBCD and Dechlorane Plus used in wires and cables in electronics and vehicles. Refer to Section 15 for management of these waste streams.

7.4 End-of-waste criteria

For the forms identified as being consistent with Phase 2 requirements, an assessment against end-ofwaste criteria is provided in Table 19. As mentioned previously, there are multiple considerations (i.e. the



waste source, re-manufacturing machinery and intended application) that require critical analysis, based on evidence provided, for a material to meet the Phase 2 requirements and/or end-of-waste criteria. The table below provides an indication of the known considerations for the polymer forms to meet end-ofwaste criteria and should be used in conjunction with the remanufacture considerations tabled above.

Meeting a legitimate technical specification is an important aspect of the end-of-waste assessment as it demonstrates that the recycled material will go into manufacturing and is not a waste. This criterion is not able to be assessed in this report as the nominated specification and legislation requirements in the importing country are not known however it is likely that analysis and testing of the polymer performance will support this.

Table 19 PP end-of-waste assessment

End-of-waste criteria	Likely to meet	Assessment
The substance or object is commonly used for specific purposes	~	 Re-processed PP flake and pellet is likely to meet this criterion if destined for common applications for re-manufacturing. Examples of major and minor applications for re-processed PP include²⁹: Major uses: crates, boxes and plant pots. Minor uses: electrical cable covers, building panels and concrete reinforcement stools (bar chairs and shims), furniture, irrigation fittings, agricultural and garden pipe, drainage products (such as drain gates) and tanks, builders film, kerbing, bollards, concrete reinforcing and a wide variety of injection moulded products.
A market or demand exists for such a substance or object	~	Based on known market pricing information, there is likely to be a demand for natural and coloured recycled PP (rPP) flake and pellet.
The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products	ļ	Dependent on the nominated specification and legislation in the importing country.
The use of the substance or object will not lead to overall adverse environmental or human health impacts	~	Potentially hazardous additives were not identified for most PP waste streams and therefore the risk of adverse impacts is low.
	ļ	Potentially hazardous additives were identified in electronic and automotive waste streams. Testing, separation and removal of plastics containing POPs is required. If not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the

²⁹ Australian Plastic Flows and Fates Study 2019-20 (2021) prepared by Envisage Works for the Department of Agriculture, Water and the Environment.



End-of-waste criteria	Likely to meet	Assessment
		product. The recycling process must manage the potential risk to recyclers.



8 PS/EPS

Polystyrene (PS) is a synthetic aromatic hydrocarbon polymer made from the monomer known as styrene. PS is a hard, stiff, transparent synthetic resin widely employed in the food-service industry as rigid trays and containers.

Polystyrene made into a foam material called expanded polystyrene (EPS), or extruded polystyrene (XPS), is valued for its insulating and cushioning properties. EPS foam is widely used to make home and appliance insulation.

The most common application areas and the proportion of PS consumed in each, as well as some common product examples are included in Table 20. EPS application areas and products are provided in Table 21.

Table 20 PS common application areas and product examples

Common application areas	Product types / examples
Electronic & electronic (52.8%)	Electrical appliances & components
Household packaging (23.0%)	Dairy containers, packaging
Other application area (11.9%)	CD cases, toys, coat hangers, protective packaging & surfboards
Built environment (11.1%)	Refrigeration
Agriculture & unidentified applications (1.1%)	

Source: Plastic infrastructure analysis update (2019) prepared by Envisage Works for the Department of the Environment and Energy.

Table 21 EPS common application areas and product examples

Common application areas	Product types / examples
Built environment (41.0%)	Flooring, roofs, walls & insulation foam
Electrical & Electronic (28.5%)	Electrical appliances
Commercial and industrial packaging (14.5%)	Fruit and vegetable trays, meat & seafood packaging
Household packaging (11.2%)	Meat trays & takeaway containers
Other application area & unidentified applications (4.8%)	Helmet padding & seeding trays

Source: Plastic infrastructure analysis update (2019) prepared by Envisage Works for the Department of the Environment and Energy.

8.1 Process flows

8.1.1 Source

PS waste plastic is generally recovered and sorted from pre-consumer sources, including packaging from electronic installation services and large format retailers.



Stakeholders advised that the most common source of pre-consumer material was from manufacturers who used PS in their processing. PS waste from electrical and electronic application areas may contain flame retardants and phthalate plasticisers of concern while other PS waste may contain antioxidants of concern.

EPS packaging waste is sourced from households through dedicated drop-off points and collected from businesses. EPS waste from built environment and electrical and electronic application areas may contain flame retardants of concern. Refer to Appendix F for a list of additives that may be found in PS/EPS waste.

8.1.2 Reprocessing

Compared with the light-weight EPS, rigid PS is more commonly recycled.

Rigid PS is reprocessed into a flake using the standard mechanical recycling process and machinery:

- Manual sorting or optical sorting machinery to pre-sort and remove physical contaminants;
- Shredders and/or granulators to form a flake;
- One or multiple washing tanks;
- A mechanical or thermal dryer;

After flaking, the flake product may be suitable for:

- Direct use in a manufacturing (extrusion) process (i.e. without pelletisation);
- An extrusion line for melting, extruding and pelletisation of the flake into a pellet;
- Further processing to remove contaminants before extrusion, for example:
 - Optical sorting;
 - Density separation, e.g. floatation/sink washing (this may also be used as a washing step); and
 - Sterilisation (primarily for food-grade processing).

It should be noted that further processing to remove contaminants and/or pelletisation may be performed by the reprocessor or by the remanufacturer.

To reprocess EPS into a form suitable for remanufacture, the process is as follows:

- Granulation into millimetre particles;
- Compression into a cold-pressed brick (or 'briquette') or melted via a thermal compaction machine into a hot melted lump (a 'glass-like' material) to reduce bulk density. Bulk density can be reduced from 20g/L to 200-400g/L; and
- The compressed material may be extruded to produce a denser product and pelletised into general purpose polystyrene (GPPS) pellets or may go directly into the manufacturing process.

Due to the small quantities of EPS collected in Australia and lack of demand for reprocessed materials, EPS material is generally exported after the compression step³⁰. EPS cannot be remanufactured into new EPS, it is extruded to make specific products such as picture frames.

8.2 Physical form/s

Remanufacture considerations regarding physical forms are outlined in Table 22.

³⁰ Expanded Polystyrene Australia website: http://epsa.org.au/about-eps/eps-recycling/



Table 22 PS/EPS Remanufacture considerations

Remanufacture considerations	PS/EPS
Physical forms capable of remanufacture	PS: Flake (for direct use in remanufacturing or for further processing within a remanufacturing process ³¹) Pellet EPS: Compacted or compressed EPS bricks/briquettes Pellet
Polymers for which processing/ machinery can be used interchangeably	 PS: Other rigid polymers, such as PET, HDPE, PVC, LDPE, PP, ABS, PC, HIPS, Acrylic and Nylon, which have a low risk of hazardous additives (refer to Appendix F). EPS: No other polymers were identified. Due to the foam structure of EPS, it is unlikely that no rigid or flexible plastic can be processed using the same machinery.
Circumstances where colour sorting is required	 PS: PS may be colour sorted if a customer requests a specific colour for their application. The common colour streams sourced are black and silver relating to its use as WEEE. Processors can be selective with the colours they source and process or may perform manual colour sorting. EPS: EPS is usually white (packaging foam), but there is no indication that colour sorting is required for EPS reprocessing
Additional requirements for processed waste plastic intended for food grade uses	 PS: Recycling of PS for food-grade applications is currently not undertaken. Stakeholders advised that there was insufficient uniform feedstock available to MRFs to justify source separating PS from other plastic streams. EPS: Recycling of EPS for food-grade applications is currently not undertaken. The physical nature of EPS makes it unsuitable for food grade reprocessing.

³¹ As stated in Section 2.3.4: Where further processing and pelletisation is part of the remanufacturer's manufacturing process line, the flake input may be considered "capable of remanufacture" (despite requiring pelletisation prior to remanufacture) as it meets the remanufacturers input specifications. This is opposed to flake exported for further processing and pelletisation at one facility before being transported to a different facility/country for remanufacture. Evidence is required outlining the manufacturing process line (including pelletisation equipment) and input specification.



Remanufacture considerations	PS/EPS
Circumstances where lower levels of processing may be applicable	 PS: Flake is the minimum requirement for re-manufacturing however its suitability is dependent on the waste source, re-manufacturing machinery and intended application. Examples of where it may be suitable include: Feedstock is sourced from "clean" pre-consumer sources, such as PS plastic from manufacturing processes. In this instance, washing (and drying) and/or pelletising may not be required. The manufacturing extruders are robust and can accept the variable morphology and contamination present in flake. Material undergoes re-manufacturing into lower "commercial grade" or "off-grade" applications or where the end-product is more forgiving, i.e. requiring less stringent mechanical properties. In these instances, washing and pelletisation may not be required. EPS: Lower levels of processing may be appropriate where: The intended remanufacturing machinery/processes can accept lower levels of processing. This may include EPS that is pressed into "bricks" and transported to dedicated EPS processing facilities³². It was noted that EPS is exported in the brick form, not the pellet form. One stakeholder noted that there was not sufficient EPS feedstock in Australia to justify a specialty EPS processing facility.
The forms are not consistent with Phase 2 requirements	 PS: Baled PS Shredded PS (unless flaked to a uniform dimension) EPS: Baled EPS Shredded EPS Shredded EPS Flaked/granulated EPS EPS recycled from sources of EPS waste with hazardous additives classified as POPs (if the additive is not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.) For example construction waffle EPS with hazardous flame retardants.
Commonly used industry specifications that could be "listed specifications" consistent with the Phase 2 export ban	 The department has published the following specification as <i>listed specification</i> for EPS: Expanded Polystyrene Australia – Export Densified EPS: Model Specifications No new commonly used industry specifications were identified.
Common co-polymers/ polymer blends	PS is sometimes blended with other polymers, including polyolefins and engineering plastic, however these blends were not reported to be common.

³² Expanded Polystyrene Australia website: http://epsa.org.au/about-eps/eps-recycling/



PS used in automotive and electronic products may contain flame retardants that are potentially hazardous. Refer to Section 15 for management of these waste streams. Other applications of PS may contain antioxidants of concern. Methods to identify and remove these additives was not identified.

EPS from building construction waste may contain potentially hazardous additives. For example, construction waffle EPS is known to include flame retardant additives, some of which are classified as a POP. Advice from industry and peak bodies suggests that the building code was updated in 2018 and since then, a different flame retardant is used. It is not known if the new flame retardant is also considered hazardous. Management of this waste stream was not identified and it not known if recycling is possible.

8.4 End-of-waste criteria

For the forms identified as being consistent with Phase 2 requirements, an assessment against end-ofwaste criteria is provided in Table 23. As mentioned previously, there are multiple considerations (i.e. the waste source, re-manufacturing machinery and intended application) that require critical analysis, based on evidence provided, for a material to meet the Phase 2 requirements and/or end-of-waste criteria. The table below provides an indication of the known considerations for the polymer forms to meet end-ofwaste criteria and should be used in conjunction with the remanufacture considerations tabled above.

Meeting a legitimate technical specification is an important aspect of the end-of-waste assessment as it demonstrates that the recycled material will go into manufacturing and is not a waste. This criterion is not able to be assessed in this report as the nominated specification and legislation requirements in the importing country are not known however it is likely that analysis and testing of the polymer performance will support this.



Table 23 PS & EPS end-of-waste assessment

End-of-waste criteria	Likely to meet	Assessment
The substance or object is commonly used for specific purposes	~	 Re-processed PS flake and pellet is likely to meet this criterion if destined for common applications for re-manufacturing. Examples of major and minor applications for re-processed PS include³³: Major uses: bar chairs and industrial spools. Minor uses: office accessories, coat hangers, glasses, building components, industrial packing trays, wire spools and a range of extrusion products. Re-processed EPS bricks and pellet is likely to meet this criterion if destined for common applications for remanufacturing. Examples of major and minor applications for reprocessed EPS include³³: Major uses: waffle pods for under slab construction of buildings. Minor uses: synthetic timber applications (including photo frames, decorative architraves, fence posts), XPS (extruded polystyrene) insulation sheeting, and lightweight concrete.
A market or demand exists for such a substance or object	!	Market pricing/demand information was not identified for PS or EPS.
The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products	ļ	Dependent on the nominated specification and legislation in the importing country.
The use of the substance or object will not lead to overall adverse environmental or human health impacts	ļ	Potentially hazardous additives were identified in electronic, automotive, building/construction and potentially other PS/EPS streams. Testing, separation and removal of material containing POPs is required. If not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.

³³ Australian Plastic Flows and Fates Study 2019-20 (2021) prepared by Envisage Works for the Department of Agriculture, Water and the Environment.



