The Importance of a Three-Dimension Approach in LCA. A Screening Study on Mining

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Abstract

The present work aims at showing the potential of a three-dimension (namely environment, society, and economy) screening approach followed for the ITERAMS ("Integrated Mineral Technologies for More Sustainable Raw Material Supply") European H2020 research project. Calculations were performed with the software openLCA using well-established databases, literature research, and engineering principles. One of the most interesting outcomes of the study is linked to impacts occurring in the supply chain, which resulted significant for the social dimension and less important for the environmental aspects. Accounting for potential positive impacts on local communities emerged as a major issue as well. Finally, processes related to energy and waste rock and tailings management displayed the highest contribution in both environmental and cost screenings. It is clear that the meaningfulness of a preliminary study increases if all the three pillars of sustainability are considered, hence reducing the risks of unwittingly shifting burdens from one dimension to another.

Keywords: multidimensional, screening, mining, LCA, sustainability hotspot

Introduction

When conducting Life Cycle Assessment (LCA), it is crucial to be aware of the key issues to be addressed by the study. In order to prioritize efforts and resources, it is often useful to perform a preliminary life cycle screening to identify the main hotspots, hence contributing to a better shape of the goal and scope of the study. However, a study of this kind can be fully meaningful only if it accounts for the different environmental, social, and cost aspects. Indeed, burdens may be unwittingly shifted from one sustainability dimension to another. Furthermore, the indicators, impact categories and, hence, outcomes of the study may be not only overlapping and complementary, but even contradictory due to a number of possible trade-offs among the different aspects considered.

The present work aims at showing the potential of a three-dimension screening approach followed for the ITERAMS ("Integrated Mineral Technologies for More Sustainable Raw Material Supply") European H2020 research project.

Approach

The screening investigated a number of mining-related processes to explore the areas of interest for the project (Kinnunen et al., 2018), specifically tailings valorization, efficient water recycling, and minimization of the environmental footprint.

Table 1 displays the approach followed for the environmental LCA (ELCA), social LCA (SLCA), and Life Cycle Costing (LCC) screenings in terms of locations, databases, impact assessment methods, and processes analyzed. As for the environmental and social preliminary study, calculations were performed with the software openLCA using well-established databases. Regarding cost estimation, a first cost analysis was conducted based on the data available in ecoinvent. However, cost information in the mentioned database is not available for a number of processes (e.g. waste treatment) and cost data are not dependent on the geographic context. Therefore, an additional Life Cycle Costing was performed according to engineering principles, hence applying location factors, cost indexes, and equipment scaling factors. Regarding the processes analyzed, copper mining and metal ores related processes were investigated, as the first target of the ITERAMS solution is the mining of sulfide ores.

The second step of the screening approach was the study of the context of the mining activities, namely those preexisting background situations which may have an influence on the potential impacts and risks, either mitigating or exacerbating them. Considering that specific mining sites have been identified in northern Finland and southern Portugal for the implementation and validation of the ITERAMS combined solutions, the social, socio-economic, and environmental specific characteristics of the two areas around the sites were analyzed. For instance, the vulnerability of local communities in relation to their dependence on local water reserves was investigated together with the availability and quality of water (Finnish Environment Institute, 2015; Sistema Nacional de Informação de Recursos Hídricos, 2013) and mineral resources. Potential conflicts with other competing industries in the area, such as reindeer farming in Finland (Tuusjäarvi, 2013) and agriculture of cork and olives in Portugal, were taken into account when evaluating the results. In addition, the importance of the sector for the national and

Table 1: ELCA, SLCA, and LCC screening approach

	ELCA	**SLCA**	**LCC**
Geographic area	Finland, Portugal, South Africa, Europe, Latin America	Finland, Portugal	Finland, Portugal, South Africa, Brazil, US, Europe, Latin America
Database	Ecoinvent v3.4, EXIOBASE v.2.2	PSILCA v.2	Ecoinvent+literature research
Impact assessment method	ILCD 2011 Midpoint+, ReCiPe Midpoint H, Boulay et al. (2011), CML-IA baseline, EXIOBASE built-in LCIAM	Social impacts weighting method in PSILCA	Added value calculation, engineering principles
Process	Ecoinvent-> copper mine operation | copper concentrate; copper production, primary | copper. EXIOBASE-> copper ores and concentrates	Metal ores	Ecoinvent-> mine construction, underground and open cast; copper mine operation; copper production, primary

