Issue 8

quickstart

Design for Sustainability with Plastics

Life cycle assessment

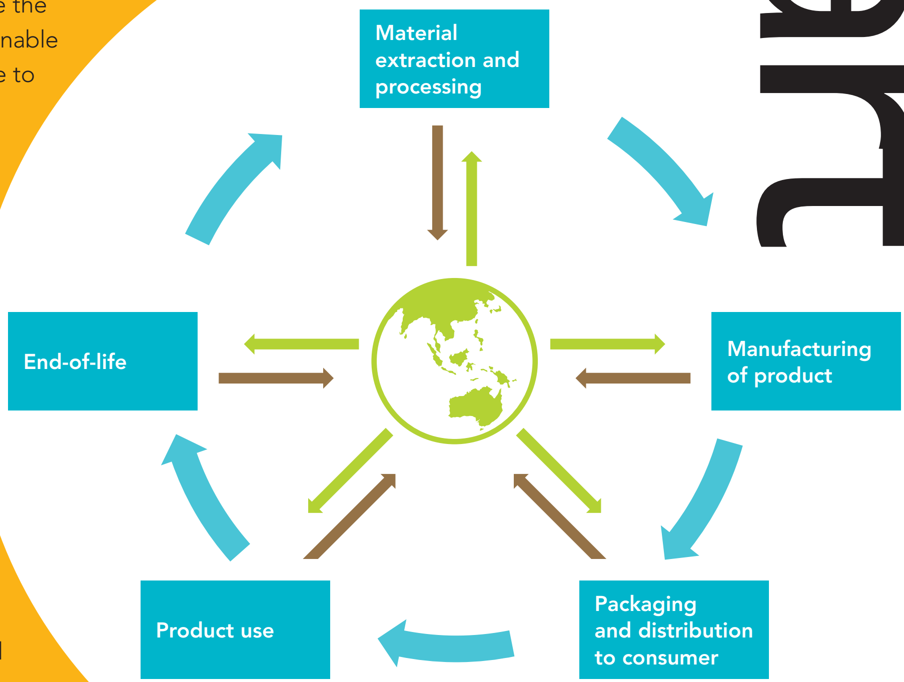
This is the eighth in a series of Quickstarts on Design for Sustainability (D4S) with Plastics. It builds on Quickstart 3 (Life cycle design tools) by discussing the potential value and application of Life Cycle Assessment (LCA) as a design tool.

The Quickstart covers:

- What is LCA?
- The benefits of LCA
- Undertaking an LCA
- Interpreting the results of an LCA
- Using LCA for marketing
- LCA case studies

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.



Generic product life cycle showing material and energy flows.

Yalumba uses LCA as an internal management tool to identify actions that can be taken to reduce environmental impacts in their supply chain. (Photograph: Helen Lewis)

LCA is an internationally recognised methodology for assessing the environmental aspects and potential impacts associated with a product over its entire life cycle, i.e. from the extraction of raw materials through to product disposal or recovery (from 'cradle to grave').

What is LCA?

LCA is governed by a series of standards developed by the International Standards Organisation (ISO), which identify four stages[1]:

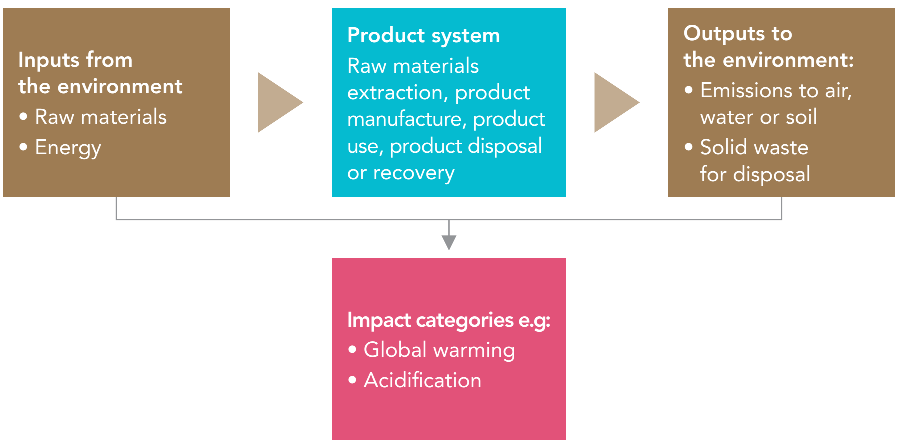
- Goal and scope definition—the reason for conducting the study, its intended audience, and the scope of the study.
- Inventory analysis—the compilation and quantification of inputs (e.g. oil, salt, coal) and outputs (e.g. carbon dioxide, solid waste) to and from the 'product system'.
- Impact assessment—evaluating the magnitude and significance of these inputs and outputs by linking them to environmental issues of concern (e.g. global warming, eco-toxicity).
- Interpretation—interpreting the inventory and impact assessment results to draw conclusions and make recommendations to help inform decision making.

