Addressing variability of life cycle based environmental impacts of metal production

Stephen Northey[1], Nawshad Haque[2], Mark Cooksey[3]
[1,2,3]Mineral Resources Flagship, CSIRO, Private Bag 10, Clayton South, VIC 3168

Keywords: Life cycle assessment, sustainability, variability

Life cycle assessment (LCA) is a key tool for assessing environmental impacts of metal production and results have been published (Norgate and Haque, 2010; Northey *et al.*, 2014). Currently the major LCA databases are populated by input data for metal production that has been developed by industry groups, packaged (Ecoinvent, 2014) and sold as part of LCA software packages such as in SimaPro (PRe, 2014) or GaBi (PE International, 2014). These data are based on site specific and company data that has been aggregated at the scale of broad regions or even globally. This aggregation is often used to make data more manageable for database developers who need to manage data for several thousand distinct unit processes.

During this process of aggregation, the variability across the data set is lost. Aggregation significantly dilutes the value of the data set and the usefulness of the LCA. In particular:

- the loss of information on regional supply chains is significant and hinders more detailed study of the actual impact of products and the options available to mitigate this;
- the underlying representativeness of much of this data is often also poor as it is comprised of site-based data for a limited number of operations that in many cases has been extrapolated to represent whole regions;
- environmental impacts associated with the primary production of metal products are highly variable between regions and even individual sites within a region;
- the current aggregation of data limits the ability to properly assess and select materials based upon their point of origin;.
- Improvements to the regionalisation of life cycle assessment data are important for certain types of impact assessment studies, such as those that consider water scarcity or changes to water quality.

Mining and primary metal production are industries where regional variability can be substantial. Differences in geology between regions and even deposits within a region can be significant. On a simplistic level this variability can be measured by differences in ore grades, strip ratios (waste rock: economic ore ratio) and ore hardness. However, mineralogy, grain sizes and particle size distributions are highly variable between sites and can vary significantly through an individual deposit. These differences in the nature of individual deposits leads to variations in initial processing routes, with processing becoming more standardised once intermediate concentrates or semi-refined products are produced. Due to this, the final stage of metal production that occurs at centralised smelters and refineries are better represented in life cycle inventory (LCI) data than the initial mining and mineral processing stages. One area where little work has been done is to systematically analyse different classes of sites that produce different co-products. This is significant as there is considerable variation in the process used by sites depending on the co-products produced.

Current LCI databases for mining and metal production seem to only include data for major producers. Inclusion of data for major mining and metal production operations only within LCI databases may lead to an unrepresentative sample for some types of impact. For instance a small, poorly managed operation may have greater impact on local waterways than a large, well managed operation. In addition, the different methods available to reproduce the various datasets for copper and gold production often lead to conflicting results. Importantly, the current datasets for metals have been developed separately and methodological decisions, such as allocation, have been applied without consideration of the needs of downstream users. This limits the types of studies that can be performed using these datasets and the interoperability between them.