9 ABS

Acrylonitrile Butadiene Styrene (ABS) is a strong, durable thermoplastic. ABS is commonly used in automotive and electrical applications where hazardous additives may added, refer to Appendix F for a list of examples. The most common applications areas and the proportion of ABS consumed in each, as well as some common product examples are included in Table 24.

Table 24 ABS common application areas and product examples

Common application areas	Product types / examples
Automotive (55.6%)	Automobile component parts (Interior trimming, casings, guards, seat belts, instrument panels.)
Electrical & electronic (25.6%)	Electrical appliances, electrical products, keyboards keys, PowerPoint sockets.
Other application area (11.7%)	Control panels, refrigerator linings, LEGO blocks, sports equipment, gardening tools, furniture feet, nebulisers and compressors.
Household packaging (5.1%)	
Built environment & unidentified applications (2.0%)	Pipes, hoses and fittings.

Source: Plastic infrastructure analysis update (2019) prepared by Envisage Works for the Department of the Environment and Energy.

9.1 Process flows

9.1.1 Source

ABS waste plastic may be sourced from:

- 1. Post-consumer sources: WEEE (e.g. laptops, televisions, keyboards) and end-of-life vehicles (e.g. car bumper panels)
- 2. Pre-consumer sources: manufacturing sources including factory offcuts and seconds

ABS sourced from WEEE and end-of-life vehicles may contain potentially hazardous additives.

Material that is sourced through industrial sources is typically cleaner and its chemical properties are well known, making it suitable for standard recycling. The additives used in WEEE and ELV are varied, making post-consumer material less uniform and potentially hazardous.

9.1.2 Reprocessing

For ABS from sources not likely to contain hazardous additives, it can be reprocessed into a flake using the standard mechanical recycling process and machinery:

- Manual sorting or optical sorting machinery to pre-sort and remove physical contaminants;
- Shredders and/or granulators to form a flake;
- One or multiple washing tanks;
- A mechanical or thermal dryer;



After flaking, the flake product may be suitable for:

- Direct use in a manufacturing (extrusion) process (i.e. without pelletisation);
- An extrusion line for melting, extruding and pelletisation of the flake into a pellet;
- Further processing to remove contaminants before extrusion, for example:
 - Optical sorting;
 - Density separation, e.g. floatation/sink washing (this may also be used as a washing step); and
 - Sterilisation (primarily for food-grade processing).

It should be noted that further processing to remove contaminants and/or pelletisation may be performed by the reprocessor or by the remanufacturer.

Re-processing of ABS from WEEE and end-of-life vehicles is outlined in Section 15.

9.2 Physical form/s

Remanufacture considerations regarding physical forms are outlined in Table 25.

Table 25 ABS Remanufacture considerations

Remanufacture considerations	ABS
Physical forms capable of remanufacture	Flake (for direct use in remanufacturing or for further processing within a remanufacturing process ³⁴) Pellet
Polymers for which processing/ machinery can be used interchangeably	Other rigid polymers, such as HDPE, PVC, LDPE, PP, PS, ABS, PC, HIPS, Acrylic and Nylon, which have a low risk of hazardous additives (refer to Appendix F). Stakeholders advised that 'flushing' of the processing line and machinery is performed between polymers to reduce the risk of contamination and remove residual plastic waste.
Circumstances where colour sorting is required	ABS may be colour sorted if a customer requests a specific colour for their application. The common colour streams are black and colour. Stakeholders noted that there was limited domestic demand for ABS in any processed form therefore colour separation was rarely considered.
Additional requirements for processed waste plastic intended for food grade uses	ABS is not currently recycled into food grade applications.
Circumstances where lower levels of	Flake is the minimum requirement for re-manufacturing however its suitability is dependent on the waste source, re-manufacturing machinery and intended application. Examples of where it may be suitable include:

³⁴ As stated in Section 2.3.4: Where further processing and pelletisation is part of the remanufacturer's manufacturing process line, the flake input may be considered "capable of remanufacture" (despite requiring pelletisation prior to remanufacture) as it meets the remanufacturers input specifications. This is opposed to flake exported for further processing and pelletisation at one facility before being transported to a different facility/country for remanufacture. Evidence is required outlining the manufacturing process line (including pelletisation equipment) and input specification.



Remanufacture considerations	ABS
processing may be applicable	 Feedstock is sourced from "clean" pre-consumer sources, such as ABS plastic from manufacturing processes. In this instance, washing (and drying) and/or pelletising may not be required. The manufacturing extruders are robust and can accept the variable morphology and contamination present in flake. Material undergoes re-manufacturing into lower "commercial grade" or "off-grade" applications or where the end-product is more forgiving, i.e. requiring less stringent mechanical properties. In these instances, washing, sterilisation and pelletisation may not be required.
The forms are not consistent with Phase 2 requirements	 Baled ABS. Shredded ABS (unless flaked to a uniform dimension) ABS recycled from sources of ABS waste with hazardous additives classified as POPs (if the additive is not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.)
Commonly used industry specifications that could be "listed specifications" consistent with the Phase 2 export ban	No new commonly used industry specifications were identified.
Common co- polymers/polymer blends	ABS is a co-polymer. It is also often blended with other polymers such as polycarbonate in a PC/ABS blend. Refer to Section 11 on PC. Stakeholders reported that recycling of ABS blends is possible and the output could be used in re-manufacturing applications requiring the specific ABS blend. For example, electronic and automotive applications.

ABS used in automotive and electronic products may contain additives that are potentially hazardous, refer to Appendix C. Refer to Section 15 for management of these waste streams.

9.4 End-of-waste criteria

For the forms identified as being consistent with Phase 2 requirements, an assessment against end-ofwaste criteria is provided in Table 26. As mentioned previously, there are multiple considerations (i.e. the waste source, re-manufacturing machinery and intended application) that require critical analysis, based on evidence provided, for a material to meet the Phase 2 requirements and/or end-of-waste criteria. The table below provides an indication of the known considerations for the polymer forms to meet end-ofwaste criteria and should be used in conjunction with the remanufacture considerations tabled above.

Meeting a legitimate technical specification is an important aspect of the end-of-waste assessment as it demonstrates that the recycled material will go into manufacturing and is not a waste. This criterion is not able to be assessed in this report as the nominated specification and legislation requirements in the importing country are not known however it is likely that analysis and testing of the polymer performance will support this.



Table 26 ABS end-of-waste assessment

End-of-waste criteria	Likely to meet	Assessment
The substance or object is commonly used for specific purposes	~	 Re-processed ABS flake and pellet is likely to meet this criterion if destined for common applications for remanufacturing. Examples of major and minor applications for re-processed ABS include³⁵: Major uses: injection moulded products. Minor uses: automotive components, laminate edging, sheet extrusion, coffin handles, drainage covers, auto parts and a range of injection moulded products.
A market or demand exists for such a substance or object	!	Market pricing/demand information was not identified for ABS.
The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products	ļ	Dependent on the nominated specification and legislation in the importing country.
The use of the substance or object will not lead to overall adverse environmental or human health impacts	ļ	Potentially hazardous additives were identified in electronic and automotive waste streams. Testing, separation and removal of material containing POPs is required. If not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.

³⁵ Australian Plastic Flows and Fates Study 2019-20 (2021) prepared by Envisage Works for the Department of Agriculture, Water and the Environment.



10 PU

Polyurethane (PU) is a versatile plastic used in manufacturing appliances for consumer and industrial products. It can be tailored to be either rigid or flexible. The majority of PU are thermoset plastics (i.e. does not melt when heated) however some thermoplastic polyurethanes also exist³⁶.

Flexible PU foam (sometimes referred to as 'PUR') is the largest single application, accounting for 67% of worldwide PU production in 2016³⁷. PUR may contain flame retardants, phthalate plasticisers and stabilising additives of concern, refer to Appendix F for a list of examples.

The most common application areas and the proportion of PU consumed in each, as well as some common product examples are included in Table 27.

Common application areas	Product types / examples
Other (40.0%)	Carpet underlay, mattresses, high chairs, upholstered furniture, seat foam, headrest foam, roof liners
Built environment (28.8%)	Paints and varnishes, glue, insulation & composite wood panels
Automotive (27.8%)	Car seats, solid tyres and wheels & insulation
Unidentified applications (2.2%)	Clothing elastic, shoe soles & cleaning sponges
Electrical & electronic (1.2%)	Fridge and freezer insulation

Table 27 PU common application areas and product examples

Source: Plastic infrastructure analysis update (2019) prepared by Envisage Works for the Department of the Environment and Energy.

10.1 Process flows

10.1.1 Source

The most likely source of PU plastic waste available for recycling will be direct single source suppliers including from:

- End-of-life mattresses and furniture foam
- Manufacturing scrap
- Reject components
- Excess and redundant resin stock

Pre-consumer sources contain less contamination and may require less processing than post-consumer – although no stakeholders interviewed processed PU.

Post-consumer PU products such as mattresses and foam in upholstered furniture and cars, may contain flame retardants, phthalate plasticisers and stabilising additives of concern. Generally, the PU foam is stripped from the product, e.g. a mattress, and baled for reprocessing.

³⁶ Sheppard et al., Reprocessing postconsumer polyurethane foam using carbamate exchange catalysis and twinscrew extrusion (2020) ACS Cent. Sci. 6, 6, 921-927.

³⁷ Gama et al., Polyurethane Foams: Past, Present and Future (2018) Materials (Basel) 11(10): 1841.



10.1.2 Reprocessing

Most commonly, PU foam is a thermoset plastic and undergoes particle bonding for remanufacture into a low-value foam product. Processing includes:

- Shredding;
- Granulating into smaller pieces;
- Mixing and coating with a binding agent before moulding into a large 'log' of a pre-defined density;
- Steaming the log under high pressure to cure the binding agent and bond the material together; and
- Drying the log to remove residual moisture and peeling to a pre-defined product thickness³⁸.

The process may also consist of a magnet to remove metal contamination, such as staples and springs, after shredding. A separator utilising cyclone air separation may also be used on the granulated material to further remove contamination (the foam is blown upwards while heavier material falls down).

The low-value foam product is used as carpet underlay and in mattresses.

10.2 Physical form/s

Remanufacture considerations regarding physical forms are outlined in Table 28.

Table 28 PU Remanufacture considerations

Remanufacture considerations	PU
Physical forms capable of remanufacture	Moulded log
Polymers for which processing/ machinery can be used interchangeably	As PU waste cannot be remelted and extruded into pellets, it is unlikely that it can use the machinery and processing methods of other polymers.
Circumstances where colour sorting is required	None identified
Additional requirements for processed waste plastic intended for food grade uses	Not applicable
Circumstances where lower levels of processing may be applicable	The moulded log is the minimum requirement for re- manufacturing.
The forms not consistent with Phase 2 requirements	 Baled PU foam Shredded or granulated PU foam PU recycled from sources of PU waste with hazardous additives classified as POPs (if the additive is not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.)

³⁸ Interfloor website: https://www.interfloor.com/underlay-manufacturing/



Remanufacture considerations	PU
Commonly used industry specifications that could be "listed specifications" consistent with the Phase 2 export ban	No commonly used industry specifications were identified.
Common co-polymers/polymer blends	None identified

Common methods to identify, remove and manage hazardous additives in PU were not identified. It is not known if re-processors or re-manufacturers require laboratory tests demonstrating that input material does not contain potentially hazardous additives such as HBCD.

10.4 End-of-waste criteria

For the forms identified as being consistent with Phase 2 requirements, an assessment against end-ofwaste criteria is provided in Table 29. As mentioned previously, there are multiple considerations (i.e. the waste source, re-manufacturing machinery and intended application) that require critical analysis, based on evidence provided, for a material to meet the Phase 2 requirements and/or end-of-waste criteria. The table below provides an indication of the known considerations for the polymer forms to meet end-ofwaste criteria and should be used in conjunction with the remanufacture considerations tabled above.

Meeting a legitimate technical specification is an important aspect of the end-of-waste assessment as it demonstrates that the recycled material will go into manufacturing and is not a waste. This criterion is not able to be assessed in this report as the nominated specification and legislation requirements in the importing country are not known however it is likely that analysis and testing of the polymer performance will support this.



Table 29 PU end-of-waste assessment

End-of-waste criteria	Likely to meet	Assessment
The substance or object is commonly used for specific purposes	~	 Re-processed PU is likely to meet this criterion if destined for common applications for re-manufacturing. Examples of major and minor applications for re-processed PU include³⁹: Major uses: carpet underlay. Minor uses: mattresses.
A market or demand exists for such a substance or object	!	Market pricing/demand information was not identified for recycled PU.
The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products	!	Dependent on the nominated specification and legislation in the importing country.
The use of the substance or object will not lead to overall adverse environmental or human health impacts	ļ	Potentially hazardous additives were identified as a risk in some PU foam products. Testing, separation, and removal of hazardous PVC material containing POPs is required. If not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.

