LIMITATIONS AND RECOMMENDATIONS OF LCA DATABASES OF MINING ACTIVITIES FOR SOME RAW MATERIALS

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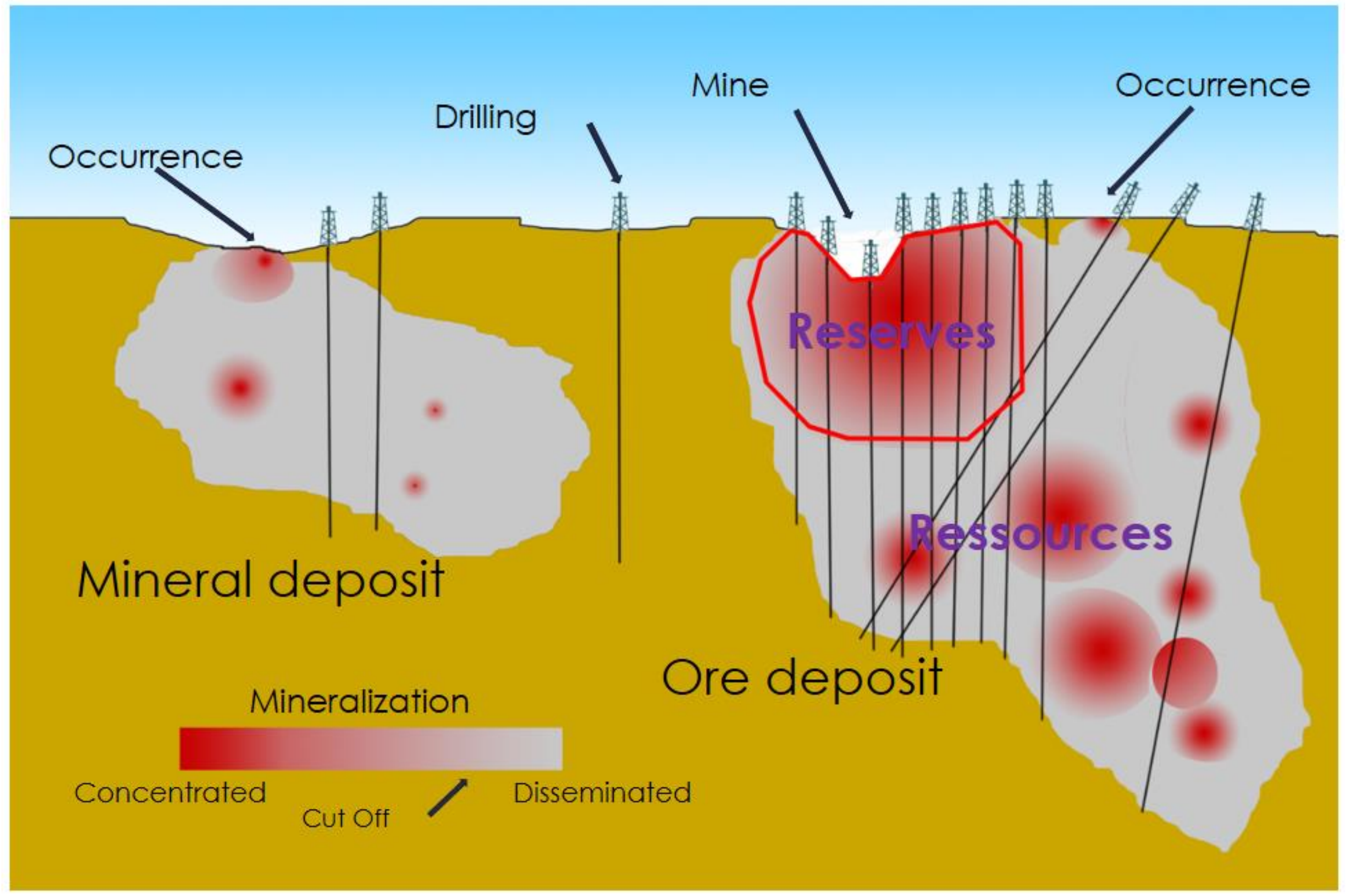
CONTENT

