Life Cycle Analysis Primer

Materials Stewardship and Life Cycle Analysis

The Australian minerals industry is committed to the principles and practices of materials stewardship, founded on a shared responsibility of all participants in the product life cycle to mitigate the adverse environmental and social effects of products whilst enhancing societal value.

Materials stewardship is fundamental to sustainable development, and should provide a unifying approach to the development and implementation of policies directed at sustainable use of materials.

Life cycle analysis (LCA, or 'assessment') is an analytical methodology that is used to quantify the environmental impacts of products, processes or services (see Fig 1 for a 'life cycle'). Life cycle analysis is one tool that the minerals industry can use to deliver sustainable development through enhanced materials stewardship.

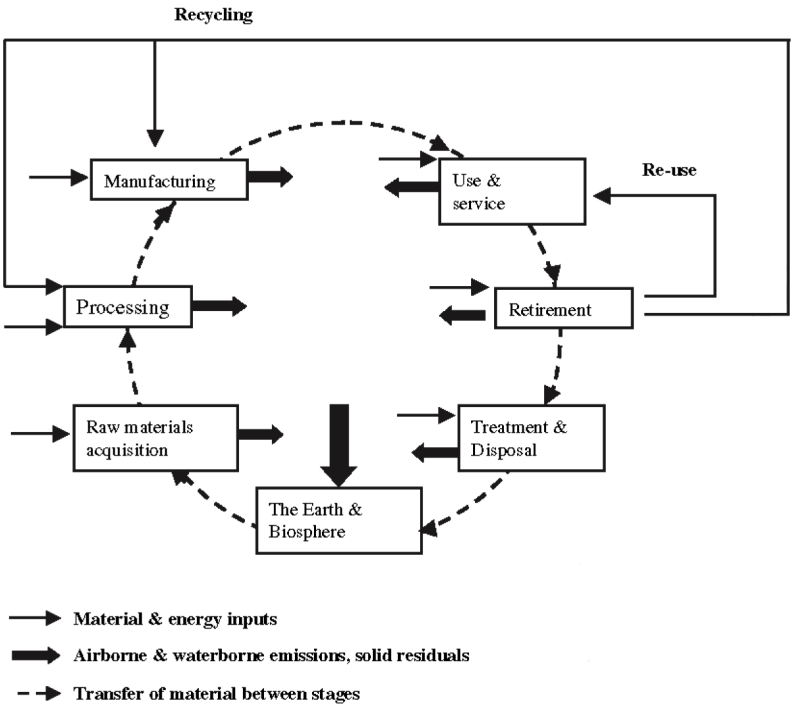

Figure 1. Example of a life cycle for a product, commodity or tool used by industry (Norgate et al. 2007)

Introduction to Life Cycle Analysis

Life cycle analysis typically comprises four stages; (1) the goal definition and scoping stage; (2) the life cycle inventory stage, (3) the life cycle impact assessment stage, and (4) the interpretation or improvement stage (Norgate and Rankin 2000; Monhemius 2006). Life cycle impact assessment can also be re-framed as life cycle 'costing', using a variety of techniques to place a monetary value on the socio-economic and environmental impacts of alternative decisions (Krozer 2008).

Life cycle analysis tools assess impacts on a variety of environmental values, including air and water quality, greenhouse emissions and land use for a suite of activities undertaken in mining and minerals processing. 'Cradle-to-gate' LCA assesses alternative mining and minerals processing activities through exploration to extraction and export, whilst 'cradle-to-grave' LCA assesses the commodity throughout its life-cycle, both during and after direct responsibility of the minerals company.

Life-cycle-analysis for cradle-to-gate applications can be demarcated into the following stages of production: exploration, extraction / production, processing, waste handling and rehabilitation (Durucan et al. 2006; Fourie and Brent 2006; McKay et al. 2006). The inventory stage outlines the context of the LCA, whether it will be processing-only, cradle-to-gate, cradle-to-grave or cradle-to-cradle. The inventory also determines what data is available, and which operations and environmental parameters will be included.

A risk-based assessment should be used to determine which operations in the production process should be assessed, and which environmental parameters / impacts within each operation should be quantified. Usually problem-oriented (mid-point) or damage-oriented (end-point) approaches are use to define impact categories (Mangena and Brent 2006).

Following the inventory, the life cycle impact assessment phase typically has three components (Mangena and Brent 2006):

1. Classification: where the results of the inventory are categorised into impact categories;
2. Characterisation: where the contribution of inventory data to each impact category is determined; and
3. Valuation; whereby the different impacts are normalised and weighted against each other.