³⁹ Australian Plastic Flows and Fates Study 2019-20 (2021) prepared by Envisage Works for the Department of Agriculture, Water and the Environment.



11 PC

Polycarbonate (PC) is a transparent, strong and stable engineering thermoplastic. PC and PC blends used in automotive and electronic products as well as in construction applications may contain additives of concern, refer to Appendix F for a list of examples.

Data regarding the most common application areas was not available for PC however examples are provided in Table 30.

Common application areas	Product types / examples
Automotive	Dashboards, light housings, lenses, Automotive, aircraft and railway parts
Consumer goods	CDs/DVDs, glass lenses, water dispenser water bottles, coffee machines, food mixers, hair dryers, face shields, stationary products, furniture, vacuums
Medical	Surgical instruments, dialysis machines, blood filters, humidifiers
Construction	Roof sheeting, security windows, facades, skylights
Electronic	Phone screens

Table 30 PC common application areas and product examples

11.1 Process flows

11.1.1 Source

Materially may be collected from the following sources:

- Post-consumer: WEEE and ELV
- Pre-consumer: manufacturing sources including factory offcuts and seconds

Most PC recycling happens where source segregated PC-rich waste streams exist, such as used CD and DVD discs⁴⁰.

Material that is sourced through industrial sources is cleaner and its chemical properties are well known, making it suitable for standard recycling. The additives used in WEEE and ELV are varied, making post-consumer material less uniform and potentially hazardous.

11.1.2 Reprocessing

PC is reprocessed into a flake using the standard mechanical recycling process and machinery:

- Manual sorting or optical sorting machinery to pre-sort and remove physical contaminants;
- Shredders and/or granulators to form a flake;
- One or multiple washing tanks;
- A mechanical or thermal dryer;

After flaking, the flake product may be suitable for:

⁴⁰ Technical guidelines on the environmentally sound management of plastic wastes (draft, October 2021) author unknown.



- Direct use in a manufacturing (extrusion) process (i.e. without pelletisation);
- An extrusion line for melting, extruding and pelletisation of the flake into a pellet;
- Further processing to remove contaminants before extrusion, for example:
 - Optical sorting; and
 - Density separation, e.g. floatation/sink washing (this may also be used as a washing step).

It should be noted that further processing to remove contaminants and/or pelletisation may be performed by the reprocessor or by the remanufacturer.

Washing is often not required if it is coming from a clean source and used to manufacture engineering material, such as roof sheeting. If there are signs of dirt or contamination, washing is likely required.

Re-processing of PC from WEEE and end-of-life vehicles is outlined in Section 15.

11.2 Physical form/s

Remanufacture considerations regarding physical forms are outlined in Table 31.

Table 31 PC remanufacture considerations

Remanufacture considerations	PC
Physical forms capable of remanufacture	Flake (for direct use in remanufacturing or for further processing within a remanufacturing process ⁴¹)
	Pellet
Polymers for which processing/ machinery can be used interchangeably	Other rigid polymers, such as PET, HDPE, PVC, LDPE, PP, PS, ABS, HIPS, Acrylic and Nylon, which have a low risk of hazardous additives (refer to Appendix F). Stakeholders advised that 'flushing' of the processing line and machinery is performed between polymers to reduce the risk of contamination and remove residual plastic waste.
Circumstances where colour sorting is required	PC is naturally transparent however can come in colours. It is likely that clear PC is separated from coloured PC or PC with ink in it to produce a higher value product. PC may be colour sorted if a customer requests a specific colour for their application. The common colour streams include "water clear" and coloured. Stakeholders noted that for "water clear" PC reprocessing, small instances of colour contamination is likely to result in visual defects.
Additional requirements for processed waste plastic intended for food grade uses	PC is not currently recycled into food grade applications.

⁴¹ As stated in Section 2.3.4: Where further processing and pelletisation is part of the remanufacturer's manufacturing process line, the flake input may be considered "capable of remanufacture" (despite requiring pelletisation prior to remanufacture) as it meets the remanufacturers input specifications. This is opposed to flake exported for further processing and pelletisation at one facility before being transported to a different facility/country for remanufacture. Evidence is required outlining the manufacturing process line (including pelletisation equipment) and input specification.



Remanufacture considerations	PC
Circumstances where lower levels of processing may be applicable	 Flake is the minimum requirement for re-manufacturing however its suitability is dependent on the waste source, re-manufacturing machinery and intended application. Examples of where it may be suitable include: Feedstock is sourced from "clean" pre-consumer sources, such as PC plastic from manufacturing processes. In this instance, washing (and drying) and/or pelletising may not be required. The manufacturing extruders are robust and can accept the variable morphology and contamination present in flake. Material undergoes re-manufacturing into lower "commercial grade" or "off-grade" applications or where the end-product is more forgiving, i.e. requiring less stringent mechanical properties. In these instances, washing and pelletisation may not be required.
The forms not consistent with Phase 2 requirements	 Baled PC Shredded PC (unless it has been flaked to a uniform dimension) PC recycled from sources of PC waste with hazardous additives classified as POPs (if the additive is not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.)
Commonly used industry specifications that could be "listed specifications" consistent with the Phase 2 export ban	No commonly used industry specifications were identified.
Common co-polymers/ polymer blends	PC may be blended with other polymers, such as ABS and HIPS, to provide increased performance characteristics to specific plastic products, such as electrical products and automotive products ⁴² . PC/ABS was reported to be one of the most common polymer blends of engineering plastics.
	It was reported by several stakeholders that polymer blends, such as PC-ABS, are recyclable however they are unable to be separated into their individual polymers. The blended polymer can be melted and extruded into a recycled blended pellet to be used to manufacture new blended polymer products.

PC and PC blends used in automotive and electronic products may contain additives that are potentially hazardous. Refer to Section 15 for management of these waste streams.

11.4 End-of-waste criteria

For the forms identified as being consistent with Phase 2 requirements, an assessment against end-ofwaste criteria is provided in Table 32. As mentioned previously, there are multiple considerations (i.e. the

⁴² Impacts of Brominated Flame Retardants on WEEE recycling 2020, Sofies.



waste source, re-manufacturing machinery and intended application) that require critical analysis, based on evidence provided, for a material to meet the Phase 2 requirements and/or end-of-waste criteria. The table below provides an indication of the known considerations for the polymer forms to meet end-ofwaste criteria and should be used in conjunction with the remanufacture considerations tabled above.

Meeting a legitimate technical specification is an important aspect of the end-of-waste assessment as it demonstrates that the recycled material will go into manufacturing and is not a waste. This criterion is not able to be assessed in this report as the nominated specification and legislation requirements in the importing country are not known however it is likely that analysis and testing of the polymer performance will support this.

Table 32 PC end-of-waste assessment

End-of-waste criteria	Likely to meet	Assessment
The substance or object is commonly used for specific purposes	ļ	Re-processed PC flake and pellet is likely to meet this criterion if destined for common applications for re-manufacturing. Examples of major and minor applications for re-processed PC were not available ⁴³ however it is likely to be used to manufacture engineering material, such as roof sheeting.
A market or demand exists for such a substance or object	ļ	Market pricing/demand information was not identified for PC.
The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products	ļ	Dependent on the nominated specification and legislation in the importing country.
The use of the substance or object will not lead to overall adverse environmental or human health impacts	ļ	Potentially hazardous additives were identified in electronic and automotive waste streams. Testing, separation and removal of hazardous PC material containing POPs is required. If not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.

12 HIPS

High Impact Polystyrene (HIPS) is a lightweight, typically rigid, thermoplastic. HIPS and HIPS blends used in automotive and electronic products as other applications may contain additives of concern, refer to Appendix F for a list of examples.

Data regarding the most common application areas was not available for HIPS however examples are provided in Table 33.

⁴³ Australian Plastic Flows and Fates Study 2019-20 (2021) prepared by Envisage Works for the Department of Agriculture, Water and the Environment.



Common application areas	Product types / examples
Electrical & electronic	Computer casings, keyboards, mouses, monitors, television casings
Consumer goods	Store displays, ID cards, shelving, fixtures and fittings

Table 33 HIPS common application areas and product examples

12.1.1 Source

Materially may be collected from pre-consumer sources, although stakeholders did not provide specific examples and one stakeholder noted that there was insufficient feedstock in Australia to justify collecting and pelletising waste HIPS.

HIPS may also be sourced from post-consumer WEEE and may contain potentially hazardous additives.

12.1.2 Reprocessing

HIPS is reprocessed into a flake using the standard mechanical recycling process and machinery:

- Manual sorting or optical sorting machinery to pre-sort and remove physical contaminants;
- Shredders and/or granulators to form a flake;
- One or multiple washing tanks;
- A mechanical or thermal dryer;

After flaking, the flake product may be suitable for:

- Direct use in a manufacturing (extrusion) process (i.e. without pelletisation);
- An extrusion line for melting, extruding and pelletisation of the flake into a pellet;
- Further processing to remove contaminants before extrusion, for example:
 - Optical sorting; and
 - Density separation, e.g. floatation/sink washing (this may also be used as a washing step).

It should be noted that further processing to remove contaminants and/or pelletisation may be performed by the reprocessor or by the remanufacturer.

Washing is often not required if it is coming from a clean source and used to manufacture engineering material. If there are signs of dirt or contamination, washing is likely required.

Re-processing of HIPS from WEEE is outlined in Section 15.

12.2 Physical form/s

Remanufacture considerations regarding physical forms are outlined in Table 34.



Table 34 HIPS remanufacture considerations

Remanufacture considerations	HIPS	
Physical forms capable of remanufacture	Flake (for direct use in remanufacturing or for further processing within a remanufacturing process ⁴⁴) Pellet	
Polymers for which processing/ machinery can be used interchangeably	Other rigid polymers, such as PET, HDPE, PVC, LDPE, PP, PS, ABS, PC, Acrylic and Nylon, which have a low risk of hazardous additives (refer to Appendix F). Stakeholders advised that 'flushing' of the processing line and machinery is performed between polymers to reduce the risk of contamination and remove residual plastic waste.	
Circumstances where colour sorting is required	HIPS may be colour sorted if a customer requests a specific colour for their application. Due to the low volume of HIPS processed in Australia there is limited information available where colour sorting is commonly required. Stakeholders noted that there was limited domestic demand for HIPS in any processed form so colour separation was rarely a consideration.	
Additional requirements for processed waste plastic intended for food grade uses	HIPS is not currently recycled into food grade applications.	
Circumstances where lower levels of processing may be applicable	 Flake is the minimum requirement for re-manufacturing however its suitability is dependent on the waste source, re-manufacturing machinery and intended application. Examples of where it may be suitable include: Feedstock is sourced from "clean" pre-consumer sources, such as HIPS plastic from manufacturing processes. In this instance, washing (and drying) and/or pelletising may not be required. The manufacturing extruders are robust and can accept the variable morphology and contamination present in flake. Material undergoes re-manufacturing into lower "commercial grade" or "off-grade" applications or where the end-product is more forgiving, i.e. requiring less stringent mechanical properties. In these instances, washing and pelletisation may not be required. 	

⁴⁴ As stated in Section 2.3.4: Where further processing and pelletisation is part of the remanufacturer's manufacturing process line, the flake input may be considered "capable of remanufacture" (despite requiring pelletisation prior to remanufacture) as it meets the remanufacturers input specifications. This is opposed to flake exported for further processing and pelletisation at one facility before being transported to a different facility/country for remanufacture. Evidence is required outlining the manufacturing process line (including pelletisation equipment) and input specification.



Remanufacture considerations	HIPS
The forms not consistent with Phase 2 requirements	 Baled HIPS Shredded HIPS (unless flaked to a uniform dimension) HIPS recycled from sources of HIPS waste with hazardous additives classified as POPs (if the additive is not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to remanufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.)
Commonly used industry specifications that could be "listed specifications" consistent with the Phase 2 export ban	No commonly used industry specifications were identified.
Common co- polymers/polymer blends	HIPS may be blended with other polymers, such as ABS or PC, to provide increased performance characteristics to specific plastic products, such as electrical products ⁴⁵ .
	It was reported by several stakeholders that polymer blends, such as HIPS/ABS, are recyclable however they are unable to be separated into their individual polymers. The blended polymer can be melted and extruded into a recycled blended pellet to be used to manufacture new blended polymer products.

HIPS and HIPS blends used in automotive and electronic products may contain additives that are potentially hazardous. Refer to Section 15 for management of these waste streams.

