LCA OF METALS PRODUCTION : KEY CHALLENGES AHEAD AND POTENTIAL WAY FORWARD

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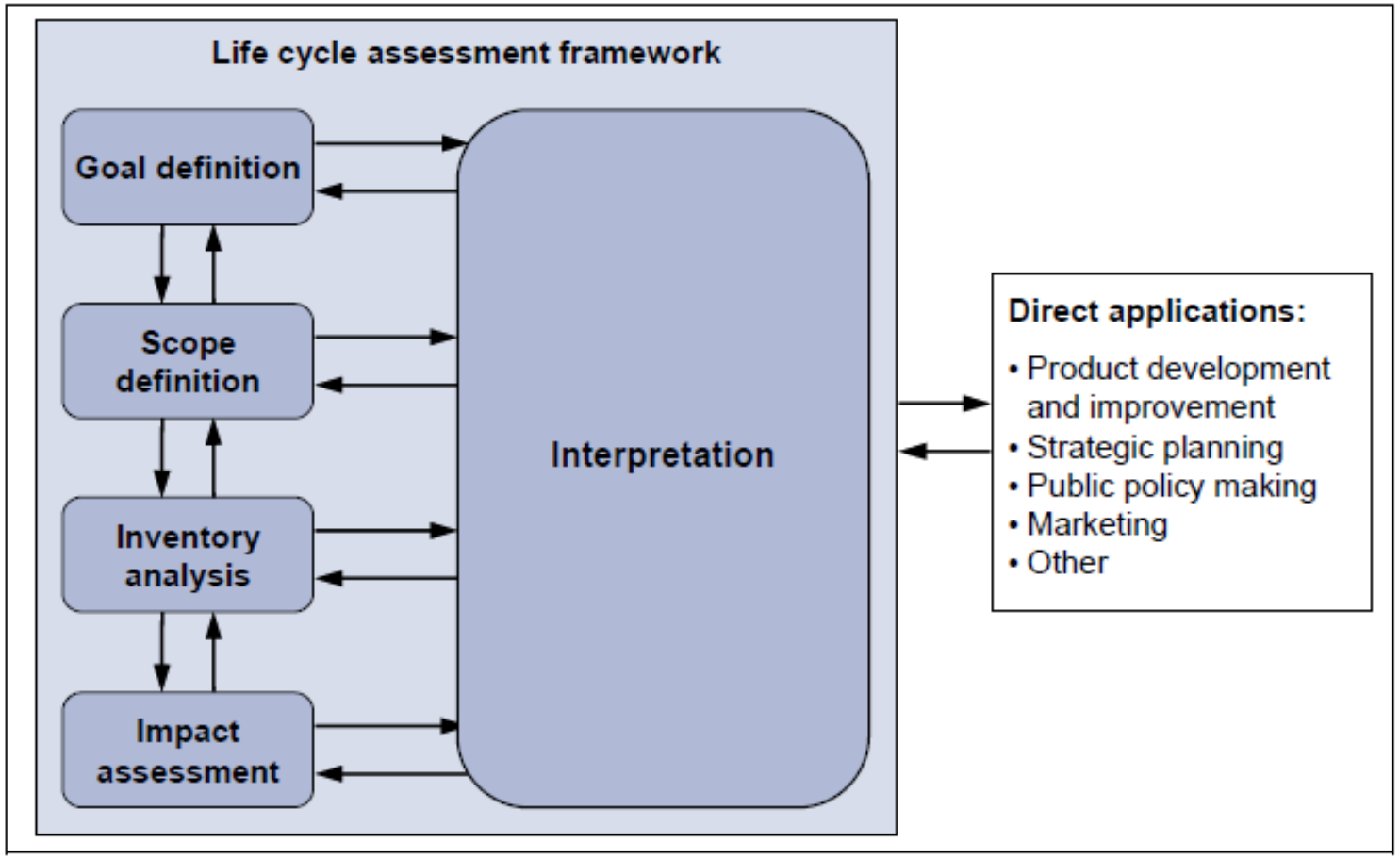
Content

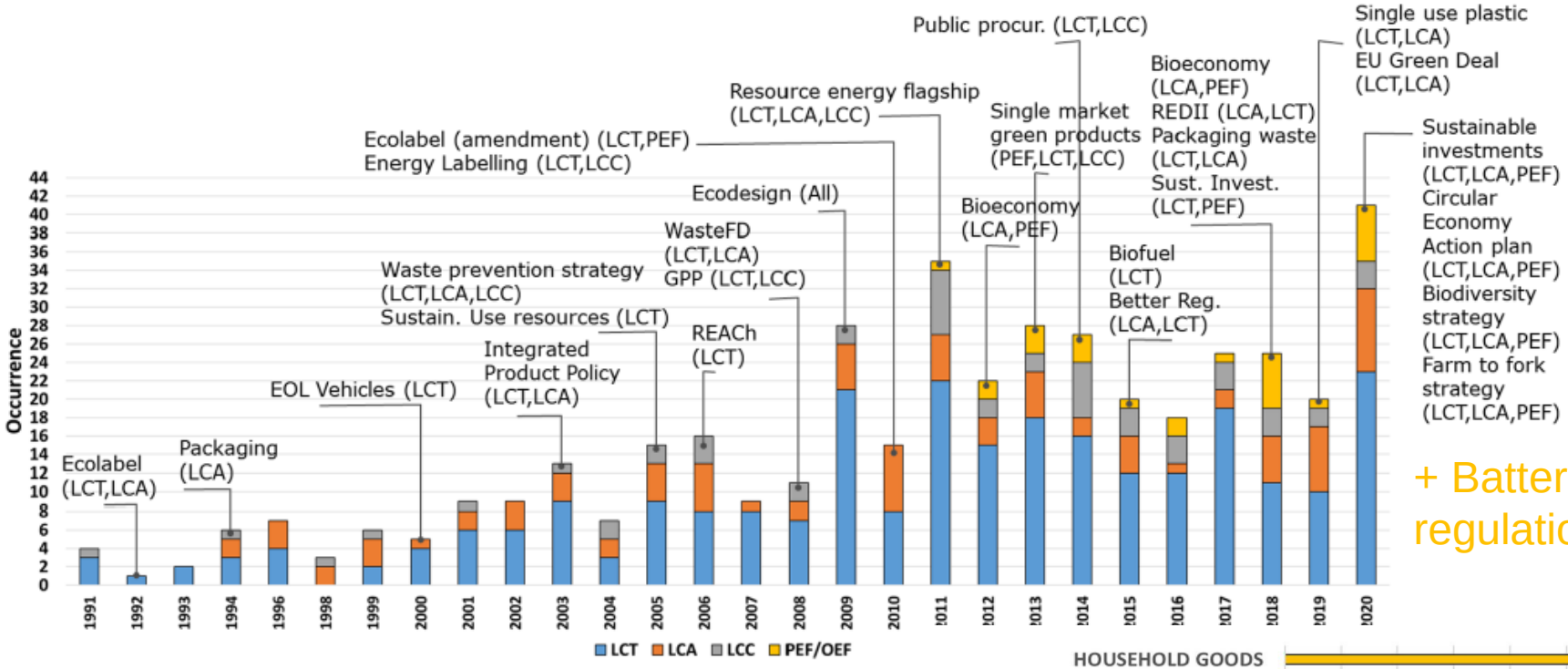
- LCA framework and implementation
- LCA of metals production: key challenges to the 4 LCA steps
- A way forward

