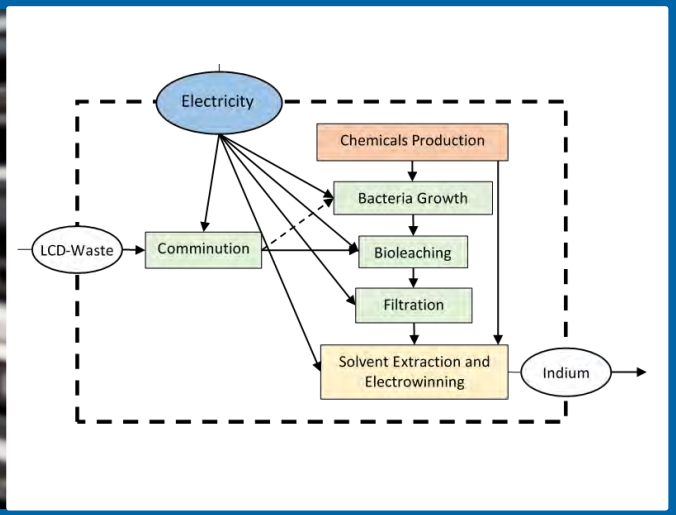
TECHNISCHE UNIVERSITÄT
BERGAKADEMIE FREIBERG
Die Ressourcenuniversität. Seit 1765.

Life Cycle Assessment of Bioleaching in Indium Recovery from LCD-Waste - an ex-ante Approach

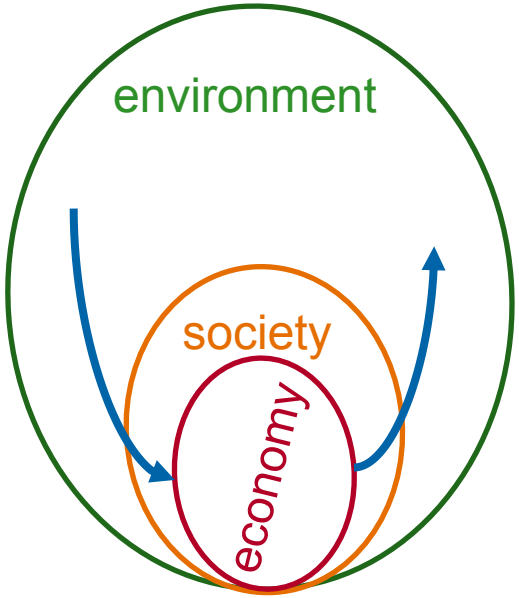


Annemarie Falke[1] Michael Höck[1]

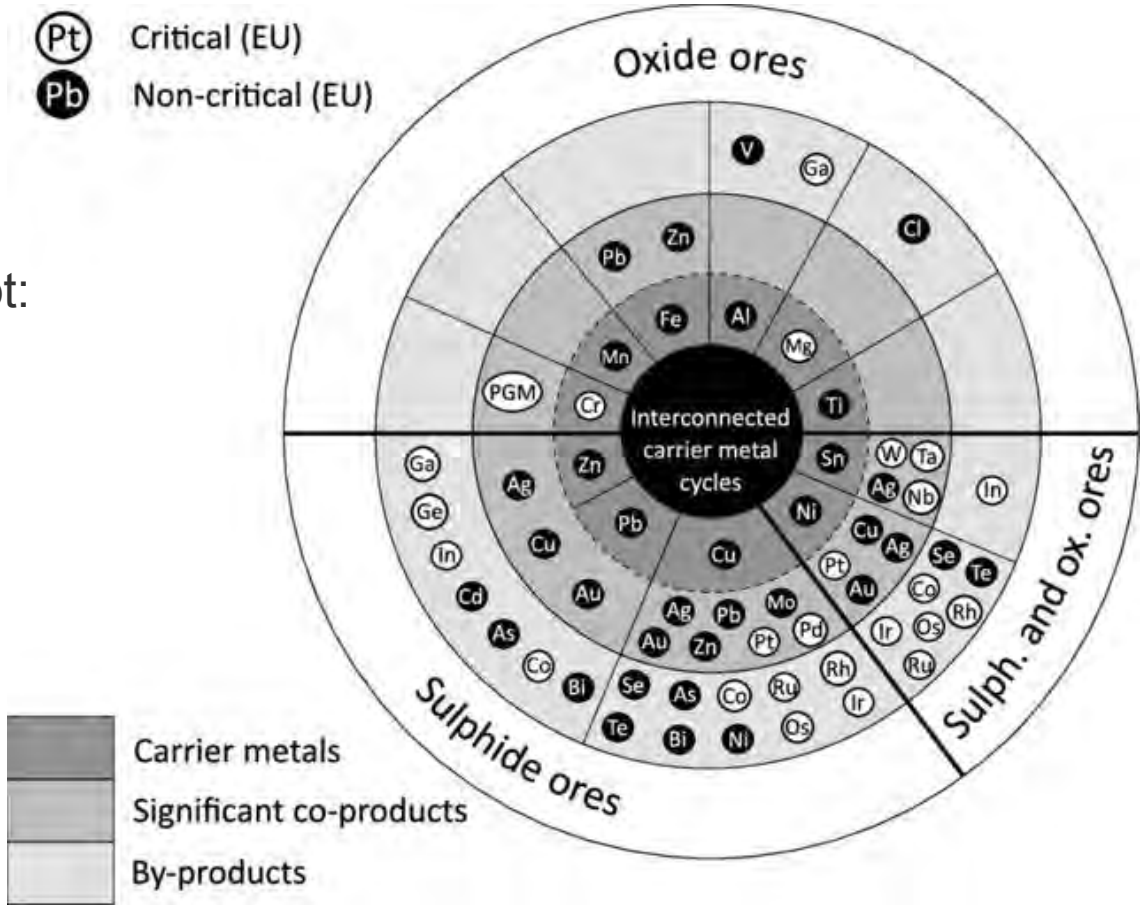
1: Technische Universität Bergakademie Freiberg