12.4 End-of-waste criteria

For the forms identified as being consistent with Phase 2 requirements, an assessment against end-ofwaste criteria is provided in Table 35. As mentioned previously, there are multiple considerations (i.e. the waste source, re-manufacturing machinery and intended application) that require critical analysis, based on evidence provided, for a material to meet the Phase 2 requirements and/or end-of-waste criteria. The table below provides an indication of the known considerations for the polymer forms to meet end-ofwaste criteria and should be used in conjunction with the remanufacture considerations table above.

Meeting a legitimate technical specification is an important aspect of the end-of-waste assessment as it demonstrates that the recycled material will go into manufacturing and is not a waste. This criterion is not able to be assessed in this report as the nominated specification and legislation requirements in the importing country are not known however it is likely that analysis and testing of the polymer performance will support this.

⁴⁵ Impacts of Brominated Flame Retardants on WEEE recycling 2020, Sofies.



Table 35 HIPS end-of-waste assessment

End-of-waste criteria	Likely to meet	Assessment
The substance or object is commonly used for specific purposes	ļ	Re-processed HIPS flake and pellet is likely to meet this criterion if destined for common applications for re- manufacturing. Examples of major and minor applications for re-processed HIPS were not available.
A market or demand exists for such a substance or object	!	Market pricing/demand information was not identified for HIPS.
The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products	ļ	Dependent on the nominated specification and legislation in the importing country.
The use of the substance or object will not lead to overall adverse environmental or human health impacts	ļ	Potentially hazardous additives were identified in electronic and automotive waste streams. Testing, separation and removal of hazardous HIPS material containing POPs is required. If not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.



13 Acrylic

Acrylic, also known as Poly(methyl methacrylate) (PMMA), is a type of engineering thermoplastic. Acrylic is very commonly used as a rigid, clear plastic sheeting and may also be referred to as Perspex or plexiglass.

Data regarding the most common application areas was not available for acrylic however examples are provided in Table 36.

Common application areas	Product types / examples
Construction	Paint, oil, Sheeting (Plexiglas/Perspex), windows
Other applications	Brochure holders, sneeze guards, furniture, helmet glass
Agriculture	Glass house sheeting
Industrial	Submarine windows, aeroplane windows
Textiles	Clothing, blankets, carpet, wool blend additive

13.1 Process flows

13.1.1 Source

There was limited knowledge among stakeholders regarding the recycling process for acrylic waste.

Materially is typically collected from pre-consumer sources, including:

- Sign board companies
- Plastic moulding offcuts
- Manufacturing facilities
- Other factory and industrial sources

Stakeholders noted that even with a single sourced feedstock stream, acrylic waste plastic is considered uneconomical to recycle in Australia due to low volumes.

13.1.2 Reprocessing

PC is reprocessed into a flake using the standard mechanical recycling process and machinery:

- Manual sorting or optical sorting machinery to pre-sort and remove physical contaminants;
- Shredders and/or granulators to form a flake;
- One or multiple washing tanks;
- A mechanical or thermal dryer;

After flaking, the flake product may be suitable for:

- Direct use in a manufacturing (extrusion) process (i.e. without pelletisation);
- An extrusion line for melting, extruding and pelletisation of the flake into a pellet;
- Further processing to remove contaminants before extrusion, for example:
 - o Optical sorting; and



 Density separation, e.g. floatation/sink washing (this may also be used as a washing step).

It should be noted that further processing to remove contaminants and/or pelletisation may be performed by the reprocessor or by the remanufacturer.

Washing is often not required if it is from a clean source.

13.2 Physical form/s

Remanufacture considerations regarding physical forms are outlined in Table 37.

Table 37 Acrylic remanufacture considerations

Remanufacture considerations	Acrylic
Physical forms capable of remanufacture	Flake (for direct use in remanufacturing or for further processing within a remanufacturing process ⁴⁶) Pellet
Polymers for which processing/ machinery can be used interchangeably	Other rigid polymers, such as PET, HDPE, PVC, LDPE, PP, PS, ABS, HIPS, Acrylic and Nylon, which have a low risk of hazardous additives (refer to Appendix F). Stakeholders advised that 'flushing' of the processing line and machinery is performed between polymers to reduce the risk of contamination and remove residual plastic waste.
Circumstances where colour sorting is required	One stakeholder noted that colour sorting was not required as most buyers of processed Acrylic accept mixed coloured batches. However, in certain cases special batches of less than 5 tonne of a single colour can be processed to meet specific customer requirements. This stakeholder mentioned that colour sorting did not correlate with higher prices for Acrylic unlike in other polymers.
Additional requirements for processed waste plastic intended for food grade uses	Acrylic is not currently recycled into food grade applications.

⁴⁶ As stated in Section 2.3.4: Where further processing and pelletisation is part of the remanufacturer's manufacturing process line, the flake input may be considered "capable of remanufacture" (despite requiring pelletisation prior to remanufacture) as it meets the remanufacturers input specifications. This is opposed to flake exported for further processing and pelletisation at one facility before being transported to a different facility/country for remanufacture. Evidence is required outlining the manufacturing process line (including pelletisation equipment) and input specification.



Remanufacture considerations	Acrylic
Circumstances where lower levels of processing may be applicable	 Flake is the minimum requirement for re-manufacturing however its suitability is dependent on the waste source, re-manufacturing machinery and intended application. Examples of where it may be suitable include: Feedstock is sourced from "clean" pre-consumer sources, such as acrylic plastic from manufacturing processes. In this instance, washing (and drying) and/or pelletising may not be required. The manufacturing extruders are robust and can accept the variable morphology and contamination present in flake. Material undergoes re-manufacturing into lower "commercial grade" or "off-grade" applications or where the end-product is more forgiving, i.e. requiring less stringent mechanical properties. In these instances, washing and pelletisation may not be required.
The forms not consistent with Phase 2 requirements	Baled acrylicShredded acrylic
Commonly used industry specifications that could be "listed specifications" consistent with the Phase 2 export ban	No commonly used industry specifications were identified.
Common co- polymers/polymer blends	No common co-polymers/polymer blends were identified.

Methods to identify, remove and manage hazardous additives in acrylic were not identified.

13.4 End-of-waste criteria

For the forms identified as being consistent with Phase 2 requirements, an assessment against end-ofwaste criteria is provided in Table 38. As mentioned previously, there are multiple considerations (i.e. the waste source, re-manufacturing machinery and intended application) that require critical analysis, based on evidence provided, for a material to meet the Phase 2 requirements and/or end-of-waste criteria. The table below provides an indication of the known considerations for the polymer forms to meet end-ofwaste criteria and should be used in conjunction with the remanufacture considerations tabled above.

Meeting a legitimate technical specification is an important aspect of the end-of-waste assessment as it demonstrates that the recycled material will go into manufacturing and is not a waste. This criterion is not able to be assessed in this report as the nominated specification and legislation requirements in the importing country are not known however it is likely that analysis and testing of the polymer performance will support this.



Table 38 Acrylic end-of-waste assessment

End-of-waste criteria	Likely to meet	Assessment
The substance or object is commonly used for specific purposes	ļ	Re-processed acrylic flake and pellet is likely to meet this criterion if destined for common applications for re- manufacturing. Examples of major and minor applications for re-processed acrylic were not available.
A market or demand exists for such a substance or object	!	Market pricing/demand information was not identified for acrylic.
The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products	ļ	Dependent on the nominated specification and legislation in the importing country.
The use of the substance or object will not lead to overall adverse environmental or human health impacts	~	Potentially hazardous additives were not identified to be common for acrylic therefore the risk of adverse impacts is low.



14 Nylon

Nylon, also known as polyamide (PA), is a low-density synthetic thermoplastic used in the production of film and fibre as well as rigid material. Nylon used for carpets and other textile products as well as nylon used in the automotive industry may contain flame retardants of concern, refer to Appendix F for a list of examples.

The most common applications areas and the proportion of nylon consumed in each, as well as some common product examples are included in Table 39.

Table 39 Nylon common application areas and product examples

Common application areas	Product types / examples
Other application area (61.2%)	Textiles including clothing & carpets
Built environment (13.9%)	Pipes, used in the rail industry as clips to hold tracks down and pads under tracks
Automotive (12.7%)	Door Handles & Radiator Grills
Unidentified applications (10.1%)	Fishing line, fishing nets, tennis racket strings, tents
Agriculture & household packaging (2.2%)	Packaging film

Source: Plastic infrastructure analysis update (2019) prepared by Envisage Works for the Department of the Environment and Energy.

14.1 Process flows

14.1.1 Source

Nylon requires collection through source segregated pre-consumer sources.

Flexible or textile nylon such as carpets or fishing nets, can be sourced through post-consumer takeback schemes or pre-consumer sources (e.g. manufacturing and installation offcuts).

There was limited knowledge among stakeholders regarding the recycling process for nylon waste. One stakeholder processed plumbing accessories such as piping offcuts from industrial sources and another previously processed nylon from carpet manufacturers however this operation ceased due to low volume.

14.1.2 Reprocessing

Rigid nylon is reprocessed into a flake using the standard mechanical recycling process and machinery:

- Manual sorting or optical sorting machinery to pre-sort and remove physical contaminants;
- Shredders and/or granulators to form a flake;
- One or multiple washing tanks;
- A mechanical or thermal dryer;

After flaking, the flake product may be suitable for:

- Direct use in a manufacturing (extrusion) process (i.e. without pelletisation);
- An extrusion line for melting, extruding and pelletisation of the flake into a pellet;


- Further processing to remove contaminants before extrusion, for example:
 - Optical sorting; and
 - Density separation, e.g. floatation/sink washing (this may also be used as a washing step).

It should be noted that further processing to remove contaminants and/or pelletisation may be performed by the reprocessor or by the remanufacturer.

Washing may not be required if it is coming from a clean source. If there are signs of dirt or contamination, washing is likely required.

It is unknown if flexible or textile nylon clothing can be mechanically recycled.

The process for recycling nylon fibres from products such as carpet was not known by stakeholders. Desktop research identified that nylon carpet can be recycled using a combination of mechanical and chemical (depolymerization) processes⁴⁷. The process involves collection, mechanical shredding and separation, followed by chemical depolymerization to separate the nylon from the polypropylene. The separated nylon fraction is then pelletised for re-manufacture⁴⁸.

14.2 Physical form/s

Remanufacture considerations regarding physical forms are outlined in Table 40.

Table 40 Nylon remanufacture considerations

Remanufacture considerations	Nylon
Physical forms capable of remanufacture	Flake (which may or may not require further processing within a remanufacturing process ⁴⁹) Pellet
Polymers for which processing/ machinery can be used interchangeably	Other rigid polymers, such as PET, HDPE, PVC, LDPE, PP, PS, ABS, HIPS, Acrylic and Nylon, which have a low risk of hazardous additives (refer to Appendix F). Stakeholders advised that 'flushing' of the processing line and machinery is performed between polymers to reduce the risk of contamination and remove residual plastic waste.
Circumstances where colour sorting is required	Colour sorting may be required when recycling rigid nylon if a customer requests a specific colour for their application. It may be sorted into natural and jazz or black streams. One processing stakeholder noted that most nylon processed was from engineering applications (grey or black) – however there was generally no requirements to sort to specific colours when processing material.

⁴⁷ Technical guidelines on the environmentally sound management of plastic wastes (draft, October 2021) author unknown.

⁴⁸ Aquafil website: https://www.aquafil.com/sustainability/econyl/#econyl-01

⁴⁹ As stated in Section 2.3.4: Where further processing and pelletisation is part of the remanufacturer's manufacturing process line, the flake input may be considered "capable of remanufacture" (despite requiring pelletisation prior to remanufacture) as it meets the remanufacturers input specifications. This is opposed to flake exported for further processing and pelletisation at one facility before being transported to a different facility/country for remanufacture. Evidence is required outlining the manufacturing process line (including pelletisation equipment) and input specification.



Remanufacture considerations	Nylon
Additional requirements for processed waste plastic intended for food grade uses	Nylon is not currently recycled into food grade applications.
Circumstances where lower levels of processing may be applicable	 Flake is the minimum requirement for re-manufacturing rigid nylon however its suitability is dependent on the waste source, remanufacturing machinery and intended application. Examples of where it may be suitable include: Feedstock is sourced from "clean" pre-consumer sources, such as nylon plastic from manufacturing processes. In this instance, washing (and drying) and/or pelletising may not be required. The manufacturing extruders are robust and can accept the variable morphology and contamination present in flake. Material undergoes re-manufacturing into lower "commercial grade" or "off-grade" applications or where the end-product is more forgiving, i.e. requiring less stringent mechanical properties. In these instances, washing and pelletisation may not be required.
The forms not consistent with Phase 2 requirements	Baled nylonShredded nylon (unless flaked to a uniform dimension)
Commonly used industry specifications that could be "listed specifications" consistent with the Phase 2 export ban	No commonly used industry specifications were identified.
Common co- polymers/polymer blends	No common co-polymers/polymer blends were identified.

