Integrating Circularity into LCA: circularity with a life-cycle perspective

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openLCA

Introduction

LCA ⟶

Circular Economy strategies ⟶

Sustainable development

- LCA older in the field
- Circular Economy starts having more traction

- Circularity Indicators can quantify Circular Economy solutions
- -> BUT conceptual approach, usually not reflected in LCA data

WHAT HAPPENS IF WE LOOK AT CIRCULAR ECONOMY WITH A LIFE CYCLE PERSPECTIVE?

- We modified an LCA database to track circularity variables
- We enhanced the software to make circularity indicator calculations
- We investigated how does circularity look in an LCA dataset

Does a solution of LCA & CE combined exist?

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].

[1] SimaPro, "7 steps to combining circular economy and LCA in SimaPro," [Online]. Available: https://support.simapro.com/articles/Article/7-steps-to-combining-circular-economy-and-LCA-in-SimaPro/. [Accessed 20 April 2023].
[2] A. S. (. D. E. Peter Shonfield (thinkstep). [Online]. Available: https://cdn2.hubspot.net/hubfs/2591272/Circularity/GaBi-Circularity-Tool.pdf.pdf. [Accessed 28 06 2023].
[3] OneClick LCA, "Building Circularity: Circular Assessment," [Online]. Available: https://oneclicklca.zendesk.com/hc/en-us/articles/360014998199-Building-Circularity-Circular-Assessment. [Accessed 28 06 2023].

Circularity Indicators

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

- **Material Circularity Indicator**

$$MCI_P = 1 - LFI \cdot F(X) \quad ; \quad LFI = \frac{V + W}{2M + \frac{W_F - W_C}{2}} \quad ; \quad X = \frac{L}{L_{av}} \cdot \frac{U}{U_{av}}$$

$V = virgin\ material$
$W = waste$
$L = life\ duration$
$U = utility$

- **Circularity Index**

$$CI = \frac{recovered\ EOL\ material}{total\ material\ demand} \cdot \left(1 - \frac{energy\ required\ to\ recover\ material}{energy\ required\ for\ primary\ production}\right)$$

Ellen MacArthur Foundation, "Material Circularity Indicator (MCI) Methodology," 2019. [Online]. Available: https://emf.thirdlight.com/link/3jtevhlkbukz-90f4s4/@/preview/1?0. [Accessed 18 April 2023].
J. Cullen, "Theoretical Benchmark or Perpetual Motion Machine?," Journal of Industrial Ecology, 21, pp. 483-486, 2017.

How is an LCA database adapted for CE?

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(applied to ecoinvent 3.8 cut-off)

