



RawMaterials

Connecting matters



2nd Seminar – Delft, the 6th December 2022

Life Cycle Assessment of VALOMAG recycling routes

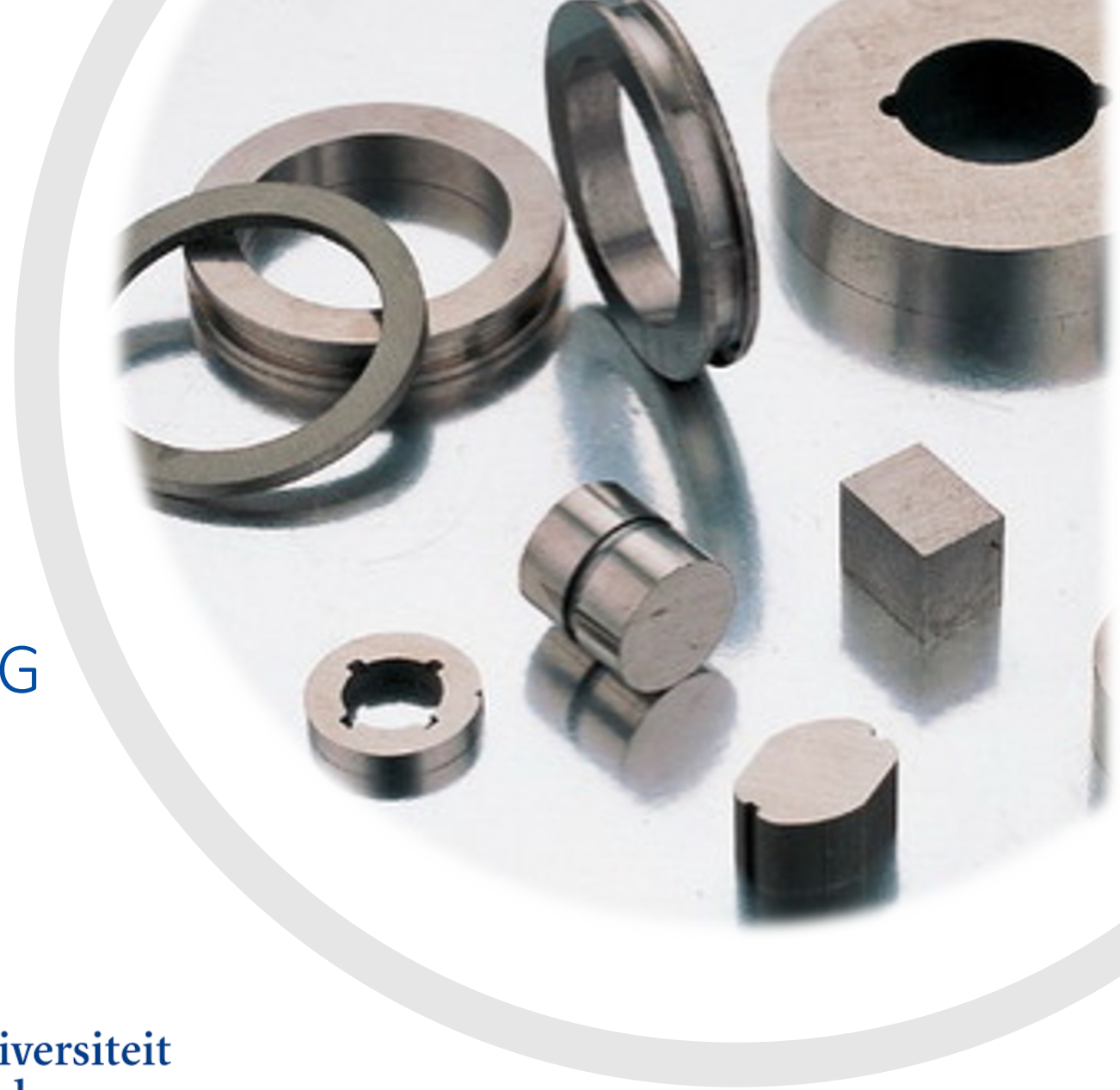
Zhijie Li | Delft



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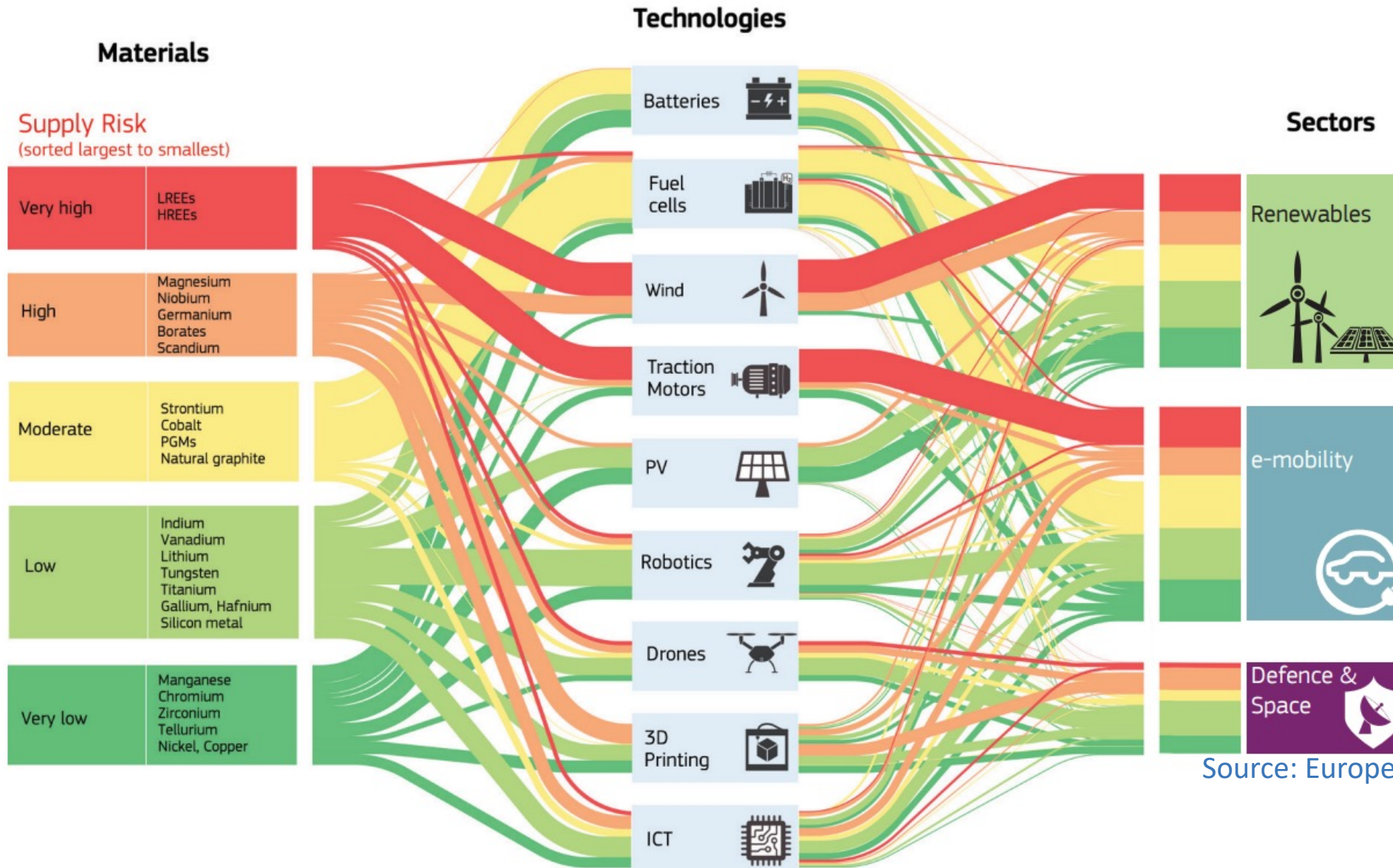
SUMMARY

1. Challenges in rare earth magnets
2. LCA methodology
3. LCA of virgin RE magnet production
4. LCAs of VALOMAG recycling technologies



Challenges in rare earth magnets:

Vulnerable supply of critical metals



Source: European Commission, 2018.