14.3 Hazardous waste processing

Methods to identify, remove and manage hazardous additives in nylon used for carpets and other textile products were not identified. It is not known if re-processors or re-manufacturers require laboratory tests demonstrating that input material does not contain potentially hazardous additives.

14.4 End-of-waste criteria

For the forms identified as being consistent with Phase 2 requirements, an assessment against end-ofwaste criteria is provided in Table 41. As mentioned previously, there are multiple considerations (i.e. the waste source, re-manufacturing machinery and intended application) that require critical analysis, based on evidence provided, for a material to meet the Phase 2 requirements and/or end-of-waste criteria. The table below provides an indication of the known considerations for the polymer forms to meet end-ofwaste criteria and should be used in conjunction with the remanufacture considerations tabled above.

Meeting a legitimate technical specification is an important aspect of the end-of-waste assessment as it demonstrates that the recycled material will go into manufacturing and is not a waste. This criterion is not able to be assessed in this report as the nominated specification and legislation requirements in the importing country are not known however it is likely that analysis and testing of the polymer performance will support this.



Table 41 Nylon end-of-waste assessment

End-of-waste criteria	Likely to meet	Assessment
The substance or object is commonly used for specific purposes	~	 Re-processed nylon is likely to meet this criterion if destined for common applications for re-manufacturing. Examples of major and minor applications for reprocessed nylon include⁵⁰: Major uses: injection moulded products. Minor uses: furniture fittings, wheels and castors and a range of injection moulded products.
A market or demand exists for such a substance or object	~	Based on known market pricing information, there is likely to be a demand for natural nylon pellet and jazz/black pellet.
The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products	!	Dependent on the nominated specification and legislation in the importing country.
The use of the substance or object will not lead to overall adverse environmental or human health impacts	ļ	Potentially hazardous additives were identified in nylon textile applications. Testing, separation and removal of hazardous nylon material containing POPs is required. If not a POP, the plastic may be recycled into a suitable new product with the potentially hazardous additive, i.e. there must be no risk to re-manufacturers and consumers of the product. The recycling process must manage the potential risk to recyclers.

⁵⁰ Australian Plastic Flows and Fates Study 2019-20 (2021) prepared by Envisage Works for the Department of Agriculture, Water and the Environment.



15 Management of Hazardous Additives

Methods and processes to remove potentially hazardous additives from the polymer structure were not identified. However, it was generally reported that these plastics could be separated from the non-hazardous plastics allowing the non-hazardous plastics to be recycled. This is also what is recommended in the Stockholm Convention on POPs:

Article 6(1)(d)(iii)) of the Stockholm Convention on POPs requires that POPs are generally not to be recovered, recycled, or reused. Yet in 2010... parties to the Convention agreed to an exemption that permits recycling of materials such as foam and plastics that contain these substances until 2030⁵¹.

The most common applications areas or waste streams for plastics with potentially hazardous additives include WEEE and ELV. Common re-processing methods are described below.

15.1 WEEE processing

WEEE plastic processing involves steps to identify and separate plastics containing hazardous substances, such as BFRs.

A study on the impact of BFRs on WEEE plastics recycling in Europe (2020) undertaken by Sofies identified the polymer composition of WEEE plastics⁵²:

- PP: 20%
- ABS: 19%
- HIPS: 18%
- PC/PC-ABS: 7%
- BFR ABS: 4%
- BFR Epoxy: 3%
- BFR HIPS: 1%

Sofies.

• The remaining 27% includes other engineering polymers such PMMA, PA6, PA66 and POM.

A breakdown of electronic products by polymer types, including BFR HIPS, BRF ABS and BFR epoxy, is presented in Figure 3 and a list of potentially hazardous substances by polymer type in WEEE and example products is presented in Table 42.

⁵¹ Hazardous Waste in Australia (2021) prepared by Blue Environment for the Department of Agriculture, Water and the Environment.
 ⁵² Study on the Impacts of Brominated Flame Retardants on the Recycling of WEEE plastics in Europe (2020)





Figure 3 Electronic product composition by polymer type

Source: Study on the Impacts of Brominated Flame Retardants on the Recycling of WEEE plastics in Europe (2020) Sofies.

Polymer	Potentially hazardous substance	Examples of products
ABS	decaBDE, DP, c-octaBDE, DBDPE, BTBPE, TBBPA	Housing and other moulded parts
Epoxy resins	decaBDE, c-pentaBDE, DP	Circuit boards, adhesives
HIPS	HBCDD, decaBDE, c-octaBDE, DBDPE, BTBPE, TBBPA, DP	Housing, video cassettes casing, keyboards
PC	decaBDE	Keyboards, panels, casings
PE	PBDE, DP, decaBDE	Wires, cables
PET	decaBDE, DBDPE	Switches, sockets
PP	decaBDE, DBDPE, DP	Wires, cables
PVC	c-pentaBDE, SCCP, MCCP	Wires, cables, hoses, connector

Table 42 Potentially hazardous substances by polymer type in WEEE and example products

Source: Environmental Pollutants in Post-Consumer Plastics (2021) Norwegian Environment Agency.

BFR plastics account for approximately 9% of WEEE plastics (mainly present in BFR HIPS, BFR ABS and BFR epoxy) however, up to 45% of WEEE plastics are not suitable for recycling due to the presence of other additives, such as fillers or plasticisers, or they cannot be sorted using conventional sorting



technologies⁵³. For example, density separation is commonly used to remove polymers with high loads of additives (due to their high density), such as BFRs, however this technique does not distinguish between BFRs and other flame retardants (FRs) so all are sorted into one high density stream.

Following collection of WEEE, it is taken to a primary processing facility (also known as a WEEE preprocessing facility) where the main processing steps typically include:

- Manual disassembly to remove valuable material, such as metals for recovery, and potentially hazardous components, such as mercury, leaded glass and plastics containing BFRs;
- After separation of valuable and hazardous material, the remaining material is shredded; and
- From the shredded stream, ferrous metal is separated leaving a mixed plastics stream.
- Separation of non-ferrous metal may also occur.

Some primary facilities will not remove potentially hazardous plastics at the first disassembly step and therefore the shredded mixed plastic stream may have a high risk of containing BFR plastics. Some primary facilities may decide to separate the potentially hazardous material through techniques such as X-ray transmission (XRT), X-ray fluorescence (XRF), Fourier transform infrared spectroscopy (FTIR) or density separation. The mixed plastic stream is sent for further processing at a secondary processing facility (or sent for disposal or incineration/energy recovery)⁵³.

The steps undertaken at a secondary processing facility typically include:

- Removal of contamination may be achieved through magnetic sorting, eddy current separation or air classification⁵³;
- Sorting by polymer type and/or plastics with hazardous additives may utilise density separation, optical sorting, electrostatic separation, or other processes;
- Washing; and
- Flaking and/or granulating.

The process flow of WEEE is presented in Figure 4.

⁵³ Study on the Impacts of Brominated Flame Retardants on the Recycling of WEEE plastics in Europe (2020) Sofies.





Figure 4 Typical WEEE processing

Source: Study on the Impacts of Brominated Flame Retardants on the Recycling of WEEE plastics in Europe (2020) Sofies.

Stakeholders suggested that secondary processing of the mixed plastic stream is likely to occur overseas due to Australia's limited capacity to process WEEE mixed plastics.

A number of stakeholders stated that BFR-containing plastic waste would be suitable for remanufacture of products with similar applications as the source products, i.e. products requiring flame retardancy such as electrical products, as long as the BFR is not a POP listed in the Stockholm Convention. If the BFR is a POP, Australia has an obligation to not recycle these plastics and should not allow their export to other countries without appropriate regulatory structures.

Despite the belief that BFR-containing plastic can be recycled, some stakeholders raised doubts surrounding the end users' ability/willingness to properly process and produce suitable material without causing harm to human health or the environment. Correspondingly, there is sometimes a limited market demand for recycled WEEE plastic pellets due to concerns over quality and potential presence of hazardous additives⁵⁴. Recycling of pellets containing BFRs (not listed as a POP) within a secure supply chain should be explored in the future as an alternative to landfill.

Stakeholders identified Australian Standard (AS/NZS 5377:2013) for the collection, storage, transport and treatment of end-of-life electrical and electronic equipment (AS5377) as an industry standard for WEEE however it is not an output specification. AS5377 requires certified recyclers to trace materials from the point of receiving them through to final disposition.

15.2 End-of-life vehicles processing

A list of potentially hazardous substances by polymer type in ELV and example products is presented in Table 43.

⁵⁴ Study on the Impacts of Brominated Flame Retardants on the Recycling of WEEE plastics in Europe (2020) Sofies.



Polymer	Potentially hazardous substance	Examples of products
ABS	decaBDE, DBDPE, TBBPA	Bumpers
Epoxy resins	decaBDE	Adhesives
Nylon	decaBDE	Wheel covers, seat belt, under hood applications
PC	decaBDE, TBBPA	Lights, bumpers, mirror housing, keyboards
PE	decaBDE	Wires, cables
PP	decaBDE, DBDPE	Wires, cables
PVC	SCCP, MCCP	Dashboards, wires, cables
PU	c-pentaBDE, decaBDE, SCCP, MCCP	Sealant, adhesive, upholstery

Table 43 Potentially hazardous substances by polymer type in ELV and example products

Source: Environmental Pollutants in Post-Consumer Plastics (2021) Norwegian Environment Agency.

Similar steps to WEEE processing apply to ELV, including:

- Depollution and dismantling of major components such as removal of batteries, tyres, large plastics, glass, fuel, oil and other liquids.
- Shredding and separation of metals, a shredder heavy fraction and a shredder light fraction.

The extent of plastics removal in the dismantling step depends on the facility as well as the market for the parts or re-processed plastics (and the capacity to re-process it)⁵⁵. Bumpers, wheel covers, and dashboards are typically easy to dissemble and may be repaired and reused. As legitimate recyclers do not receive large volumes and the market for re-processed ELV plastics in Australia is low, there is little incentive for reprocessing of ELV plastics⁵⁶.

Re-processing methods for these plastic for re-manufacturing of new plastic products were not identified. One stakeholder contacted stated that they previously recycled PP bumper bars however stopped due to contamination from non-plastic contaminants such as metal screws and bolts. Management of hazardous additives within the bumper bar was not performed.

It is likely that similar techniques to separate BFR plastics in WEEE could be used such as density separation.

⁵⁵ Environmental Pollutants in Post-Consumer Plastics (2021) Norwegian Environment Agency.
 ⁵⁶ Soo, V.K. et al., Comparative Study of End-of-Life Vehicle Recycling in Australia and Belgium (2017) The 24th CIRP Conference on Life Cycle Engineering.



16 Industry Capacity

16.1 Existing processing capacity

Almost all plastics recycling in Australia is currently undertaken mechanically, where the use of physical processes such as sorting, shredding, grinding, washing and extruding is undertaken. Mechanical recycling options are common for rigid plastics but in Australia there is currently limited capacity for soft plastics recycling as there is sufficient supply of rigid plastics that are easier to recycle. Moreover, processing soft plastics is more expensive than rigid plastics, due to many differences such as density and contamination affecting the inherent value of soft plastics. The mechanical recycling of soft plastics occurs on a small scale around Australia.

The main alternative to mechanical plastics recycling is chemical recycling. There is currently no chemical recycling of plastics occurring at commercial scale in Australia, however, the planned development of one major facility has recently been announced (refer below).

According to a report provided to the Department, in 2019-20 Australian facilities reprocessed 200,200 tonnes of waste plastic for local and international use. In comparison, 126,400 tonnes were recovered and sent unprocessed (e.g. loose or baled) overseas, while domestic reprocessing facilities had a total of 364,800 tonnes of processing capacity⁵⁷. Table 44 provides the breakdown of these numbers by polymer type and Table 45 compares the total recovered plastic (reprocessed and exported) against the processing capacity.

Polymer type	Locally reprocessed	Exported for reprocessing	Total recovered
PET	30,700	35,900	66,600
HDPE	56,100	23,000	79,100
PVC	5,300	1,100	6,400
LDPE/LLD	36,300	4,000	40,300
PP	38,600	7,300	45,900
PS	3,700	5,100	8,800
PS-E	6,100	1,700	7,800
ABS/SAN/ASA	900	6,600	7,500
PU	3,400	- /	3,400
PA	200	7,000	7,200
Bioplastic	100	-	100
Other	1,400	2,600	4,000
Unknown	17,400	32,100	49,500
Total	200,200	126,400	326,600

Table 44 Australian plastics recycling by polymer type in 2019–20 (tonnes)

⁵⁷ Plastic infrastructure analysis update (2019) prepared by Envisage Works for the Department of the Environment and Energy.