Motivation

The strong sustainability concept:

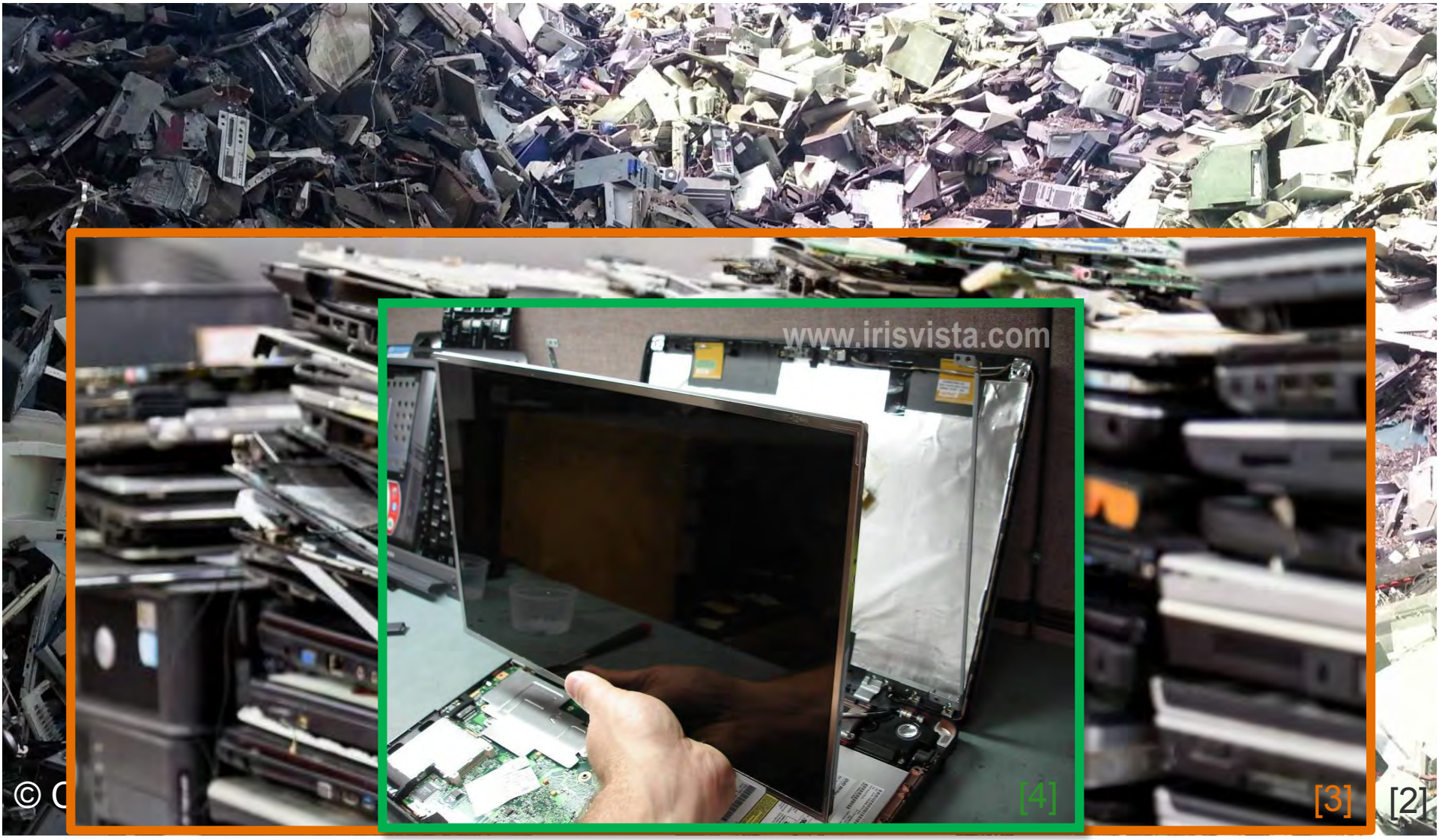


The Metal Wheel, cf. [1]



[1] M. Frenzel, J. Kullik, M. A. Reuter, and J. Gutzmer. *Journal of Physics D: Applied Physics*,2017.

Motivation

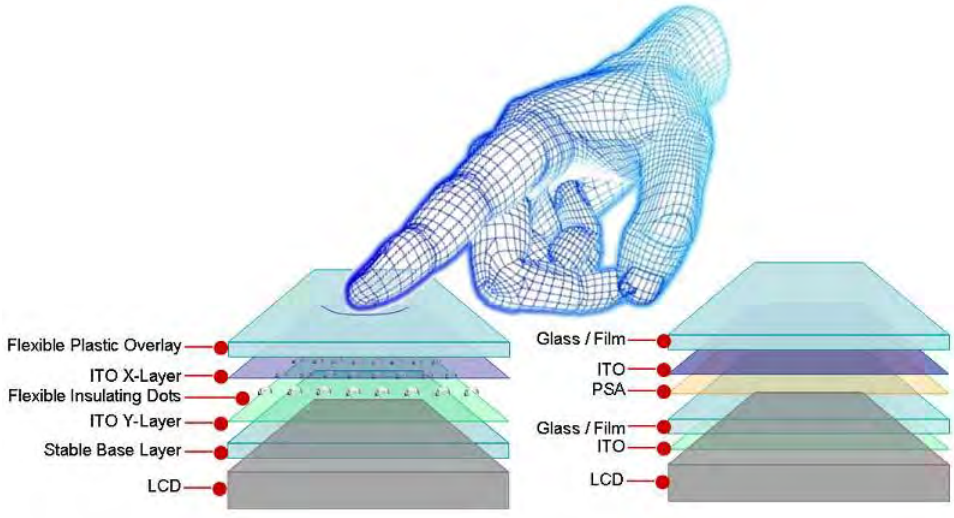


Motivation

Composition of discarded LCD powder, cf. [6]

Element	Weight (mg/kg LCDs)
In	405
Si	2013
Co	223
Zn	816
Fe	3992
Cu	211
Ni	651

[6] M. J. Jowkar et al. Journal of Cleaner Production, 2018.