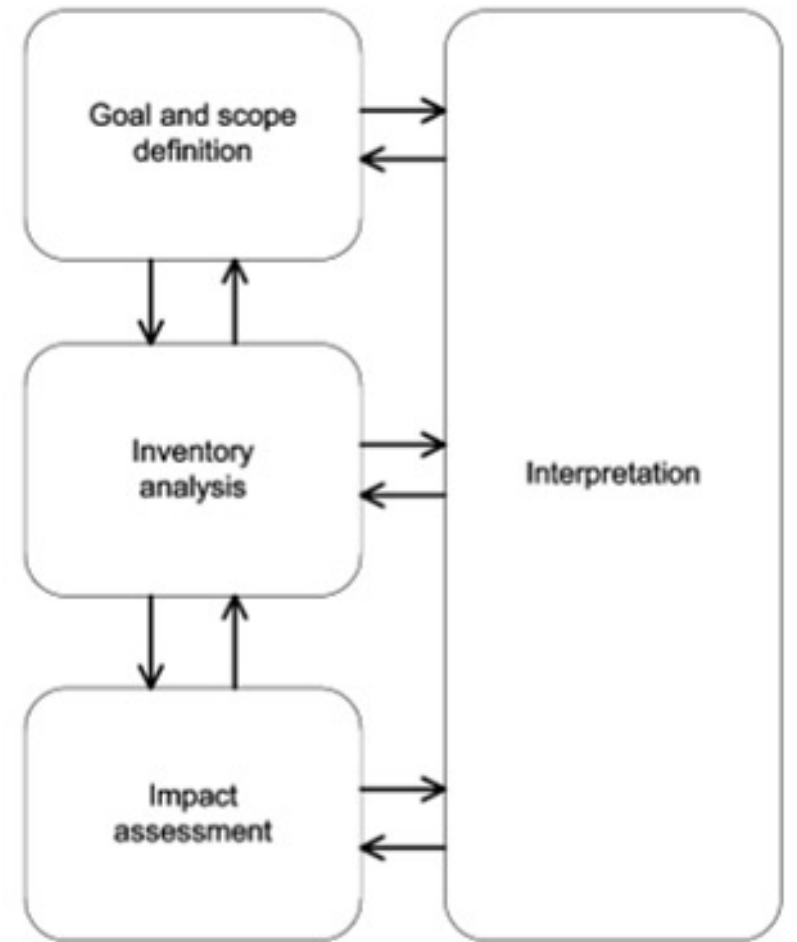
Challenges in rare earth magnets:

Environmental concern about rare earth mining and manufacturing



Life cycle assessment (LCA) methodology

- “Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle”
- Necessary steps:
 - Goal and scope definition
 - Life cycle inventory
 - Impact assessment
 - Interpretation



Goal and scope definition

- Research question:


What is the environmental impacts of producing 1kg primary NdFeB magnets

compared to

1kg of equivalent secondary Nd magnets from different VALOMAG recycling routes?



Life cycle inventory

Edit Activity Description Show Uncertainty 

Name: REE acid roasting, baseline

Location:

Database: REM2014

Products:


Amount	Unit	Product	Formula
0 1	kilogram	61% REO RE2(SO4)3, at acid roasting, primary, baseline	

Technosphere Inputs:

Amount	Unit	Product	Activity
0 0.171	ton kilometer	transport, freight, lorry 16-32 metric ton, EUROS	market for transport, freight, lorry 16-32 metric ton
1 3.08	ton kilometer	transport, freight train	market for transport, freight train
2 1.55	kilogram	sulfuric acid	sulfuric acid production
3 6.59	megajoule	heavy fuel oil, burned in refinery furnace	market for heavy fuel oil, burned in refinery furnace
4 0.505	kilogram	sulfidic tailings, generic	treatment of sulfidic tailings, generic, tailings ...
5 1.11	kilogram	61% REO concentrate from beneficiation, primar...	beneficiation of REE ore, baseline_1

Biosphere Flows:

Amount	Unit	Flow Name	Compartments	Database	Formula
0 0.154	kilogram	Carbon dioxide, fossil	air - urban air close to ground	biosphere3	
1 0.00911	kilogram	Sulfur dioxide	air - non-urban air or from high stacks	biosphere3	
2 0.0245	kilogram	Hydrogen fluoride	air	biosphere3	

Edit Activity Description Show Uncertainty 

Name: vacuum sintering of NdFeB, recycled, hand picking

Location:

Database: REM2014

Products:

Amount	Unit	Product	Formula
0 1	kilogram	sintered NdFeB, recycled, hand picking	

Technosphere Inputs:

Amount	Unit	Product	Activity	Location
0 2.4	kilowatt hour	electricity, medium voltage	market for electricity, medium voltage	GB
1 1	kilogram	pressed NdFeB, recycled, hand picking	aligning and pressing of NdFeB, recycled, hand picking	Unknown

Biosphere Flows:

Amount	Unit	Flow Name	Compartments	Database	Formula
0 0.0005	cubic meter	Water, unspecified natural origin	natural resource - ...	biosphere3	
1 0.204	kilogram	Carbon dioxide, fossil	air	biosphere3	
2 0.000527	kilogram	Nitrogen oxides	air	biosphere3	
3 3.76e-05	kilogram	Hydrogen chloride	air	biosphere3	
4 2.25e-06	kilogram	Hydrogen fluoride	air	biosphere3	
5 0.0257	kilogram	Carbon monoxide, fossil	air	biosphere3	
6 0.00126	kilogram	Sulfur dioxide	air	biosphere3	
7 1.93e-08	kilogram	Cadmium	air	biosphere3	
8 2.52e-08	kilogram	Chromium	air	biosphere3	
9 7.66e-08	kilogram	Copper	air	biosphere3	
10 1.93e-08	kilogram	Nickel	air	biosphere3	
11 8.26e-07	kilogram	Zinc	air	biosphere3	
12 4.72e-07	kilogram	PAH, polycyclic aromatic hydrocarbons	air	biosphere3	
13 3.23e-06	kilogram	Lead	air	biosphere3	
14 1.54	megajoule	Heat, waste	air	biosphere3	
15 7e-12	kilogram	Dioxins, measured as 2,3,7,8-...	air	biosphere3	
16 7.57e-08	kilogram	Mercury	air	biosphere3	
17 1.15e-08	kilogram	Vanadium	air	biosphere3	
18 0.000206	kilogram	Particulates, > 2.5 um, and < 10um	air	biosphere3	
19 0.000138	kilogram	Hydrocarbons, aliphatic, alkanes, ...	air	biosphere3	
20 1.93e-07	kilogram	Manganese	air	biosphere3	



Welcome to the Activity Browser !

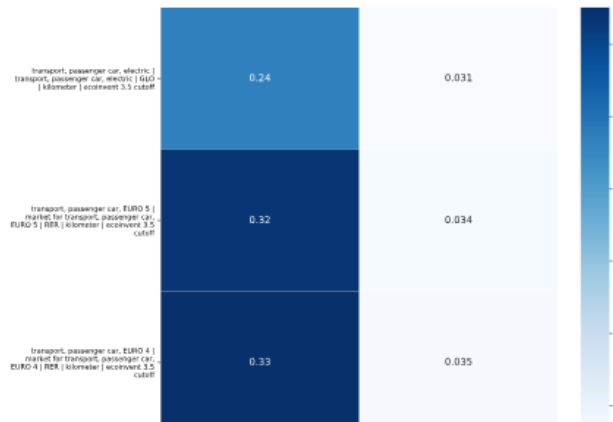
The [Activity Browser](#) is an open source graphical user interface designed to increase the productivity when working with the [Brightway2](#) advanced life cycle assessment framework.