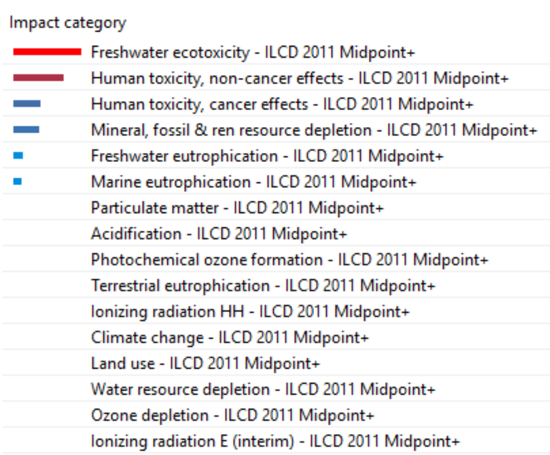
local economy as well as social risks on a national scale were subject of research to further contextualize the results.

Results and interpretation

The results of the screening provided quite a comprehensive overview on the potential impacts deriving from the new ITERAMS combined technologies.

The ELCA screening highlighted the importance of the toxicity categories (for instance, freshwater and marine ecotoxicity, and human toxicity) for the mining processes analyzed, see Figure 2.

Figure 2: Normalized results for "Copper production, primary | copper | RER", ecoinvent database, ILCD 2011 Midpoint+ impact assessment method, normalization set "EU27 ILCD Midpoint+, 2010" (screenshot from openLCA)

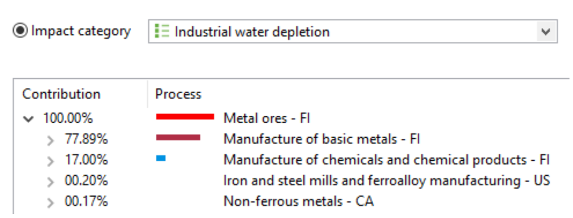


The main driver for these impacts related to water and human toxicity is sulfidic tailings treatment due to heavy metals emissions. This outcome reinforces the purpose of the ITERAMS project as the solution foresees an improvement in waste rock and tailing handling together with their valorization via geopolymerization processes.

Furthermore, climate change emerged from literature review as an important impact category due to the high energy demand from ore crushing and grinding processes, as studied by Norgate et al., 2010.

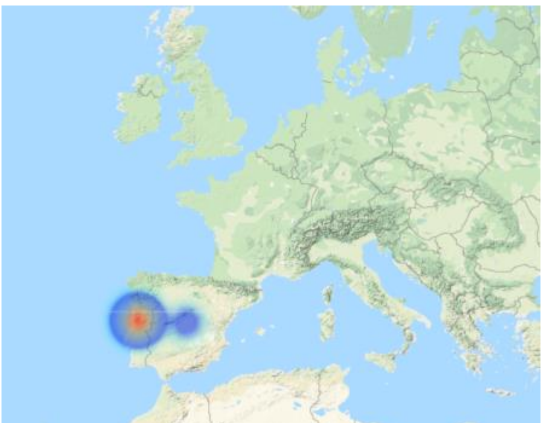
Although results for the ELCA present a number of differences according to the diverse geographic locations, the impacts are not excessively globally widespread. On the other side, the supply chain emerged as important from the SLCA screening, with reference to a number of social indicators and specific countries under study. In the case of mining of metal ores in Finland, for instance, a very high risk of industrial water depletion could be identified, meaning that there is a very high risk of withdrawal of water resources for industrial activities in relation to total water withdrawal and total actual renewable resources in the country (Eisfeldt, 2017). It is worth mentioning that most impacts do not occur in the Finnish mining sector itself, but they are associated with other processes part of the supply chain. In fact, manufacture of basic metals and chemicals in Finland (see Figure 3), machineries in Russia, and chemicals and plastics produced in China and India can be detected as social hotspots linked to the Finnish mining of metal ores.

Figure 3: Process contribution to the impact category "Industrial water depletion". "Metal ores" in Finland, PSILCA database (screenshot from openLCA)



However, if the same process is analyzed for Portugal in PSILCA, the mining of metal ores itself is responsible for the majority of the impacts. In fact, in the case of the Portuguese sector, the contribution of the upstream chain is notably smaller and the impacts are less geographically widespread in comparison to Finland, see Figure 4.

