Non-Ferrous Metals
Consultative Forum on
Sustainable Development

SCIENCE, RESEARCH AND DEVELOPMENT WORKING GROUP

Report on Policy Making, Non-Ferrous Metals and Life Cycle Studies

Life Cycle Assessment Sub-Group led by Christian Bauer, Aachen University of Technology

Draft of 5 Nov 02

International Copper Study Group
International Nickel Study Group
International Lead and Zinc Study Group

Policy Making, Non-Ferrous Metals and Life Cycle Studies

Non Ferrous Metal Sustainable Development Forum – Science Working Group
Sub Group on Life Cycle Assessment
Draft of 31 October 2002

This Paper summarises the Sub Group's consideration of issues related to policy making for metals using life cycle assessments (LCA's). In November 2001 the Sub Group presented a comprehensive analysis of contentious issues related to the treatment of non-ferrous metals in LCA's. This detailed study was focused on issues within the LCA process. A missing link to policy making based on the tool LCA itself was identified. It was felt that the tool is misused and misunderstood in decision contexts regarding non-ferrous metals within the framework of Sustainable Development.

The aim of this paper is to make regulatory and other agencies aware of strengths but also limitations of using such an analytical tool in different decision contexts.

Discussion tracks

Based on the Oporto-meeting of the Forum where a number of key issues for consideration of metals in life cycle studies were highlighted the following tasks where suggested:

- compile "lessons learned" from previous and ongoing initiatives (UNEP)
- derive "do's and dont's" through the evaluation of current "best practice" documents (SETAC)
- participate in ongoing initiatives (UNEP)
- identify linkages to supplementary tools towards Sustainable Development (Risk Assessment , Environmental Impact Assessment,)

These tasks were not necessarily identified for the Group itself but as general requirements. Within the ongoing discussion several additional tracks and key questions can be summarized as:

- How important is LCA to Sustainable Development?
- How is LCA used and misused in decision making?

The last issue is particularly important with regard to legislative processes that increasingly incorporate LCA-results. The use of LCA to support decision making in general is an issue that is addressed by numerous publications ranging from general strategy papers (UNEP) to single dissertations.

The gap which might be considered for the discussion in the NFMSD Science Research and Development Working Group includes aspects relevant to non-ferrous metals. These may be focused on specific issues related to metals in comparison to other materials, substances or mineral resources or on other specific issues that have to be identified.

The Risk Assessment considerations of the Science Research and Development Group clearly address science and policy issues and conclude with clear-cut statements to draw the regulators' attention to pitfalls in current Risk Assessment logic. The same is true for LCA and if it is to be used as a tool to aid in decision making several pitfalls that apply predominantly to general issues in LCA application need to be addressed.

Pitfalls

The following section highlights metal specific issues for which the Working Group identified discrepancies between reality and applications of LCA which may lead to a decline in the quality of decision making rather than an improvement. In figure 1, LCA as a tool is positioned as a part of more integrated Life Cycle Management (LCM) approaches and the philosophical concept of life cycle thinking. This graphic implies, that a decision towards "more" sustainability must acknowledge the Life Cycle Philosophy and management aspects (e.g. Life Cycle Costing – LCC) which enclose LCA as one tool.

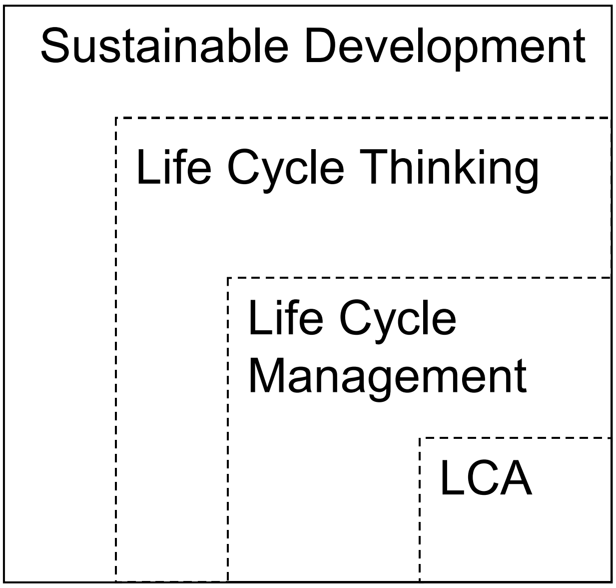

Figure 1: LCA as one tool within the life cycle philosophy.