✓ Avoid double counting

Apply new **elementary flows to shadow** circularity information

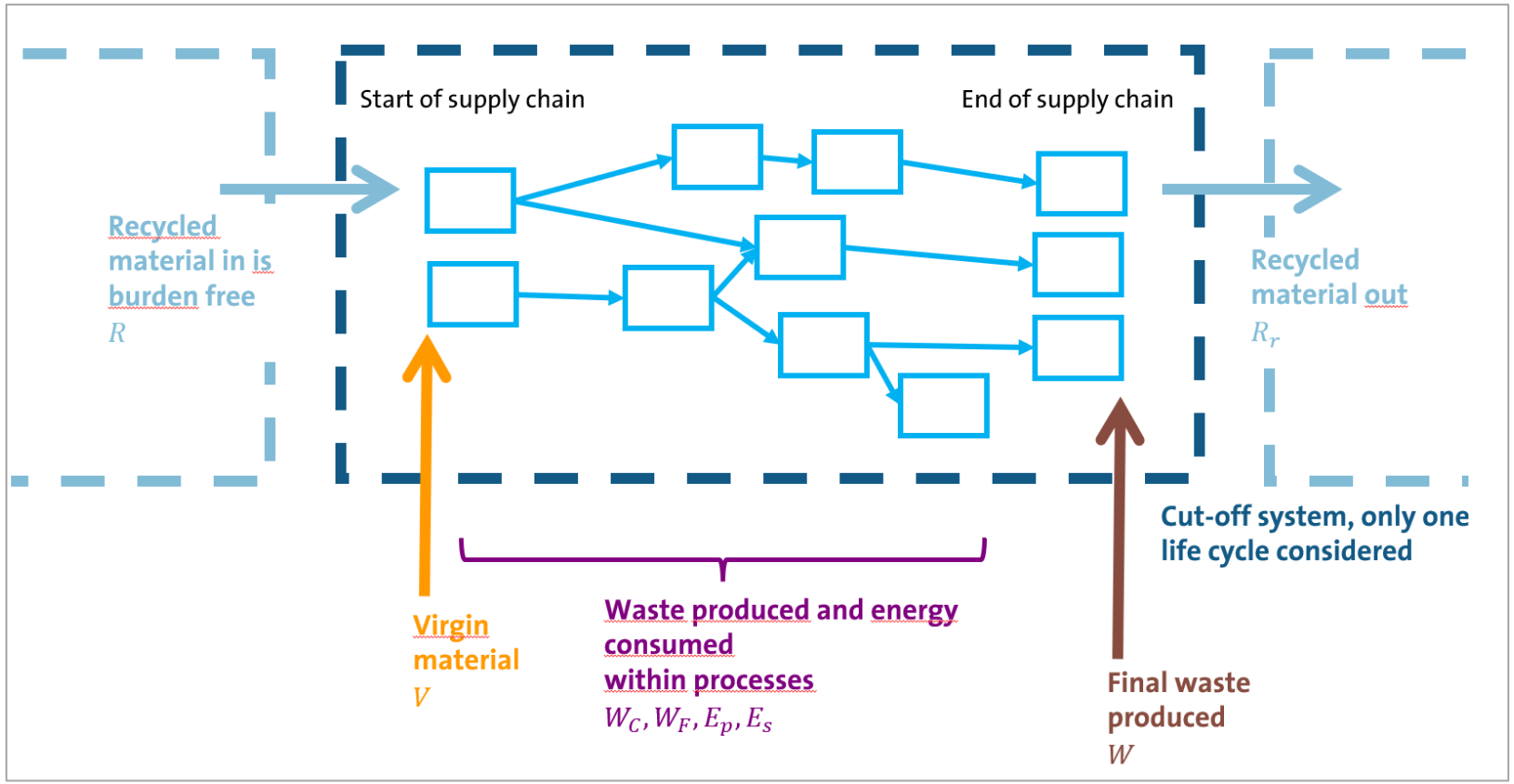


Figure 1: Circularity variables and their placing in an LCA database

Rest of variables can be calculated from these or from user input

Implementation in ecoinvent

Variables required for circularity indicator calculations, and their respective location in the ecoinvent database:

Found in database

Internal calculation

User input

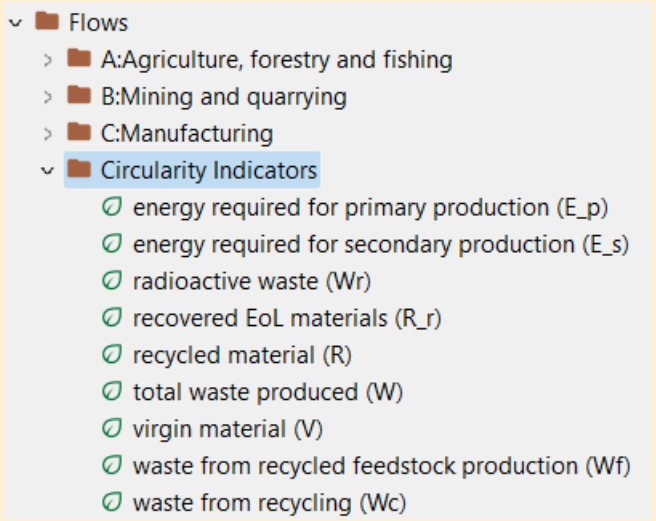
Circularity Variable		MCI	CI	Circularity Package	Location in ecoinvent database
Virgin material	V	x		x	Elementary flows with names "*Material name*, in ground"
Recycled material	R	x		x	Processes that contain "Recycled Content cut-off" in their name.
Recovered recycled materials	R_r	x		x	Input flows with negative amounts. These are recovered materials in ecoinvent.
Input recycled materials	R_i	x		(x)	Calculated variable: $R_i = R + R_r$
Mass	M	x		(x)	Calculated variable: $M = V + R_i$
Total waste for final disposal	W	x		x	Mainly processes under the category "3821: Treatment and disposal of non-hazardous waste" and "3822: Treatment and disposal of hazardous waste"
Waste from recycling processes	W_C	x		x	Mainly processes under the category "3811: Collection of non-hazardous waste"
Waste from the production of secondary material feedstock for second life material	W_F	x		x	Processes that produce recycled material, at the category "C: Manufacturing"
Energy required for primary material production	E_p		x	x	Energy required in processes that involve the production of primary materials or products
Energy required for secondary material production	E_s		x	x	Energy required in processes that involve the production of secondary materials
Life time of product	L	x		(x)	Input by user
Utility of product (number of uses)	U	x		(x)	Input by user