The LCA framework

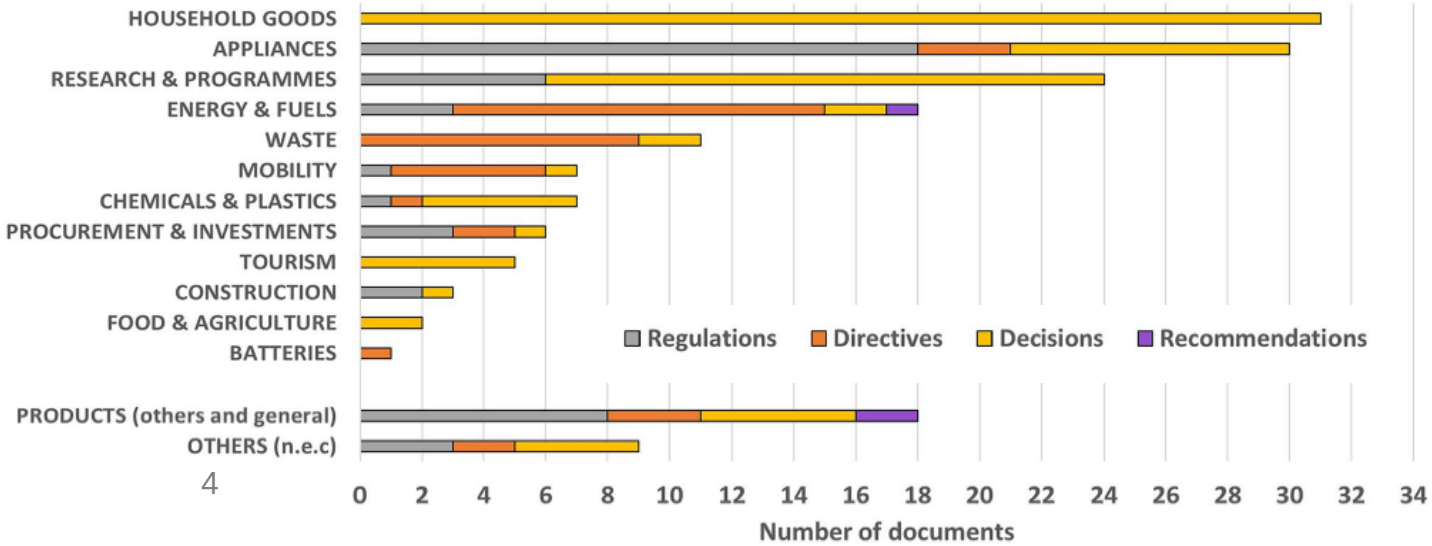


EC-JRC, 2010. ILCD Handbook

LCT, LCA, LCC and PEF/OEF in EU Policies



+ Battery regulation



Sala, S., et al. 2021. *The evolution of life cycle assessment in European policies over three decades*. Int J Life Cycle Assess. https://doi.org/10.1007/s11367-021-01893-2

How can LCA support process developments?

Identification of environmental hotspots

- Key **process steps**
- Key **inputs to the processes** (e.g. energy, reagents), **direct emissions** to the environment

Comparison of alternative design solutions

- determination of the **most favourable option**
- identification of **potential trade-offs** between
  - **life cycle phases** / process steps
  - **impact categories**

Support to the ecodesign of processes

Focus of this presentation

LCA: status…

- **Larger and larger implementation** in the last decades, e.g. in **EU policies**
- A **standardized approach**
- LCA classically aimed at **supporting the ecodesign of processes** (e.g. H2020, Horizon Europe)

… and remaining issues

- **Not** that much implemented in **binding policies**
- **Standards shall be applied**… and **best practices** can/should **be improved**

… So what?

Current challenges regarding LCA *application to metals production*?

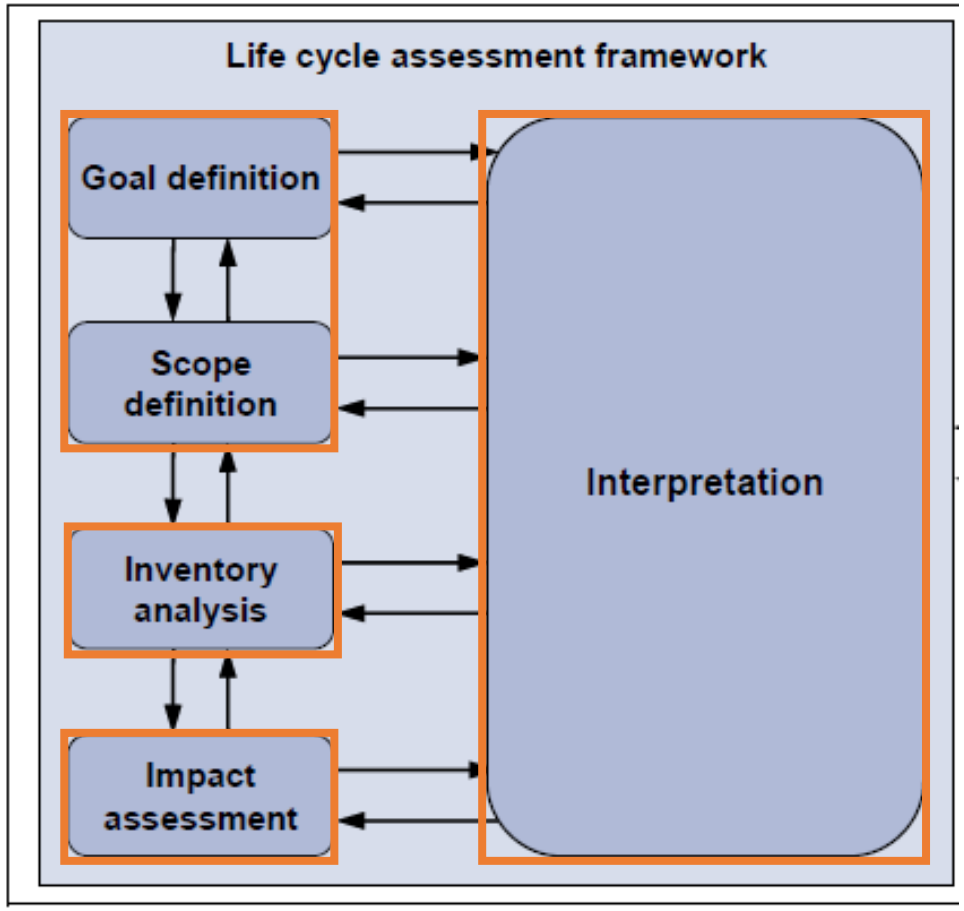
- Building on published articles on **case studies, method development, literature review**
- Focus: metals from **primary ores** */* **tailings** management
- *A **non-exhaustive** vision here… probably completed today!*

Challenges in the LCA of metals production

1

2

3



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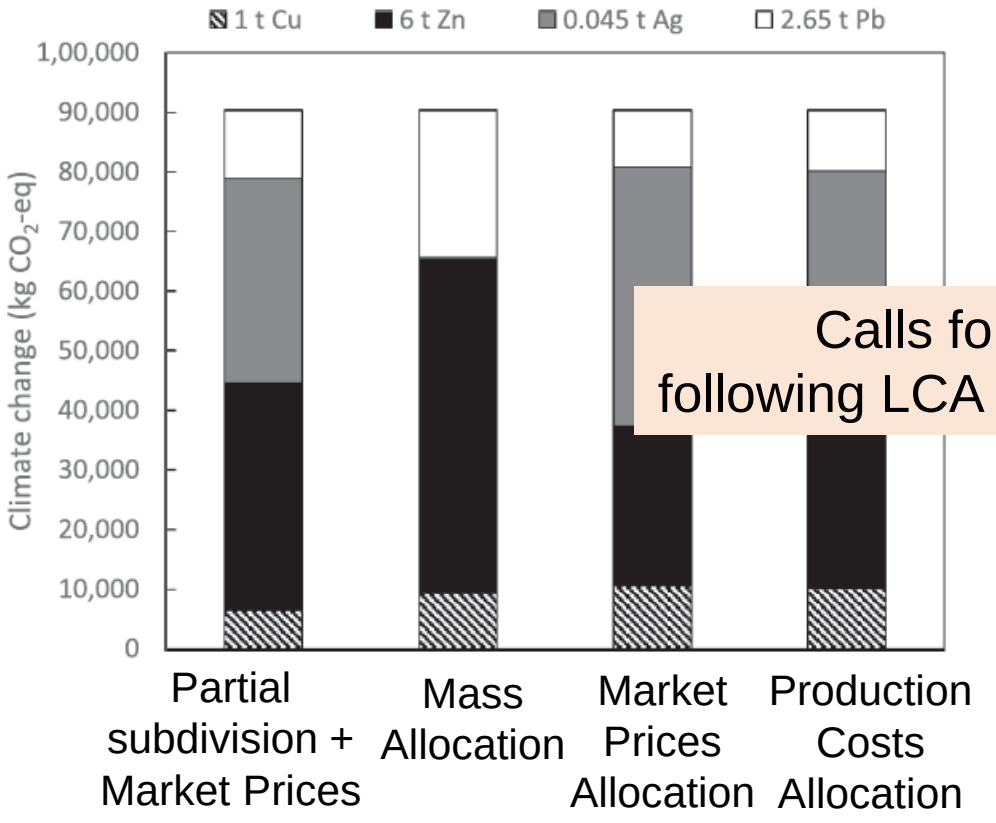
Goal and scope definition: multi-functionality