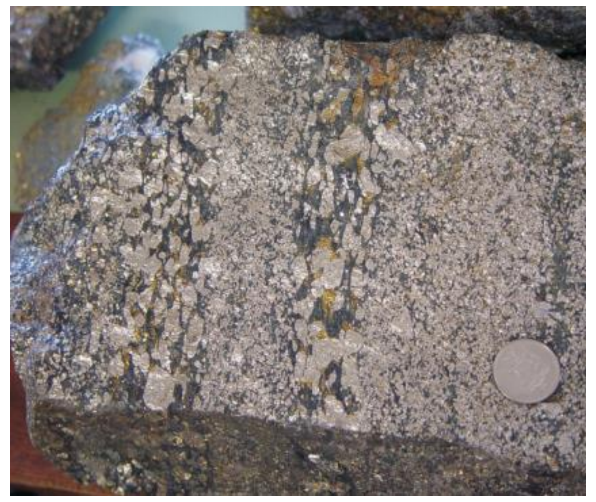
1 INTRODUCTION

Problematics linked with the analysis of the mining sector and impact on LCA

- The impact of mining is determined by the nature of the ore. It is less dependent of the metal's nature which gathers in families in the deposits. The main families are:
    - **Massive sulfides ore**
    - **Disseminated sulfides ore**
    - **Oxidized ores (massive or disseminated)**
    - **Magmatic rocks without sulfides**



- The nature of the ores depends on the deposit model.
    - **Underground mining**
    - **Open pit**



- Large mines export mineral concentrates. Metal production, in the strictest sense, is often carried out far from the extraction site and often abroad. Thus, the metal production attributed to a country is not identical to its mining production.
- The mineral associations in the deposits are very diverse. Sometimes they can even be used as an "identity card" for a deposit. The environmental impact will have to be studied on a case-by-case basis.

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Methodological approach of the study

State-of-the-art on the LCA modelling of mining activities	Analysis of the state-of-the-art	Recommendations
Life Cycle Inventories of mining activities in LCA databases LCA modelling of mining activities in the literature Complementary data Synthesis	Identification of the different limitations of the data used for the performance of an LCA Analysis if the on-going available data and work which can overcome these limitations	Formulation of recommendations regarding: • Data choice • Their use • Sensitivity analyses • Use limitations
Step 1: State-of-the-art on the LCA modelling of mining activities	**Step 2:** Analysis of the state-of-the-art	**Step 3:** Recommendations

Metals selected for the analysis:

- **<u>Copper</u>**
- Aluminum
- Lithium
- Platinum group metals
- Rare earth elements
- Nickel
- Cobalt
- Cadmium

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2 EXAMPLE OF COPPER

Copper production in 2018

Copper deposit main models	Associated metals	Operating techniques
Massive sulfide deposits Worldwide distribution Old Proterozoic shields About 16% of world reserves	Nickel Platinum Zinc - Lead	Underground mining
Porphyry copper deposit Montain ranges: Andes, Rocky Montains, Indonesia… About 53 % world reserves	Gold Molybdenum	Giant open pits
Red Bed deposits Democratic Republic of Congo About 22% world reserves	Cobalt About 70% world mining production	Underground mining