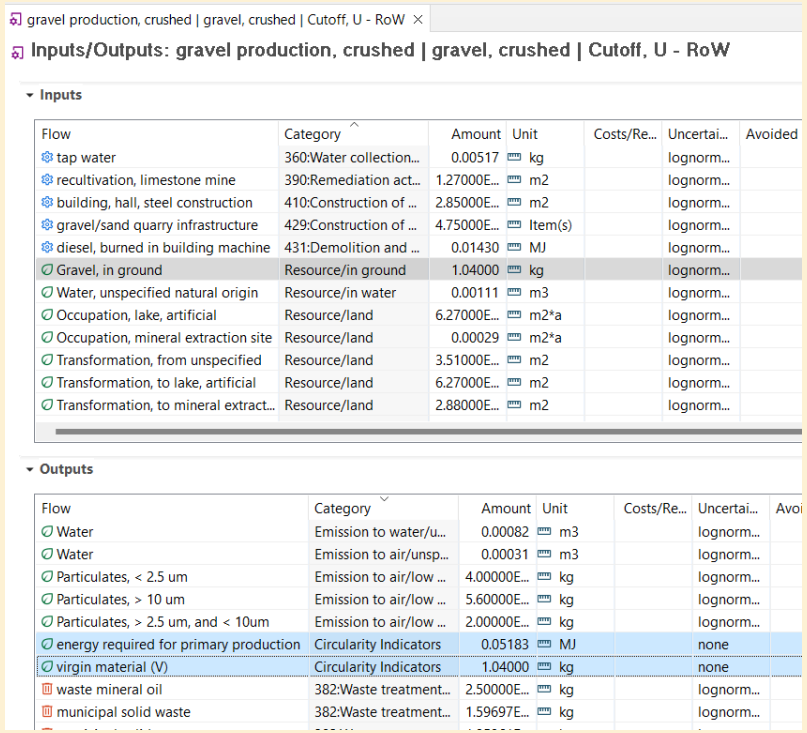
https://ecoinvent.org/

Circularity Methodology in openLCA I

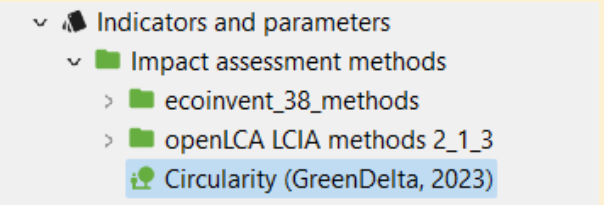
Applied per database

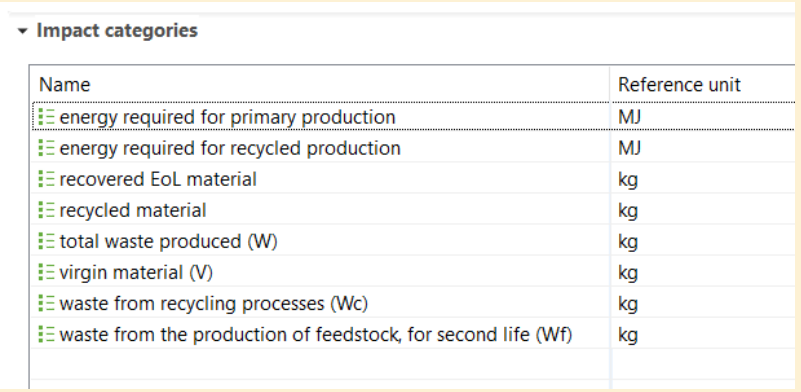
1. Placed **elementary flows to shadow the circularity variables** across the database





