



Society of Mining Professors
Societät der Bergbaukunde

Traditional and Innovative Life Cycle Analysis (LCA) tools for the Mineral Industries

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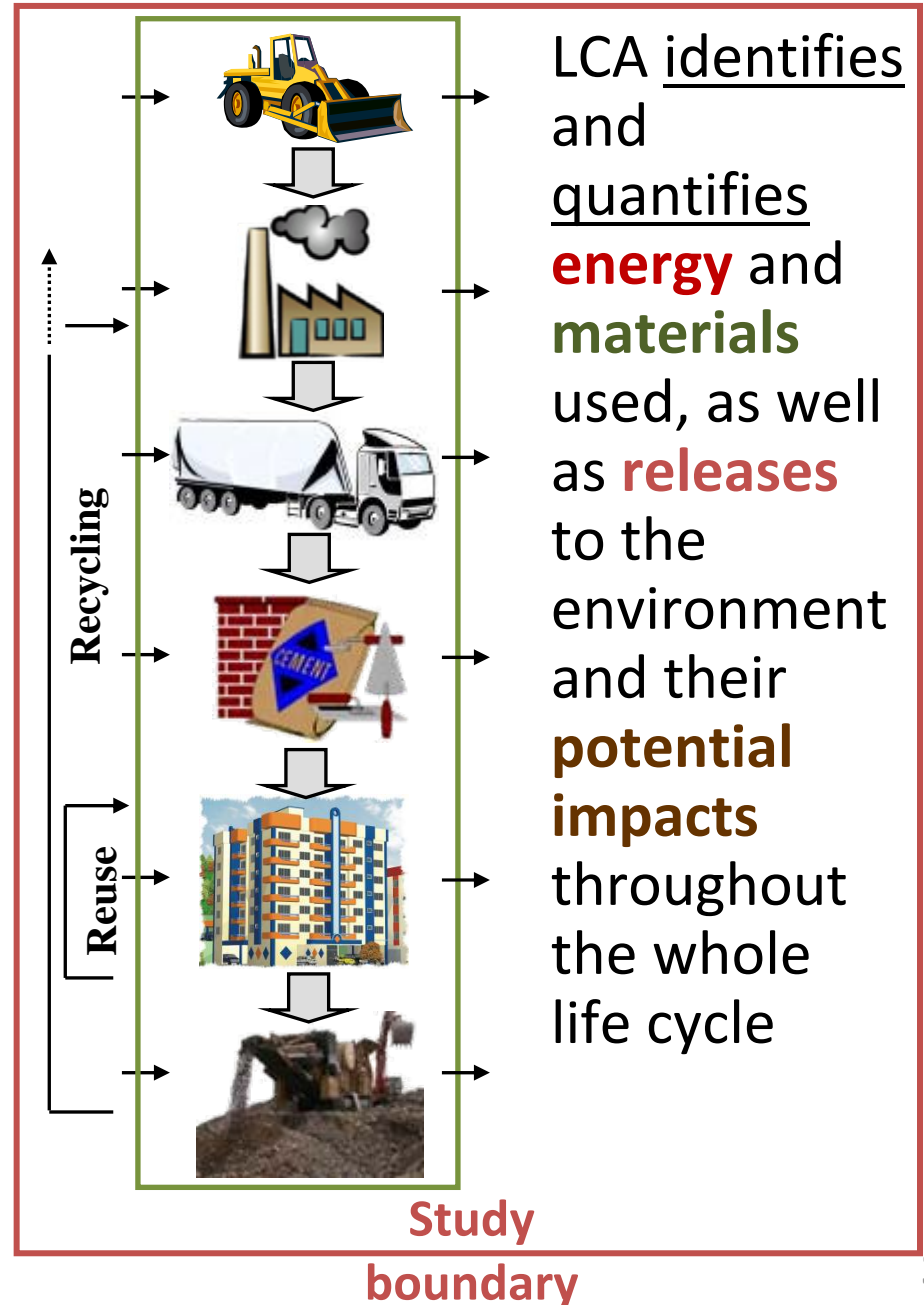
Outline

- LCA basics (traditional LCA tools)
- LCA & mineral products (non-mining/mining LCAs)
- Current status of LCA research
- Unresolved problems in Mining LCAs
- Land use in LCA
- Product LCA vs. mine site LCA
- Future research to improve land use in LCA