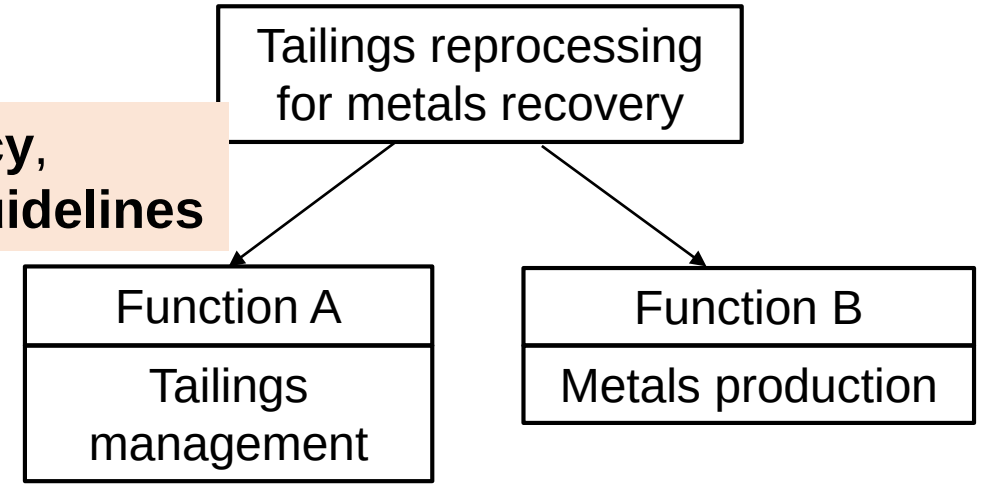
Metals production processes are classically multi-functional

- **co-production** of several metals



Calls for **transparency**, following LCA **standards/guidelines**

- secondary resources: **waste treatment *and* metal production**
  - E.g.: classically **disregarded in the LCA of tailings reprocessing**



Beylot et al., 2021. *How to account for environmental and resource issues of tailings management in LCA ? A critical review and potential way forward.* To be submitted

Lai, F., et al. 2021. *Solving multifunctionality in the carbon footprint assessment of primary metals production: Comparison of different approaches,* Minerals Engineering, https://doi.org/10.1016/j.mineng.2021.107053.

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Goal and scope definition: other issues

This step aims at defining

- **System boundaries**
- **Temporal scope**
- **Choice of impact categories**

…

Calls for **transparency**, following LCA **standards/guidelines**

…

- **Decision-making context, e.g.:**
  - Policy: e.g. metal supply chain
  - Company scale
  - Process development:

  at a **lab-scale**?

  at a **pilot-scale**?

Tailings management

- **Considered** in the LCA of metals production? And if yes, how **complete?**
- **Long-term vs short-term emissions:** crucial for some impact categories
- **Climate change** is ***one*** impact category

Beylot et al., 2021. *How to account for environmental and resource issues of tailings management in LCA ? A critical review and potential way forward.* To be submitted

Has implications on the next LCA steps: **data collection, sensitivity/uncertainty analysis**, etc.

Challenges in the LCA of metals production

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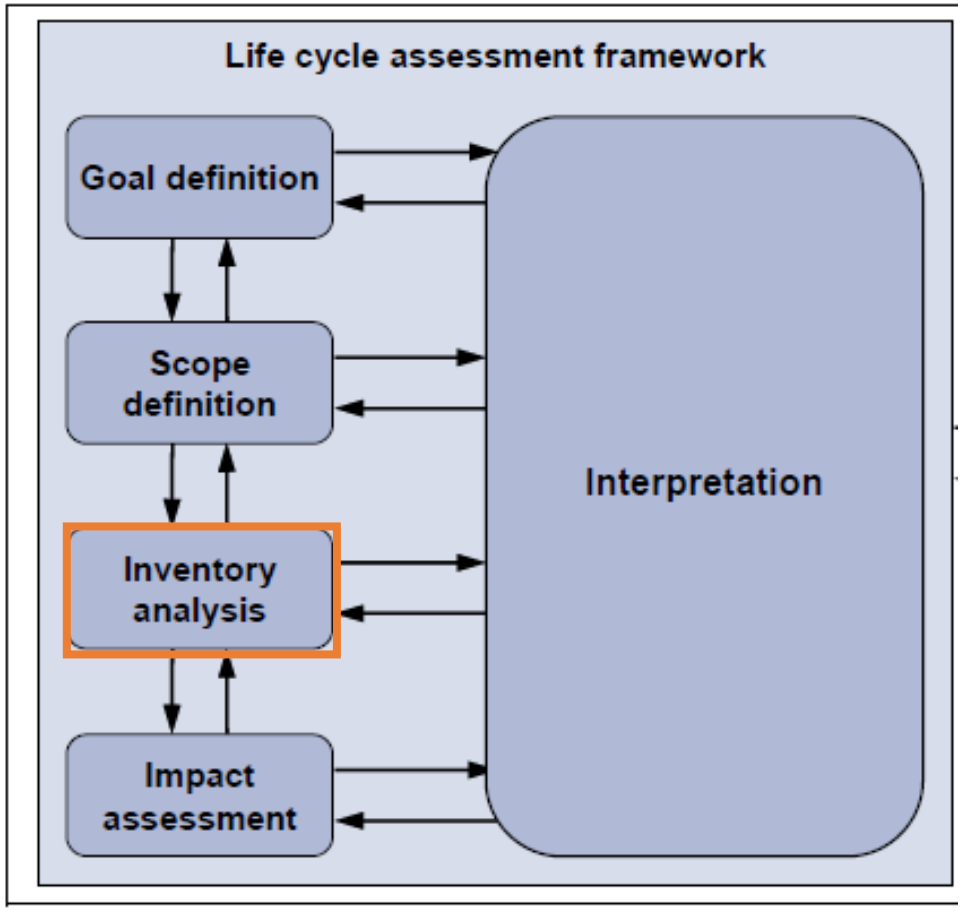

Inventory analysis

Challenges in LCA? Data, data, data!