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

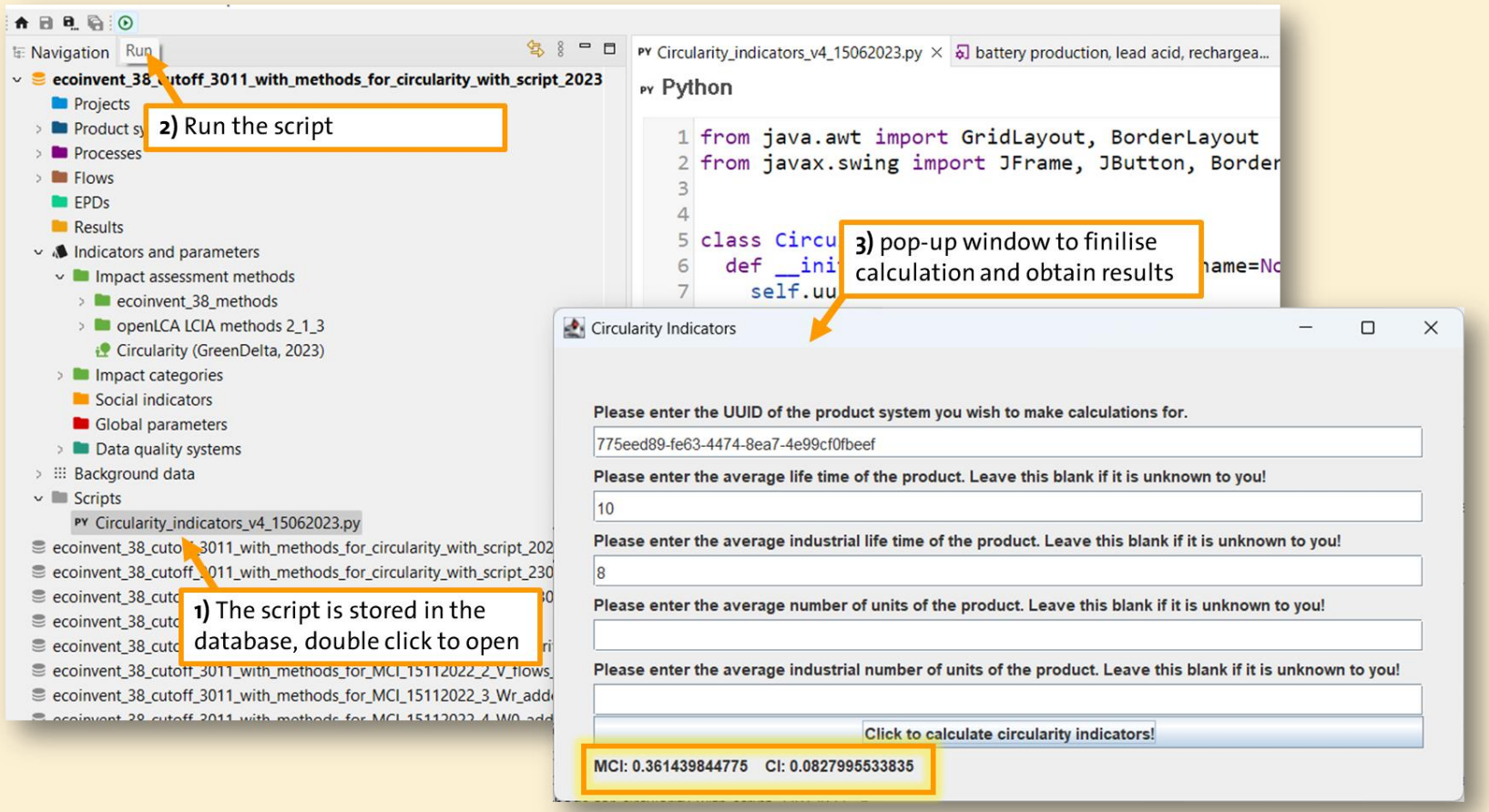




Circularity Methodology in openLCA II

Extra software functionality

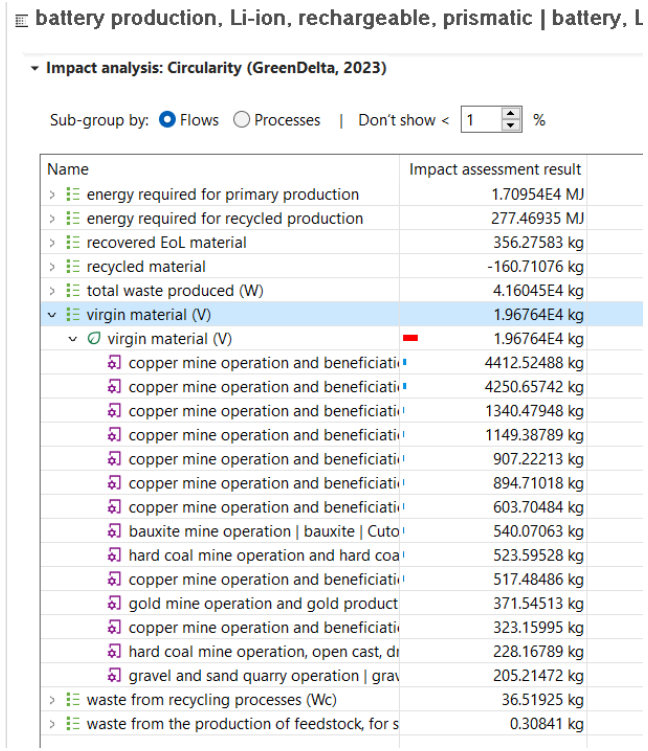
3. Allow to add extra variables through a pop-up window
which displays results