LCA (Life Cycle Assessment)

LCA is an objective tool for *analysing* and quantifying the *environmental implications* of *products* (services) during all their *life-cycle*, from the extraction of raw materials, through industrial production, including the use phase and the end-of-life disposal **“from-cradle-to-grave”**

Environmental consequences of production/use systems encompass resource conservation issues as well as all kind of emissions harmful to human health and ecosystem quality



Traditional (current) LCA tools:

ISO 14040/44: Environmental Management - Life Cycle Assessment - Principles and Framework / Requirements and Guidelines, International Organization for Standardization, Geneva, Switzerland, 2006

ILCD Handbook



International Reference Life Cycle Data System (ILCD) Handbook

Supporting business and public authorities towards sustainable production and consumption

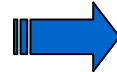


European Platform on Life Cycle Assessment - European Commission,
Joint Research Centre (JRC) - <http://lct.jrc.ec.europa.eu>

LCA is gaining importance in several sectors for a wide range of purposes where:



(1) THERE IS NEED OF AN ENGINEERING APPROACH TO ENVIRONMENTAL/RESOURCE USE ASSESSMENT



(2) THERE IS EVIDENCE OR RISK OF ENVIRONMENTAL IMPACT SHIFTING



(3) THERE IS NEED TO MEASURE THE ENVIRON. PERFORMANCE OF COMPLEX AND INTER-DEPENDENT SYSTEMS

LCA and mineral products

WHERE?