Decision making is the task of choosing the right route between two points. Sustainable Development itself is a vaguely defined route with a known departure point but with several destinations in time and space. A commonly held view is that we do not know exactly in which direction to move, but at least we should move. On an operational level we assume that a decision can be made between a less and a more sustainable route. It is generally agreed with regard to services or products, that all stages from cradle to grave must be recognised. The aspects along a life cycle that must be taken into account are economic, social and environmental interdependencies. As a route finder LCA is one tool amongst others, which is designed to detect environmentally sound route segments of the journey.

It is obvious that a sound solution can only be reached by exactly specifying A (a departure point) and B (a destination). Examples for such route finding problems are listed in table 1.

Table 1: Different decision contexts for LCA

Case	Decision	Example
1	within the life cycle of a metal	Decision about mining technologies or processing technologies
2	between two metals	Decision about using Copper or Aluminium in power transmission lines
3	between metals and materials	Decision about Copper or Plastics in plumbing
4	between two products	Decision about two different cellular phones
5	between two services	Decision between bus or rail services

The right specifications of A and B as the major route are much more important than precisely quantifying (to two digits of precision) the minor adjunct routes. The cases illustrated could also be addressed with other tools (case 1 – environmental risk assessment ERA, case 5 – technology assessment TA). Choosing LCA in such cases is a subjective value choice. Moreover, basic assumptions on the system boundaries are subjective and aligned more to the decision than to the real world system (e.g. where does mining start and stop in time and space?). It is also assumed that we are able to determine the principles of environmental mechanisms even if they are not yet fully understood.

1: The uncertainties in using LCA as such are much larger than a single elementary flow.

Within a full assessment the decision context (A to B), inventory modelling and impact assessment is fixed before starting. Parts of the inventory model may be used in other contexts (C to D) like a road junction, but do not necessarily fulfil all requirements. According to the examples shown in figure 1, detailed knowledge of hard rock mining technologies is necessary for case 1. In case 2 generally speaking hard rock mining must be compared with soft rock mining amongst other tasks. Consequently different inventories must be set up. The inventory of case 1 might have to be extended or simplified according to the difference in the unit processes considered. Many initiatives are actively attempting to create universal route segments. At present the results available are suitable for specific cases and are not yet fully operational.

2: There is no universal life cycle inventory (LCI) which enables a multitude of decisions. Each LCI is individually aligned to a specific decision context.

The elementary flows of an LCI are classified and characterised by using equivalence factors on which there is scientific agreement. The classification and characterisation depends on goal and scope (A and B). This route defines how many categories are necessary and how the elementary flows are modelled within or between the categories. Each case requires a careful choice to reduce categories to a manageable number and to aggregate elementary flows accordingly.

According to the use phase and the end-of-life scenario categories may be discussed differently. Examples are:

- Renewable and non renewable materials
- Toxicity and bio-availability of metals

The categories considered are based on simplifying assumptions and some degree of abstraction. They have a trend suggestive character and are used to indicate clearly differences between two alternatives. Therefore they must be modelled according to the properties of the system and the intended decision prior to assigning an absolute potential environmental damage to a material.

3: There is no universal Impact Assessment (LCIA). The decision context is inevitable for the number of categories and their definition.

Even if A and B are defined the same, such as materials choice for a battery, interpretations depend heavily on the spatial and temporal scope. For instance to make an environmentally sound decision on battery-composition in Norway, may require results different from those needed to decide on battery composition for the Asian market (Consumers' behaviour, battery powered products). Taking the route metaphor careful decisions on distance and speed should be made before undertaking the LCA.

4: There is no universal interpretation. Each interpretation has to include additional information that can not be expressed in LCIA. One LCIA may have two or more valid interpretations considering different spatial and temporal aspects.

Annex I: Metals in Life Cycle Studies

A Roadmap towards harmonisation of life cycle studies for metals (Oporto 2001)

Non Ferrous Metal Sustainable Development Forum – Science Working Group
Sub Group on Life Cycle Assessment[1]

This Paper summarises the Sub Group's consideration of issues related to the life cycle assessment of metals. The intention is examine the specific characteristics of metals to understand how those characteristics will affect the comparability, reliability and usefulness of life cycle studies and their interpretation.