Data is (one of) the most crucial issue in LCA of metals production

- **Representativeness**
  - Geographical
  - Process/technological (e.g. tailings final disposal)
  - Temporal (no obsolete data from the past)
- **Level of disaggregation** (“black-box” issue)
- **Completeness**
- **Consistency**

→ ***Incomplete, inconsistent mineral resource balances in LCI datasets***

Coping with data challenges

- **Extensive data collection**
- Use of **complementary models** (particularly relevant in context of **process development**)

And:
Beylot, A., et al. 2021. Mineral resource dissipation in life cycle inventories. Int J Life Cycle Assess 26, 497–510. https://doi.org/10.1007/s11367-021-01875-4

Example of extensive data collection

Case of an operating mine: Lujar fluorspar underground mine (Spain)

https://www.slim-project.eu/

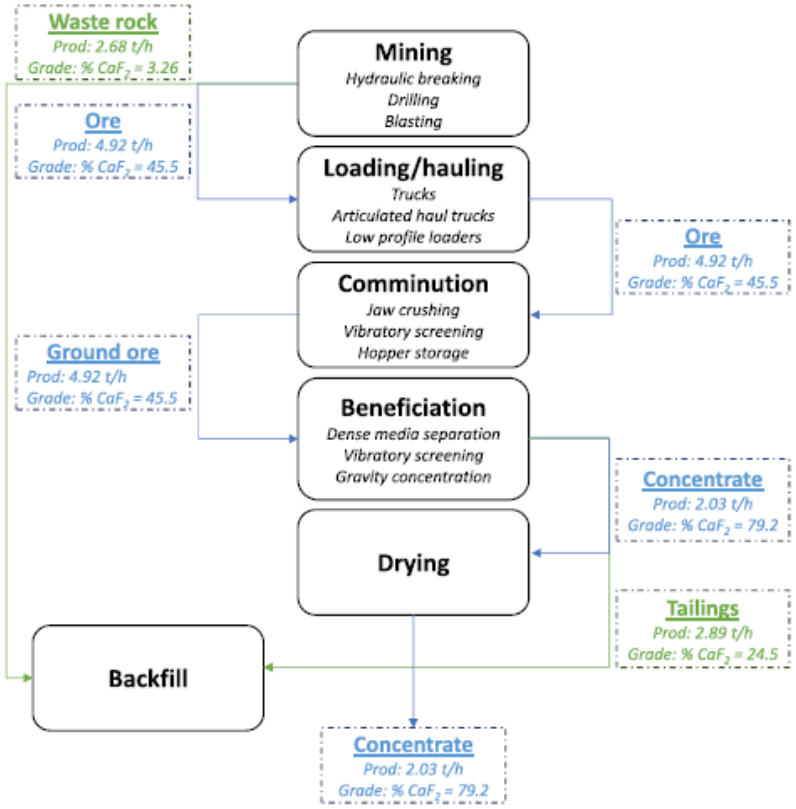

Table 1
Overview of the data inventory relative to the Lujar mining operations.

Data	Value for 1 ton concentrate (FU)	Unit	Corresponding unit operation(s)
Inputs			
Diesel for	338	MJ	Mining
machinery	448	MJ	Loading/hauling
Electricity	116	kWh	Mining
consumption	57.2	kWh	Comminution
	53.4	kWh	Beneficiation
	16.6	kWh	Drying
Explosives (ANFO)	0.6	kg	Mining
Explosives (Dynamite)	0.2	kg	Mining
Ferrosilicon (FeSi)	1.4	kg	Beneficiation
Steel	0.08	kg	Mining
	0.6	kg	Comminution
	0.2	kg	Beneficiation
Water	123	L	Mining
	113	L	Beneficiation
Outputs			
Diesel losses (to soil)	0.06	kg	Loading/hauling

Lai, F. et al. 2021. *The environmental performance of mining operations: Comparison of alternative mining solutions in a life cycle perspective*, Journal of Cleaner Production, https://doi.org/10.1016/j.jclepro.2021.128030.

+ measurements on NOx, CO, etc. emissions from blasting

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Complementing data collection with models: mineral processing simulation (1)

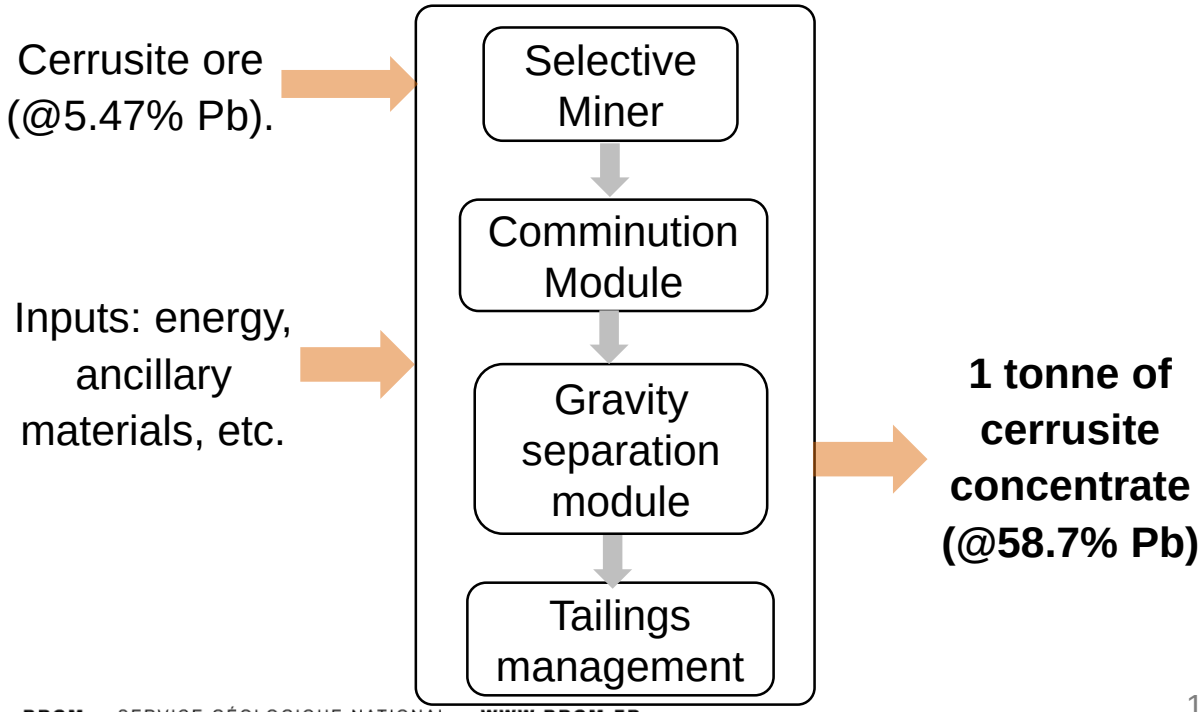
SOSO Mining

- Integrated **modular** and **mobile** plant
- For **rapid start-up and cessation** of production

H2020 IMP@CT

- **Pilot-scale** implementation on a **high-grade lead deposit, Bosnia-Herzegovina**

http://blogs.exeter.ac.uk/impactmine/



Complementing data collection with models: mineral processing simulation (2)