GROUP (1)
LCAs

Life cycle analysis of Products*

→ 1st and last steps of the product life cycle

* **NON-MINING LCAs**

Traditional LCA TOOLS

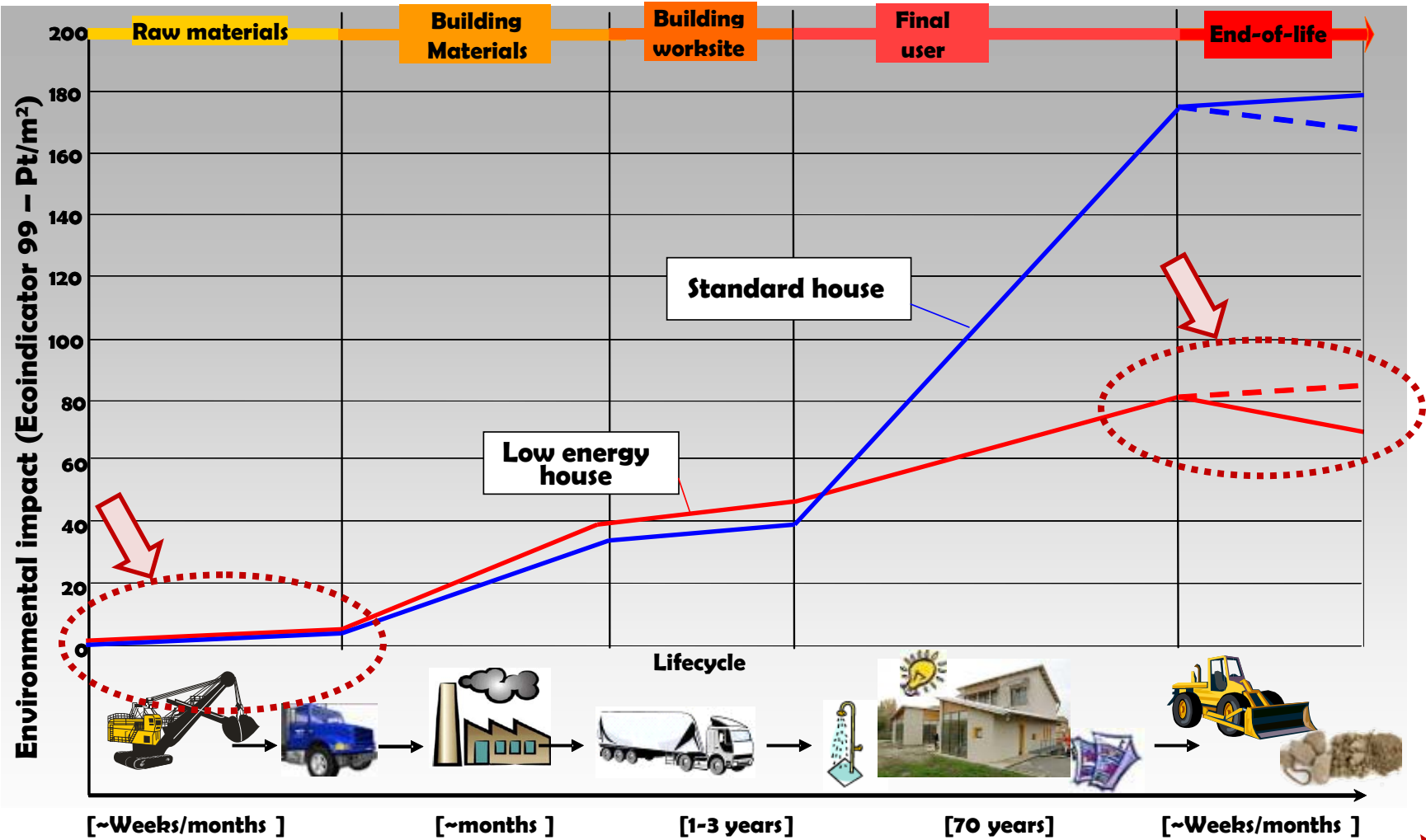


GROUP (2)
LCAs

MINING LCAs

→ LCA of mineral products or mining activities

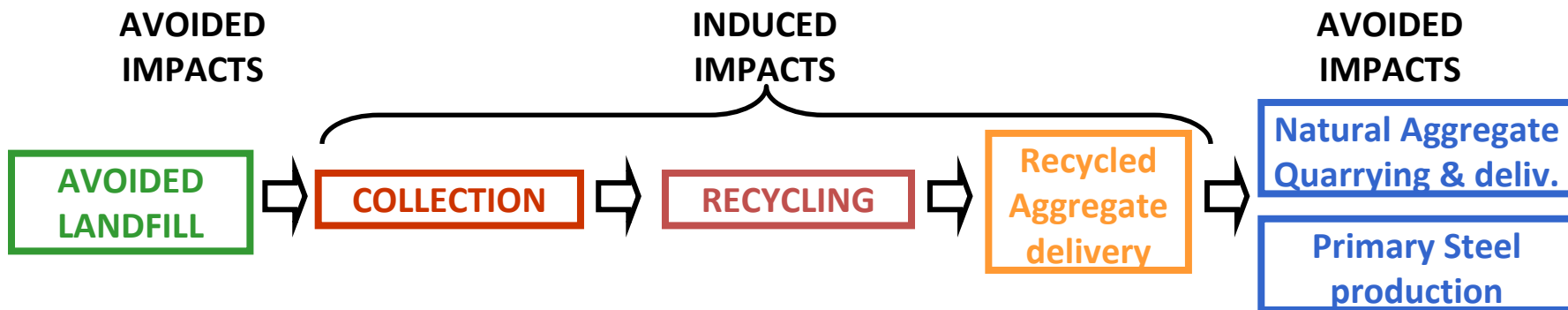
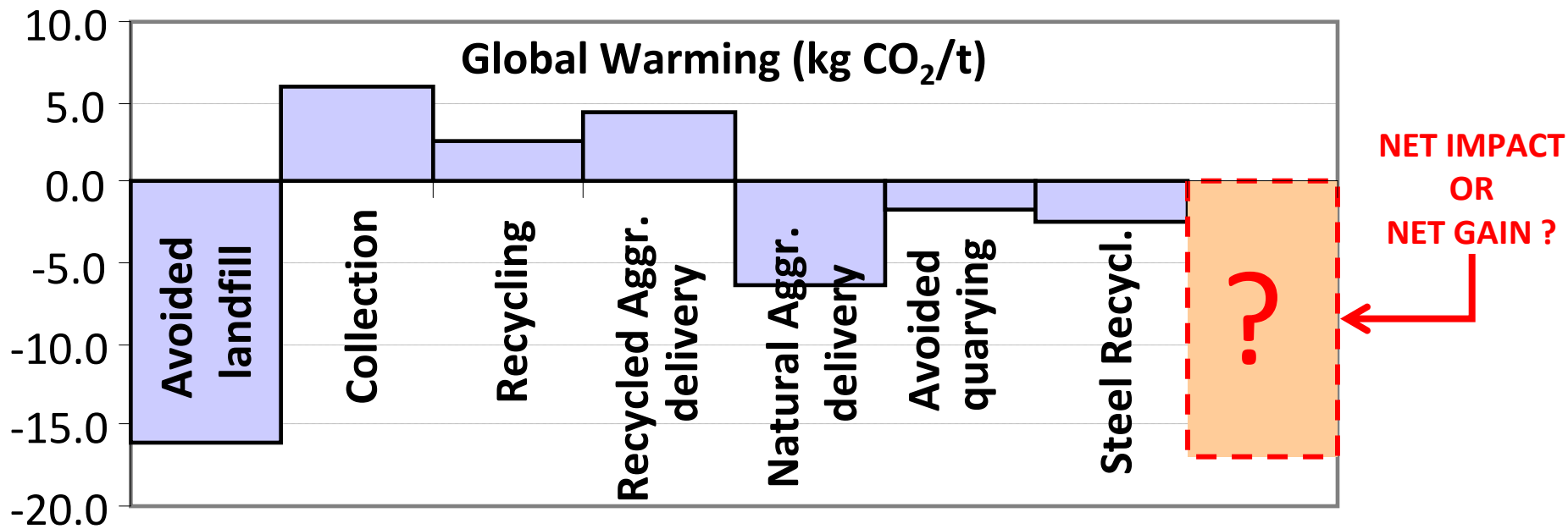
Example of GROUP (1) LCAs: Low energy vs standard houses