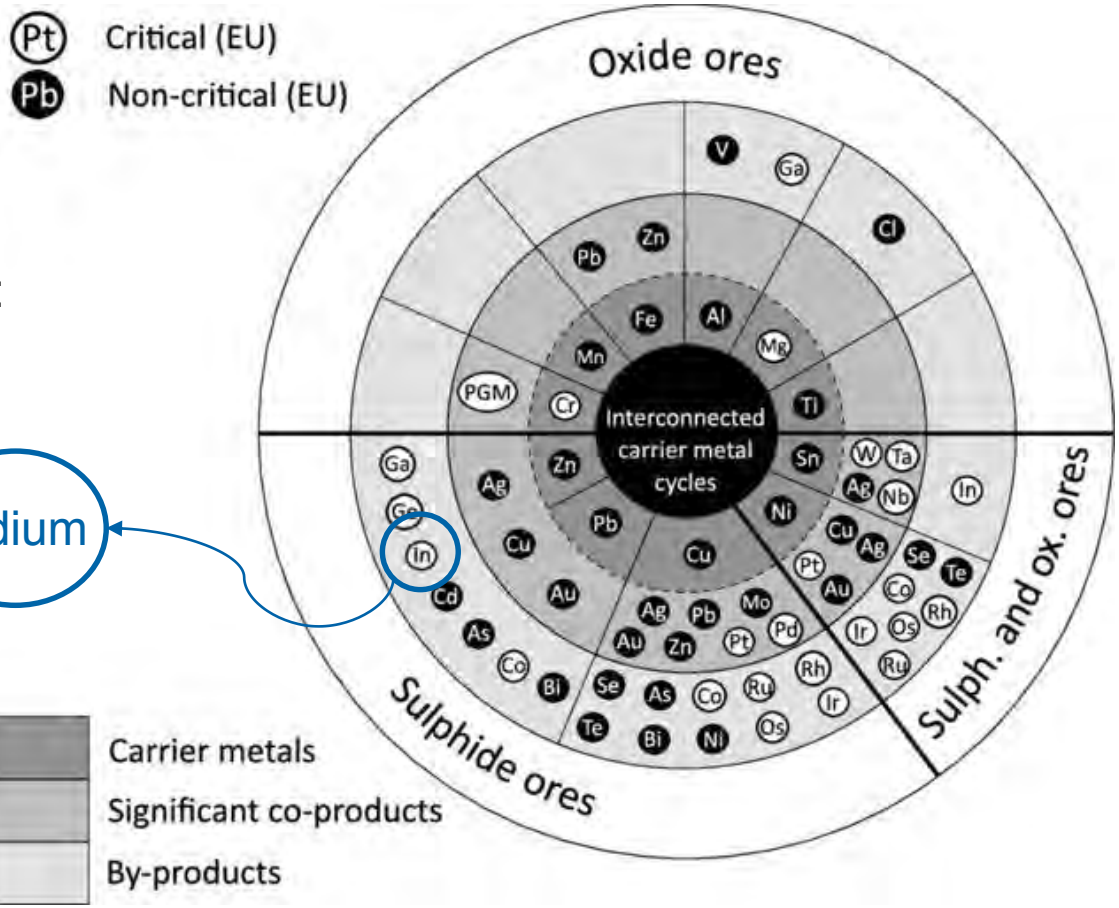
composition of LCD screen; resistive (left), capacitive (right) cf.[5]

vs

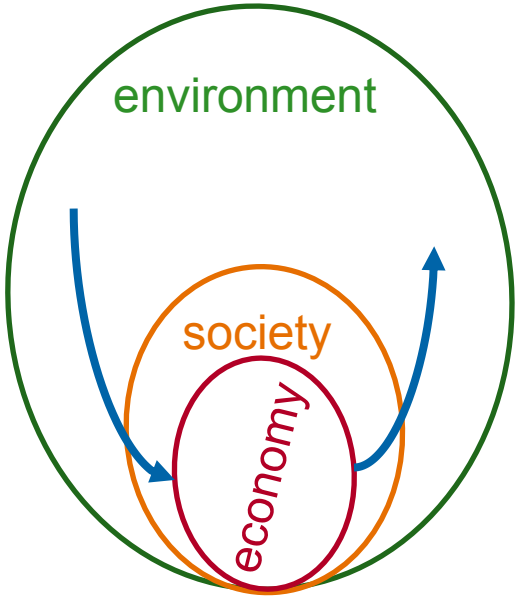
1-100 ppm indium in extracted ores, cf. [7,8]

[7] A.M. Alfantazi et al. Minerals Engineering, 2003.
[8] L. Rocchetti et al. Waste Management, 2015.

The Metal Wheel, cf. [1]



The strong sustainability concept:



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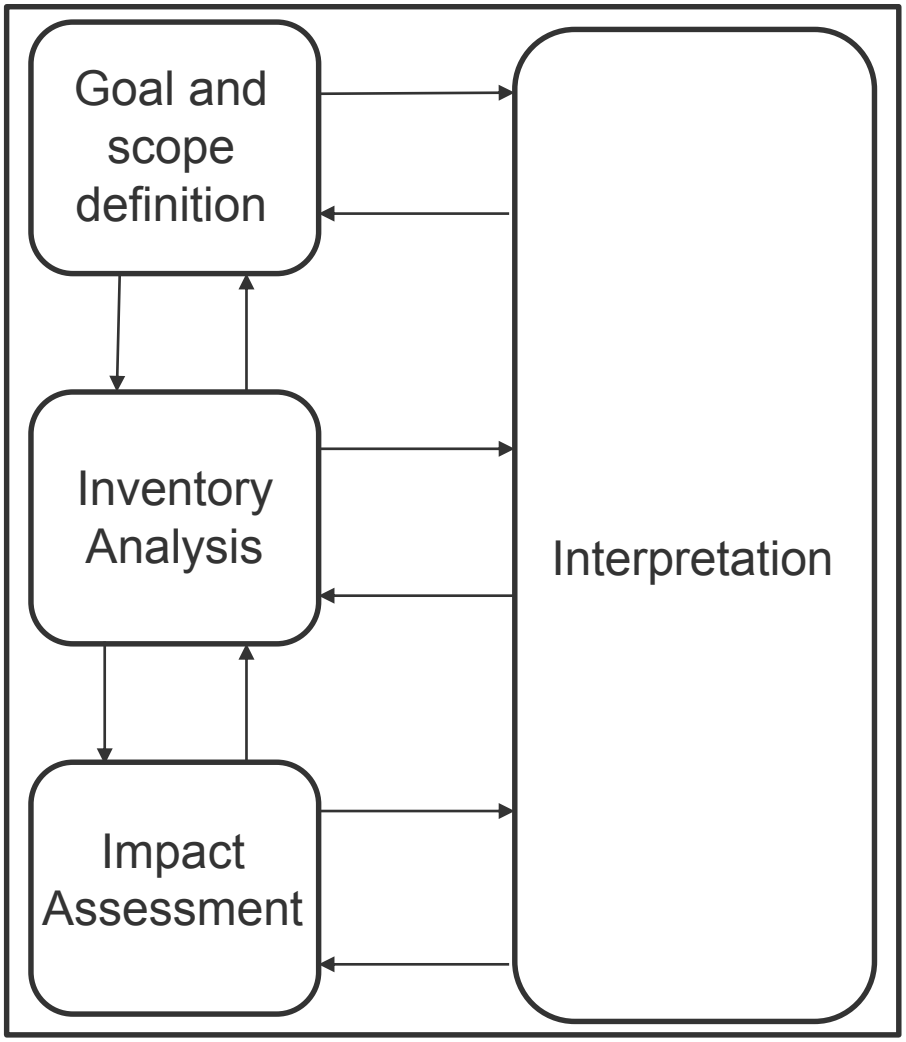
Life Cycle Assessment (LCA)



cf. DIN EN ISO 14040:2009-11

Applied in:

- Product development and improvement
- Strategic planning
- Public policy making
- Marketing
- other

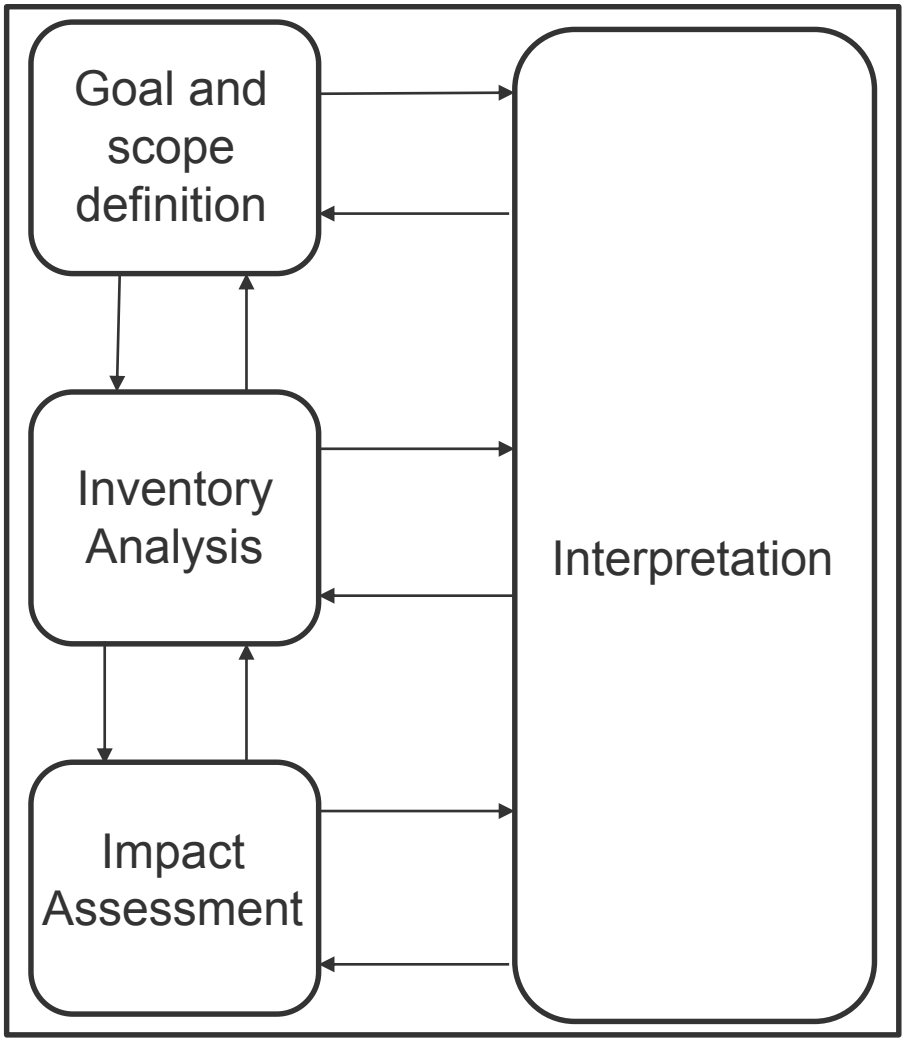
LCA for established processes [9]

Use of LCA as a development tool within early research [10]

[9] S. Cucurachi et al. Procedia CIRP, 69:463 – 468, 2018. 25th CIRP Life Cycle Engineering (LCE) Conference, Denmark.