Result

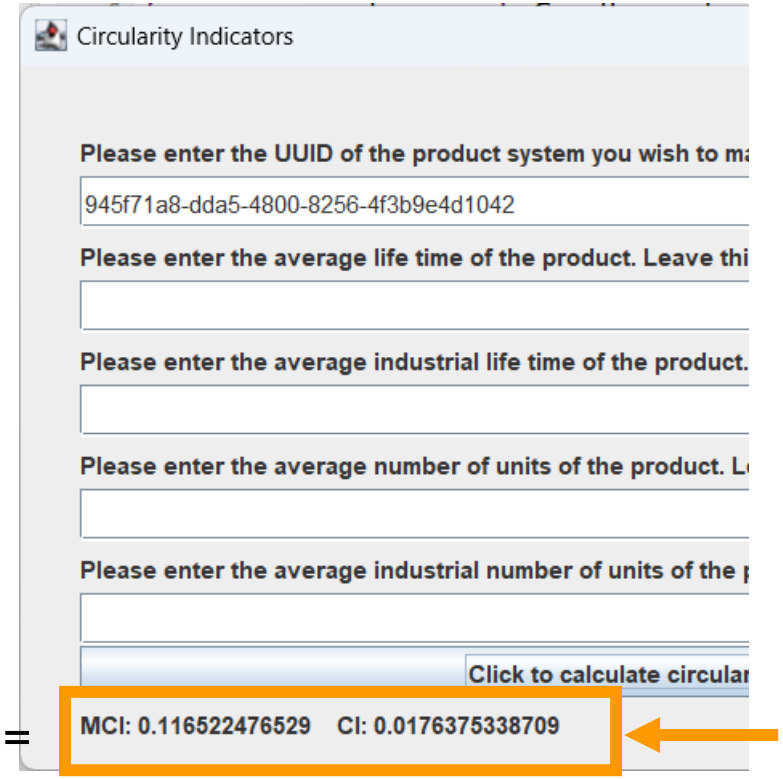
battery production, Li-ion, rechargeable, prismatic | battery, Li-ion, rechargeable, prismatic | Cutoff, U
FU = 1 item (**454kg**, EV battery)

Circularity Results



- **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

Linear System =



Result II

Improvements in circularity

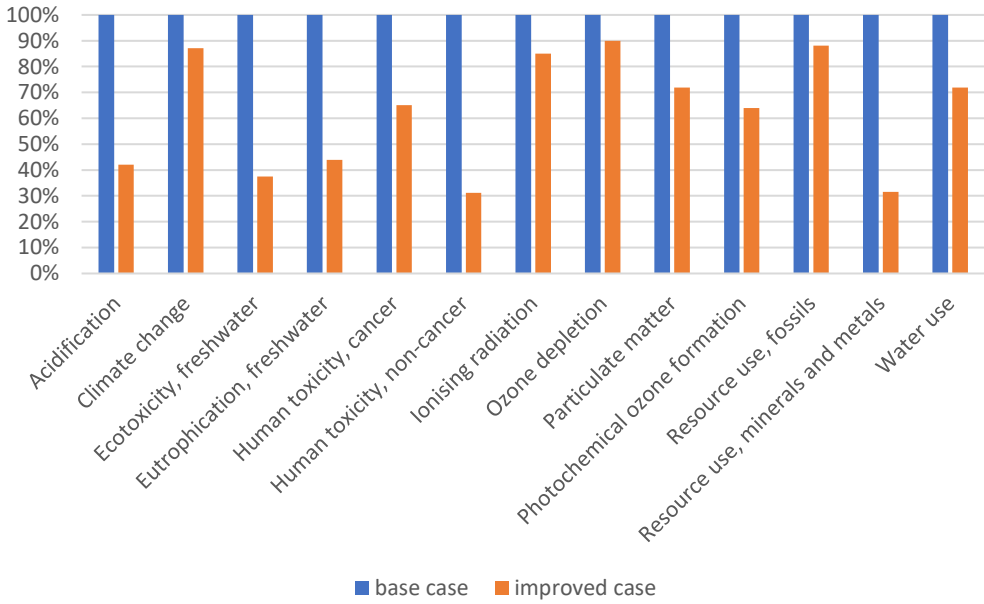
VIRGIN MATERIAL -> We saw that copper was a hotspot from the big amounts of “Gangue, in ground” extracted in copper mining.

Improved case: use 50% copper from recycled sources

Circularity Indicators

	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**		

LCA normalised results (EF3.0)



Next steps: investigate EoL circular strategies

Summary & Conclusion

WE HAVE SHOWN:

- The integration of Circularity Indicators into an LCA database and software.

RESULTS DEMONSTRATE:

- There are big numbers of virgin material used, and waste produced, in the supply chain of the investigated system, which should not be ingored.

- Targeting improvements for the Circular Economy will benefit from a life cycle perspective.

Thank you!

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