Environmental impacts to be quantified are selected for each operation, within each stage of production. These models can be built with customised versions of existing software (e.g. Microsoft Excel).

A major concern with LCA, like any impact assessment process, is the way that values are attributed for different types of impacts. Regardless, once values are quantified, LCA can be a useful decision support tool for comparing project or process options within an agreed values framework. The LCA science is still developing. Since life cycle costs cannot be unambiguously attributed, especially in multi-product process chains (Johns et al. 2008), LCA must only be used as a decision support tool, rather than a decision making tool.

An international standard (ISO) has been developed for LCA (ISO 14040-2), as part of the Environmental Management series. This was developed with considerable input from the Society of Environmental Toxicology and Chemistry (SETAC).

An excellent international example of the application of LCA can be found in the comparison of environmental impacts from using disposable or reusable nappies:

The Environment Agency (2005) Life Cycle Assessment of Disposable and Reusable Nappies in the UK. The Environment Agency, Bristol. w.w.w.environment-agency.gov.uk

LCA in the Australian Minerals Industry

Most effort to date in LCA for the mining industry has been on the processing phase of production, but new models have been developed to include the extraction, waste handling and rehabilitation stages (Durucan et al. 2006; McKay et al. 2006). Most LCAs quantify impacts on the following criteria: land use, waste production, greenhouse gas emissions / energy use, air quality impacts, and water quality impacts. The relative weighting of these different impacts is subjective, and should be developed through engaging stakeholders (as per multi-criteria analyses).

A generalised flow diagram has been developed to define a life cycle inventory for processing of minerals in Australia (Fig 2); outlining the typical activities involved following extraction and before export (Stewart and Petrie 2006). For a full cradle-to-grave assessment, several further steps require attention, including exploration, extraction, transport, export, use and recycling.