Mining products/processes influence the life cycle impacts
Life Cycle Inventories of minerals are used in all LCAs

Example of GROUP (2) LCAs: the role of natural and recycled aggregates in the Sustainable Supply Mix

Recycling avoids landfill and partially displaces environmental impacts of quarrying but is source of environmental impacts and can increase transport-related impacts



Examples of GROUP (2) LCAs:

Reid, C., Bécaert, V., Aubertin, M., Rosenbaum, R.K., Deschênes, L. **Life cycle assessment of mine tailings management in Canada** (2009) Journal of Cleaner Production, 17 (4), pp. 471-479.

Yellishetty, M., Ranjith, P.G., Tharumarajah, A., Bhosale, S. **Life cycle assessment in the minerals and metals sector: A critical review of selected issues and challenges** (2009) International Journal of Life Cycle Assessment, 14 (3), pp. 257-267.

Stewart, M., Petrie, J. **A process systems approach to life cycle inventories for minerals: South African and Australian case studies** (2006) Journal of Cleaner Production, 14 (12-13 SPEC. ISS.), pp. 1042-1056.

Current status of LCA research (with a mineral industries perspective)



GROUP (1) LCAs

NON-MINING LCAs

- Incomplete and not always reliable Life Cycle Inventories of mineral products
- Available Inventories of mineral products are currently used in **traditional LCA tools** (everywhere!)



GROUP (2) LCAs

MINING LCAs

- **traditional LCA tools** are not yet operational to the mineral industries

GROUP (1) LCAs: NON-MINING LCAs (made with MINING LCAs?)

Life Cycle Inventories available in the **Ecoinvent database**

(<http://www.ecoinvent.ch>)

Metals

- Alluminum
- Iron and Steel
- Copper
- Nickel
- Platinum group
- Chromium
- Manganese
- Other metals
- ...

Building products

- Aggregates
- Clay
- Cement
- Lime
- Gypsum
- Limestone
- Perlite
- Dimension stones
- ...

Industrial minerals

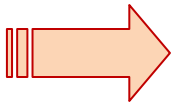
- Asbestos
- Baryte
- Bentonite
- Feldspar
- Fluorspar
- Dolomite
- Kaolin
- Silica
- ...

***UNEP/SETAC Life Cycle Initiative in cooperation with ICMM
(International Council on Mining and Metals)***

UNRESOLVED PROBLEMS (MAIN)

- LAND USE IMPACTS
- SPATIAL AND TEMPORAL ISSUES
- ALLOCATION IN OPEN LOOP RECYCLING
- *...resource depletion (mineral scarcity)...*
- ...