Key features:

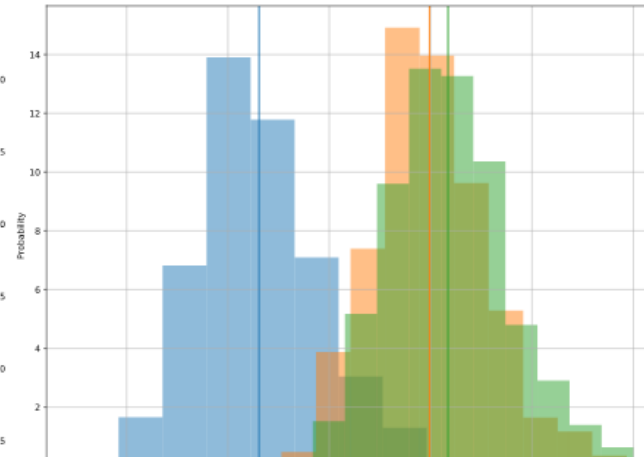
- Manage brightway2 projects, databases and activities (increasing your productivity with brightway)
- Calculate fast LCA results (use "calculation setups" to calculate LCA results for several reference flow and impact categories at once)
- Easily plot and export your LCA results (contribution analyses, Monte Carlo simulations)
- Visualize your results in Sankey diagrams or explore your database with the Graph Explorer