Polymer type	Total recovered	Current reprocessing capacity	Additional Capacity Required
PET	66,600	45,200	21,400
HDPE	79,100	109,100	(30,000)
PVC	6,400	11,600	(5,200)
LDPE/LLD	40,300	87,900	(47,600)
PP	45,900	60,200	(14,300)
PS	8,800	10,600	(1,800)
PS-E	7,800	14,500	(6,700)
ABS/SAN/ASA	7,500	1,400	6,100
PU	3,400	4,400	(1,000)
PA	7,200	600	6,600
Bioplastic	100	100	-
Other	4,000	1,800	2,200
Unknown	49,500	17,400	32,100
Total	326,600	364,800	68,400

Table 45 Australian plastics reprocessing capacity 2019–20 (tonnes)

By a cursory comparison of the recovered tonnes and reprocessing capacity for each polymer in Table 45, it appears that there are potential gaps in Australia's capacity to process PET, ABS/SAN/ASA, PA and Other and Unknown plastics.

However, this assessment is provisional as the domestic reprocessing capacity does not:

- Provide information on the compatibility of the reprocessing capacity with the form of plastic being recovered. For example, capacity may be available to process rigid polymers but current recovery is in a flexible form;
- Differentiate between high value and low value remanufactured plastic products (discussed further in Section 17). For example, clear flexible LDPE is currently reprocessed overseas into a high value clear film as there is limited capacity to reprocess it into this product domestically; and
- Account for the geographical distribution of facilities.

Consistent feedback from the stakeholder consultation regarding limitations to industry reprocessing capacity was that there will be a significant gap in Australia's capacity to reprocess LDPE/LLDPE and other flexible plastics such as PP bulka bags. However, this is not reflected in the data available.

16.2 Projects funded through the Australian Government Recycling Modernisation Fund

The Australian Government is working with states, territories and industry to deliver infrastructure solutions for the material impacted by the export bans. The Recycling Modernisation Fund (RMF) established by the Australian Government is investing \$190 million into the RMF and leveraging over \$800 million of recycling infrastructure investment from states and territories and industry.



The Department provided information for the additional plastic processing capacity funded by the RMF, which is summarised in Table 46 (for polymers 1-6 only).

Polymer type	FY 20-21	FY 21-22	FY 22-23	TOTAL	Remaining shortfall at FY22-23*
PET	0	0	25,142	25,142	3,742
HDPE	0	13,320	9,146	22,466	Nil
PVC	0	0	1,125	1,125	Nil
LDPE	0	2,950	6,324	9,274	Nil
PP	0	3,154	13,130	16,284	Nil
PS	0	1,929	3,458	5,387	Nil
Mixed	8,004	33,120	57,727	98,851	Not known

Table 46 Additional plastic processing capacity funded by RMF (tonnes)

*Does not take into consideration likely increases in plastic consumption and plastic waste generation in FY22-23 and the reprocessing capacity limitations discussed above.

The investment appears to fill the gap in reprocessing capacity for PET. While the additional mixed plastics processing capacity funded by the RMF exceeds the current processing deficit for ABS/SAN/ASA, PA and Other and Unknown plastics, it is not clear whether the additional planned capacity will be compatible with these forms of plastic currently recovered.

16.2.1 Other recently announced facilities or projects processing waste plastic

Brightmark, a global waste solutions provider, recently announced plans to construct an advanced plastics renewal facility for the Parkes Special Activation Precinct in New South Wales Australia. The plant is expected to be in operation by 2025, with construction planned to start in mid-2023. It will be capable of processing 200,000 tonnes of waste plastics.

The facility will re-purpose all types of plastics (1-7) to be ultra-low sulfur diesel, wax and naphtha to produce fully circular plastics. Special Activation Precincts are delivered by the NSW Government and funded from the \$4.2 billion Snowy Hydro Legacy Fund.

Qenos and Cleanaway have signed a Memorandum of Understanding to undertake a joint feasibility study for plastic-to-plastic advanced recycling to convert up to 100,000 tonnes per year of household soft plastic waste and mixed plastics into feedstock for Qenos' existing manufacturing facilities.



17 Other Considerations raised by stakeholders

• Re-processing of low volume and wide distribution waste plastics is not economically feasible

A number of stakeholders raised the issue regarding limitations of transport and aggregating low volume waste streams across Australia. For waste streams with low volume and wide distribution, such as PVC in building and construction waste, flexible LDPE and flexible PP bulka bags, the cost to aggregate and transport this waste is too high to justify recycling it.

CSIRO's report PVC recycling in Australia (2022) outlines the challenges and barriers of recycling PVC. Some of these were echoed by stakeholders. For PVC waste in the building and construction industry, stakeholders stated that while domestic recycling capacity for this material exists and it is collected from end-of-life building material, it is not commonly separated and transported to recycling facilities. PVC pipe is the biggest available source for recycling however it is not deemed valuable compared to other construction material, such as concrete and metals, and the transport costs are too high (due to long distances and poor packing density). It is therefore cheaper to landfill. Australia PVC recyclers are instead importing scrap from New Zealand. To increase recovery of PVC, primary sorting and transport of this waste stream is required.

For flexible LDPE waste, there is limited domestic recycling capacity for this material as the low volume and wide distribution has meant that historically, few recyclers have deemed it economically feasible (not enough volume to get return on capital). LDPE has a low collection efficiency with collection costing approximately \$200-400/t. Instead, the material has been exported as there is a strong international market for clean, clear flexible LDPE (approx. \$800/t in Asia)⁵⁸.

Some domestic capacity exists however stakeholders said this produces a lower grade product from post-consumer LDPE waste such as agricultural film. Re-processors may be able to acquire more cheap extrusion equipment from Asian equipment suppliers for black pellet later this year, however it will not arrive in time for the start of Phase 2.

High quality European equipment for clean, clear LDPE is more expensive and will take longer to be established in Australia. This is in addition to the issues with collecting quality feedstock material economically. It is possible that the high-quality reprocessed pellet will not be able to compete with international prices. Multiple stakeholders stated that it would be cheaper to landfill. Alternatively, the material could be recycled into a lower grade product.

It was reported that there is little domestic capacity for processing flexible PP bulka bags. The same issues surrounding high collection costs exist for this material.

A temporary exemption to the waste plastic licence regulation for flexible LDPE and PP waste was suggested by multiple stakeholders as well as subsidies to cover capital costs of reprocessing equipment.

Current stockpiling limits hinder recovery

Another barrier mentioned by reprocessors is the limit on stockpiling material. To process enough volumes to make recycling economically feasible, stakeholders would need to stockpile large quantities of material however the current stockpiling regulations do not allow them to do this. Amendments to stockpiling regulations should be considered.

⁵⁸ Estimated by stakeholder.



Appendix A Industry Stakeholders

	Organisation
Industry Body	National Waste & Recycling Industry Council (NWRIC)
Industry Body	Chemistry Australia
Industry Body	Vinyl Council
Industry Body	Plastics Industry Manufacturers of Australia (PIMA)
Materials Engineer	UNSW SMaRT Centre
Re-processor	TES-AM
Re-processor	YCA Recycling
Re-processor	Martogg
Re-processor	Cryogrind
Re-processor	Welvic
Re-processor & re-manufacturer	Visy
Re-processor & re-manufacturer	Cleanaway
Re-processor & re-manufacturer	Envorinex
Manufacturer	Lyondell Basell
Equipment supplier	CEMAC
Trader/exporter	Oatley Resources

Appendix B Bottle to flake processing flow example

An example of processing equipment flow for processing of bottles to flake is provided in Figure 5. It is suitable for food grade PET as well as non-food grade rigid plastics such as PET, HDPE, LDPE and PP.

Figure 5 Separation, size reduction and washing equipment line example



Source: Telford Smith Engineering



Appendix C Optical sorting equipment example

Figure 6 is an example of an optical sorter, the TOMRA AUTOSORT® FLAKE, used to sort PP flake from post-consumer mixed HDPE and PP plastic. It can also be used to sort other polymer types such as PET, HDPE and PVC. The machine specifications are:

- Width: 1,900mm
- Length: 2,300mm
- Height: 2,000mm
- Weight: 1,850kg
- Power consumption: 10kW
- Flake size range: 4-12mm

Figure 6 Optical sorting equipment example



Source: TOMRA



Appendix D Extrusion processing equipment example

Figure 7 is an example of an extrusion and pelletising processing line, the EREMA INTAREMA® TVEplus®, suitable for HDPE, PP and LDPE/LLDPE flake. Material is fed into the machine where it is cut, mixed, heated, dried and pre-compacted before being degassed, filtered and extruded into pellets.

Figure 7 Extrusion line equipment example



Source: EREMA



Appendix E Hazardous chemicals resources

The following resources list plastic additives of concern that may be considered hazardous. Plastic additives by polymer type are included in Appendix F.

The Stockholm Convention on Persistent Organics Pollutants (POPs)

The Stockholm Convention on Persistent Organic Pollutants (POPs) provides a list of POP chemicals and requires POP-containing wastes to be destroyed or managed in an environmentally sound manner. Australia is a party of the Stockholm Convention and last ratified the Stockholm Convention in 2004. Since then, more POPs have been listed and the Department works to ensure that these newly-listed POPs are managed according to the Stockholm Convention (however these amendments have not been ratified)⁵⁹.

Article 6(1)(d)(iii) of the Stockholm Convention requires that wastes containing POPs are generally not to be recovered, recycled or reused.

The Rotterdam Convention (Annex III)

The Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (the Rotterdam Convention) covers pesticides and industrial chemicals that have been banned or severely restricted for health or environmental reasons by Parties. The export of these chemicals requires written permission, i.e. PIC.

REACH, EU (Annex XIV)

Registration, Evaluation, Authorisation and restriction of Chemicals (REACH) is a European Union regulation requiring manufacturers and importers to register chemical substances with the European Chemicals Agency (ECHA). Annex XIV of the REACH regulation lists substances of very high concern (SVHC)⁶⁰.

Restriction of Hazardous Substances (RoHS)

The EU RoHS Directive restricts the use of hazardous chemicals found in electrical and electronic products in Europe. The following substances and maximum levels are specified in RoHS:

- Cadmium (Cd): < 100 ppm
- Lead (Pb): < 1000 ppm
- Mercury (Hg): < 1000 ppm
- Hexavalent Chromium: (Cr VI) < 1000 ppm
- Polybrominated Biphenyls (PBB): < 1000 ppm
- Polybrominated Diphenyl Ethers (PBDE): < 1000 ppm
- Bis(2-Ethylhexyl) phthalate (DEHP): < 1000 ppm
- Benzyl butyl phthalate (BBP): < 1000 ppm
- Dibutyl phthalate (DBP): < 1000 ppm
- Diisobutyl phthalate (DIBP): < 1000 ppm



Australian Government website

The Department website provides a list of chemicals of concern in plastics, as identified through publicly available, peer reviewed sources⁶¹. The list is a priority for future regulatory controls under the new Industrial Chemicals Environmental Management Standard (IChEMS).

Appendix F provides examples of chemicals of concern in plastic and the polymer and products they may be found in. This list is not exhaustive and does not necessary trigger a hazardous waste classification under the Basel Convention.

⁶¹ The Department website, Chemicals of concern in plastics: https://www.awe.gov.au/environment/protection/chemicals-management/chemicals-of-concern-plastics



Appendix F Additives of concern in plastic examples

Table 47 provides examples of chemicals of concern in plastic and the polymer and products they may be found in. Resources outlined in Appendix A were used to compile this list however it is not exhaustive and these resources update their lists based on the latest research available.

Table 47 Additives of concern in plastic

Additive	Type/ function	Polymer	Products	Source/inclusion	Use
Diethylhexyl phthalate (DEHP)	Plasticiser	PVC	Toys, medical products, building material such as flooring, cables, profiles and roofs.	The Department website, REACH SVHC	Reported by one stakeholder to still being used in PVC products in Australia however it is likely to be phased out in the next year.
Dibutyl phthalate (DBP)	Plasticiser	PVC	Floor coverings, automotive industry, garden hoses.	The Department website, REACH SVHC	Production was terminated but they can still be found in old products and recycled products ⁶² .
Bisphenol A (BPA)	Antioxidant	PVC PC	Stretch films for food packaging, infant feeding bottles, plates, mugs, etc.	The Department website	In 2010, the Aus. Gov. announced a voluntary phase out of BPA use in PC baby bottles ⁶³ .
Nonylphenol (4NP)	Antioxidant	PVC, PS	Unknown	The Department website	
Nonylphenol (NP)	Antioxidant	PVC, PS	Unknown	The Department website	
Hexabromocyclododecane (HBCD ⁶⁴)	Flame retardant	Nylon PS/EPS ABS PP	Mainly used in expanded and extruded PS foam insulation. Less use in textiles, electric & electronic appliances.	The Department website, SC Annex A (Elimination), RC	Production decreased in the last few years. Alternatives to replace it in HIPS and textile back-coating ⁶⁵ .