**URGENT NEED OF INNOVATIVE LCA
TOOLS**



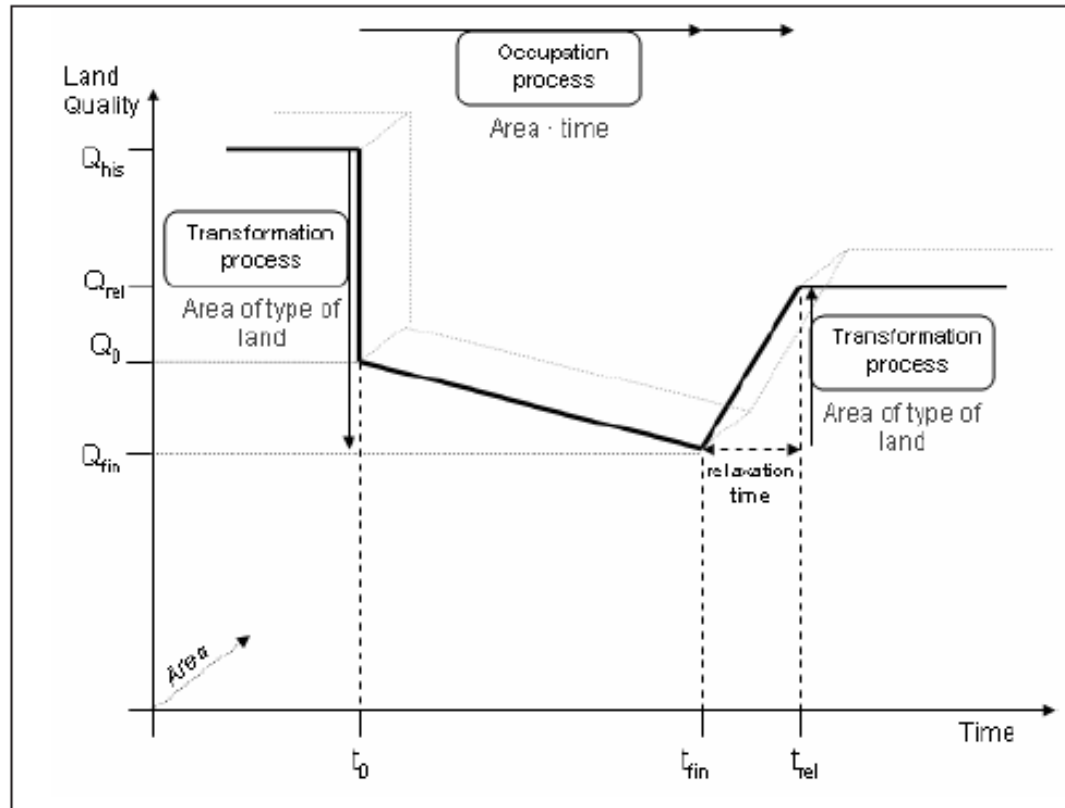
Land Use during the Mine Life Cycle

- The magnitude of temporal land use at mining operations changes during the mine life cycle
- Land use increases from exploration to the end of operations
- Land use is determined by:
 - Mining method (underground vs. open pit)
 - Site climate and topography
 - Mine management, e.g. concurrent reclamation
 - Overall mine environmental practices

Land Use in LCA

- “There is to date no consensus as to how land use impacts may be incorporated in LCA” - Editorial Note in the International Journal for Life Cycle Assessment (Milà i Canals, 2007)
- Two land use indicators are currently used in LCA:
 - Land transformation expressed in square meters (m^2) and land occupation expressed as square meter years ($m^2\text{yr}$).
- Land use is expressed in terms of “PDF” (Potentially Disappeared Fraction) of species per square meter years ($\text{PDF } m^2\text{yr}$), i.e. it is effectively using a loss in biodiversity to measure the impact on ecosystems
- Land use information for metal mines in Ecoinvent 2.0 (one of the main commercial LCI databases) is based on 1998 data plus information from aggregate mines in Switzerland