[10] A. C. Hetherington et al. The International Journal of Life Cycle Assessment, 2014.

Life Cycle Assessment (LCA)



cf. DIN EN ISO 14040:2009-11

Applied in:

- Product development and improvement
- Strategic planning
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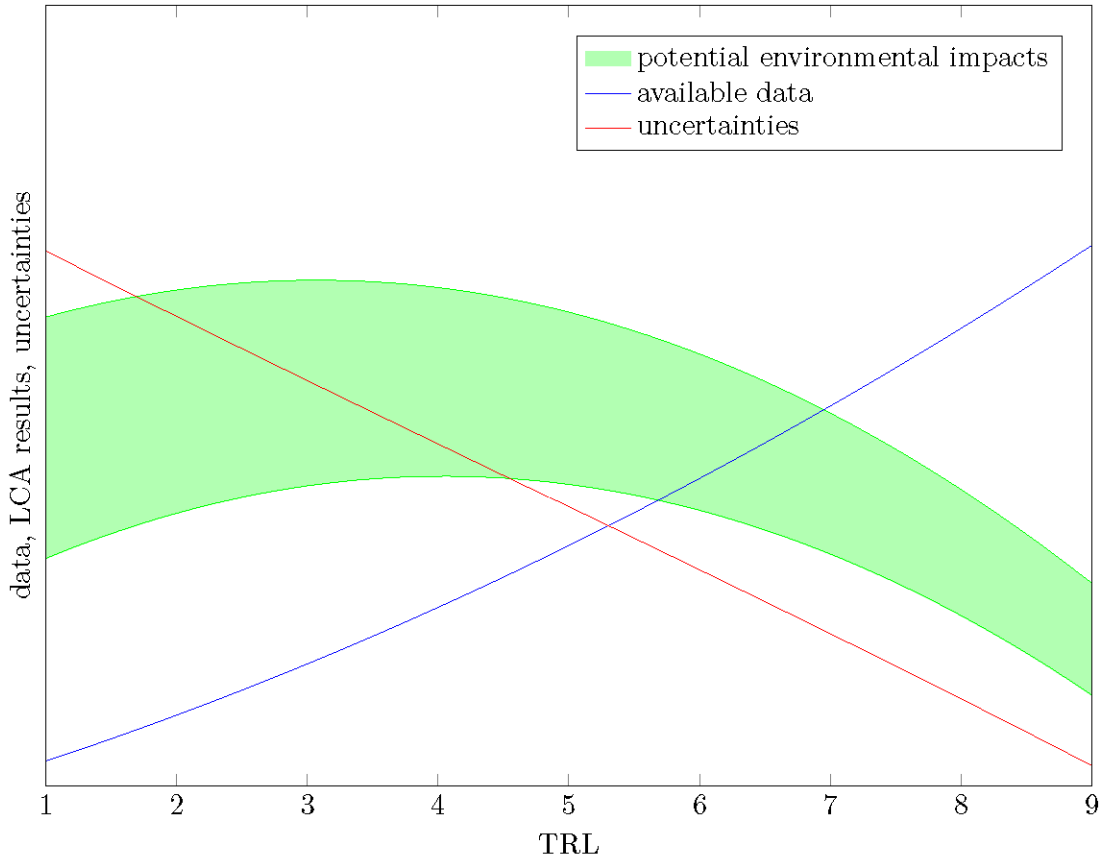
- other

Software: openLCA 1.7.4 *(https://openlca.org)*

Method: CML 2011 (all impact categories)

Motivation



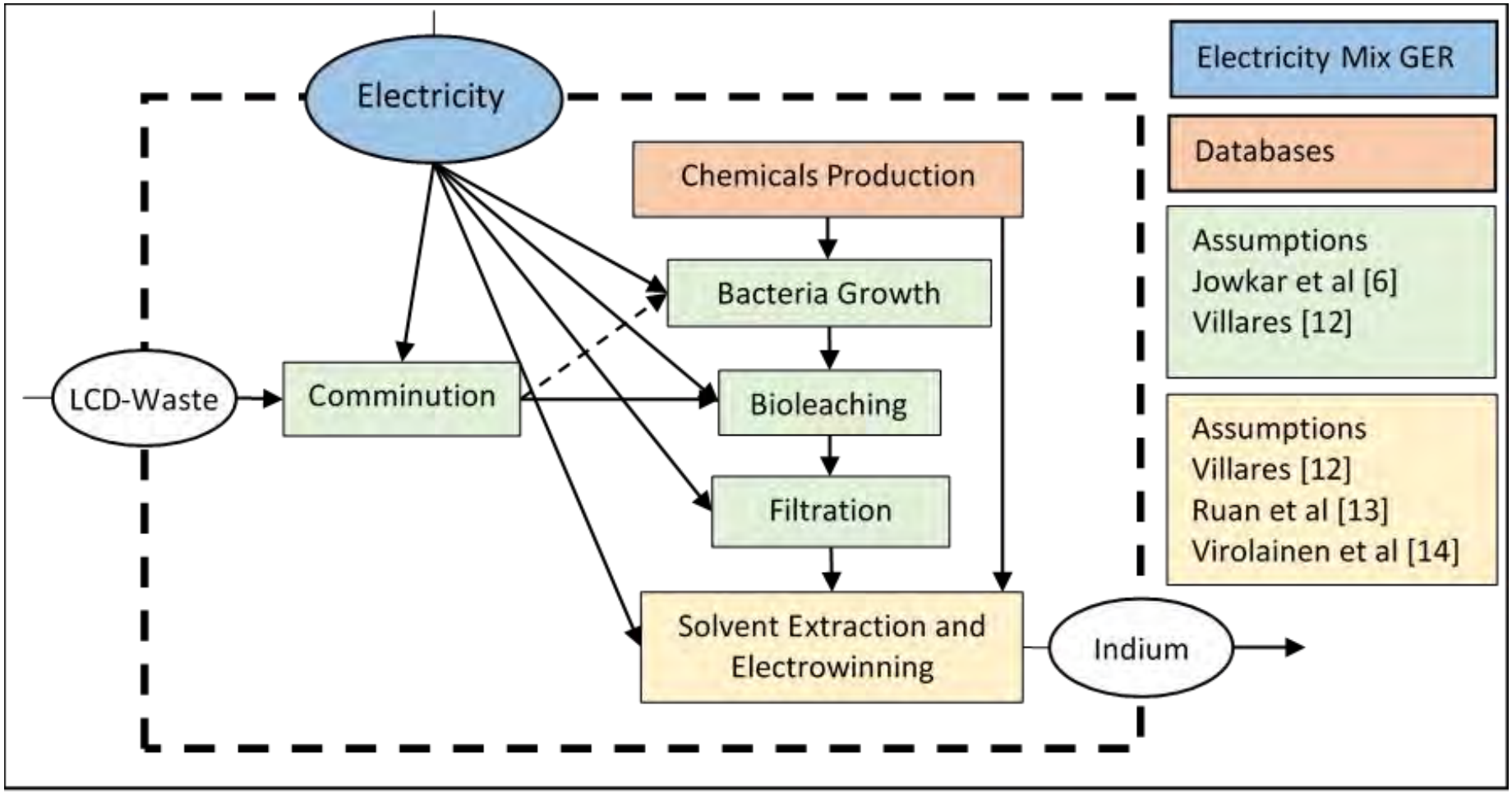
- Discover environmental hotspots at low TRL of process
- LCA as development tool
- Decrease environmental impact of processes