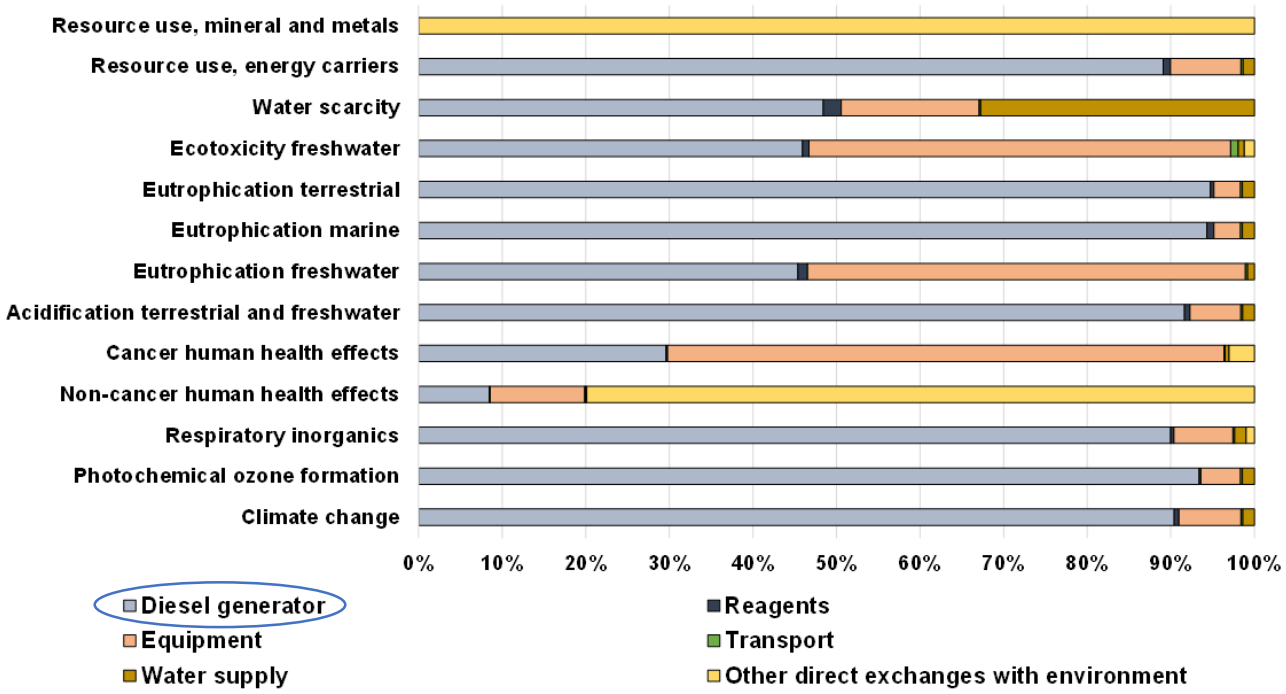
Data collection
on-site pilot scale implementation
+ secondary data (e.g. scenarios)

Process simulation
(material and water balances, reagents)

Improved data quality
(completeness, consistency)

LCA
calculations

Identification of environmental hotspots in the process chain

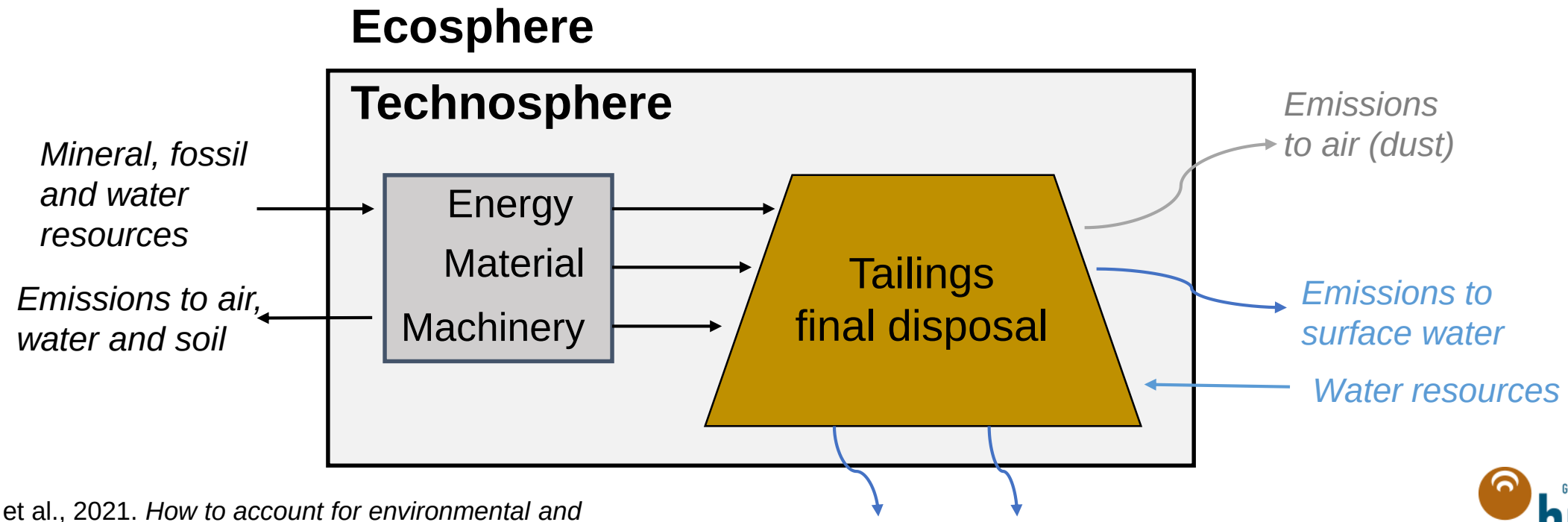


Beylot, A. et al. 2021.*Switch on-switch off small-scale mining: Environmental performance in a life cycle perspective,* Journal of Cleaner Production, https://doi.org/10.1016/j.jclepro.2021.127647

Complementing data collection with models: reactive transport modelling

LCA of tailings final disposal

- **Emissions to groundwater: hotspots** for some impact categories
- Yet **few case studies**; often based on **uncertain** and **incomplete data** collected on-site
- **High-quality data required** for sound decision-making also on **reprocessing techniques**



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Complementing data collection with models: reactive transport modelling

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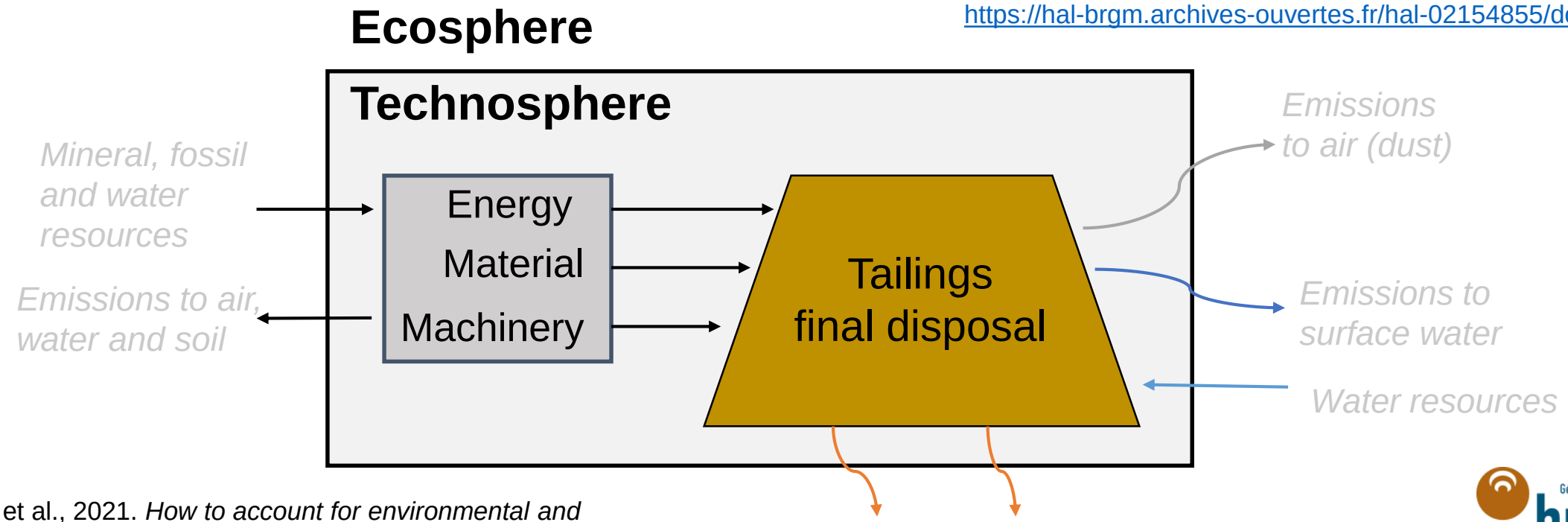
Reactive transport modelling to feed the LCI

- Determining the concentration of chemical species at the outlet of the system
- Resulting in **mass of chemical species emitted to groundwater** over time

