Issue 5

Quickstart

Design for Sustainability with Plastics

Design for recovery at end of life

This is the fifth in a series of Quickstarts on Design for Sustainability (D4S) with Plastics. It provides a guide to product design strategies that support the recovery of plastic products at the end of their useful life.

Mechanical recycling is the primary strategy described in this Quickstart, as this currently offers the most feasible option for recovery of plastic products in Australia. Biological recycling is covered elsewhere (Quickstart 4), and both feedstock recycling and energy recovery are still in their infancy in Australia.

The aim of the Quickstart series is to promote the design of products and services that are sustainable - that is, products and services that contribute to social progress and economic growth, as well as providing ecological benefit, throughout their life cycle. The sustainability of a product is largely locked in at the design phase, which is why D4S is so important.

The Quickstarts are written for practitioners at every stage of the plastics product chain, including designers, polymer suppliers, product manufacturers, brand owners, specifiers and recyclers. The series also supports the implementation of PACIA's Sustainability Leadership Framework (2008), which promotes a whole-of-life approach to product innovation and stewardship and the need for step-change 'transformations' in material and resource use.

Road cone manufactured from recycled polyvinyl chloride (PVC) (image supplied by Vinyl Council Australia)

Three principles of D4S were identified in Quickstart 1: triple bottom line sustainability; a life cycle approach; and step-change transformations. The implications of these for the recovery of plastic products are highlighted in **Figure 1.**

Principles of design for recovery

Figure 1: Sustainable design principles and the recovery of plastic products

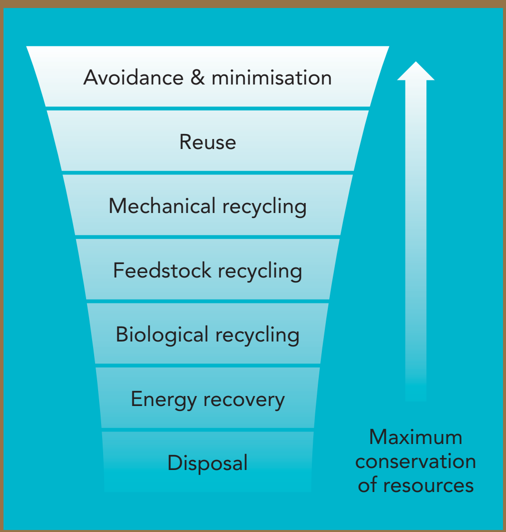
Sustainable design principle	Implications for design for recovery
Triple bottom line sustainability – considering the long term benefits and impacts on human health and quality of life, commercial feasibility, and the natural environment	• The sustainability of plastics recovery at end of life will depend on: - the quality and quantity of the plastic waste - the availability and capability of recovery systems - environmental impacts and benefits of recovery - the costs of recovery and - access to markets for products from recycled plastic[1]. • The willingness and ability of consumers to participate in a recovery scheme also needs to be addressed through system design and education.
Life cycle approach – considering the benefits and impacts of a product within the context of its total life cycle	• The importance of design for recovery will depend on the product application and its durability. • The environmental and financial costs associated with short-life products such as packaging over their life cycle are largely related to the manufacture of materials. Recoverability of short-life products is therefore a priority for D4S. • Durable products have a longer life, and are often more complex to recover due to their construction (e.g. computers) or the fact that they are embedded within buildings (e.g. pipes and insulation). The durability of these products and the contribution they make to energy and water efficiency may be more important D4S considerations than recovery.
Step-change transformations – developing new and innovative ways to deliver product value with significantly less environmental impact	• Technologies are being developed to recover the energy content of plastics. • New business models are also being developed around product stewardship, remanufacture and upgradability (see Figure 6).

Computers collected for the Byteback recycling program in Victoria

The waste hierarchy provides a guide to the selection of waste minimisation and recovery strategies which maximise the conservation of resources (Figure 2). Avoidance is always preferable to recovery, however there are a number of options available for the recovery of plastic products.

Recovery systems

Figure 2: The waste hierarchy[6]



Product repair, reuse or remanufacture

Reuse may be a feasible option but this will depend on the environmental impacts of reuse, e.g. from cleaning or transport. Reuse is increasingly being used as a D4S strategy for distribution packaging, for example reusable produce crates for transporting fruit and vegetables from growers to retailers[2]. Remanufacturing is undertaken on a smaller scale for electrical or electronic products such as toner cartridges and photocopiers.

Mechanical recycling

Mechanical recycling means reprocessing of materials into secondary raw materials and products.

Mechanical recycling is the focus of this Quickstart because the infrastructure for collection and reprocessing is relatively well established in Australia for some products such as packaging. It is also generally preferable to biological or feedstock recycling because it maintains the economic value of the polymer at a relatively high level and significantly reduces the amount of energy required to manufacture new plastic products.

