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Issue 2

quickstart

Design for Sustainability with Plastics

Plastics and the environment

This is the second in a series of Quickstarts on Design for Sustainability (D4S) with Plastics. It provides an overview of some of the environmental issues that need to be considered for plastics throughout their life cycle. These include materials, energy and water efficiency, and the control of wastes and emissions.

Other Quickstarts in the series explore some of these considerations in more detail.

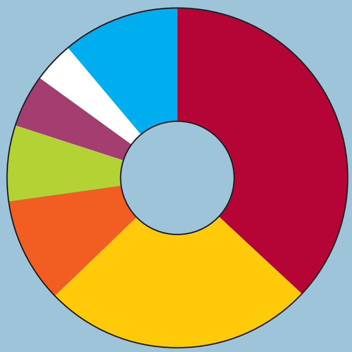
The aim of the Quickstart series is to promote the design of products and services that are sustainable - that is, products and services that contribute to social progress and economic growth, as well as providing ecological benefit, throughout their life cycle. The sustainability of a product is largely 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 and specifiers. 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.

D4S is based on a life cycle approach which considers the benefits and impacts of a product at every stage. For plastics these include the extraction or harvesting of raw materials, manufacture of polymers, product manufacture, product use and recovery or disposal. Refer to page 3 for a diagram of the plastics life cycle.

Environmental issues across the plastics life cycle

Figure 1: Market sectors for plastics use in Australia[2]



- 37% Packaging/materials handling
- 26% Building
- 10% Furniture, housewares, leisure and clothing
- 7% Electrical and electronic equipment and appliances
- 5% Transport and marine
- 4% Agriculture
- 11% Other

It is important to consider the environmental impacts of a product at each stage of the product life cycle. However, designers also need to think about and optimise environmental benefits across the total life cycle, to ensure that environmental impacts are not simply transferred from one stage of the life cycle to another.

Raw materials

- Most polymers are currently manufactured from crude oil or natural gas, which are non-renewable resources. Environmental impacts are also generated during exploration, extraction, transport and processing.
- The plastics industry uses around 2% of all energy resources (oil, gas and coal) consumed in Australia each year[1]. The remaining 98% of these resources are burnt to generate electricity or energy for transport, and in the process greenhouse gases such as carbon dioxide are released into the atmosphere. In comparison, the carbon in plastics remains relatively inert throughout its life cycle after it has been converted to a product.
- The production of biopolymers from crops such as corn and soy is increasing but still only comprises a very small percentage of the total market. The environmental impacts of these materials are associated with land use and management, including use of equipment, consumption of energy, fertilisers and pesticides.

Polymerisation

- The polymerisation process involves chemical reactions which combine small molecules - called monomers - into long-chain molecules called polymers.
- Polymerisation consumes energy and water and generates some process wastes.
- Modifiers are added during the compounding stage to enhance performance. For example fillers are used to increase strength; stabilisers to protect polymers against heat and light; colours to change appearance; flame retardants to protect against fire; and plasticisers to make rigid polymers more flexible.

Product manufacture

- Polymers are manufactured into plastic products using a variety of processes such as blow moulding, injection moulding, thermoforming, calendering and extrusion. These processes consume energy and generate some process wastes including plastic waste. This 'pre-consumer' plastic waste is generally clean and easily recycled.

Product use

- Plastics are used to manufacture an enormous range of products in every sector of the economy (Figure 1).
- The design and innovation advantages of plastics include their ability to be moulded into almost any shape, size and colour, the wide range of properties which can be achieved, such as water and chemical resistance, high strength to weight ratio, sound and heat insulation, hygiene and food safety, water or gas barrier, and their relatively low cost.
- The life-span of plastic products ranges from short-term for packaging and single-use products, through to long-term for building and construction products (Figure 3).