LCA throughout the technological development of processes cf. [10,11].
TRL=Technology Readiness Level

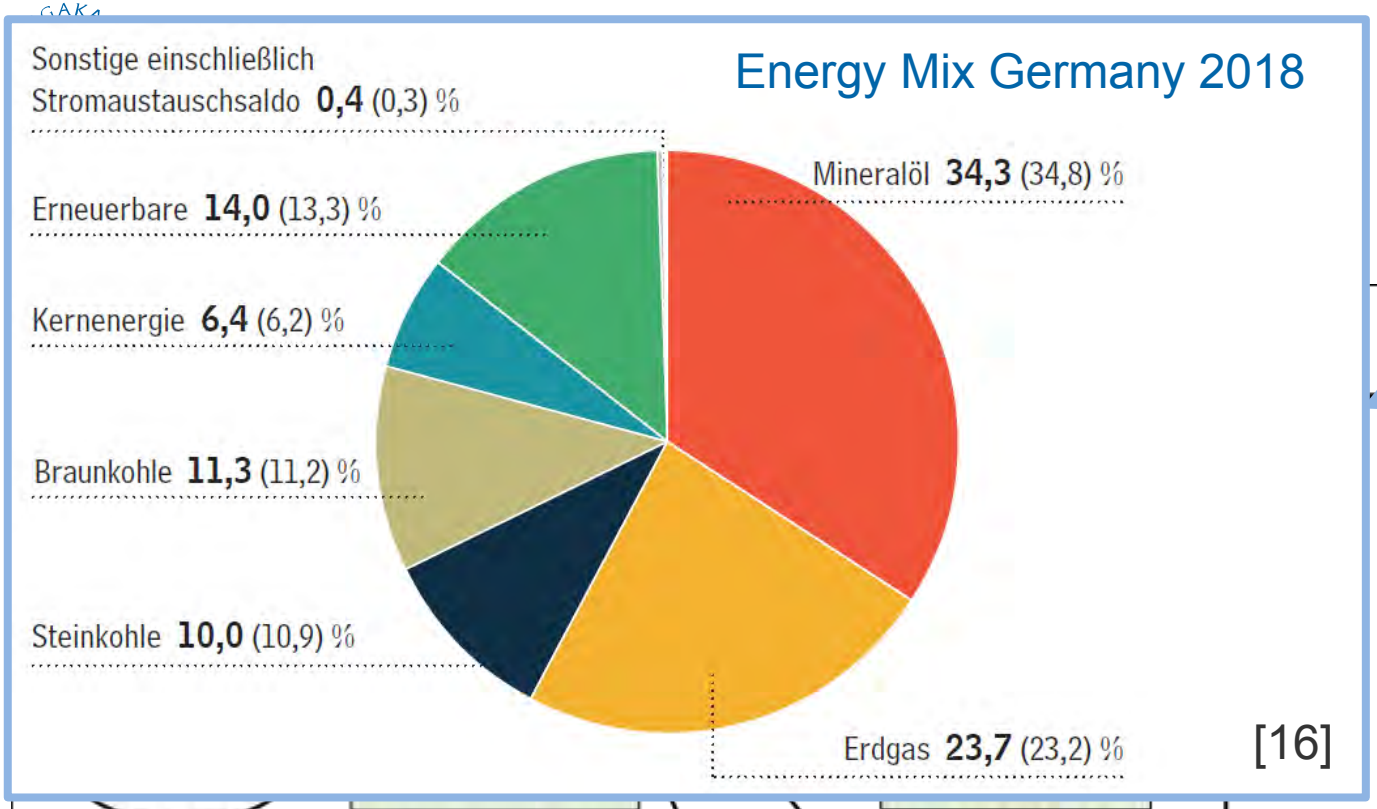
[10] A. C. Hetherington et al. The International Journal of Life Cycle Assessment, 2014.
[11] M. Villares. mathesis, Delft University of Technology, 2015

Bioleaching process assumed in LCA

Functional unit: 1 mg Indium



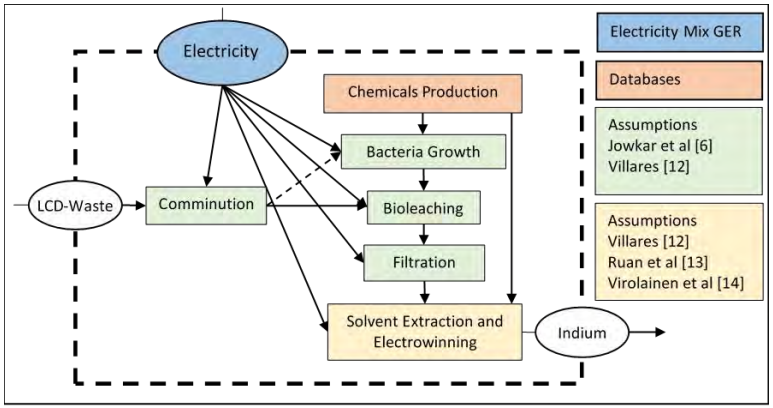
[17] A. Falke et al. MRS Advances, 2019.