⁶² Technical guidelines on the environmentally sound management of plastic wastes (draft, October 2021) author unknown.

⁶³ Food Standards Australia New Zealand website: https://www.foodstandards.gov.au/consumer/chemicals/bpa/Pages/default.aspx

⁶⁴ HBCD is also used as an acronym for Hexachlorobutadiene (also listed in the Stockholm Convention).

⁶⁵ Stockholm Convention website: http://chm.pops.int/TheConvention/ThePOPs/AllPOPs/tabid/2509/Default.aspx



Additive	Type/ function	Polymer	Products	Source/inclusion	Use
Decabromodiphenyl ether (decaBDE) And other polybrominated diphenyl ethers (PBDEs) including pentaBDE & octaBDE.	Flame retardant	ABS Nylon PU foam	Computer & TV housings, wires, cables, pipes, carpets, PU foam for building insulation	The Department website, SC Annex A (Elimination), REACH SVHC	decaBDE is still used worldwide. Decabromodiphenyl ethane (DBDPE) is used as an alternative to decaBDE and can be found in similar applications. It may also be considered hazardous ⁶⁶ .
Dechlorane Plus	Flame retardant	ABS, PU, Nylon, PP	Mechanical appliances, electrical & electronic products and vehicles.	The Department website, SC proposed for listing	
Short-chain chlorinated paraffins (SCCP)	Plasticiser/flame retardant	PVC		The Department website, SC Annex A (Elimination), RC, REACH SVHC	Technically feasible alternatives are commercially available for all known uses ⁶⁷ .
Medium-chain chlorinated paraffins (MCCP)	Flame retardant	PVC		The Department website	
UV 328	UV stabiliser	PVC,PU, ABS, PC, Polyolefin s	Automotive and industrial plastics.	The Department website, SC proposed for listing, REACH SVHC	
Tetralead trioxide sulphate (TTS)	Heat stabiliser	PVC	PVC wire insulation, rigid and flexible PVC foams.	The Department website	
Lead distearate and other lead-based stabilisers	Heat stabiliser	PVC		The Department website, REACH SVHC	
Hexabromodiphenyl	Flame retardant	Unknown	Plastics and cables	Annex A (Elimination)	Mainly in the 1970s. No longer used in most countries.

⁶⁶ Environmental Pollutants in Post-Consumer Plastics (2021) Norwegian Environment Agency.
 ⁶⁷ Stockholm Convention website: http://chm.pops.int/TheConvention/ThePOPs/AllPOPs/tabid/2509/Default.aspx



Additive	Type/ function	Polymer	Products	Source/inclusion	Use
Hexabromodiphenyl ether & heptabromodiphenyl ether (components of octabromodiphenyl ether (octaBDE))	Flame retardant	ABS ⁶⁸	Computer & TV housings, wires, cables and others	SC Annex A (Elimination)	Unknown
Polychlorinated biphenyls (PCB)	Plasticiser	Unknown	Unknown	SC Annex A (Elimination), RC	Manufacture banned in the United States in 1979 ⁶⁹ .
Polybrominated biphenyls (PBBs) including commercial PBBs (hexaBB, octaBB, decaBB)	Flame retardant	ABS, foams (unknown polymer)	Textiles, appliances	SC Annex A (Elimination), RC, REACH SVHC	Banned in the US in 1976 ⁷⁰ .
Benzyl butyl phthalate (BBP)	Plasticiser	PVC	Unknown	REACH SVHC	Production was terminated but they can still be found in old products and recycled products ⁷¹ .
Diisobutyl phthalate (DIBP)	Plasticiser	PVC	Unknown	REACH SVHC	Production was terminated but they can still be found in old products and recycled products ⁷¹ .
Cadmium compounds	Stabiliser	PVC	Unknown	REACH SVHC	Production was terminated but they can still be found in old products and recycled products ⁷¹ .

⁶⁸ Diphenyl ether, octabromo derivative: summary risk assessment report (2003) European Commission Joint Research Centre: https://echa.europa.eu/documents/10162/01e59081-67a9-473b-8093-4df8bf646ee5

69 PCBs (2011) K. von Stackelberg in Encyclopaedia of Environmental Health: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/polychlorinated-biphenyl

⁷⁰ Technical Fact Sheet - PBBs (2017) US EPA.

⁷¹ Technical guidelines on the environmentally sound management of plastic wastes (draft, October 2021) author unknown.



Appendix G Polymer Laboratory Techniques

Table 48 Laboratory techniques related to analysis of polymers and additives

Technique	Purpose/ function	Description	Procedure	Examples of relevant standards
Fourier Transform Infrared Spectroscopy (FTIR)	Polymer identification, detection of surface contamination (e.g. additives that have migrated to the surface of the polymer) and the composition of copolymers and polymer blends.	Usually the first step in identifying a polymer. Further identification may be aided by DSC or an ash test.	A plastic material's absorbance of infrared light at different frequencies produces a "spectral fingerprint" unique to the polymer. This can be compared to spectral scans of known materials to identify the polymer type.	ASTM D3677 Standard Test Methods for Rubber – Identification by Infrared Spectrophotometry
Differential Scanning Calorimetry (DSC)	Polymer identification	Determines the glass transition temperature (Tg), crystallisation temperature and melting point (Tm) and other properties to analyse the type of polymer present and purity. These temperatures can be compared against those of virgin plastics.	The sample is heated at a controlled rate and a plot of heat flow versus temperature is produced. The resulting thermal scan is analysed against a reference library.	ASTM D3418 Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallisation of Polymers by Differential Scanning Calorimetry, ISO 11357 Plastics – Differential scanning calorimetry (DSC)
Thermo-gravimetric analysis (TGA)	Polymer identification & composition	Measures the percent weight loss of a test sample, providing an indication of the composition of the sample. E.g. PET will have a TGA profile different to PP.	The sample is heated at a controlled rate and a plot of percent weight loss versus temperature is produced. During this process, the plastic's carbon is burned leaving the oxides (additives) which can be further analysed.	ISO 11358 Plastics – Thermogravimetry of polymers, ASTM E1131 Standard Test Method for Compositional Analysis by Thermogravimetry



Technique	Purpose/ function	Description	Procedure	Examples of relevant standards
Gas Chromatography (GC) with Mass Spectrometry (MS) (Liquid Chromatography (LC) can also be used for liquids)	Additive analysis (identification and quantification)	GC or LC separates and isolates the gases or liquids, respectively, in the sample from the polymer matrix and MS identifies them.	The sample is injected into a gas chromatograph to separate the components based on size and/or polarity. The separated molecules are ionised and identified by their mass-to-charge ratio in a mass spectrometer.	ASTM D8133 Standard Test Method for Determination of Low Level Phthalates in Poly(Vinyl Chloride) Plastics by Solvent Extraction – Gas Chromatography/ Mass Spectrometry, ASTM D6953 Standard Test Method for Determination of Antioxidants and Erucamide Slip Additives in Polyethylene Using Liquid Chromatography
High Performance Liquid Chromatography (HPLC)	Additive analysis	Technique to separate liquids in the sample and analyse organic additives.	The sample mixture flows through a column with a fixed excess of coated support particles that separate the chemical compounds present in the sample. Various detectors can be used to identify the compounds such as MS, fluorescence, etc.	ASTM D8266 Standard Test Method for Analysis of Bisphenol A by High Performance Liquid Chromatography
lon chromatography (IC)	Additive analysis (ions such as bromine and chlorine)	Technique to analyse ions (not metals), such as bromine and chlorine.	lon-exchange resins are used to separate atomic and molecular ions for analysis.	ASTM D8280 Standard Test Method for Determination of the Blooming of Brominated Flame Retardants onto the Surface of Plastic Materials by Ion Chromatography
Atomic absorption spectrometry (AAS)	Additive analysis (metals)	Technique to identify and quantify specific metals and heavy metal content.	A light source emitting light at a specific wavelength of electromagnetic radiation passes through the sample. Individual elements will absorb wavelengths differently and these absorbances are measured against standards to identify elements present.	ASTM D4004 Standard Test Methods for Rubber – Determination of Metal Content by Flame AAS Analysis



Technique	Purpose/ function	Description	Procedure	Examples of relevant standards
X-Ray Fluorescence (XRF)	Additive analysis (detects bromine and chlorine)	Spectroscopic anslysis of existing elements from the periodic system. Can be performed with a handheld device or in a laboratory.	All elements in the sample are excited simultaneously and the fluorescence radiation emitted is separated and detected based on the characteristic x-rays of different elements.	ASTM F2617 Standard Test Method for Identification and Quantification of Chromium, Bromine, Cadmium, Mercury and Lead in Polymeric Material Using Energy Dispersive X-ray Spectrometry, ASTM D6247 Standard Test Method for Determination of Elemental Content of Polyolefins by Wavelength Dispersive X-ray Fluorescence Spectrometry
X-ray Transmission (XRT)	Additive analysis (e.g. heavy metals and organic materials)	Detection of different materials based on atomic particle density. Commonly used in sorting of e-waste plastic to detect BFRs.	An X-ray radiation beam penetrates the material and provides spectral absorption information based on the density of the material.	None identified.
Ash content analysis	Additive analysis	Determines the proportion of additives (ash) present in a sample. Further analysis of the ash can identify the additive, e.g. FTIR or TGA.	The polymer in the sample is burned away leaving an ash residue, expressed as % ash (weight of the ash as a percentage of the weight of the original sample).	ASTM D4574 Standard Test Methods for Rubber Compounding Materials – Determination of Ash Content, ISO 3451 Plastics – Determination of ash



Appendix H Hazardous Waste Regulation

The Basel Convention

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal ("the Convention") is an international treaty designed to reduce the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries. There are 189 parties to the Convention including countries that are OECD members and non-members⁷².

Waste covered by the Basel Convention falls into one of two categories:

- 1) Hazardous waste
- 2) Wastes requiring special consideration (also referred to as 'other wastes')

Generally, for a waste to be considered hazardous and subject to regulation under the Convention, it must contain a constituent listed in Annex I AND possess a characteristic listed in Annex III. Other annexes help to determine the types of wastes that fall within the scope of the convention.

Annex I of the Convention provides a list of waste streams and hazardous constituents, including but not limited to:

- Clinical wastes;
- Waste oils/water, hydrocarbons/water mixtures, emulsions;
- Wastes from the production, formulation and use of resins, latex, plasticizers, glues/adhesives;
- Wastes resulting from surface treatment of metals and plastics;
- Residues arising from industry waste disposal operations; and
- Wastes which contain certain compounds such as copper, zinc, cadmium, mercury, lead and asbestos.

Annex III provides a list of hazardous characteristics⁷³, including but not limited to:

- Explosive;
- Flammable liquids/solids;
- Poisonous;
- Toxic;
- Ecotoxic; and

Infectious substances.

Recent amendments regarding waste plastic

In 2019, at the Fourteenth Meeting of the Conference of the Parties to the Basel Convention (COP-14), amendments to the Convention were adopted due to changes to the scope of plastic waste controlled by the Basel Convention⁷⁴. Changes were made to three annexes:

• Annex II (waste requiring special consideration and subject to the control procedure, i.e. they require notification to be given and they must receive consent for export prior to movement): new entry **Y48** covering all plastic waste except for that covered by entries A3210 and B3011;

⁷² Basel Convention webpage: http://www.basel.int/?tabid=4499

⁷³ Parliament of Australia, Bills Digest No. 75, 2020-21,

https://www.aph.gov.au/Parliamentary_Business/Bills_Legislation/bd/bd2021a/21bd075 ⁷⁴ Basel Convention webpage:

http://www.basel.int/Implementation/Plasticwaste/PlasticWasteAmendments/FAQs/tabid/8427/Default.aspx



- Annex VIII (waste presumed to be hazardous): new entry A3210 covering hazardous plastic waste; and
- Annex IX (waste presumed to not be hazardous and are prohibited from transboundary movements): new entry **B3011** (replacing B3010) covering plastic waste consisting exclusively of one non-halogenated polymer or resin, some fluorinated polymers and mixtures of PE, PP and/or PET, that is destined for recycling in an environmentally sound manner and almost free from contamination.

The Hazardous Waste Act

The HW Act, regulates the export, import and transit of hazardous waste to ensure that hazardous waste is dealt with appropriately so that human beings and the environment, both within and outside Australia, are protected from the harmful effects of the waste⁷⁵. The HW Act was developed to ratify into law Australia's commitment to the Basel Convention.