1. Life Cycle Studies & Sustainable Development

There is increasing demand for methodologies that support, within the economic, social and environmental dimensions of sustainability, the holistic consideration of the multitude of effects (both beneficial and adverse) resulting from today's usage patterns of metals. This demand is coming from governments, investors and the general public.

The transition in regulatory approaches from "end of pipe" solutions to the precautionary principle, additional complexities resulting from the need to integrate broader considerations such as global change into decision making, the opportunities presented by the "information age" and numerous other issues require methodologies that can cope with the complexity of current concerns.

Life cycle studies, as conducted in the last decades, attempt to identify the complete set of environmental impacts caused by the production, consumption or use, and disposal of products or services. Beyond Life Cycle Assessment (LCA) Material Flow Accounting, Eco-Audits, EuroMat as well as concepts for Industrial Ecology or Material Intensity Analyses are very close to the subject area.

The common element of life cycle approaches is the analysis of processes and their inputs as well as outputs upstream and downstream of the use phase. The overall life cycle encompasses all stages of materials and services from resource extraction to the product or service, its disposal after use and potential

[1] The Sub Group includes representatives of government, industry and NGOs and is chaired by Christian Bauer of Aachen University of Technology.

recycling paths. Colloquial “cradle to grave” is used to describe the scope for such studies. For systems with recycling loops “cradle to cradle” is a more appropriate terminology. “Cradle to gate” addresses inventories of primary production processes disregarding the use phase.

LCA in general is sufficiently treated in current ISO standards. Table 1 gives an overview on currently available standards. It is important to understand the relationship between the LCA approach and sustainable development (SD). LCA provides an analytical interpretation of technical inventories. Sustainable Development involves the application of certain principles and values to current operations and procedures. It also involves monitoring the impact of these operations on the environment, economy and society. LCA can support SD by delivering indicators of aggregate environmental interventions but it is only one tool among others.

Table 1: ISO standards for LCA.

ISO no.	Title of International Standard / Guideline / Report	Publication Date	Sub-committee
ISO 14040	Environmental management - Life cycle assessment - Principles and framework	June 1997	SC 5/WG 1
ISO 14041	Environmental management - Life cycle assessment - Goal and scope definition and inventory analysis	October 1998	SC 5/WG 1
ISO 14042	Environmental management - Life cycle assessment - Life cycle impact assessment	March 2000	SC 5/WG 4
ISO 14043	Environmental management - Life cycle assessment - Life cycle interpretation	March 2000	SC 5/WG 5
ISO/WD TR 14047	Environmental management - Life cycle assessment - Examples of application of ISO 14042	1999	SC 5
ISO/CD TR 14048	Environmental management - Life cycle assessment - Life cycle assessment data documentation format	1999	SC 5
ISO/TR 14049	Environmental management - Life cycle assessment - Examples of application of ISO 14041 to goal and scope definition and inventory analysis	March 2000	SC 5/WG 3

2. Metals & Life Cycle Studies

Metals are pervasive and inevitable in today’s society, not least because they are a natural part of our environment. Life cycle studies of metals can help provide a better understanding of the impact the production and use of metals can have on our environment.

Metal production, trading, use and recycling involves a global network of cradles and graves with the global network of business relationships based on (usually) profitable transactions as turntable. Deposit locations, physical / chemical / mechanical properties and recycling potential differ for each metal and together form the unique properties of a metal. This complicates current approaches that attempt to apply similar standards and methodologies to ensure comparability between different metals in life cycle studies.

Furthermore, subjective perceptions and biased perspectives can cause contradictory outcomes for life cycle studies, even when they have been conducted under an ISO framework.

Dispute endangers the process of developing commonly agreed methodologies able to support scientifically based decision making and suitable for communicating policy targets and strategies. Marketing, once centred around the advantages which a product or service might have for the customer, has discovered environmental or even sustainability issues as selling strategies. This has led to an inflation and mis-use of these terms and their relevance. The fact that providers of investment funds are increasingly demanding the application of sound sustainable development principles by the companies and projects that they support means that the issue is not trivial.

