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## ► To cite this version:

Jair Santillan Saldivar, Antoine Beylot, Stéphanie Muller, Emmanuelle Cor, Elise Monnier. Estimation of potential economic value losses due to resource dissipation in LCA through the EVDP method: A case on LIB recycling. SETAC 2023, Apr 2023, Dublin, Ireland. cea-04662935

**HAL Id: cea-04662935**

**<https://cea.hal.science/cea-04662935>**

Submitted on 26 Jul 2024

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# Estimation of potential economic value losses due to resource dissipation in LCA through the EVDP method: A case on LIB recycling

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## 1. Introduction

Resource dissipation (RD) is a phenomenon that has been identified as a barrier towards circular economy (CE) due to causing potential losses of value and functionality in the technosphere along the life cycle (LC) of products. Specifically when addressing mineral resources, an identified safeguard subject is the potential to make use of the value that a resource holds for humans; therefore a damage would be the reduction or loss of this potential due to human activity in the technosphere (Berger et al., 2020). Life cycle assessment (LCA) and Life Cycle Sustainability Assessment (LCSA) have been proposed as suitable methodologies to quantify and analyse the impacts (positive or negative) of the application of CE strategies in the three pillars of sustainability: Environment, Economy and Society.

From an environmental perspective, LCA is arguably able to support decision-making processes in the Areas of Protection (AoP) Ecosystem Quality and Human Health; however the same level of consensus is not applicable when measuring impacts in the AoP Natural Resources, questions and debates remain among the community on what are we trying to protect when discussing natural resources in LCA (Berger et al., 2020; Sonderegger et al., 2017, 2020; Sonnemann et al., 2015). Various Life Cycle Impact Assessment (LCIA) methods try to assess the impacts of mineral resource extraction, focusing on the questions of resource depletion and criticality (Sonderegger et al., 2020; Berger et al., 2020); however, a topic that remains under discussion is Resource Dissipation (RD), made apparent by the limited number of proposals to assess the impacts of dissipative losses; which are defined as resource flows no longer accessible to future users due to multiple constraints, preventing them to benefit from their potential functions (Beylot et al., 2020).

## 2. Materials and methods

Building upon the JRC-LCI and the JRC-LCIA methods (Beylot et al., 2020; Ardente et al., in press), we propose the Economic Value Dissipation Potential (EVDP) method, an impact assessment method in LCA that integrates two aspects in the evaluation of RD: the identification of dissipative flows, and the potential value loss associated to them. First, the method proposes a function that estimates the fraction of a mass flow that can be considered dissipative based on the comparison between a global average minimum grade in primary sources and resource concentration in dissipation compartments. Next, the method assigns a value to this flows based on the integration of the price and economic importance of the analyzed resources to model a potential value loss due to dissipation.

In the first version of the method, it is possible to present characterisation factors (CF) for fifteen resources based on average information from the literature. A first application is based on CFs valid for the year 2020 from the perspective of the European Union (EU); the method is applied to a case study on Lithium-ion batteries (LIB) recycling through hydrometallurgy. Improvements were made to the LC inventory (LCI) to achieve the level of granularity required to assess the impacts of RD.

## 3. Results and discussion

Partial results of the application of the EVDP method include the development of a resource flow analysis based on the JRC-LCI method (Beylot et al., 2020) to better trace the target materials of the analyzed recycling process. Results estimated with the EVDP method show that the recycling of a kilogram of battery NMC 111 allows the avoidance of the equivalent to 3.79 USD in dissipative losses. The biggest contributors being Co due to its high price and economic importance from the point of view of the EU, and Al, due to being the element with greater recovered mass in the analyzed process.

The proposal and first application of the EVDP method allows to quantify potential value losses due to resource dissipation when analyzing processes and product systems through LCA. The way the method is constructed responds to the need to estimate the impact of barriers that prevent us to benefit from the value of resources in the technosphere. Limitations for a wide application of the method are associated to the level of detail required in LCIs; the limited number of resources characterized by the method; and, the need to regularly

update the CFs due to the dynamic nature of prices, economic importance and global average minimum grades. The results of the application of the EVDP method based on economic considerations provide complementary information to current impact assessment methods, therefore having the potential to support decision-making processes based on LCA.

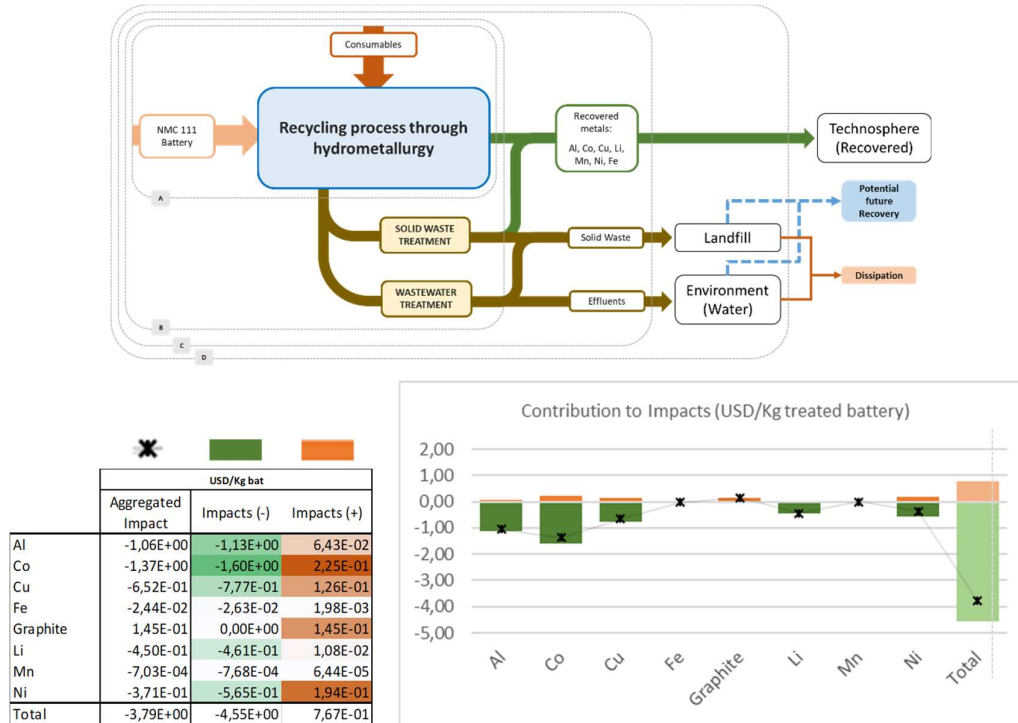


Figure 1: Impact assessment of the recycling of 1 kg of NMC111 battery through the EVDP method

#### 4. Conclusions

The Economic Value Dissipation Potential (EVDP) method provides a way to associate potentially dissipative flows to potential value losses measured in monetary units along the life cycle of product systems. It also provides an indicator to quantify the effectiveness of circular economy strategies in maintaining the value of resources in the technosphere. The application of the method to a case study on LIB recycling through hydrometallurgy shows the potential benefits of this type of practices from a life cycle perspective; further replication of the method is suggested along with other traditional impact assessment methods to support decision-making processes regarding the implementation of circular economy strategies.

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