Production in 2018: **21 Mt of metal**
Resources > **3,000 Mt**

LCA databases and System boundaries

Ecoinvent V3.6

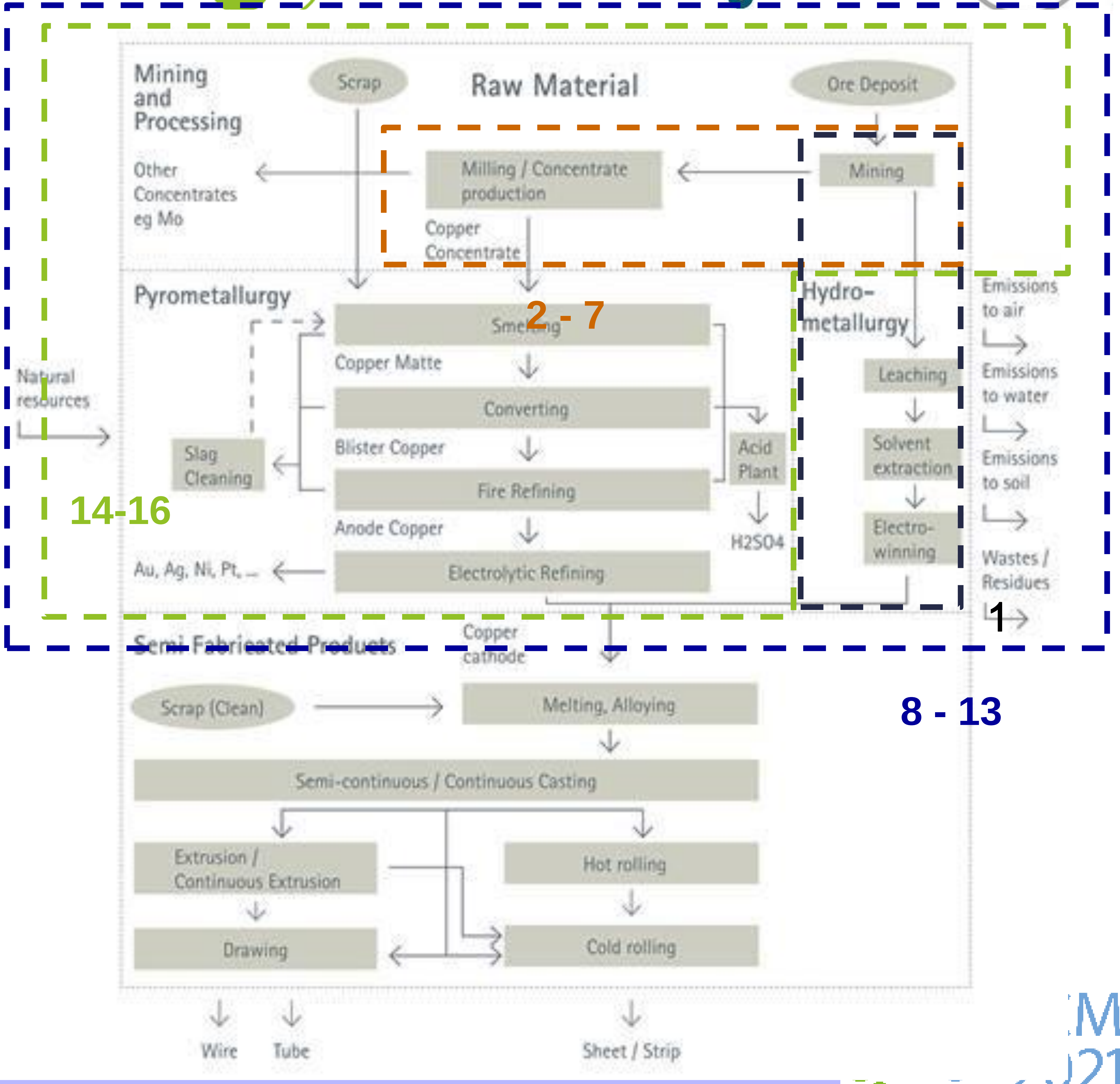
1. Copper, from solvent-extraction electro-winning {GLO}| copper production, solvent-extraction electro-winning | APOS, U

2. Copper concentrate, sulfide ore {RoW}| copper mine operation, sulfide ore | APOS, U
3. Copper concentrate, sulfide ore {RNA}| copper mine operation, sulfide ore | APOS, U
4. Copper concentrate, sulfide ore {RLA}| copper mine operation, sulfide ore | APOS, U
5. Copper concentrate, sulfide ore {RER}| copper mine operation, sulfide ore | APOS, U
6. Copper concentrate, sulfide ore {RAS}| copper mine operation, sulfide ore | APOS, U
7. Copper concentrate, sulfide ore {AU}| copper mine operation, sulfide ore | APOS, U

8. Copper {SE}| gold-silver-zinc-lead-copper mine operation and refining | APOS, U
9. Copper {RoW}| gold-silver-zinc-lead-copper mine operation and refining | APOS, U
10. Copper {ZA}| platinum group metal mine operation, ore with high rhodium content | APOS, U
11. Copper {RU}| platinum group metal mine operation, ore with high palladium content | APOS, U
12. Copper {GLO}| nickel mine operation, sulfidic ore | APOS, U

GaBi V8.7

13. Copper (99.99%; cathode) from pyrometallurgical (including secondary) and hydrometallurgical production GLO
14. Copper mix (99,999% from electrolysis); from electrolysis; consumption mix, to consumer GLO
15. Copper (99.999%; electrolyte copper) production; technology mix; production mix, at plant IN
16. Copper; from electrolysis; production mix, at plant; 99,999% Cu SE



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Use of resources : contribution of raw materials in Ecoinvent and Gabi datasets

GaBi processes

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Summary of the databases analysis for Cu