[6] M. J. Jowkar et al. Journal of Cleaner Production, 2018.
[12] M.Villares et al. The International Journal of Life Cycle Assessment, 2017.
[13] J. Ruan et al. Procedia Environmental Sciences 2012. The Seventh International Conference on Waste Management and Technology (ICWMT 7).
[14] S. Virolainen et al. Hydrometallurgy, 2011.

[17] A. Falke et al. MRS Advances, 2019.

Bioleaching process assumed in LCA



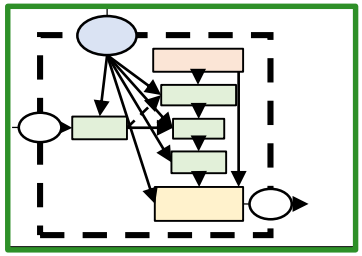
[13] J. Ruan et al. Procedia Environmental Sciences 2012. The Seventh International Conference on Waste Management and Technology (ICWMT 7).

[15] A.Amato et al. Waste Management, 2017.

Functional unit: 1 mg Indium

Process step / Process	Comminution	Leaching	Solvent Extraction & Electrowinning	Cementation
Bioleaching as shown	grinding	bacterial aided, adapted Acidithiobacillus thiooxidans, sulphuric acid	D2EHPA	
Chemical leaching A [13]	freezing in liquid nitrogen, breaking in cutting mill	chemically, sulphuric acid	D2EHPA	
Chemical leaching B [15]	shredding	chemically, sulphuric acid		sodium hydroxide, zinc

LCA Results for three different leaching processes

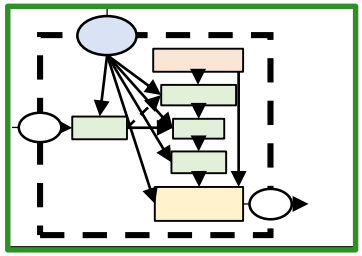


Functional unit: 1 mg Indium

Processes		Total process as shown	Bioleaching as shown	Chemical leaching A [13]	Chemical leaching B [15]
Impact category	**Reference Unit**				
Acidification	kg SO2 eq	0.06029	0.05930	0.00042	0.00004
Eutrophication	kg PO4 eq	0.00555	0.00536	0.00004	1.60916E-06
Global warming 100a	kg CO2 eq	63.63001	62.74802	0.17209	0.00368
Human Toxicity 100a	kg 1,4-DB eq	0.89796	0.88550	0.00251	0.00037

[17] A. Falke et al. MRS Advances, 2019.

LCA Results for three different leaching processes



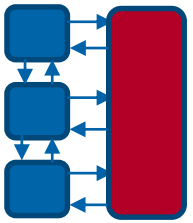
Without electricity:

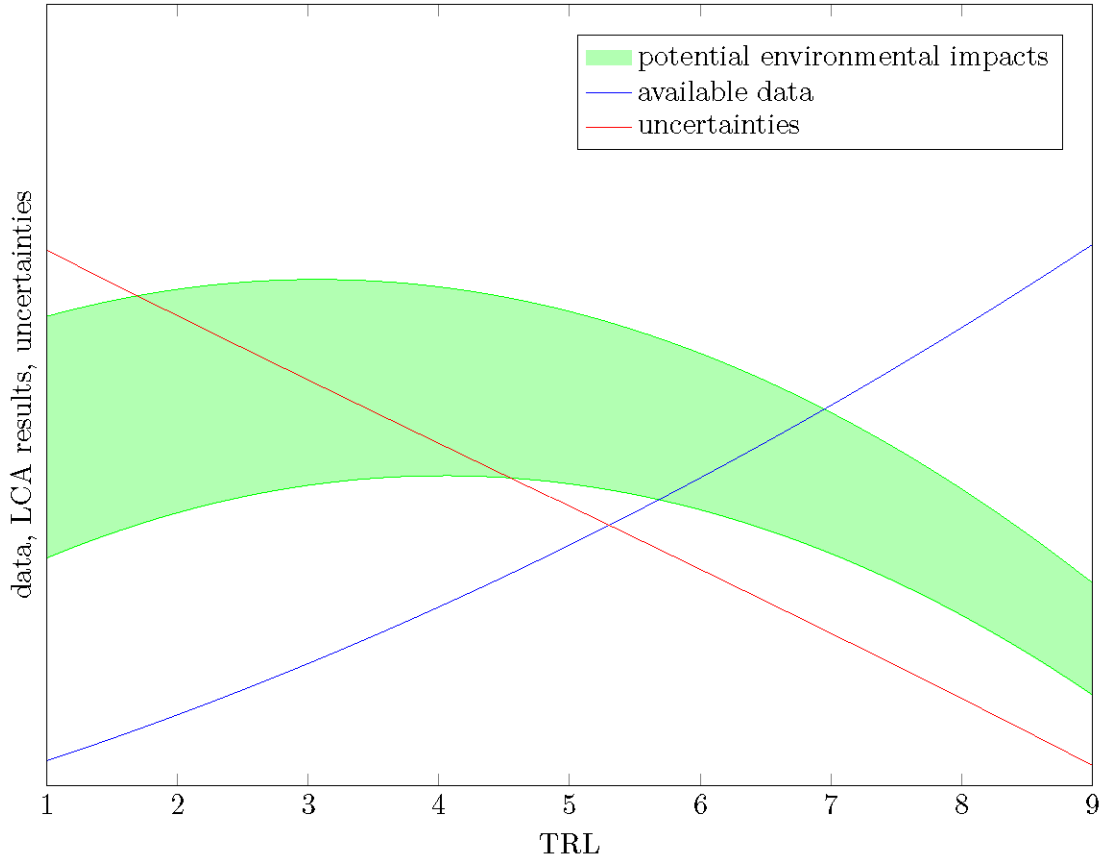
Functional unit: 1 mg Indium

Processes		Total process as shown	Bioleaching as shown	Chemical leaching A [13]	Chemical leaching B [15]
Impact category	**Reference Unit**				
Acidification	kg SO2 eq	0.00016	9.81516E-09	0.00026	0.00003
Eutrophication	kg PO4 eq	0.00011	2.99192E-08	0.00002	1.34722E-06
Global warming 100a	kg CO2 eq	0.00083	9.60638E-08	0.00027	0.00061
Human Toxicity 100a	kg 1,4-DB eq	0.00002	8.91997E-08	0.00009	0.00033

[17] A. Falke et al. MRS Advances, 2019.

Conclusion





- Ex-ante LCA is possible
- Hotspots were identified
- High uncertainty
- High dependence
- Bioleaching of e-waste to win indium can be feasible

- Further experiments
- Upscaling
- More data
  → higher certainty
- Reduce environmental impact of processes

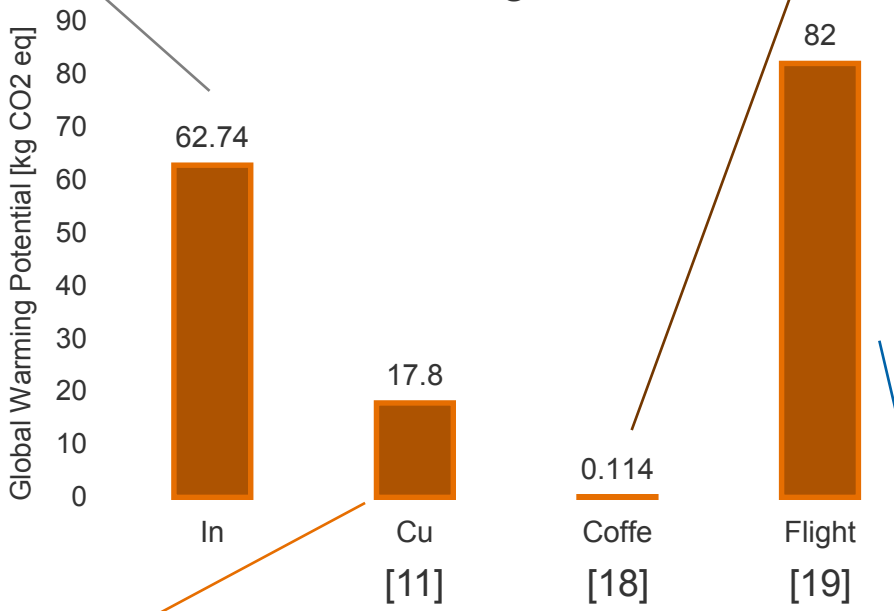
LCA throughout the technological development of processes cf. [10,11].

[10] A. C. Hetherington et al. The International Journal of Life Cycle Assessment, 2014.
[11] M. Villares. mathesis, Delft University of Technology, 2015

Conclusion & Outlook

indium [20]

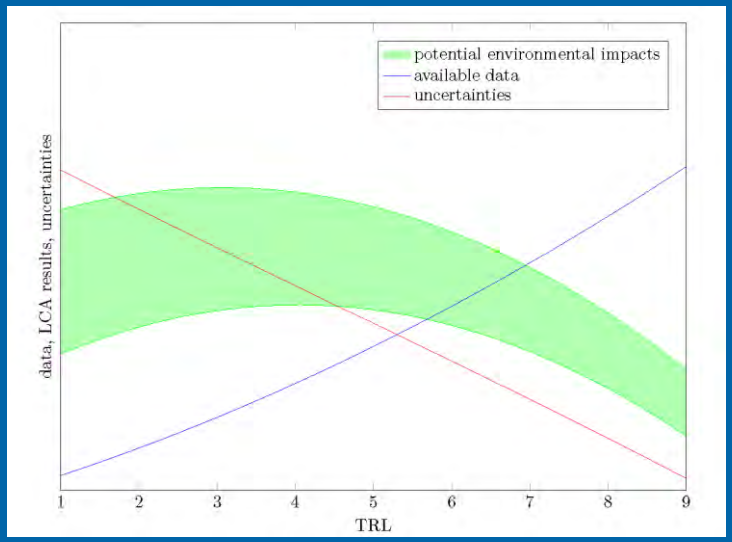
coffee [22]



copper [21]

Boeing 737 [23]

indium [19]



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IMPRESSUM

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[4] 3:http://www.irisvista.com/tech/laptops/Toshiba-Satellite-A305/display-big/remove-replace-lcd-screen-inverter-19.jpg, accessed on 18.04.2019.

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[18] https://www.appropedia.org/LCA_of_coffee, accessed on 18.04.2019.

[19] https://escholarship.org/content/qt6m5865v5/qt6m5865v5.pdf, accessed on 18.04.2019.

[20] http://german.highpurity-metals.com/sale-10132729-high-pure-99-99-purity-indium-bar-indium-ingots-for-led-application.html, accessed on 18.04.2019.

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[23] https://simpleflying.com/boeing-737-max-flying-again-soon/, accessed on 18.04.2019.