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Integrating Circularity into Life Cycle Assessment: Circularity with a life-cycle perspective

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Introduction

Both Life Cycle Assessment (LCA) as a tool and Circular Economy (CE) as a concept work towards sustainable development, only that both approaches are currently done individually: one assessment doesn't include the other.

Circularity indicators, which aim to quantify **Circular Economy, can benefit hugely from a life cycle perspective, where circularity is considered not only in the last production stages but from the very beginning of raw material extraction**. However, there is no current well-rounded and transparent solution for the integration of both, even though there have been initiatives from common LCA software.

In this research, a methodology of integrating LCA and CE is proposed and practically applied in an LCA database.

Recent History

Well-known LCA software have launched initiatives/products:

- SimaPro proposes a calculation of the MCI within the software with the use of parameters for the variables required for the MCI calculation [1], but stays in the superficial model and doesn't look into the supply chain (background database)
- GaBi proposed in 2018 a circularity tool with an approach similar to that proposed in this presentation. It is no longer available in the market [2].
- OneClick LCA promotes the calculation of a "building circularity score", which applies circularity for the buildings sector [3].

Methodology

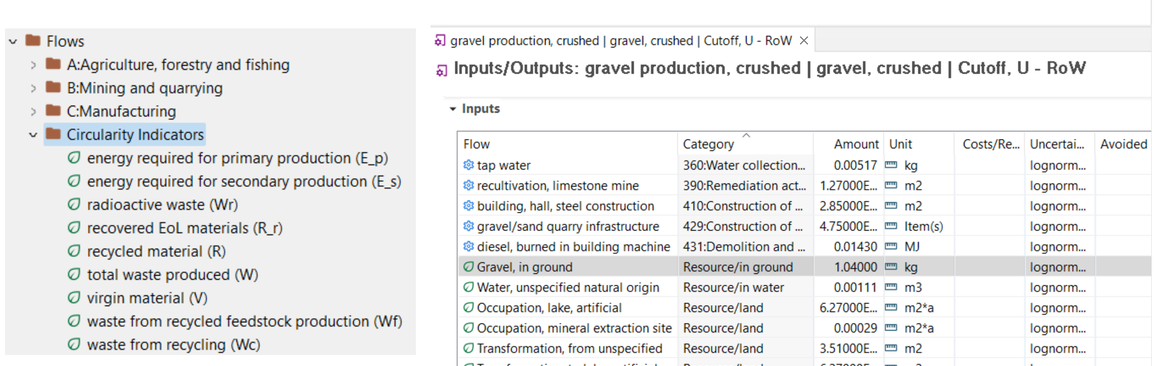
After an initial assessment, two indicators were chosen for their completeness and ability to be integrated into LCA.

- **Material Circularity Indicator (MCI)** [4]
- **Circularity Index (CI)** [5]

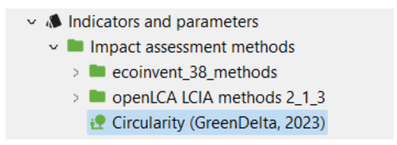
	Fully linear system	Fully circular system
MCI	0.1	1
CI	0	1

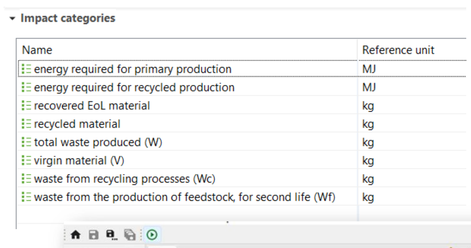
The ecoinvent 3.8 cut-off database was modified with the following:

1. Placed **elementary flows to shadow the circularity variables** across the database.

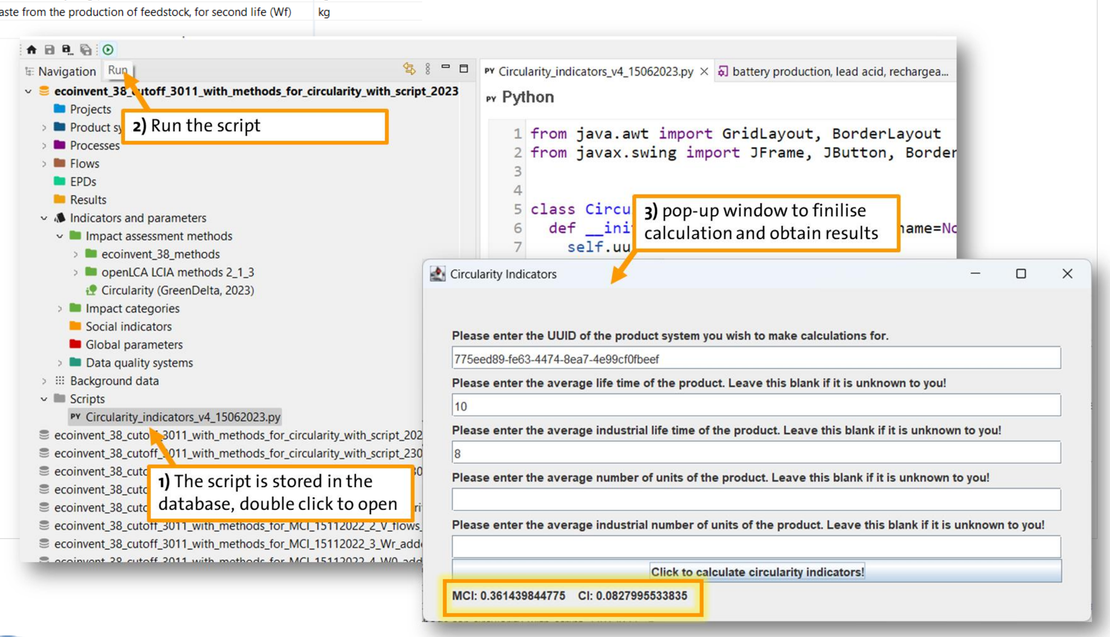


2. Collected those flows in the **Circularity LCIA Method.**



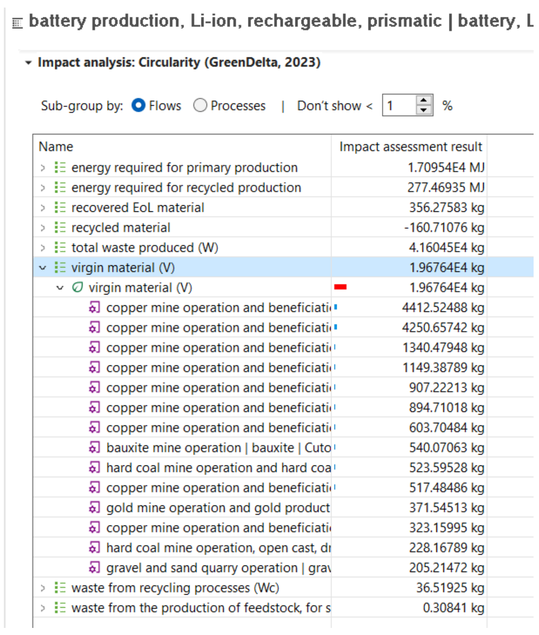


3. Python script for final calculation and to **allow to add extra variables through a pop-up window** which also displays results.



Visualisation of the database (Results)

A dataset for the production (& EoL) of an EV battery was run with the methodology.
Functional Unit: 1 EV battery (454kg)
battery production, Li-ion, rechargeable, prismatic | battery, Li-ion, rechargeable, prismatic | Cutoff, U



- **Material extracted** from Earth **is 43x the weight of the battery**
- **356kg of recovered material**
  - 122kg from EoL treatment
  - 234kg from supply chain
- **1709MJ for primary production**
  - 38% anode supply chain
  - 38% cathode supply chain
  - 20% Al. supply chain

Proposed improvement:
Hotspot: Copper mining from the huge amounts of virgin material extracted:
83kg of "Gangue, in ground" / 1kg of copper.
Use 50% recycled copper for battery production.

	Base case	Improved case		
Name	**Impact assessment result**		**Unit**	**% decrease**
energy required for primary production	17095.4	14242.8	MJ	17
energy required for recycled production	277.5	115.3	MJ	58
recovered EoL material	356.3	327.1	kg	8
recycled material	-160.7	-168.9	kg	-5
total waste produced (W)	41604.5	15815.8	kg	62
virgin material (V)	19676.4	7292.6	kg	63
waste from recycling processes (Wc)	36.5	27.8	kg	24
waste from the production of secondary feedstock, (Wf)	0.3	0.3	kg	10
MCI (from LCA)	**0.11652**	**0.13807**		
CI (from LCA)	**0.01764**	**0.04355**		

Triggering a hotspot reduced the need of virgin material by 63%, and improved all of the other circularity variables.

The **circularity indicators show that the system is close to fully linear**, proving that LCA datasets represent a linear world reality. The proposed improvement also shows improvements in both circularity indicators. The same model can also be run with LCA.

References

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