A generic life cycle model for one metal is illustrated in Figure 1. Within each of the four iterative phases of an LCA, the level of detail for the single process and the boundary definition for each considered system is crucial for the result. Within the current standards many examples and recommendations are available to assist in this modelling process. However, the NFMSD- Science Working group believes there is still a need for harmonisation, especially regarding the comparability of different LCAs. Currently metals are treated very differently from case to case. Therefore it is desirable to highlight some of those issues, which could also be detected by strictly applying the standards.

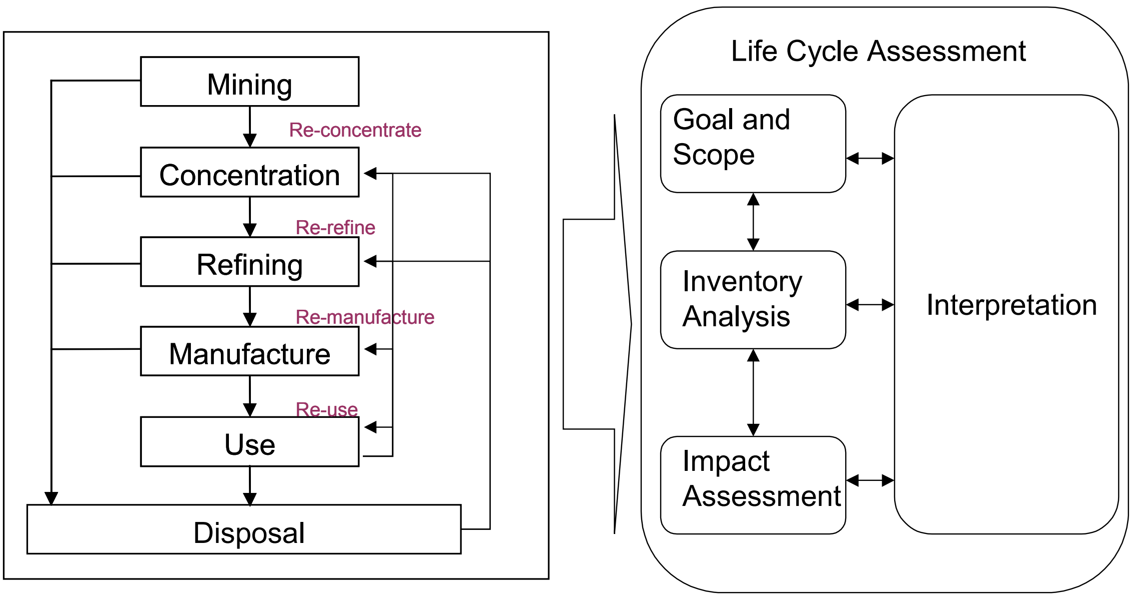

Figure 1: A metals life cycle and the 4 phases of a LCA. [left: Report on the MMSD Life Cycle Assessment Workshop, Mary Stewart, 2001; right: ISO 14040]

In the following a list of key questions is given. These questions might help in setting up a life cycle study and will also help interpret its results. The listed questions supplement the recommendations that are given in the ISO 14040 framework. It is not intended in any case to deal with general LCA problems and deficits but rather to address the specific issues that arise in conducting LCAs of metals.

3. Key questions for metals in LCA

- **Metals in Goal & Scope Definition**
    - How to reflect upstream conditions? Markets mask the upstream origin. (It is not really known whether the copper or copper-wire comes from Ok Tedi or Chuquicamata)
    - How to reflect international down stream trading of products, especially for recycling? (Is the recycling of cars exported to eastern Europe as efficient as assumed in a German LCA?)
    - How to To deal with varying qualities in scrap trading? (It is not really known whether recycled metals have been cans or window frames. Moreover, there are different views concerning the relevance of past use of a metal to its future use.)
    - How to define commonly agreed system boundaries for handling sub-process chains? (mass cut-offs are overruled if e.g. ecotoxicity is of interest)
- **Metals in the Inventory Analysis**
    - How to address recycling in a universally applicable way? Which benefits may be assigned? (recycling potential is not always exhausted)
    - How to address ores of a variety of metals? How to allocate? (there are copper mines which are only operated because they contain gold and lead is increasingly seen as a by-product of zinc mining etc.)
    - How to address calorific values in ores? (e.g. Sulphur in Copper ores)
    - How to report on more or less unique issues with mining & processing? (large volume wastes, mine water, subsidence, mine closure)
    - How to deal with the difference in service life (measured in months or centuries) that some metals can have in products and applications (Should durability necessarily be considered an indication of an open loop and eventual down-cycling?)