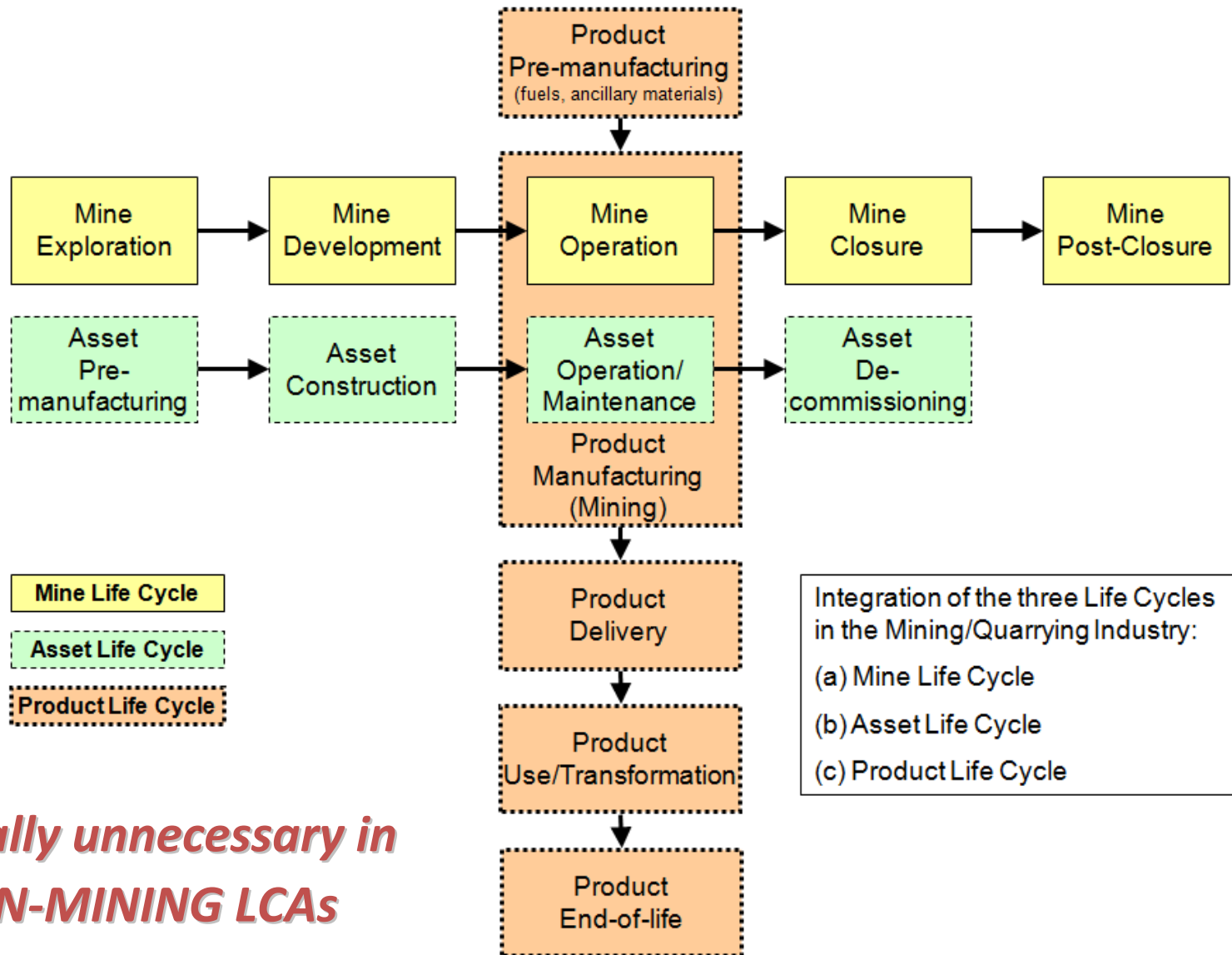
Evolution of Land Quality During Life Cycle



Milà i Canals, L., Bauer, C., Depestele, J., Dubreuil, A., Knuchel, R.F., Gaillard, G., Micehlsen, O., Müller-Wenk, R. and Rydgren, B. (2007) **Key elements on a framework for land use impact assessment within LCA**, *Int J LCA* 12 (1) 5-15

SPATIAL AND TEMPORAL ISSUES:

Integration* of the three life cycles in the mining/quarrying industry

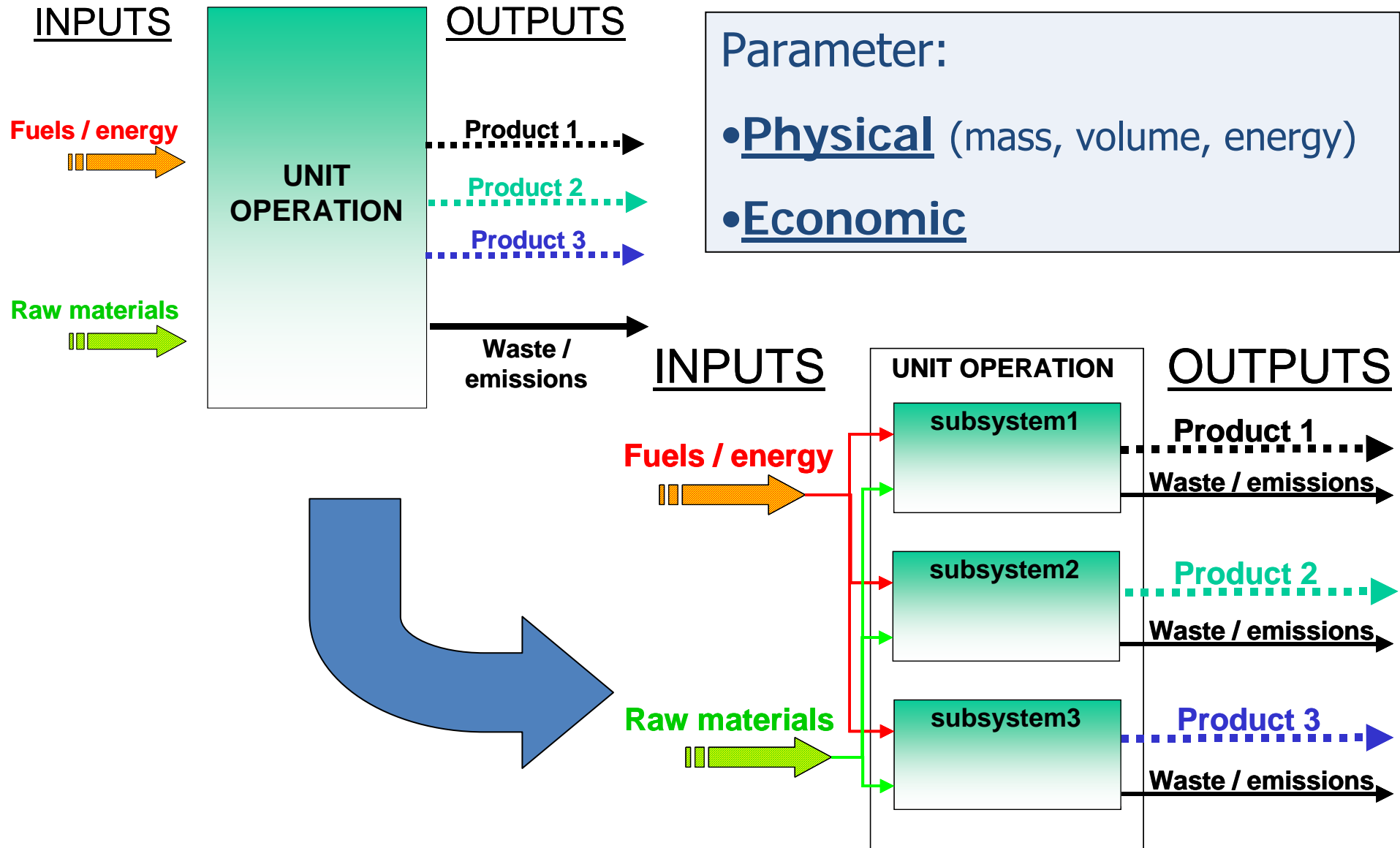


** Usually unnecessary in
NON-MINING LCAs*

Product LCA vs. Mine Site LCA

- LCA originally developed for products and services
- LCA can also be a very useful at the mine site level, e.g. to evaluate tailings management and closure options
- Recent evaluations show that present LCA procedures are not well suited for mine site evaluations

Allocation criteria in open loop recycling



Future Research to Improve Land Use in LCA

- Main focus is mine site LCA vs. product LCA
- Review of existing land use databases
- Develop extensive mine life cycle land use databases for metal mines in multiple climatic regions
- Evaluate and select appropriate measures for soil and environmental quality impacts of mining land use, hopefully to improve on the “loss of biodiversity” based approach
- Implementation of land use and land quality inventory for mine site LCA, including improved land use indicators

Closing Comments

- LCA is a well-developed methodology for product evaluations
- “There is to date no consensus as to how land use impacts may be incorporated in LCA”
- Improved mine life cycle databases will contribute to LCA applications
- Appropriate measures for soil and environmental quality impacts of mining land use will be evaluated as part of the proposed research
- The new data will be included in updated mine site and product LCA analyses