This recovery option is most economically viable for plastics that are available in large quantities, in a clean and homogenous form, and in locations with reasonable access to recycling facilities. Mixed plastics can be problematic if they are not compatible in recycling and therefore need to be separated (see Figure 3).

Feedstock recycling

Feedstock recycling is the conversion of polymers back into a monomer or new raw materials by changing their chemical structure[3]. Feedstock recycling back into monomers is undertaken on a small scale overseas but not in Australia. However, research is underway to replace coke as a reducing agent in steel production[4].

Biological recycling

Biological recycling (i.e. through composting or anaerobic digestion) is undertaken on a small scale for packaging, but facilities are limited.

For more information see Quickstart 4.

Energy recovery

Energy can be recovered from plastics through controlled combustion or conversion to a liquid fuel. Controlled combustion and conversion to oil are practiced overseas but not yet in Australia[5].

Energy recovery through incineration may be a good option for plastics that are not suitable for mechanical recycling, such as contaminated products. At this stage in Australia, energy recovery is used to treat medical waste but is not currently used for general household and industrial waste However, small amounts of plastic waste are used as an alternative fuel for cement kilns. For example, Adelaide Brighton burns construction and demolition waste with approximately 10% plastics.

Closing the loop – recycled plastics

The specification of recycled materials in the design of new products—both packaging and durable products—supports the recovery of plastics by providing a market for reprocessed material. Other advantages include a potential cost saving, marketing benefits and reduced environmental impact. More detail is provided in Quickstart 7.

Compatibility in recycling

Understanding the extent to which different polymers can be recycled together can improve D4S outcomes. The aim is to minimise the number of different plastics used, and to specify plastics that can be recycled together or easily separated in the recycling process. These strategies will make the product easier and more cost effective to recycle.

Figure 3: Compatibility of polymers in mechanical recycling[7]

Plastics Identification Code		LDPE	LLDPE	ULDPE/VLDPE	ETHYLENE COPOLYMERS	HDPE	PP	EPM/EPDM	PS (GEN PURPOSE, HIGH IMPACT)	SAN	ABS	PVC	PA	PC	PMMA	PBT	PET	SBS
	Plastics Identification Code	4	4	4	7	2	5	7	6	7	7	3	7	7	7	7	1	7
4	LDPE																	
4	LLDPE	1																
4	ULDPE/VLDPE	1	1															
7	ETHYLENE COPOLYMERS	1	1	1														
2	HDPE	1	1	1	1													
5	PP	4	3	(1)	2	3												
7	EPM/EPDM	4	4	3	3	4	1											
6	PS (GEN PURPOSE, HIGH IMPACT)	4	4	4	4	4	4	4										
7	SAN	4	4	4	4	4	4	4	4									
7	ABS	4	4	4	4	4	4	4	4	1								
3	PVC	4	4	4	(3)	4	4	4	4	(3)	(3)							
7	PA	4	4	4	(1)	4	4	(1)	4	4	4	4						
7	PC	4	4	4	4	4	4	4	4	(3)	2	4	4					
7	PMMA	4	4	4	(3)	4	4	4	4	(3)	2	2	4	(3)				
7	PBT	4	4	4	(2)	4	4	4	4	4	4	4	4	(2)	4			
1	PET	4	4	4	(3)	4	4	4	4	4	4	4	3	1	4	3		
7	SBS	4	4	4	4	4	4	4	1	(3)	2	3	3	4	4	4	4	

KEY

- 1 Excellent
- 2 Good
- 3 Fair
- 4 Incompatible
- (N) Dependent upon composition

Note: This table should be used as a guide only. Consultation with recyclers is recommended. Compatibility also depends on the percentage of mixed resin, how it is dispersed, and whether the resins are co-existing or compounded together. Any products that contain mixed resins should always be checked for suitability before use.

Key to polymer acronyms

ABS = Acrylonitrile butadiene styrene.
EPDM = Ethylene-propylene-diene monomer (elastomer).
EPM = Ethylene-propylene rubber.
EVA = Poly (ethylene-co-vinyl acetate).
HDPE = High density polyethylene.
LDPE = Low density polyethylene.
LLDPE = Linear low density polyethylene.
PP = Polypropylene.
PS = Polystyrene.
PVC = Polyvinyl chloride.
PA = Polyamide (nylon).
PC = Polycarbonate.
PMMA = Polymethyl methacrylate (acrylic).
PBT = Polybutylene terephthalate.
PET = Polyethylene terephthalate.
SAN = Styrene acrylonitrile.
SBS = Styrene-butadiene-styrene.
ULDPE = Ultra low density polyethylene.
VLDPE = Very low density polyethylene.

Baled plastic bottles ready for recycling

The feasibility and environmental benefit of each recovery option will vary depending on the design of the product, its durability and the availability of a suitable recovery system. For this reason, an important distinction needs to be made between short-life products such as packaging, and more durable products such as appliances, furniture and building products.