- **Metals in Impact Assessment**
  - How to account for the removal of metals from deposits on the one hand and the creation of stocks in the technosphere on the other hand?
  - How to address land use and its effects (ultra short term - strip mining, ultra long term - waste disposal)
  - How to account for exploration but also post closure activities?
  - What are the impacts of Acid Mine Drainage and Acid Rock Drainage and how can they be treated in the impact category framework?
  - How to deal with metals as emissions regarding current eco-toxicity and human toxicity issues? Are equivalence factors useful and appropriate? How to address their life support functions in low doses and natural background concentrations?
  - Are there metal specific occupational health issues? Which ones must be addressed and how can they be folded into the LCA?
- **Other Contentious Issues for metals related to the LCA-perspective**
  - Mining and foreign investment flows contribute to north-south tensions. Environmental issues and development perspectives of the South may not be covered sufficiently in metal LCAs by currently available impact categories.
  - Metals & mining can have an un-organised structure which has not been addressed within life cycle studies so far (guarimperos – small scale mining in developing countries).
  - Some highly efficient recycling systems work only due to poverty and unsustainable living conditions (eg collecting aluminium cans on waste disposal sites).
  - Abandoned mine sites and demolished plants may be related to the burdens of presently available secondary resources.
  - The risk of tailing dam leakage or dam breaks is still frequent but also not part of systematic life cycle studies.
  - Legal frameworks have a large influence on secondary raw material flows and waste treatment. How to account for benefits, but also disadvantages of this artificial environment?
- **Data documentation for metals**

The ISO 14048 for LCA-documentation should be interpreted to recommend documentation needs for data to ensure transparency and re-usability.

- **Credibility of outcomes in comparative LCAs**
  - How to identify reliable and consistent data and sources of information?
  - How to define and report on quality and coverage of data (time horizon, technologies, and geography)?

Who should review scope, data and methodological approaches?

- **Stakeholder participation for metals**
  - What is the role of stakeholder participation given that LCA is meant to be a scientific/technical and rational analysis providing objective data? There is no stakeholder participation in financial accounting - although there may be broader participation in developing accounting standards.
  - At what stages of carrying out an LCA study for metals is the participation of stakeholders useful, recommended, or requested? (e.g. in defining scope, collecting and compiling data, setting priorities and cut-off criteria, selecting impact categories, analysing and discussing results)
  - How to set up an efficient and trustworthy roundtable of stakeholders?

Many of these listed questions are treated in publications or in active initiatives. The following list contains initiatives, currently known to the Sub Group:

- MMSD-New York Workshop on LCA and SD (August 2001); final report available at http://www.iied.org/mmsd
- Working Group SD-Indicators on minerals and metals (EU DG Enterprises)
- ISO TR 4047 draft: Illustrative examples on how to apply ISO 14042 LCA - LCIA
- Best Practice LCA 2001 (forthcoming publication of the 6 SETAC Working Groups on LCA)
- CML-cookbook: LCA – an operational guide to the ISO standards available at http://www.leidenuniv.nl/interfac/cml/lca2/
- UNEP-SETAC Initiative (Globalisation of LCA & LCIA)
- Published cradle to gate studies on metals (CSIRO Australia, BGR Germany)
- Forthcoming LCA & Metals-Workshop on LCA in Canada in spring 2002 (UNEP/SETAC/APEC/ICME/NRCan)

4. Conclusions

It is desirable to develop a commonly agreed framework which aids in conducting repeatable and trustworthy life cycle studies on metals and on products and services that contain or relate to metal production and use. It is important from the start to emphasise that LCA should cover benefits as well as any adverse effects. LCA does not provide a philosophy about how to make decisions but provides objective data that feed into the decision making process. However, the LCA of one material has to be compared with that of possible substitute materials to obtain a maximum benefit in a decision-making or policy development process.

The results of any harmonisation process for metal specific challenges have to be applicable to all NF-metals and will have to find acceptance for all substitute materials. The universal and flexible character of the LCA-framework which allows the decision specific adaptation of methods should not be restrained. Methodologies and the collection of relevant data should build on the already significant LCA work for different NF-metals.