During the first stage of the LCA, the 'product system' needs to be carefully defined to make sure that the project reflects the goal of the study but is also manageable. For example, the system will generally include the energy used to manufacture the polymer and the product, but not the energy used to make the processing equipment. A 'functional unit' must also be identified for the analysis. This is the measure used to describe the output of a product system (results of an LCA), and to enable similar functions to be compared.

For example, the functional unit for an LCA comparing different types of packaging might be 'packaging used for 1 litre of milk'. The environmental impacts are then calculated across the different packaging material systems for that functional unit.

At the inventory analysis stage, quantitative data are collected for every process step within the product system, and aggregated into a list of all resources consumed and all wastes and emissions generated. These are then converted into an 'impact score' for each category. Finally, these results must be interpreted to draw conclusions about the product system and inform decision making.

Figure 1: Simple representation of an LCA



The benefits of LCA

LCA can be helpful in answering questions such as:

- What are the environmental impacts of the product?
- How much energy will it consume throughout its life?
- Which stage of the life cycle generates the most significant impacts?
- How can the carbon footprint of the product be reduced?
- Which material or finish is better for the environment?
- Does recycling have an environmental benefit?

LCA can identify and quantify the most significant environmental impacts of a product. These impacts can then be modified through changes to product design, manufacturing processes, product use (via education and awareness-raising) or end-of-life management.

At the design stage it can highlight priorities for the design brief. For example, if the LCA results show that the environmental impacts of a product are highest during the use stage of the life cycle, then D4S strategies should focus on improving in-use efficiency (e.g. the energy consumption of cars, household appliances and electronic products). LCA can also be used during the design process to compare the environmental impacts of different concept designs, materials or manufacturing processes.

After a product has been designed, the results of an LCA can be used to educate specifiers or consumers about its environmental benefits compared to alternative products, or about how to use the product appropriately in order to minimise impacts. LCA can also help to build partnerships in the supply chain if the information gained is shared with suppliers and used to further reduce the environmental impacts of materials, processes and distribution systems.

Undertaking a full LCA can be costly and time consuming and is therefore not feasible as a routine diagnostic tool for all products. However, depending on the objective of the study there are a number of streamlined life cycle design tools which might be more useful and effective (see Quickstart 3).

Plantic Technologies commissioned RMIT to undertake an LCA in 2002 (updated 2008) to compare their biodegradable trays with those manufactured from conventional polymers. The study compared the environmental impacts (including resource depletion, acidification and waste to landfill) under various end of life scenarios. (Image supplied by Plantic)

Case study: LCA and office furniture

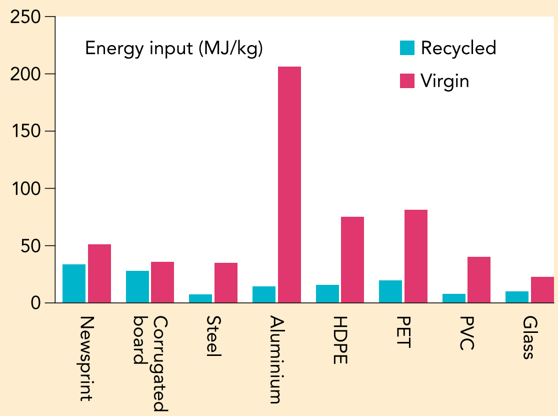
Schiavello Group uses LCA to assist in the design of environmentally improved products such as their QED workstation (pictured):

"When we first started to use LCA around six years ago it gave us a really good understanding of the environmental issues associated with our products. We now know which materials and processes are better than others, and this knowledge has been built into our product development process.

These days we use LCA less often but more strategically, for example to evaluate a new material which has come onto the market. It can also be useful in helping us to inform and educate our customers about design options, so that they can make more informed choices."

Michael Pitcher, Environmental and OHS Manager, Schiavello Group

The QED uses significantly less materials than a conventional workstation while providing the same functionality. It has also been designed as a series of modular units which extend product life because they can be easily reconfigured to meet changing workplace requirements. (Image supplied by Schiavello)



An LCA of kerbside recycling systems for packaging in Victoria, using SimaPro software, found that recycled packaging consumes less energy across its life cycle than virgin packaging. Note: energy data is based on weight[2].