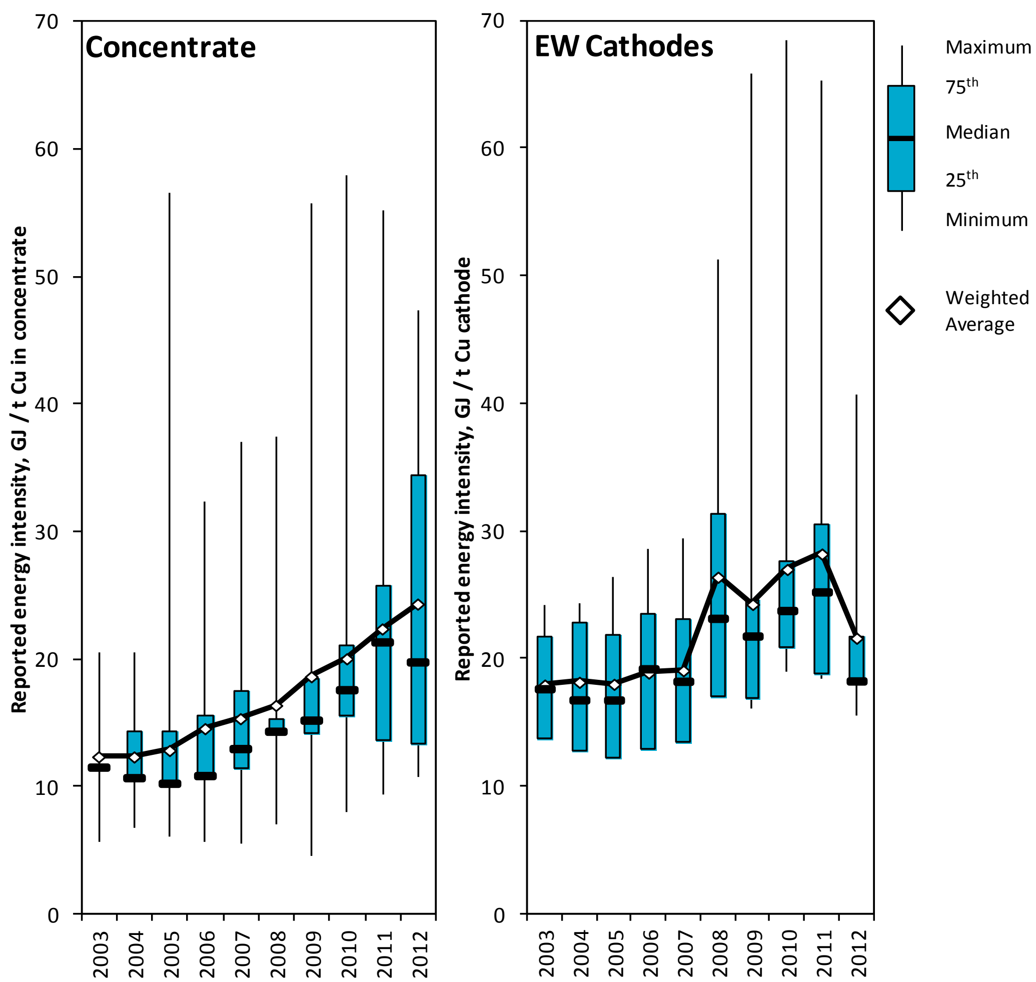

Figure 1: Reported variability of energy footprint for copper over several years.

It is difficult to use the results from many LCA studies of primary metal production for decision making due to absence of variability information. For example, the results for global warming potential (e.g. greenhouse gas emissions expressed in kg CO_2 equivalent) for aluminium production can vary by over five times depending on the plant efficiency, source of inputs and electricity. Similarly, the results for copper (particularly water impact) can vary by an order of magnitude depending on resource quality and technology used (Figure 1). The reported energy intensity of copper production over time is shown for copper concentrate production and electro-won (EW) cathode production. The data available suggests that the energy intensity of concentrate production has increased significantly through this time. The data also shows an increase in the energy intensity of EW cathode production for much of the period between 2003 and 2011. The subsequent fall in energy intensity of EW cathode production is likely to be a consequent change in the mines included within the dataset and also decreased copper prices leading to higher grade ores being processed.

Energy intensity of electro-refined (ER) cathodes has not been determined because of the limited number of sites in the data set. Similarly, total cathode production (ER cathodes + EW cathodes) is also not shown for the same reason; a higher proportion of data is available for EW cathodes, rather than ER cathodes that represent around 80% of the industry.

Although there are a variety of different drivers for the energy intensity at different sites, there are several conclusions that can be reached from this data. Firstly, the energy intensity of concentrate production has generally appeared to increase through the period. There are several potential drivers for this change:

- increasing mine depth for the operations that data was available for;
- changes in the operations that data was available for through the period;
- decreasing ore grade through the period, possibly in response to higher copper prices.

The energy consumption data that has been developed in this study provides some baseline data that can be used as the first part of developing embodied energy estimates for the industry.

The challenge for undertaking any LCA study including variability is significant due to extensive nature of the study and resources required. In this paper, the underlying issues are highlighted in particular reference to primary metal production.

A project is currently underway to address issues of variability of input data between various plant and production sites for selected primary metal production. The analysis of this data is expected to reveal the benchmark impact, identify the major contributing inputs on life cycle based environmental impact and potentially recommendation for new technology that can reduce these impacts.

References

1. Norgate, T. and Haque, N. 2010. Energy and greenhouse gas impacts of mining and mineral processing operations. Journal of Cleaner Production 18:266-274.
2. Northey, S.A., Haque, N., Lovel, R., Cooksey, M. 2014. Evaluating the application of water footprint methods to primary metal production systems. Minerals Engineering 69:65-80.
3. Ecoinvent, 2014. Ecoinvent centre, Swiss Centre for Life Cycle Inventory. Available online: http://www.ecoinvent.ch (accessed on 11 December 2014).
4. PRe, 2014. SimaPro software by PRe Sustainability. Available online: http://pre-sustainability.com (accessed on 11 December 2014).
5. GaBi (2014) Life Cycle Assessment LCA Software: GaBi Software. Available online: http://www.gabi-software.com/australia/index (accessed on 11 December 2014).