A review of relevant studies would serve to identify data needs, data sources, and appropriate methodologies. A review would also help identify the level, nature and source of criticism of past studies and the level of support and acceptance these studies have received from different stakeholders.

“Metals in the environment” is a complex research issue. The work of this Sub-Group does not address fate and exposure studies. However, a clear understanding of ecotoxicity and human toxicity must provide the context for the work of the group. Linking risk assessment studies and life cycle analysis should be explored in an overall SD approach. While the two kinds of studies address quite different issues, they each form part of what should be a scientifically based approach to policy development and decision making.

In order to reach a high level of acceptance and confidence, representatives of the industry (directors of life cycles and those affected by life cycle studies) and practitioners (those who collect data, develop and sell life cycle assessment software & studies and ensure ISO-conformance) should collaborate. NGOs (representing the public’s voice), governments (legislation, decision makers on the macro-level), designers & engineers (those who are responsible for the material decision on micro-level) should be consulted to ensure, that important issues are recognised but also to guarantee a common understanding of the results of an LCA.

Annex II Life Cycle Assessment in Practice

A Case Study of DaimlerChrysler's Car CARE Program

The following is a small example of a larger trend: corporations that sell to consumers are going up the supply chain, working with suppliers to improve a process, a product or a practice. Here it is DaimlerChrysler that is providing the case study but it could just as well have been Electrolux, IKEA, or Panasonic, to name some other leaders in this kind of activity. The common thread is that in every case, LCA is one of the tools influencing what the companies target and how they judge whether the changes in fact constitute an improvement in the overall environmental performance of the system.

The Concepts for Advanced Recycling and Environmental (CARE) Car Program was set up by DaimlerChrysler to tackle the issue of end-of-life vehicles (ELV) and their impact on the environment. Regulations governing ELVs are becoming commonplace in Japan, the European Union and North America. They have raised the threshold requiring recycling of new vehicles from around 75% currently (composed almost entirely of non-ferrous metals) towards 95% (and to include material that went previously to landfill).

Life Cycle Management considerations for auto manufacturers begin with parts production that precedes product manufacture. As well as the component's price the auto producer takes into account its weight, costs of tooling for production as well as the presence of any substances that are deemed to be hazardous. The Life Cycle Management system boundary for product manufacture has tended to concentrate on differences in the cost of production and includes elements such as costs relating to assembly, ancillary parts, permitting, pollution control, health and safety as well as air, water and solid wastes. The development of end-of-life regulations has pushed out this envelope so that auto manufacturers have now begun to consider Life Cycle Management in the use-phase (relating to performance, quality and maintenance aspects of the vehicle) and at end-of -life.

Extending the system boundary of auto manufacturer's Life Cycle Management consideration to end-of-life has focused attention on the challenges of disassembling vehicles, recycling components and disposal of those parts that cannot be recovered for re-use. Life Cycle policy in DaimlerChrysler CARE program is focused on the latter - specifically the challenge posed by shredder residue that is composed mainly of plastic, foam and some residual metals. To this end DaimlerChrysler's CARE program has resulted in the development of a proprietary flotation technique that automatically separates, extracts and dries different types of plastic residues from ELVs. These are then melted and mixed with virgin plastic to create new vehicle parts.

An integral part DaimlerChrysler's CARE program approach is to work with its component suppliers to ensure from the outset that recycled materials meet the same materials specifications as the company's production parts. Two metal recycling companies have invested in the research aspect of the CARE program. Metal recycling is being promoted actively within the company's manufacturing plants. In one of DaimlerChrysler's transmission plants (at Kokomo, Indiana in the United States) a compactor which works as a hydraulic press is being used to squeeze aluminium chips and extract much of the machining oil that coats them. Previously these chips were regarded as production process scrap. The compactor produces aluminium bricks which the vendor cleans, dries, removes any remaining oil and then re-melts for production. Work is underway in the plant to remove all the oil in house for re-use in house. Metal scrap volume at the plant has been cut by a factor of eight.

Rising landfill costs are expected to impact positively on DaimlerChrysler's drive to increase the use of recycled materials and improve the comparative cost of recycling. The spread of "take back" laws and regulations relating to ELVs are likely to promote the use of life cycle tools which incorporate environmental factors and shape materials choice within the automobile manufacturing industry.