Undertaking an LCA

A full LCA is most easily performed using one of the LCA software modelling tools that are available to assist practitioners. These tools include publicly available inventory data on the most common materials and processes, and they also allow the user to add their own product-specific and local data.

The two that are most commonly used in Australia are SimaPro and GaBi, which both include Australian data when sold locally.

The most time-consuming part of an LCA is the collection of life cycle inventory data. A large proportion of this information will need to be obtained from suppliers, customers and other organisations in the product supply chain. The value of the LCA will depend on the accuracy and relevance of this data.

PACIA and other stakeholders from industry, government and research institutions are developing more accurate Australian data for LCA studies through the Australian Life Cycle Inventory (AusLCI) project. This will provide a national database with easy access to authoritative, comprehensive and transparent environmental information on a wide range of Australian products and services over their entire life cycle.

Learning from an 'off-the-shelf' LCA

There are many published LCAs that can be used to inform the design process without the need to undertake a new study.

This is particularly the case if the objective is simply to gain a general understanding of a product's life cycle impacts, rather than to collect and analyse specific data. Some of these studies are listed under 'Further information' on page 7. However, it is important to note that the results of an LCA will not necessarily translate directly to other circumstances.

Interpreting the results of an LCA

The results of an LCA need to be interpreted carefully to determine the implications for design or procurement.

First of all, the scope and quality of an LCA needs to be understood before the results can be accepted with a reasonable degree of confidence. For example:

- Was it carried out according to ISO standards on LCA?
- Has it been peer-reviewed?
- Do the assumptions on which the LCA is based appear to be reasonable?
- How accurate are the data that were used?
- Does it cover the entire product life cycle, or only one part?[3]

The results of an LCA can sometimes appear difficult to interpret because they provide environmental impact data across different categories, such as greenhouse gas emissions, eco-toxicity and ozone depletion. If two products or services are being compared, each is likely to have some environmental advantages and disadvantages[4].

Depending on the organisation's environmental priorities and objectives, one or two impact categories may be more significant than others and should be addressed first. For example, a company that has a policy to become 'carbon neutral' by a certain date might choose to focus on reducing the greenhouse gas emissions associated with a product during manufacture and transport. However, it is also important to remember that improvements in one area might result in a greater impact in another category.

Finally, LCA is only one input to the decision-making process. It should be used in conjunction with other relevant information such as the implications of product design for cost, social impact and performance. Some environmental issues such as species biodiversity, land degradation and litter impacts are also difficult to quantify and are therefore not currently covered by LCA methods.

(Cups photograph: Joan Kalute)

The environmental impacts of drinking cups, including reusable ceramic mugs and single-use cups, have been studied extensively. The overall results have been relatively consistent, but the following two examples illustrate the different ways that LCAs can be used to inform decision-making.

Case study: LCA and drinking cups

A Dutch study[5] compared the environmental impacts of a reusable ceramic mug and cup (with the assumption that they are used 3,000 times before disposal), a single-use polystyrene (PS) cup, a single-use PS cup in a reusable cup holder, and a single-use paper cup. Ten environmental impact categories were studied, including resource depletion, global warming potential, ozone depletion and eco-toxicity.

The reusable ceramic mug was found to have the highest impact in 7 of the 10 categories, including global warming potential. The single-use paper cup had the lowest impact in 5 of the 10 categories, and the single-use PS cup had the lowest impact in the other 5 categories.

These results indicate that from an environmental perspective, reusable cups and mugs are, in general, more environmentally damaging than single-use cups. However, the sensitivity analyses which were undertaken for the study highlighted potential improvements to each of the drinking cup systems.

For example, the environmental impacts of reusable mugs and cups are primarily due to the cleaning process used, so a more efficient dishwasher can reduce their life cycle impacts significantly (they were still found to have a higher impact than single-use cups but with a reduced margin).

The environmental impacts associated with the single-use PS cup are largely due to the production of raw materials and the manufacture of the cup. Strategies such as using the cup more often, reducing its weight, and recycling through mechanical recycling or energy recovery were found to further reduce its impacts.

Another LCA of drinking cups[6] focused on their energy consumption. The 'embodied energy' in reusable and single-use cups was calculated, i.e. the amount of energy used to manufacture it. The study then calculated the 'break even' point for reusable cups, defined as the number of times that the cup needs to be re-used for its energy impact to be lower than either of the single-use cups. Once again, the results were found to be highly dependent on the efficiency of the cleaning process for reusable cups. However, these findings indicate that a ceramic cup needs to be reused more than 1000 times to make it as energy-efficient as a single-use expanded polystyrene (EPS) cup.