Topic	Specific considerations
Data access and transparency	• In the free documentation, the **available data is not substantial.** • The public consultation of the payable databases does not allow the access to the specificities of the aggregated inventory or simply to the supplementary data. • The documentation **is not standardized.**
Representativeness	• The geographic coverage is **partial,** but a lot of different locations are available. Some coproducts are missing.
Allocation	• In Ecoinvent, the chosen system modelling is the « APOS » method. It uses the average production and prefers the **economic allocation**. It is **difficult to extrapolate the specific allocation** used in each unit process, since numbers in the inventory flows are already allocated. • In GaBi the only available modelling is **attributional**.
Obsolescence	• Validity period until **2000-2005**. • The **technological evolution** of the copper mining industry is **slow**. • The increasing exploitation makes the raw material **less and less accessible** which means more efforts for the mining (economic and technological). • Some burgeoning technologies will have a considerable role in a near future because of **their low cost and environmental impact**.
Completeness and scope	• Some inventories **are less complete compared with others** even with the same denomination. • Datasets often simplify the variety of mines and existing mining technologies.
Likelihood	• After a confrontation with the literature and a discussion with mining experts, it seems that the datasets from ecoinvent and GaBi are **credible** (evaluation by order of magnitude).

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Literature review

Hong et al., 2017

Life cycle assessment of copper production: a case study in China

➔ FU: **1 ton of refined copper.**

➔ **Industrial data** collected from Chinese production plants.

➔ Geographical coverage: **China.**

➔ **Inventory:** energy, water, ancillary materials, chemicals consumption; land use; direct emissions to air and water; solid waste flows.

➔ Recent data representative of the **Chinese copper mining and metallurgical industry** (3rd producer of copper ore, and 1st producer of copper metal worldwide).

Case studies	Carbon footprint (t CO2 eq./t Cu conc. Or Refined)	Description
Norgate and Haque, 2010	0,63	Copper concentrate in Australia
Song et al., 2017	0,69	Copper concentrate in Norway
Giurco et al., 2001	15	Copper refined, from pyrometallurgy, world
Giurco et al., 2001	20	Copper refined, from hydrometallurgy, world
Norgate and Haque, 2007	3,3	Copper refined, from pyrometallurgy, Australia
Norgate and Haque, 2007	6,2	Copper refined, from hydrometallurgy, Australia
Yang et al., 2014	9,02	Copper refined, from pyrometallurgy, China
Yang et al., 2014	3,08	Copper refined, from hydrometallurgy, China
Hong et al., 2017	1,91	Copper refined, from pyrometallurgy, China

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3 CONCLUSIONS

Specific recommendations

Zinc and Cadmium

Modelling of the product	Foreground process	Background process
Zinc concentrate	• Use specific data or from literature (e.g., Van Genderen et al., 2016).	• Use the ecoinvent "GLO" process and adapt the energy mix to the country of origin if it is known.
Cadmium sludge	• Avoid the use of processes resulting from molybdenum production. • Use specific data.	• Avoid the use of processes resulting from molybdenum production. • Use the "CA-QC" or "GLO" ecoinvent process, adapt the energy mix to the country of origin if known. • Adjust the allocation factors according to the scope of the study. • Be careful when interpreting the results if cut-off is used.
Cadmium	• Use specific data or from literature (e.g., Fthenakis et al., 2009).	• Use the "CA-QC", "GLO" or "market for" ecoinvent process and adapt the energy mix to the country of origin if known. • Be careful when interpreting the results if cut-off is used.

Rare Earth

Product \ Origin		China	Rest of the World	Unknown
Rare Earth concentrate		Use the « **CN** » **ecoinvent dataset**.	Use the « **RoW** » **ecoinvent dataset** and modify the electricity mix according to the specific origin.	Modify the « **market for** » **ecoinvent dataset** with the current market share between China and the rest of the world.
Rare Earth Oxide	Cerium Dysprosium Neodymium Samarium Europium Gadolinium	Use the « **CN** » **ecoinvent dataset** and modify the economic allocation according to the current market values of the coproducts.	Use the « **RoW** » **ecoinvent dataset** and modify the economic allocation according to the current market values of the coproducts and adapt the electricity mix.	Modify the « **market for** » **ecoinvent process** and the economic allocation of the « CN » and « RoW » processes with the current market share and market values.
	Other **heavy rare** earth	Use specific data or buy the GaBi extension (a priori no available data in the literature).		
Rare Earth Metals		Use data from the literature (e.g. Vahidi and Zhao, 2018) or buy the GaBi extension.		

General limitations of the databases

Limits linked with the modelling in the LCA approach:

- The **allocation methodology is often not described in details**
- Data are **sometimes aggregated**
- The support documentation from the databases is not totally transparent: **not complete** for the **limits of the systems**, the **type of mines** considered, the **proxies used** etc.