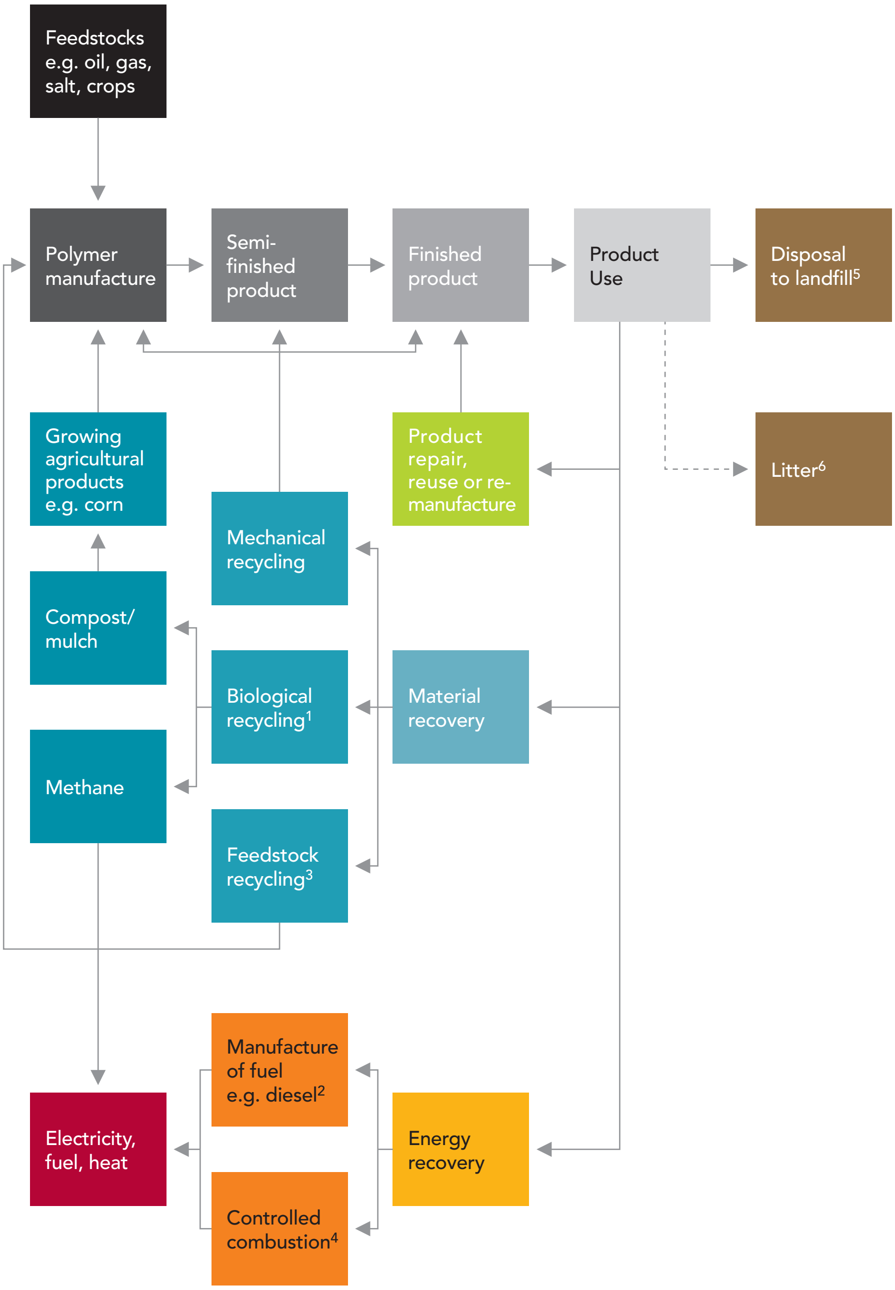
Reuse or remanufacture

- Some plastic products are designed for reuse, such as crates for fresh produce and milk. Reuse systems reduce the quantity of single-use products consumed, but there may be additional impacts associated with transport and washing.
- More complex products such as photocopiers can be remanufactured by replacing components that are no longer working or damaged, with new or remanufactured components[3]. Design for remanufacturing improves durability and reduces overall product waste.

Sustainable products and services can only be achieved by considering the benefits and impacts across the total life cycle.

The plastics life cycle

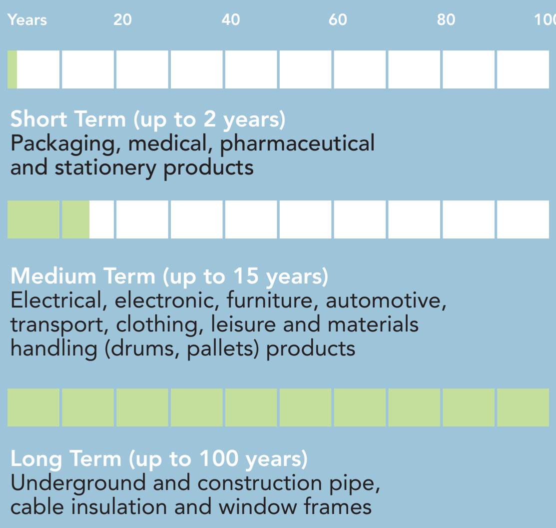
Figure 2: Life cycles and material flows for plastics