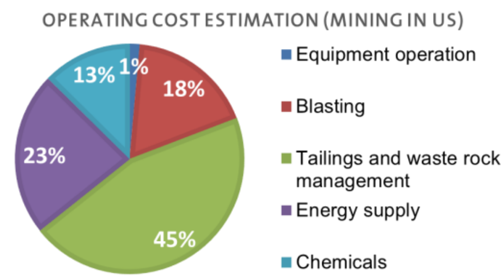
Figure 4: Geographic localization of the impact category "Non-fatal accidents", "Metal ores" in Portugal, PSILCA database (screenshot from openLCA)



Accounting for positive impacts in mining emerged as a major issue as well (Mancini et al., 2018), in particular regarding potential social benefits for local communities and workers. This includes job creation, establishment of infrastructures (roads, schools, hospitals), and the reduction of the gap between living wage and minimum wage.

As for Life Cycle Costing, the added value calculation in openLCA based on ecoinvent displays that 98% of the economic impacts are referred to the mine operation as such and the rest is due to upstream processes. However, in order to offer a more detailed picture, a Cost Breakdown Structure was defined to identify the cost categories to be investigated, namely Capital Cost (CC), Operating Cost (OC) and General and Administration Cost (G&A). The most interesting outcome for ITERAMS is related to the OC which displays a high contribution coming from waste rock and tailings management and energy supply (see Figure 5). This outcome is valid for all the different geographic locations analyzed, although with slightly diverse contribution shares.

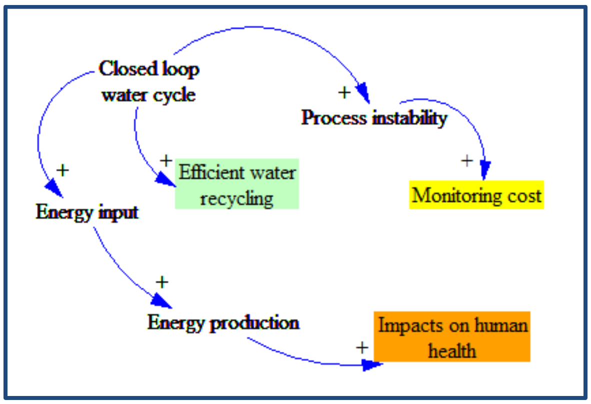
Figure 5: Process contribution to Operating Cost (OC) estimation for mining activities in the United States



For the further interpretation of the results of the screening it was crucial to reflect on how the different sustainability dimensions could complement and overlap each other. For instance, environmental and social impact categories may address the same issue; however, they may express different characters and consequences as they are referred to two different spheres. If water resource depletion due to water withdrawal and consumption for mining processes is considered, this may lead both to the destruction of material resources and environmental degradation. and to the destruction of local economies, causing poverty and resettlement if the local population depends on local water reserves for its livelihood.

On the other side, a number of tradeoffs could be identified across the different dimensions. For example, the closed loop water cycle foreseen by the project to enhance an efficient water recycling may generate some impacts on human health due to more energy required and, hence, produced to close the water cycle. Furthermore, the solution may lead to a higher process instability and, related to this, to higher monitoring cost. See Figure 6.

Figure 6: Excerpt from the qualitative causal loop diagram created for the ITERAMS project



Limitations of the study

When working with databases, a number of uncertainties in the results may be due to statistical data collected from different sources (ILO, 2017) and related gaps, assumptions, and harmonization procedures. Furthermore, it must be mentioned that the collection and harmonization of the cost information obtained from a wide range of literature sources was not always straightforward and even not always feasible. In fact, the study highlighted how costs vary by region and country, by the scale of the mine, and the type of ore mined. An important step to overcome the limitations and difficulties encountered was, at first, to document and assess the data quality of the processes analyzed in openLCA and, afterwards, to interpret the results in the context of the mining activities with the help of literature research (Northey and Mudd, 2016; Wessman, 2016; Wessman et al., 2014) and a qualitative causal loop modelling.

Conclusions and further development

It is clear that the meaningfulness of a preliminary study increases if all the three pillars of sustainability are considered. The present screening study, in fact, provided a valuable input to the project, leading to the definition of important sustainability issues to be further developed and investigated by the subsequent LCA study. Furthermore, an interesting outcome is that environmental and cost impacts and risks often end up on impacts and risks on societal stakeholders. However, the social dimension is the most difficult to assess due to the presence of a number of qualitative and semi-quantitative social indicators and the intrinsic subjectivity linked to the evaluation of several social issues.

Finally, this preliminary study and the presentation of its outcomes was crucial to establish a dialogue among the different project partners, whose engagement is fundamental for the successful continuation of the work of the sustainability package within the ITERAMS project.

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