Recovery strategies for packaging

The environmental impacts of short life products such as some packaging are generally associated with the production of materials.

Appropriate D4S strategies for packaging therefore include lightweighting (using less material) and material recovery. However, the environmental impacts and financial costs associated with packaged products tend to be many times higher than for the packaging itself[8], so D4S strategies need to ensure that product protection and integrity are not compromised (for more detail see Quickstart 11).

In Australia most plastic bottles, tubs and trays are recovered through kerbside collection services (Figure 4). Through initiatives including the National Packaging Covenant (NPC), the infrastructure for collecting packaging from public places, events and workplaces is also improving[9]. Most packaging is collected as a mixed (commingled) stream and then sorted at a Materials Recovery Facility (MRF). MRF operators are starting to sort plastics automatically, for example with near-infrared optical sort machines. The plastics are then baled and sent to a recycler, where they are granulated, washed (if required), extruded and pelletised. The washing process is used to remove incompatible polymers through a floatation process. For example, PET is heavier than water and will sink. In the PET washing process, caps or labels manufactured from polypropylene (PP) or high density polyethylene (HDPE) will float and can be easily removed (see Figure 5).

Recyclability of consumer packaging can be improved by:

- ensuring that a collection and recovery system already exists for the packaging (e.g. through kerbside – see Figure 4), or by supporting the development of one;
- ensuring that all components (including caps and labels) are compatible in recycling (Figure 3), or if not compatible, ensuring that they can be separated during the washing process because of differences in their specific gravity (Figure 5)[10]; and
- labelling with the Plastics Identification Code to help consumers sort used plastics correctly.

Recovery systems are also available for some forms of industrial packaging, such as expanded polystyrene (EPS) produce boxes, chemical drums and low density polyethylene (LDPE) pallet wrap. Contact details for some recycling programs are provided on page 7, and a full list of recyclers is available on PACIA's web site.

Figure 4: Kerbside collection of packaging materials in Australia, 2007[11]

Plastics Identification Code	Packaging material	Percentage of Councils collecting (%)
1	PET - rigid	99.5%
2	HDPE - rigid	99.4%
3	PVC - rigid	75.3%
4	LDPE - rigid	63.4%
5	PP - rigid	73.6%
6	PS – rigid (excl. EPS)	41.5%
7	Other plastics (rigid)	33.9%
	Plastic films	<5%

Figure 5: Specific gravity of polymers[12]

Plastics Identification Code	Packaging material	Specific gravity
5	PP	0.90 (floats)
7	EVA	0.92 (floats)
4	LDPE	0.92 (floats)
2	HDPE	0.96 (floats)
	Water	**1.0**
7	ABS	1.05 (sinks)
6	PS	1.06 (sinks)
3	PVC	1.35 – 1.40 (sinks)
1	PET	1.38 – 1.40 (sinks)

Marine pylons manufactured from recycled plastic (image supplied by Replas)

The environmental impacts and benefits of durable products such as electrical and electronic appliances, furniture, cars and building products including insulation over their life cycle are more likely to be associated with the use stage. For this reason a high priority should be placed on social and economic value as well as resource efficiency during use.

Recovery strategies for durable products

However, recoverability should also be considered at the design stage to minimise the product's environmental impacts at end of life. Recovery systems have already been established for some durable products, while others are under development (Figure 6). Some of these are operated by associations or companies within a particular product sector.

The recyclability of durable products can be improved by:

- minimising the number of different materials;
- ensuring that all polymers are compatible in recycling (see Figure 3);
- for complex products, designing for disassembly;
- avoiding additives that may cause problems during the recycling process[13]; and
- labelling components with the international identification code for polymers (ISO 11469:2000).

Design for disassembly is important for products manufactured with materials that are incompatible in recycling. Strategies that make disassembly easier include:

- making fastening points accessible and visible;
- where possible, using snap fits instead of metal fasteners; and
- avoiding assemblies that require power tools to take them apart[14].

Figure 6: Examples of recovery systems for durable plastic products

Product	Organisation	Contact details
Mobile phones	Australian Mobile Telecommunications Association (AMTA)	www.amta.org.au
Computers	Australian Information Industry Association (AIIA) and Sustainability Victoria	www.bytebackaustralia.com.au
Computers	Sims Recycling	www.au.simsrs.com/au_erecycling/about/sims-e-recycling.asp
Printer cartridges	Planet Ark and Close the Loop (recycling)	www.recyclingnearyou.com.au
Printer cartridges	Various (remanufacturing)	www.yellowpages.com.au
TVs – under development	Product Stewardship Australia	www.productstewardship.asn.au
Fuji Xerox photocopiers	Fuji Xerox	www.fujixerox.com.au/about/eco_manufacturing.jsp
Auto bumper bars	Auto Parts Recyclers Association of Australia (APRAA)	www.apraa.com.au
PVC	Vinyl Council Australia	www.vinyl.org.au
EPS waffle pods, and other EPS	Recycling Expanded Polystyrene Australia (REPSA)	www.repsa.org.au
PVC flooring	Australian Resilient Flooring Association (ARFA)	Email: wwest@tpg.com.au
Plastic pipes	Plastic Industry Pipe Association of Australia (PIPA)	www.pipa.com.au/recycling.html
Mobile garbage bins	Sulo	www.sulo.com.au
Mobile garbage bins and plastic pallets	Brickwood Holdings	Email: tim.roberts@brickwood.com.au