Using LCA for marketing

An LCA can provide rigorous and credible data to support environmental claims in marketing. However, if the results are going to be used for marketing then the LCA needs to be conducted in full accordance with ISO standards (ISO 14040 series). The results, data, assumptions and limitations need to be transparent and presented in enough detail to allow the reader to understand the complexities and trade-offs in the study. A third-party peer review also needs to be undertaken.

'Environmental Product Declarations' (EPDs) based on LCA data are sometimes used in Europe, and these are also controlled by another ISO standard (ISO 14025). PlasticsEurope has introduced a program to generate credible and consistent EPDs for business-to-business marketing – the methodology and results are available on their web site.

Formway uses LCA to inform its design decisions and support marketing claims. (Image supplied by Formway)

Yarra Valley Water uses LCA to evaluate the environmental impact of alternative water supply systems, including the 'third pipe' system for non-potable water[7] (pictured) (image supplied by Yarra Valley Water)

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

LCA is governed by a series of international standards in the ISO 14040 series. EPDs also need to comply with ISO 14025 *(Environmental labels and declarations – Type III environmental declarations – principles and procedures).* These are listed in the D4S toolbox on PACIA's web site at www.pacia.org.au.

Further information

Reports and journal articles

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.

Grant, T., James, K. and Partl, H. 2003, *Life cycle assessment of waste and resource recovery options (including energy from waste)*, EcoRecycle Victoria, Melbourne.

Martin Hocking 1994, Reusable and disposable cups: an energy-based evaluation, *Environmental Management* 18(6), pp. 889-899 (for a summary, see www.dartcontainer.com/web/environ.nsf/files/ILEA.pdf/$FILE/ILEA.pdf)

PE Europe GMBH et al 2004, *Life cycle assessment of PVC and of principal competing materials*, Report for the European Commission.

TNO 2007, *Single use cups or reusable (coffee) drinking systems: an environmental comparison*, Report to Benelux Disposables Foundation, www.prodisposables.nl/download/TNO_Studie_Eng.pdf.

Organisations and web sites

American Chemistry Council (to download a life cycle report on common plastic polymers): www.americanchemistry.com/s_plastics/sec_content.asp?CID=1930&DID=7832

Australian Life Cycle Inventory Database Initiative (AusLCI): www.auslci.com

Australian Life Cycle Assessment Society (ALCAS) (for membership and events): www.alcas.asn.au

BASF (to learn about a methodology for eco-efficiency analysis that combines LCA and life cycle costing and access related publications): www.basf.com/group/corporate/en/content/sustainability/eco-efficiency-analysis/index

Centre for Design at RMIT (for LCA training courses and to download LCA reports by Grant *et al* – see above): www.cfd.rmit.edu.au/programs/life_cycle_assessment

Centre for Water and Waste Technology, University of UNSW (LCA consulting services and GaBi software licenses for Australia): www.cwwt.unsw.edu.au/sustainability-assessment.html

EPA Victoria (for information on life cycle management and various tools, including LCA): www.epa.vic.gov.au/Lifecycle/default.asp

Life Cycle Strategies (for SimaPro software licenses and demos for Australia, and LCA training): http://simapro.lifecycles.com.au

PE International (for GaBi software licenses and demos): www.gabi-software.com

PACIA (for information on life cycle management, D4S, plastics recycling and sustainability): www.pacia.org.au

Plastics*Europe* (to download LCA results ('Eco-profiles') for different polymers and information on Environmental Product Declarations for polymers): http://lca.plasticseurope.org/index.htm

Society of Environmental Toxicology and Chemistry (SETAC) (for information on LCA and LCA groups): www.setac.org/node/32

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

United Nations Environment Programme (UNEP) (for information and publications on life cycle and resource management): www.uneptie.org/scp/lifecycle

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 14040: 1997, *Environmental management - life cycle assessment - principles and framework.*

2 Based on 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.

3 European and Australian LCAs tend to cover the whole of life ('cradle to grave') but American LCAs often stop at the manufacturing stage ('cradle to gate').

4 Some LCAs combine the results of different impact categories into a single score, which makes it easier to compare results for different products. However, this approach is not recommended in the ISO standards because it involves subjective assumptions about the weighting of impact categories.

5 TNO 2007, *Single use cups or reusable (coffee) drinking systems: an environmental comparison*, Report to Benelux Disposables Foundation, www.prodisposables.nl/download/TNO_Studie_Eng.pdf.

6 Martin Hocking 1994, 'Reusable and disposable cups: an energy-based evaluation', *Environmental Management* 18(6), pp. 889-899.

7 Grant *et al* 2005, http://mams.rmit.edu.au/opbcqc9al01v1.pdf