If a party wants to export, import or transit hazardous waste, they must apply for a permit. The applicant must provide detailed evidence that the waste will be managed in an environmentally sound manner.

In June 2021, the HW Act 1989 was amended to give effect to the amendments relating to plastic waste in the Basel Convention. Principally, plastic waste listed in Annex II now became subject to transboundary movement controls⁷⁶.

The HW Act classifies waste as hazardous if:

- It is listed as hazardous in the Basel Convention or in the Organisation for Economic Cooperation and Development (OECD) Regulations⁷⁷;
- It is household waste⁷⁸;
- It consists of residues arising from the incineration of household waste; or
- It is plastic waste, including mixtures of such wastes, covered by Annex II of the Basel Convention

Application of the Basel Convention and Hazardous Waste Act

Classification of waste as hazardous for the purposes of export (HW Act/Basel Convention) cannot rely purely on the polymer type alone. While most of the polymer types included in the scope of this project are not considered hazardous according to the HW Act/Basel Convention, it is the application that may classify it as hazardous based on it containing hazardous characteristics or constituents, e.g. medical waste, electronic waste, vehicle waste and textile waste. The source application of the waste plastic often determines the risk of the waste plastic containing hazardous characteristics or constituents.

The below table aims to identify whether plastic waste may be considered hazardous under the Basel Convention and the HW Act based on the polymer type and the application or product type (based on knowledge of commonly used hazardous additives). Note: it is not an exhaustive list and may not include all instances.

75 https://www.awe.gov.au/environment/protection/hazardous-

waste/about#:~:text=The%20main%20purpose%20of%20the,Australia%2C%20are%20protected%20from%20t he

 ⁷⁶ https://www.aph.gov.au/Parliamentary_Business/Bills_Legislation/Bills_Search_Results/Result?bld=r6685
 ⁷⁷ OECD regulations are between OECD countries and consist of a different hazardous waste classification and different controls to the Basel Convention. Refer to the following webpage for additional information: https://www.oecd.org/environment/waste/information-controls-for-transboundary-movements-of-non-hazardous-plastic-waste.pdf

⁷⁸ From the Hazardous Waste Act: "For the purposes of the definition of *household waste* in section 4 of the Act, *household waste* does not include waste listed in Annex IX (List B) to the Basel Convention, unless the waste is mixed with other waste listed in Annex IX (List B) to that Convention."



Table 49 Guide to determining if waste plastic may be considered hazardous

Polymer type	Controlled by the HW Act/ Basel Convention	Common application areas	Product types / examples	Risk based on common use of potentially hazardous additives
PET	No* (unless hazardous)	Other application area (40.8%)	Clothing & textiles Strapping	-
		Household packaging (32.9%)	Bottles Food packaging	-
		Unidentified applications (13.7%)	Unknown	-
		Built environment (7.4%)	Carpets	-
		Agriculture, automotive & commercial and industrial packaging (5.3%)		-
HDPE	No* (unless hazardous)	Household packaging (35.0%)	Packaging film Bottles (e.g. milk) Tubs/containers Household goods	-
		Commercial and industrial packaging (20.5%)	Industrial film Gasoline tanks	-
		Other application area (19.0%)	Toys Seating Cable insulation	-
		Built environment (13.1%)	Pipes Shipping containers	-
		Agriculture, automotive, electrical, unidentified applications (12.4%)		-
PVC	Classified as a waste requiring special consideration in the Basel Convention**. Can also	Built environment (67.6%)	Piping Flooring Window frames Roof sheeting	• May contain phthalate plasticisers of concern, such as DEHP and DBP, which may possess hazardous characteristics contained in Annex III.



Polymer type	Controlled by the HW Act/ Basel Convention	Common application areas	Product types / examples	Risk based on common use of potentially hazardous additives
be classified as hazardous if it has hazardous additives. Considered a hazardous waste in the HW Act except when exported to OECD countries that don control PVC.	be classified as hazardous if it has hazardous additives. Considered a hazardous waste in the HW Act except when exported to OECD countries that don't control PVC.			 May contain antioxidants of concern such as BPA, 4NP, NP. May contain flame retardants of concern, such as SCCP, MCCP. May container stabilisers of concern, such as UV 328 and lead stabilisers. Note: chemicals of concern are only hazardous if they possess hazardous characteristics contained in Annex III of the Basel Convention.
		Other application area (9.3%)	Medical devices such as IV bags, oxygen masks and tubing (flexible PVC).	 Clinical and related wastes are included in Annex VIII as common waste streams presumed to be hazardous, although they can be proven not to be. May contain phthalate plasticisers of concern, such as DEHP and DBP. May contain antioxidants of concern such as BPA, 4NP, NP. Note: chemicals of concern are only hazardous if they possess hazardous characteristics contained in Annex III of the Basel Convention.
		Electrical & electronic (9.1%)	Cabling insulation	 May contain phthalate plasticisers of concern, such as DEHP and DBP May contain antioxidants of concern such as BPA, 4NP, NP. Note: chemicals of concern are only hazardous if they possess hazardous characteristics contained in Annex III of the Basel Convention.
		Household packaging (5.1%)	Containers	• May contain antioxidants of concern such as BPA, 4NP, NP.



Polymer type	Controlled by the HW Act/ Basel Convention	Common application areas	Product types / examples	Risk based on common use of potentially hazardous additives
				Note: chemicals of concern are only hazardous if they possess hazardous characteristics contained in Annex III of the Basel Convention.
		Automotive & unidentified applications (8.9%)		 May contain antioxidants of concern such as BPA, 4NP, NP. Note: chemicals of concern are only hazardous if they possess hazardous characteristics contained in Annex III of the Basel Convention.
LDPE/ LLDPE	No* (unless hazardous)	Household packaging (36.1%)	Packaging film Lids Flexible containers	-
		Commercial and industrial packaging (34.9%)	Packaging film	-
		Agriculture (12.8%)	Irrigation pipes	-
		Other application area (6.8%)	Toys Tubing Vehicle dashboards	-
		Built environment, electrical & unidentified applications (9.4%)		
PP	No* (unless hazardous)	Household packaging (34.8%)	Food packaging Packaging films	-
		Other application areas (25.1%)	Electrical components Carpet pile & backing Drainage goods	-



Polymer type	Controlled by the HW Act/ Basel Convention	Common application areas	Product types / examples	Risk based on common use of potentially hazardous additives
		Automotive (16.8%)	Automotive body components	• E-waste and automotive plastics may contain phthalate plasticisers and flame retardants ⁷⁹ .
		Unidentified applications (10.8%)		-
		Agriculture, built environment, electrical & commercial and industrial packaging (12.6%)		• E-waste and automotive plastics may contain phthalate plasticisers and flame retardants ⁷⁹ .
PS	No* (unless hazardous)	Electronic & electronic (52.8%)	Electrical appliances	 E-waste and automotive plastics may contain phthalate plasticisers and flame retardants⁷⁹. May contain antioxidants of concern such as BPA, 4NP, NP.
		Household packaging (23.0%)	Packaging Dairy product containers	• May contain antioxidants of concern such as BPA, 4NP, NP.
		Other application area (11.9%)	Coat hangers	May contain antioxidants of concern such as BPA, 4NP, NP.
		Built environment (11.1%)		May contain antioxidants of concern such as BPA, 4NP, NP.
		Agriculture & unidentified applications (1.1%)		 May contain antioxidants of concern such as BPA, 4NP, NP. May contain flame retardants of concern, such as HBCD.
EPS		Built environment (41.0%)		• EPS waste sourced from refurbished or demolished buildings may contain brominated flame retardants of concern, such as HBCD. HBCD can't be recycled

⁷⁹ The Department website: Export of waste plastics https://www.awe.gov.au/environment/protection/waste/exports/plastic Department of Agriculture, Water and the Environment / Waste Plastics Processing Requirements



Polymer type	Controlled by the HW Act/ Basel Convention	Common application areas	Product types / examples	Risk based on common use of potentially hazardous additives
				under the Stockholm Convention and PS containing HBCD may not be suitable for recycling or export ⁷⁹ .
		Electrical & Electronic (28.5%)		• E-waste and automotive plastics may contain phthalate plasticisers and flame retardants ⁷⁹ .
		Commercial and industrial packaging (14.5%)		-
		Household packaging (11.2%)		-
		Other application area & unidentified applications (4.8%)		-
HIPS	No* (unless hazardous)	Application data not available but examples include: Automotive Electrical product casings		• E-waste and automotive plastics may contain phthalate plasticisers and flame retardants ⁷⁹ .
ABS	No* (unless hazardous)	Automotive (55.6%)	Automobile component parts	 Automotive plastics may contain phthalate plasticisers and flame retardants, such as HBCD, decaBDE and Dechlorane Plus⁷⁹. May contain stabiliser additives of concern, such as UV328.
		Electrical & electronic (25.6%)	Electronic appliances Electrical products	• E-waste plastics may contain phthalate plasticisers and flame retardants, such as HBCD, decaBDE and Dechlorane Plus ⁷⁹ .
		Other application area (11.7%)	Toys Musical instruments	May contain stabiliser additives of concern, such as UV328.
		Household packaging (5.1%)		



Polymer type	Controlled by the HW Act/ Basel Convention	Common application areas	Product types / examples	Risk based on common use of potentially hazardous additives
		Built environment & unidentified applications (2.0%)		 May contain stabiliser additives of concern, such as UV328.
Acrylic or Polymethyl Methacrylate (PMMA)	No* (unless hazardous)	Application data not available but examples include:	Mainly used in sheet form as plexiglass: car windows, phone screens	-
Nylon N	No* (unless hazardous)	Other application area (61.2%)	Textiles such as carpet and clothing.	• Textiles and electronic appliances may contain flame retardants of concern, such as HBCD and decaBDE.
		Built environment (13.9%)	Pipes, used in the rail industry as clips to hold tracks down and pads under tracks.	-
		Automotive (12.7%)		 May contain flame retardants of concern, such as HBCD and decaBDE
		Unidentified applications (10.1%)		- / /
		Agriculture & household packaging (2.2%)		-
PU	No* (unless hazardous) Note: PU is generally not destined for R3 operations ⁸⁰ , therefore it may be controlled.	Other (40.0%)	Mattresses Highchairs Upholstered furniture	 May contain stabiliser additives of concern, such as UV 328. May contain flame retardants of concern, such as HBCD, Dechlorane Plus, decaBDE.
		Built environment (28.8%)		 May contain stabiliser additives of concern, such as UV 328. May contain flame retardants of concern, such as Dechlorane Plus, decaBDE.

⁸⁰ Technical guidelines on the environmentally sound management of plastic wastes (draft, October 2021) author unknown. Department of Agriculture, Water and the Environment / Waste Plastics Processing Requirements



Polymer type	Controlled by the HW Act/ Basel Convention	Common application areas	Product types / examples	Risk based on common use of potentially hazardous additives
		Automotive (27.8%)	Car seats	 Automotive plastics may contain phthalate plasticisers and flame retardants of concern, such as Dechlorane Plus, decaBDE⁷⁹. May contain stabiliser additives of concern, such as UV 328.
		Unidentified applications (2.2%)		 May contain stabiliser additives of concern, such as UV 328. May contain flame retardants of concern, such as Dechlorane Plus, decaBDE.
		Electrical & electronic (1.2%)		 E-waste plastics may contain phthalate plasticisers and flame retardants of concern, such as Dechlorane Plus, decaBDE⁷⁹. May contain stabiliser additives of concern, such as UV 328.
PC	No* (unless hazardous)	Application data not available but examples include: Electrical & electronics Automotive (as PC/ABS alloy)	Electronic applications such as phone screens Construction products (e.g. for glazing and sound walls) CDs and DVDs Automotive, aircraft and railway parts	 PC contains BPA which is listed as a chemical of concern in plastics***. E-waste and automotive plastics may contain phthalate plasticisers and flame retardants⁷⁹.

*Listed in Annex IX List B (B3011) as a waste not considered hazardous and exempted from Annex II Y48 as a waste requiring special consideration. This is provided the waste does not contain Annex I material to an extent causing them to exhibit an Annex III characteristic and provided the waste is destined for recycling in an environmentally sound manner and almost free from contamination and other types of waste.

**Listed in Annex II Categories of wastes requiring special consideration: Y48 Plastic waste. The waste may be considered hazardous if it contains Annex I material to an extent causing them to exhibit an Annex III characteristic.

***Leaching of BPA in PC recycling was identified in desktop research as a major issue⁸¹. It was found that small amounts of BPA were released during the use phase and large amounts released as they break down⁸¹. Some stakeholders questioned the legitimacy of concerns around BPA and how much leaching occurs.

⁸¹ https://phys.org/news/2016-06-recycle-polycarbonates-bpa-leaching.html Department of Agriculture, Water and the Environment / Waste Plastics Processing Requirements

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