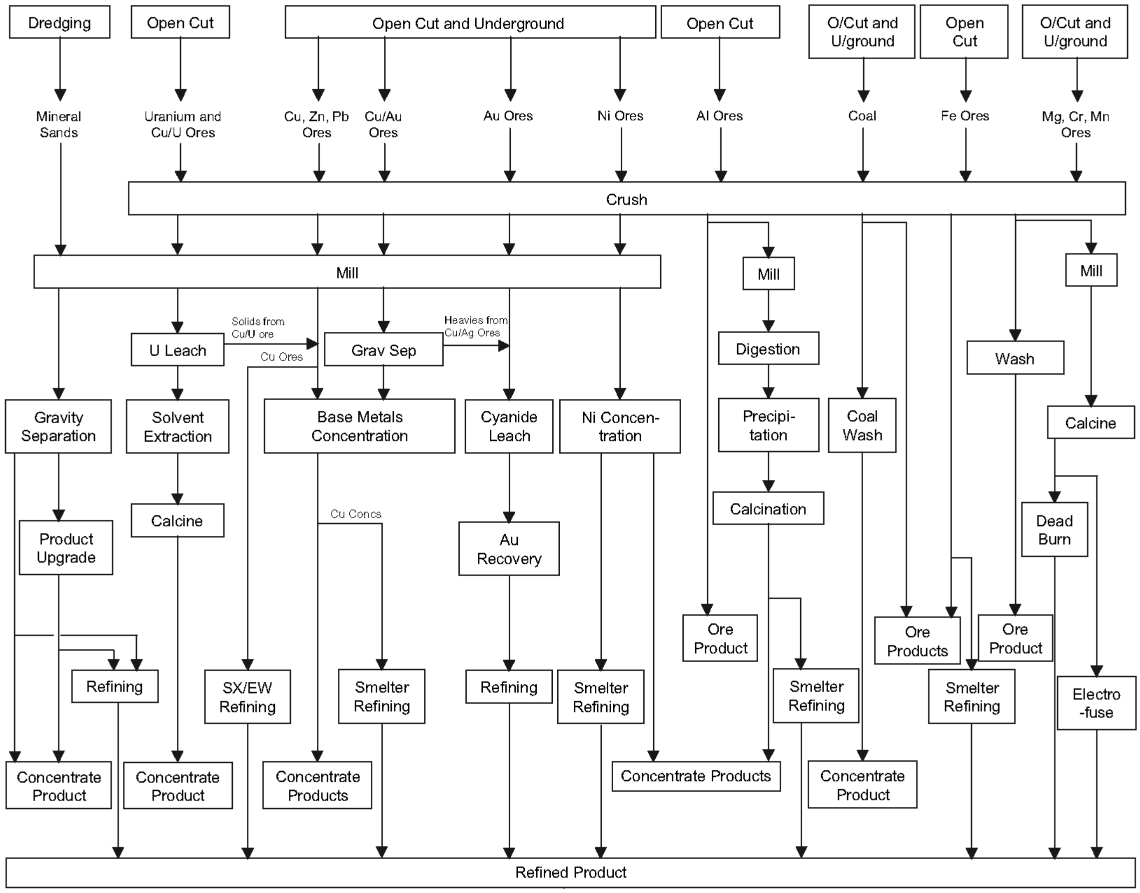

Figure 2. Life cycle activity flow sheet for minerals processing activities in Australia (Stewart and Petrie 2006)

Several case studies of LCA application or development in the minerals industry exist:

1. For the comparison of environmental impacts from the processing of various ores in Australia (Norgate et al 2007);
2. For copper at an American mine and smelter (Kennecott Utah Copper Corporation; Rio Tinto); and
3. Life cycle assessment of Aluminium: Inventory data for the worldwide primary Aluminium Industry (International Aluminium Institute)

However, there is a need for life cycle inventories to be developed for the Australian Minerals industry, for cradle-to-grave or cradle-to-cradle LCA. Good inventories exist for the ore processing stage, but not for other stages of the commodity life cycles (pers. obs.; Norgate pers. comm.). This would enable LCA to be undertaken in a systematic way across commodities, and industries, resulting in the most efficient use of resources. The Leading Practice Sustainable Development Handbook on Stewardship (DITR 2006) recognised that there remains:

'a need to further standardise LCA methodology, particularly in relation to scoping of the study…and the environmental impact categories considered'

CSIRO has advised that inventories exist for Al, Mg, and Fe, but much more has to be done to generate LCI data in other minerals industry materials. PACIA, the peak body for the chemicals and plastics industry, has developed a life cycle inventory for a sub-set of chemicals used in their industry. The inventory developed by PACIA will be used by their member companies to undertake life cycle impact assessments.

There is an existing joint government and industry initiative being pursued to develop a nationally consistent framework for developing inventories for LCA.

Reference Material

Department of Industry Tourism and Resources (DITR; 2006) Leading Practice Sustainable Development Program for the Mining Industry. Commonwealth of Australia, Canberra.

Durucan, S., Korre, A., and Munoz-Melendez (2006) Mining life cycle modelling: a cradle-to-gate approach to environmental management in the minerals industry. Journal of Cleaner Production 14: 1057-1070.

Fourie, A., and Brent, A.C. (2006) A project-based Mine Closure Model (MCM) for sustainable asset Life Cycle Management. Journal of Cleaner Production 14: 1085-1095.

Johns, W.R., Kokossis, A., and Thompson, F. (2008) A flowsheeting approach to integrated life cycle analysis. Chemical Engineering and Processing 47: 557–564.

Krozer, Y. (2008) Life cycle costings for innovations in product chains. Journal of Cleaner Production 16: 310-321.

Mangena, S.J., and Brent, A.C. (2006) Application of a Life Cycle Impact Assessment framework to evaluate and compare environmental performances with economic values of supplied coal products. Journal of Cleaner Production 14: 1071-1084.

McKay, S., Funk, W., Rimbey, S., and Butler, H. (2006) Computer simulation model for determining reclamation liability costs of the Ekati Diamond Mine in the Northwest Territories, Canada. Journal of Cleaner Production 14: 1096-1100

Monhemius, J. (2006) Editorial - Section 1: life cycle and process analysis in the mining industry. Journal of Cleaner Production 14: 1040-1041.

Norgate, T.E. and Rankin, W.J. (2000) Life cycle assessment of copper and nickel. Proceedings, Minprex 2000, International Conference on Minerals Processing and Extractive Metallurgy, pp133-138.

Norgate, T.E., Jahanshahi, S, and Rankin, W.J (2007) Assessing the environmental impact of metal production processes. Journal of Cleaner Production 15: 838-848.

Stewart, M. and Petrie, J. (2006) A process systems approach to life cycle inventories for minerals: South African and Australian case studies. Journal of Cleaner Production 14: 1042-1056.

The Environment Agency (2005) Life Cycle Assessment of Disposable and Reusable Nappies in the UK. The Environment Agency, Bristol. w.w.w.environment-agency.gov.uk