Muller, S., et al. 2019. *Taking into account final mining wastes in LCA: How to quantify the impacts of tailings?* In: LCM. Poznan, Poland https://hal-brgm.archives-ouvertes.fr/hal-02154855/document



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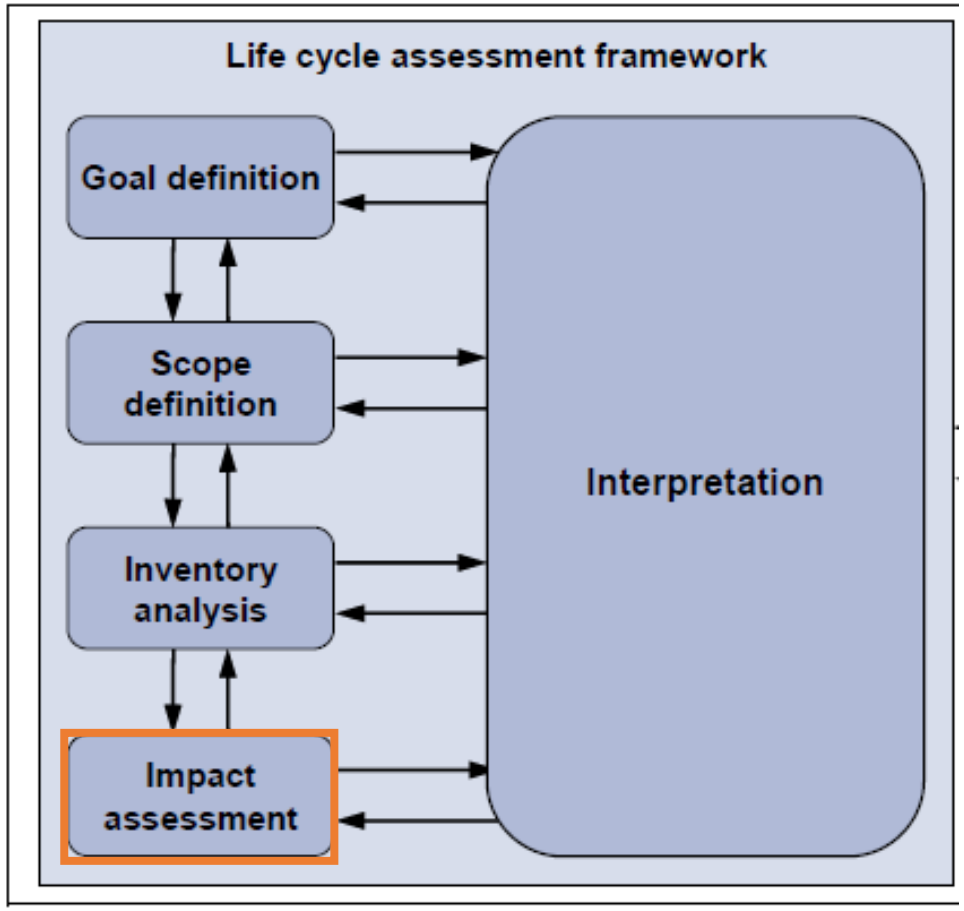
Challenges in the LCA of metals production



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Impact assessment

LCA a multi-criteria approach

In the context of metals production

- A number of **relevant impact categories:** e.g. climate change, toxicity, fossil and mineral resources

Different levels of model robustness for characterization models

- e.g. climate change more robust than toxicity indicators
- Recent intense debates in the LCA community regarding **mineral resource** use: **depletion**-based versus **dissipation**-based (or **accessibility**-based) **indicators**

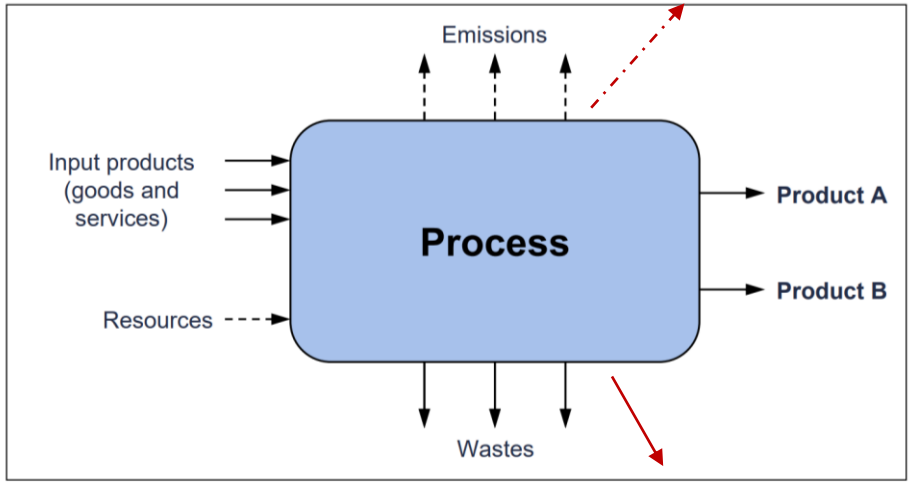
The focus in the following

Resource dissipation at the LCI level

JRC approach to resource dissipation accounting

- Suggestion to account for **dissipative resource flows** at the **unit process** level
- Considering a **set of dissipative flows** (e.g. metals to tailings)
- With **application to case studies**

Resources dissipated



Resources dissipated

Abiotic and biotic resources impact categories in LCA: development of new approaches

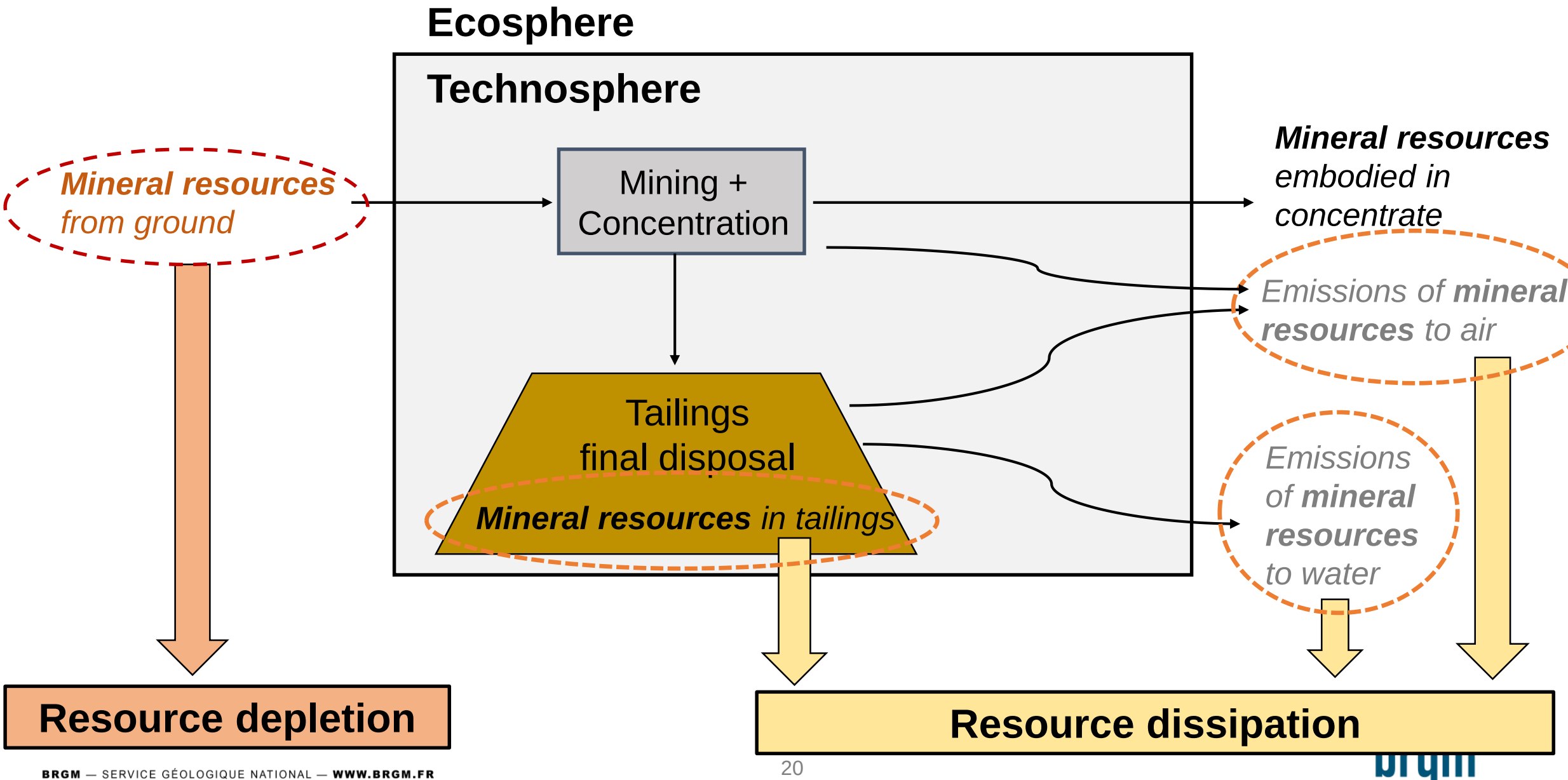
Accounting for abiotic resources dissipation and biotic resources