Limits linked with the variety and updating of LCA databases:

- The **geographic representativeness** is not complete,
- A **relative obsolescence** and a **default inclusion of new technologies.**

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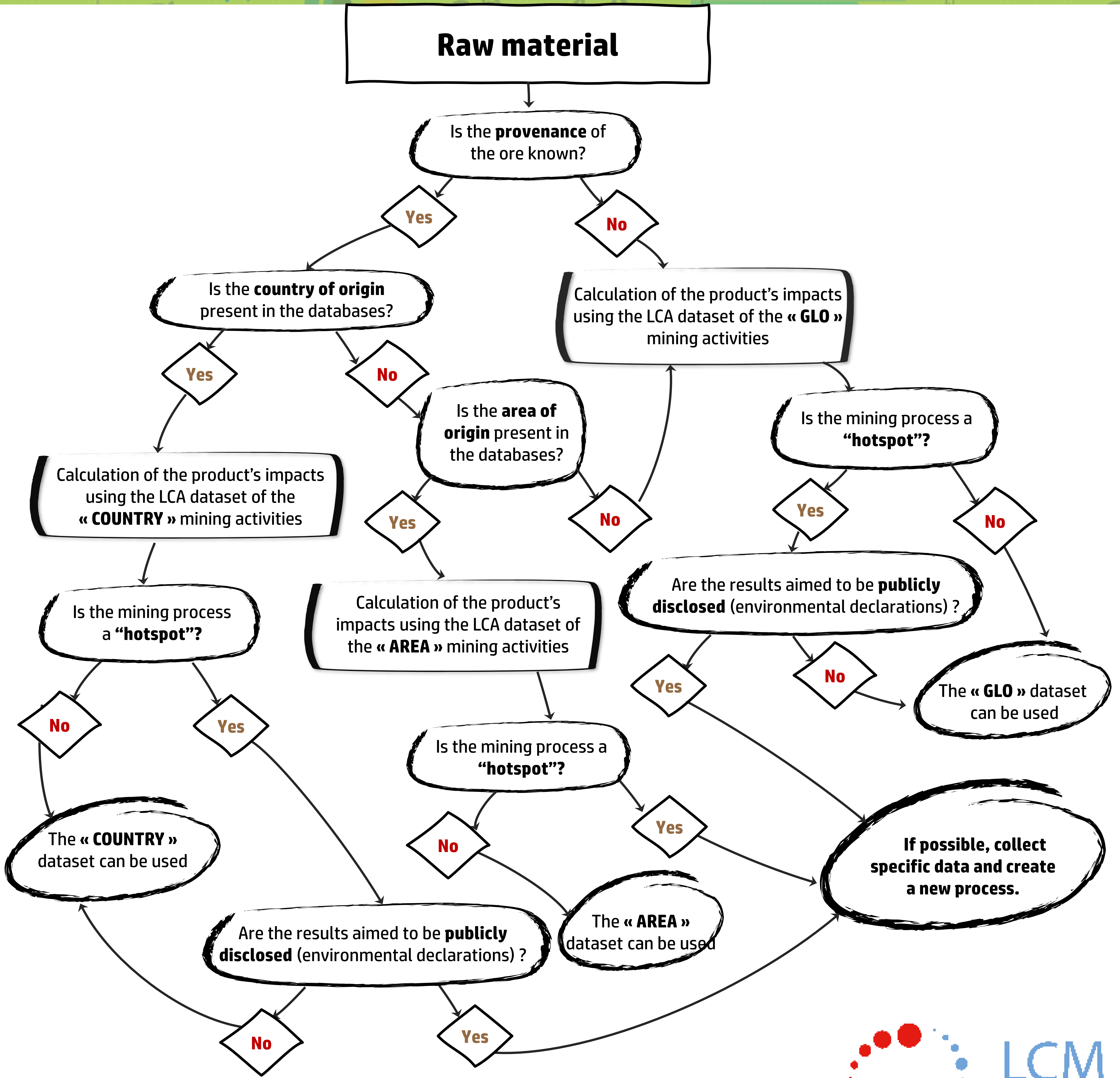
General recommendations

- Choose processes in which the **system boundaries** are adapted to the product of interest (concentrated ore, refined metal, inclusion of transportation).
- Choose processes which are **representative of the supply country** (when available), or of the geographic area of interest. It can lead to an important difference in the amount of LCI inputs and impacts caused by the **used electricity mixes**.
- In case of refined materials, choose processes considering the specific **type of metallurgical treatment**.



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THANK YOU FOR YOUR ATTENTION

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