Note: Some recovery systems may only apply to certain products or brands.

These stools are made from one material – expanded polypropylene (EPP) – and are fully recyclable (image supplied by Thinking Ergonomix)

The Quickstart series is part of the 'Design for Sustainability with Plastics' program managed by a collaborative partnership between Sustainability Victoria and PACIA. The Quickstart series can be downloaded from www.pacia.org.au.

Regulations and standards

There are two standards which cover the processes and terminology involved in plastics recovery: ISO 15270:2008, *Plastics – guidelines for the recovery and recycling of plastics waste*; and AS 1886 Supp1: 1994, *Glossary of terms relating to plastics – plastics recycling terminology*. The design of packaging to improve recovery is covered by the Environmental Code of Practice for Packaging, which is Schedule 5 of the *National Packaging Covenant*. Other relevant regulations and standards are listed in the D4S toolbox at www.pacia.org.au.

Further information

Books and reports

Australian Council of Recyclers 2006, *Recycling guide for fillers marketing in PET containers*

Australian Council of Recyclers 2006, *Recycling guide for fillers marketing in HDPE*

BASF 2007, *Snap-fit design manual*, www.basf.com//PLASTICSWEB/displayanyfile?id=0901a5e1801499d5

PACIA 2008, *2008 Plastics Recycling Survey*, Hyder Consulting, www.pacia.org.au

National Packaging Covenant Council 2005, *National Packaging Covenant*, www.packagingcovenant.org.au/documents/File/National_Packaging_Covenant.pdf'

Organisations and web sites

Australian Council of Recyclers (ACOR) (to download copies of recycling guides for PET and HDPE and material specifications for PET, HDPE, LDPE and PVC): www.acor.org.au

PACIA (for the D4S toolbox, to order a copy of the Plastics Identification Code, to download the latest recycling survey or to locate a plastics recycler): www.pacia.org.au

Sustainability Victoria (to download a range of D4S resources and to locate recyclers in Victoria): www.sustainability.vic.gov.au

Publication details

Quickstart: Design for Sustainability with Plastics was prepared by Helen Lewis Research for Sustainability Victoria and the Plastics and Chemicals Industries Association (PACIA) with input and advice from practitioners and others involved in the sector.

Footnotes

1 ISO 2008, ISO 15270: *Plastics - guidelines for the recovery and recycling of plastics waste*, p. 6.

2 Reusable transport packaging is most likely to be feasible in 'closed loop' distribution systems and if distribution involves short distribution distances, frequent deliveries, a small number of parties, and company-owned vehicles (Saphire, D. 1994, *Delivering the goods: benefits of reusable shipping containers*, INFORM, Inc., New York).

3 ISO, ibid, p. 3.

4 See www.materials.unsw.edu.au/research/sustainable.html.

5 For examples of liquefaction into oil see Australian company Ozmotech (www.ozmotech.com.au) and the Plastics Waste Management Institute in Japan (www.pwmi.or.jp/ei/flame4-8.htm).

6 Adapted from Wastenet, www.wastenet.net.au/System/images/waste_hierarchy/view?searchterm=waste%20hierarchy.

7 Based on Envirowise 2004, *Sustainable design of electrical and electronic products to control costs and comply with legislation*, Didcot, Oxfordshire, p. 24, with some adjustments for local reprocessing requirements.

8 Envirowise 2008, *Packguide: a guide to packaging eco-design*, Didcot, Oxfordshire, p. 11.

9 Information on NPC-funded projects is available at www.packagingcovenant.org.au.

10 For more information refer to the Australian Council of Recyclers (ACOR) materials specifications and recycling guides – www.acor.org.au.

11 Based on PACIA 2007, *2007 National Plastics Recycling Survey*, Report to the Plastic and Chemicals Industries Association, Hyder Consulting, Melbourne, p. 38.

12 Based on ACOR 2006, *Recycling guide for fillers marketing in HDPE*, p. 8.

13 For example, brominated flame retardants may inhibit recycling because they can form toxic compounds during reprocessing. Alternatives are now available – see Envirowise 2004, Ibid, p. 26.

14 Envirowise, 2004, Ibid.