Beylot A., Ardente F., Marques A., Mathieux F., Pant R., Sala S., Zampori L.

2020

Beylot, A., et al. 2021. *Mineral resource dissipation in life cycle inventories*. Int J Life Cycle Assess 26, 497–510. https://doi.org/10.1007/s11367-021-01875-4

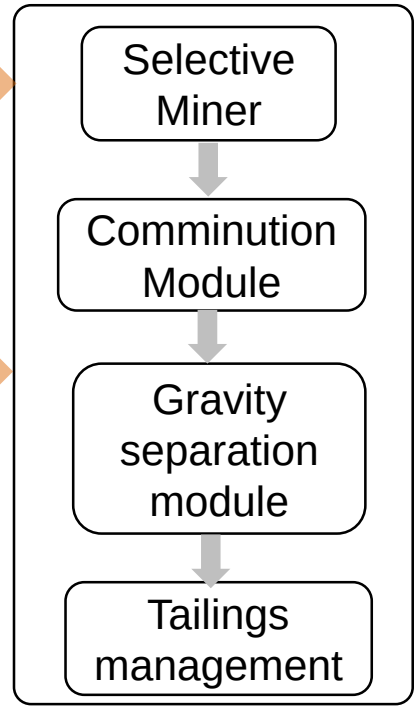
Implication for the LCA of a concentrate production



Example: mineral resource indicator in SOSO mining

Cerrusite ore (@5.47% Pb).

Inputs: energy, ancillary materials, etc.

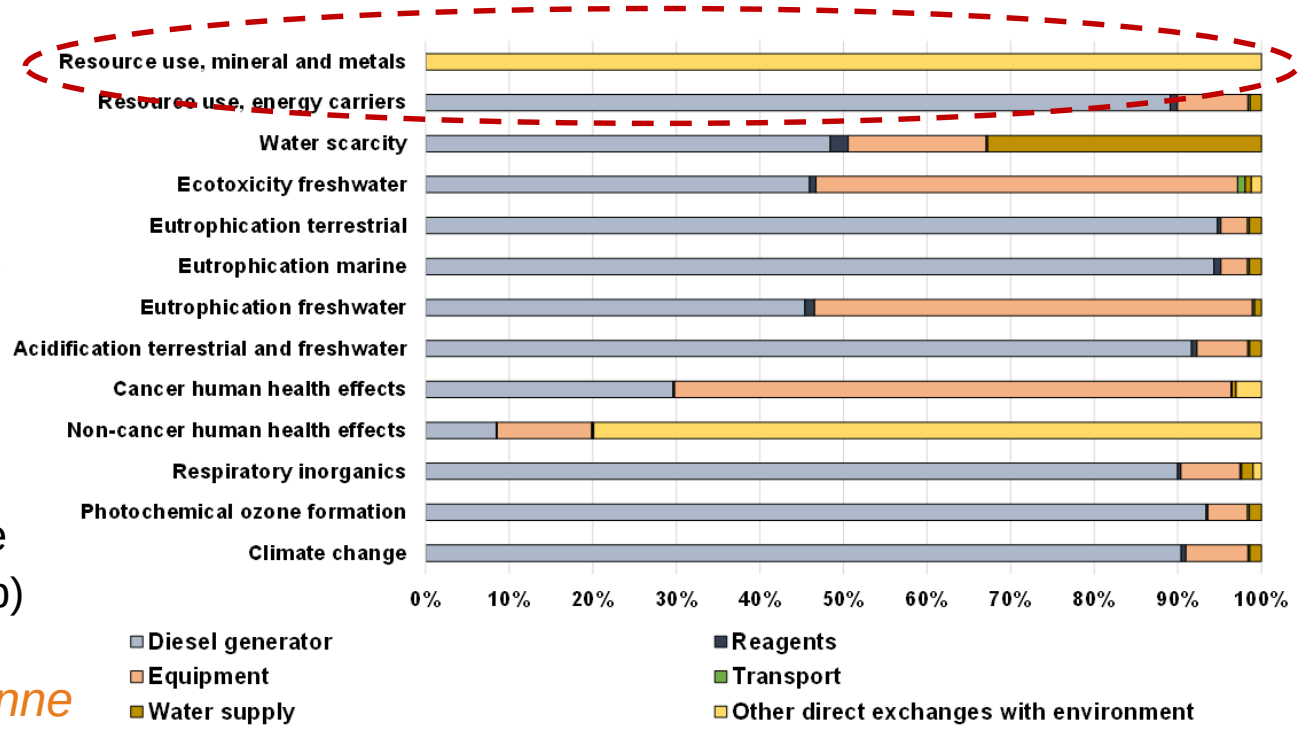


789 kg Pb in tailings
Contribution to ***dissipation***

1376 kg Pb extracted from ground
Contribution to ***depletion (ADP)***

1 tonne of cerrusite concentrate (@58.7% Pb)