Notes:
1. Commercial composting is still in its infancy in Australia
2. Pilot plants exist overseas but not currently in Australia
3. This technology is used on a small scale overseas but not currently in Australia
4. This technology is commonly used overseas but not currently in Australia
5. Whilst landfill is used, it is a least preferred destination
6. Litter is a problematic reality for some product types and needs to be eliminated

Environmental issues across the plastics life cycle

Figure 3: Life-span of products manufactured from plastics[4]



Collection and recycling

- At end-of-life, plastic products can be collected for either recovery or disposal in landfill.
- Approximately 244,000 tonnes of plastics were recycled in Australia in 2006 - representing a recycling rate of 15.9%[5].
- The municipal kerbside collection of recyclable materials consumes energy and generates emissions to air, however there is a net energy saving if recycled plastics are used to replace more energy-intensive virgin plastics. For example, it takes 76% less energy to manufacture recycled polyethylene terephthalate (PET) than virgin PET and there are similar savings for other polymers[6].
- Most plastics can be reheated and remoulded numerous times - these are referred to as thermoplastics - whereas thermoset plastics can only be moulded once, and cannot be reheated and remoulded. There is normally some degradation of thermoplastics during recycling due to contamination with other materials and additives.
- Recycled plastics can replace virgin polymers in many applications where performance requirements such as food safety or colour are not critical.

Plastics in landfill

- Plastics make up around 5.6% of commercial and industrial waste in landfill, less than 1% of construction and demolition waste and around 7.5% of municipal waste disposed to landfill by weight[7]. The best estimate of total plastics in landfill is around 4-6%[8]. Unlike most degradable materials, plastics will not break down in landfill and therefore do not contribute to emissions of methane, which is a potent greenhouse gas.

Plastics composting

- Biodegradable and compostable polymers, such as those manufactured from corn starch, are designed to break down through the action of heat, water and microorganisms. Some biopolymers have been certified to degrade under commercial or home composting conditions. In the future these may be able to be collected through kerbside systems along with food or green waste, although this would require effective product labelling and consumer education[9].
- Anaerobic composting, such as the conditions encountered in poorly managed home composting systems, can generate methane, a greenhouse gas.

Energy recovery

- Energy recovery from waste is widely practiced overseas but is still in its infancy in Australia. Rising energy prices and waste disposal costs, as well as concerns about global warming, have increased interest in energy recovery. A facility which separates recyclable materials and generates energy and compost from household waste has recently been launched in Sydney[10]. The energy and material content of biopolymers could be recovered through this type of system.
- In the longer term there is also the potential to produce electricity or biofuels from waste materials including plastics.