585 kg Pb per tonne concentrate
Higher ***accessibility***

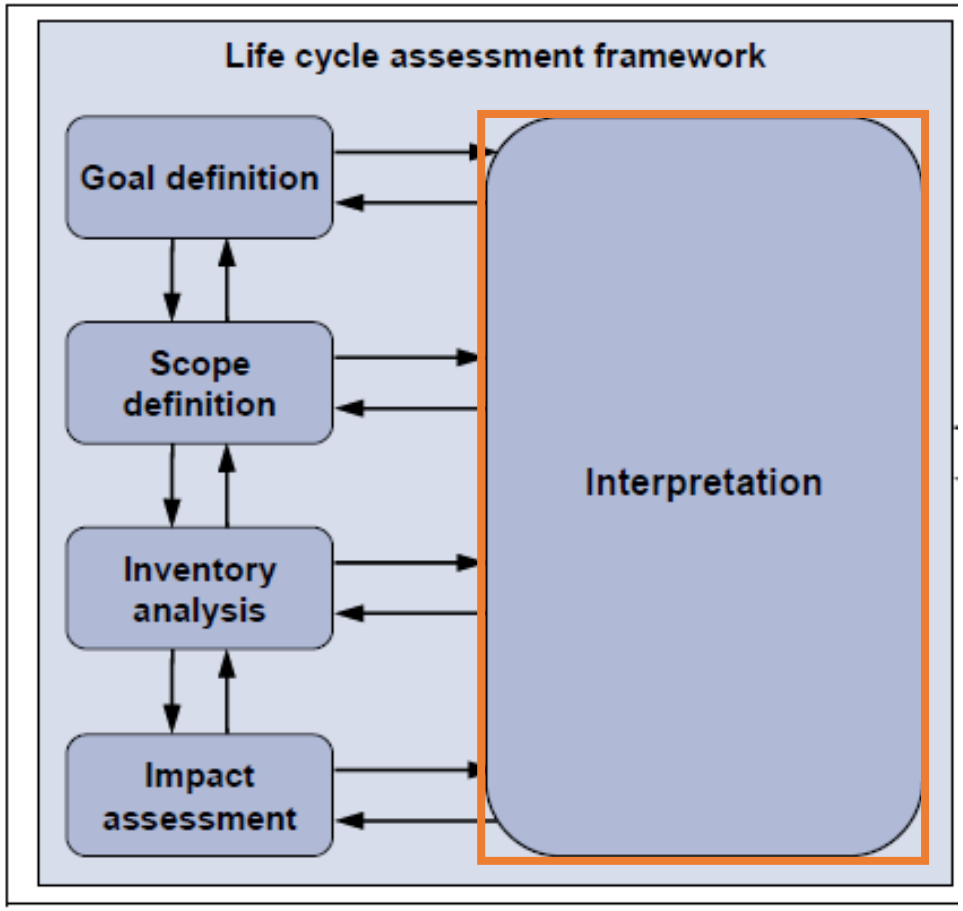


Further questions at the interface with the mineral processing community

- How far are metals in **tailings** (technologically/economically) **accessible**?
- Or on the **contrary « lost »/dissipated**?

Beylot, A. et al. 2021.*Switch on-switch off small-scale mining: Environmental performance in a life cycle perspective,*
Journal of Cleaner Production,
https://doi.org/10.1016/j.jclepro.2021.127647

Challenges in the LCA of metals production



4

Interpretation

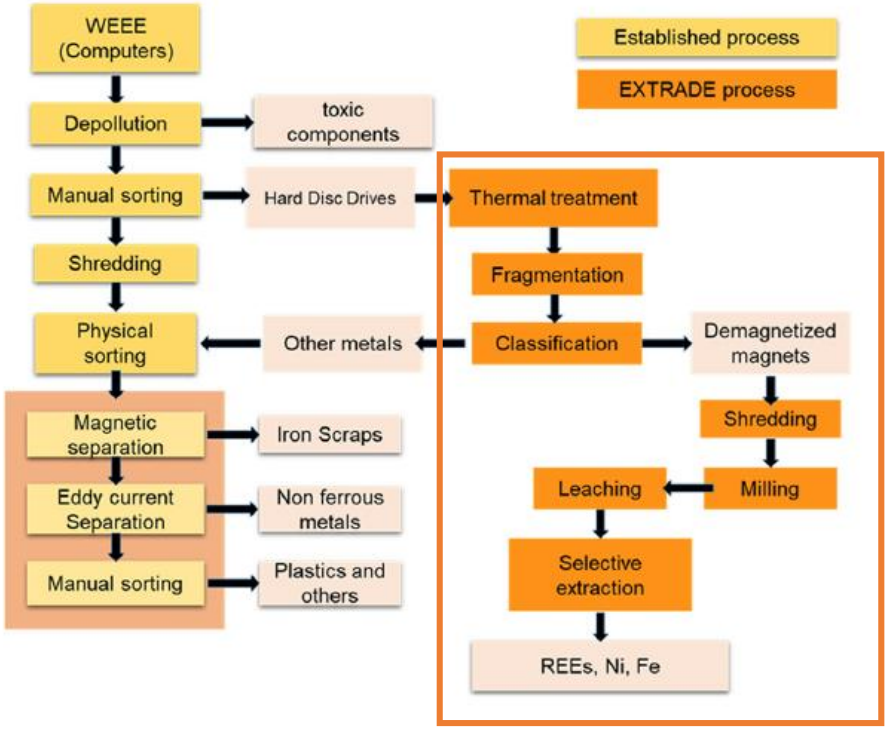
Uncertainty and sensitivity are key but still often not adressed

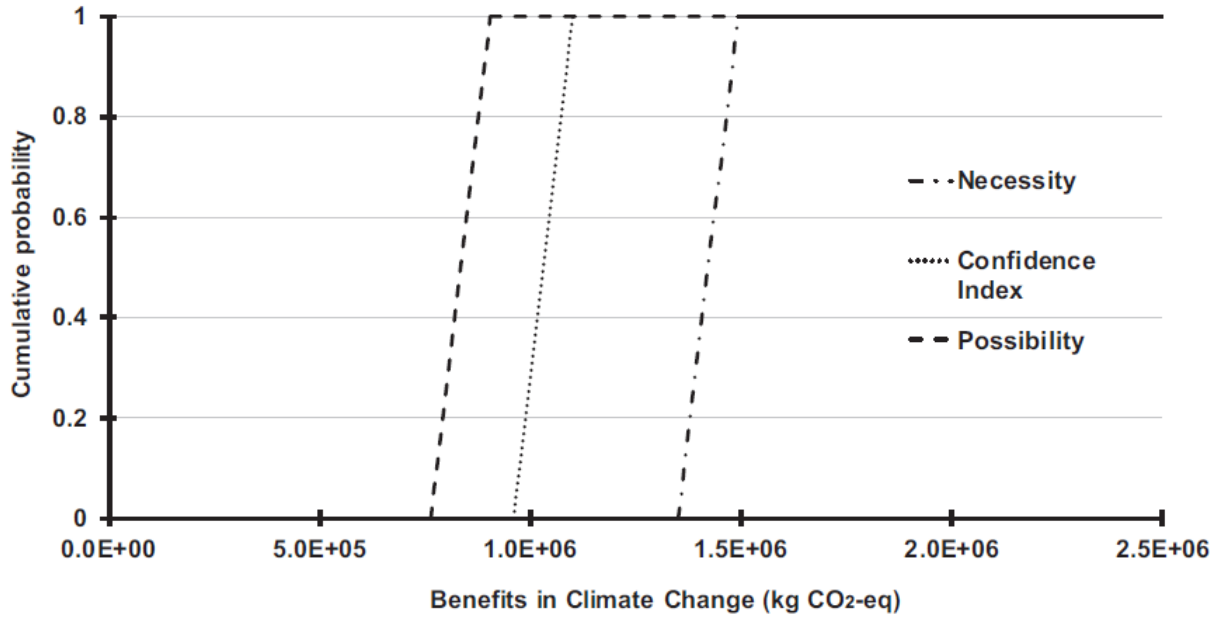
- “key”: especially at the process development level: **lowest knowledge** on the process, **largest capacity to change** its performances

Application to the carbon footprint assessment of the EXTRADE Rare Earths recycling process

- Development at the **lab-scale**
- **Incomplete and imprecise data from measurements**: use of **expert opinions** through **possibility theory** (with ranges of **“most likely” values rather than single values**)

Beylot, A., et al., 2020. *Economic assessment and carbon footprint of recycling rare earths from magnets: evaluation at lab scale paving the way toward industrialization*. J. Ind. Ecol. 24, 128e137. https://doi.org/10.1111/jiec.12943.





Conclusions

LCA as a support to the ecodesign of processes

- **Larger and larger implementation** in EU
- **Hotspots and trade-offs identification, comparison** of alternatives

A range of challenges ahead to support even sounder decision-making

- **At each step of a LCA study**
  - Data is key… but also: goal and scope definition, impact assessment, and interpretation are challenging
- **Different levels of complexity**
  - From guidelines implementation...
  - … to still open research questions (e.g. resource indicators, modelling of tailings management)
- Probably just a **sample of challenges presented** here
  - Social LCA, prospective LCA, etc. (*to be completed!*) are also challenging

The way forward

- **Collaboration is the key!**
  - Process simulation
  - Reactive transport modelling
  - Economy (prices of resources)
  - …

Thank you for your attention!

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