Properties of commonly used polymers

Plastics ID code*	Polymer	Characteristics	Typical applications	Raw materials	Common additives
1	Polyethylene therephthalate (PET)	Clear, tough, good stiffness, excellent chemical resistance, good gas barrier	Beverage bottles, food packaging, clothing, geo-textiles	Crude oil	Pigments
2	High density polyethylene (HDPE)	Hard to semi-flexible, waxy, opaque, good chemical resistance, poor gas barrier, easy to process using most methods	Milk bottles, freezer bags, milk crates, agricultural pipe, kerbside collection bins	Crude oil or natural gas	Pigments; UV stabilisers (outdoor use)
3	Polyvinyl chloride (PVC) plasticised	Flexible, clear, high abrasion resistance, good vapour barrier, medium gas barrier, flame retardant, good UV properties, easy and versatile to process	Blood bags, cable & wire insulation, floor coverings, commercial cling film, clothing	Crude oil or natural gas and salt	Plasticisers; stabilisers; pigments
3	PVC - unplasticised	Hard, rigid, can be clear, tough, chemical-oil and alcohol-resistant, flame retardant, good UV properties, easy and versatile to process	Water, sewer and drainage pipe, cordial bottles, window frames, cladding	Crude oil or natural gas and salt	Stabilisers; pigments; UV stabilisers (outdoor use)
4	Low density polyethylene (LDPE)/ Linear low density polyethylene (LLDPE)	Tough, semi-flexible, waxy surface, high impact resistance, moderate clarity, poor gas barrier, easy to process using most methods	Water tanks, squeeze bottles, irrigation and gas pipe, bread bags, bags, film	Crude oil or natural gas	Pigments; UV stabilisers (outdoor use); stretch & cling additives in pallet wrap
5	Polypropylene (PP)	Rigid or flexible, tough, high heat resistance, excellent chemical resistance, moderate barrier, good live-hinge potential, easy and versatile to process	Microwave containers, automotive components, plant pots, compost bins	Crude oil	Pigments; UV stabilisers (outdoor use)
6	Polystyrene (PS) - general purpose	Clear, glossy, rigid, brittle, semi-tough, easy to process and colour, good dimensional stability, free from odour and taste	CD cases, toys, lighting diffusers, refrigerator trays	Crude oil or BTX (benzene, toluene, xylene), a by-product of coking coal manufacture	Pigments
6	Polystyrene (PS) - high impact	Tough, opaque, rigid, poor barrier, good impact strength	Yoghurt tubs, refrigerator linings, vending machine drink cups, toilet seats	As above	Pigments
6	Expanded polystyrene (EPS)	Light weight (98% air), absorbs impact energy, excellent thermal and acoustic insulation	Under-floor insulation, produce boxes, hot drink cups	As above	Blowing agent (pentane or CO_2); flame retardant in insulation
7	Acrylonitrile butadiene styrene (ABS)	Rigid, opaque, glossy, tough, good low temperature properties, easy to electroplate	Telephone handsets, domestic appliance housings, computer housings	As above	Pigments; flame retardants
7	Polycarbonate (PC)	Rigid, clear, excellent impact resistance, good weather resistance, resistant to flame	Safety glasses, automotive headlamp lenses, CDs, DVDs	Crude oil	Pigments; flame retardants; UV stabilisers (outdoor use)
7	Polyurethane (PU) - foam	Flexible or rigid, light weight	Upholstery, bedding, insulation panels, carpet underlay	Crude oil	Blowing agents ($MeCl_2$, CO_2)

Recovery

Packaging: recycling takes a higher priority and recovery systems are readily available.

Durable products: generally designed for a long life span where durability is a key property. Recycling takes a lower priority and recovery systems are less likely to be available. Where recovery systems are available, they are more likely to be sector-based.

* PACIA (2003), Plastics Identification Code, Melbourne (denotes identification, not recyclability)

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.

Chair made with recycled ABS (image supplied by Environmentally Sustainable Objects)

Further information

Books and reports

PACIA (1992), *Know your plastics*, Melbourne

Plastics New Zealand (2006), *Design for the environment guidelines*, Auckland (www.plastics.org.nz)

Organisations and web sites

PACIA (for the D4S toolbox, to purchase the *Know your plastics* book/course or to download information on sustainability, recycling and degradable polymers): www.pacia.org.au, phone 03 9429 0670 or email info@pacia.org.au

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

British Plastics Federation (for detailed information on polymers), www.bpf.co.uk/Plastipedia_a_Guide_to_Plastics.aspx

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 PACIA (2008), *Sustainability leadership framework for industry*, p. 6.11

2 PACIA (2000), unpublished data

3 For example, Fuji Xerox Australia has a remanufacturing facility for photocopiers in Sydney - www.fujixerox.com.au/about/eco_manufacturing.jsp

4 Hyder Consulting 2007, *2007 National Plastics Recycling Survey*, Report to the Plastics and Chemicals Industries Association, Melbourne, p. 7

5 Hyder Consulting, *Ibid*, p. 9

6 Grant, T., James, K., Lundie, S. and Sonneveld, K. 2001, *Stage 2 report for life cycle assessment for paper and packaging waste management scenarios for Victoria*, EcoRecycle Victoria, Melbourne, p. xi, www.cfd.rmit.edu.au/programs/life_cycle_assessment/vic_pkg_lca_main_report

7 Golder Associates 1999, *Report on the waste profile study of Victorian landfills*, Report to the Victorian EPA, Melbourne, p. 39

8 Recent estimates include 6.3% for NSW (Wright, T. (2002), *Shaping the vision and strategy for sustainable waste management in New South Wales*, Resource NSW, Sydney, p. 19) and 4% for Victoria (EcoRecycle Victoria (2002), *Developing a solid waste strategy – a discussion paper*, Melbourne, p. 6)

9 For further information on degradable polymers, refer to Quickstart 4 and PACIA's product stewardship guide, *Using Degradable Plastics in Australia*

10 The Macarthur Resource Recovery Park, www.wsn.com.au/dir138/wsn.nsf/Content/News_Macarthur+Resource+Recovery+Park+Opens

Cover image: Returnable produce crate (image supplied by Viscount Plastics)