Examples

CA results overview



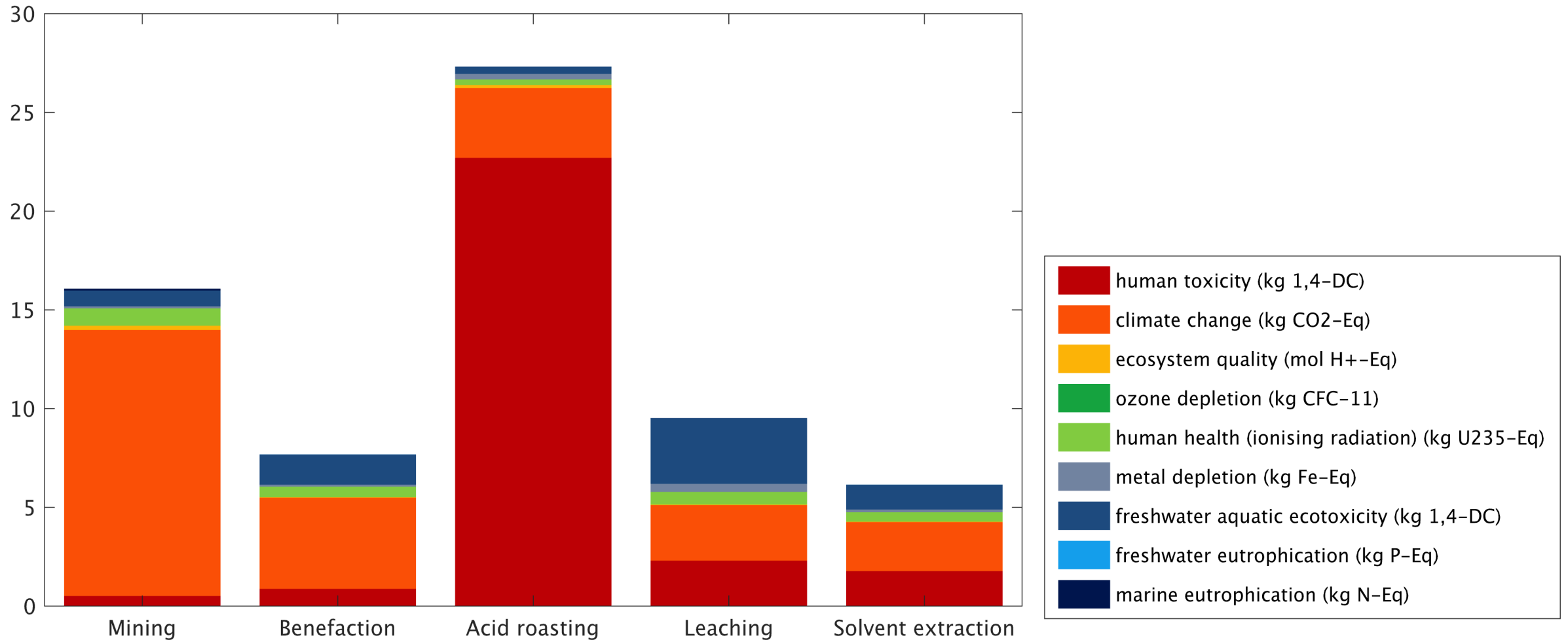
Monte Carlo simulation



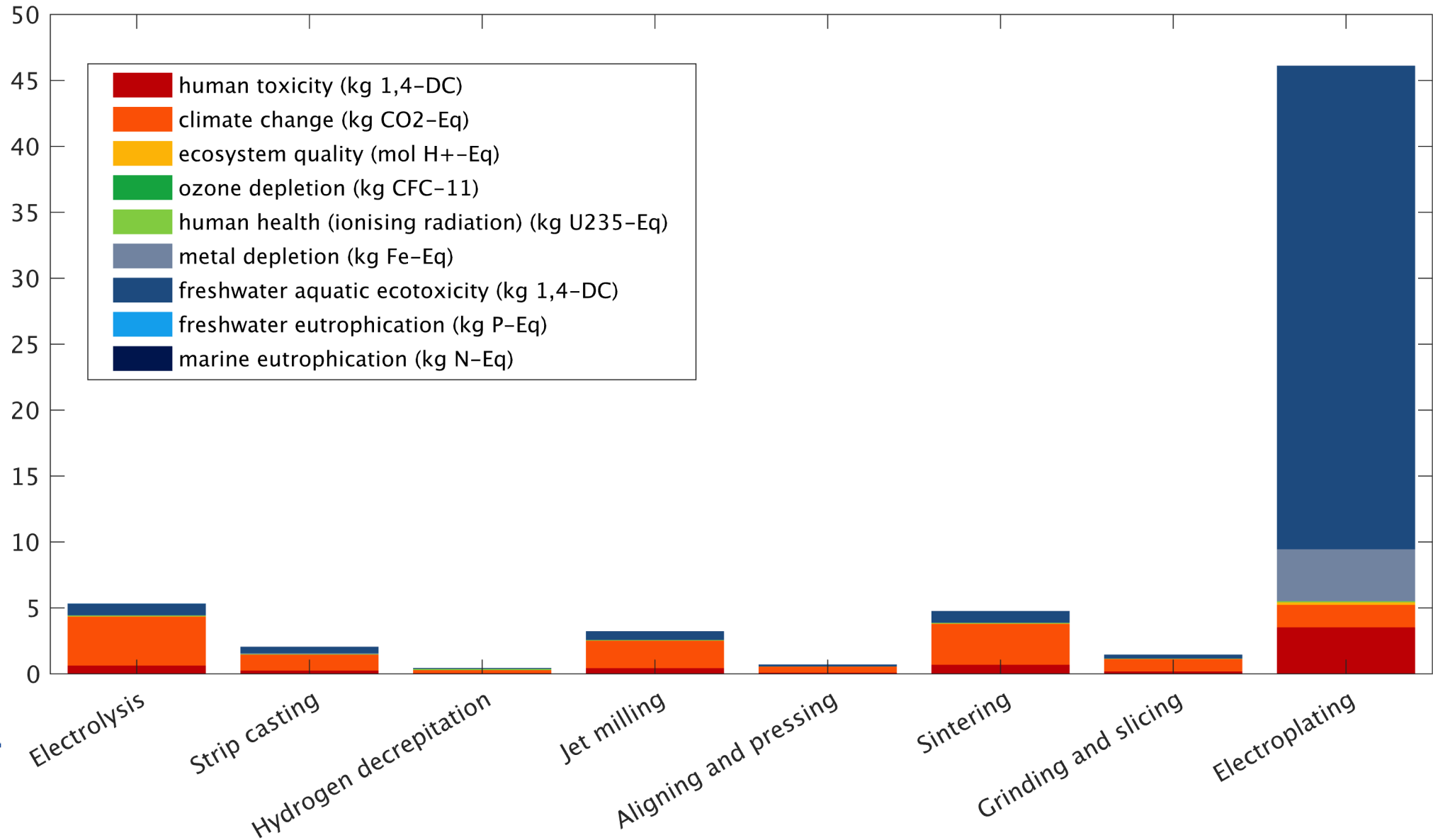
Sankey diagrams



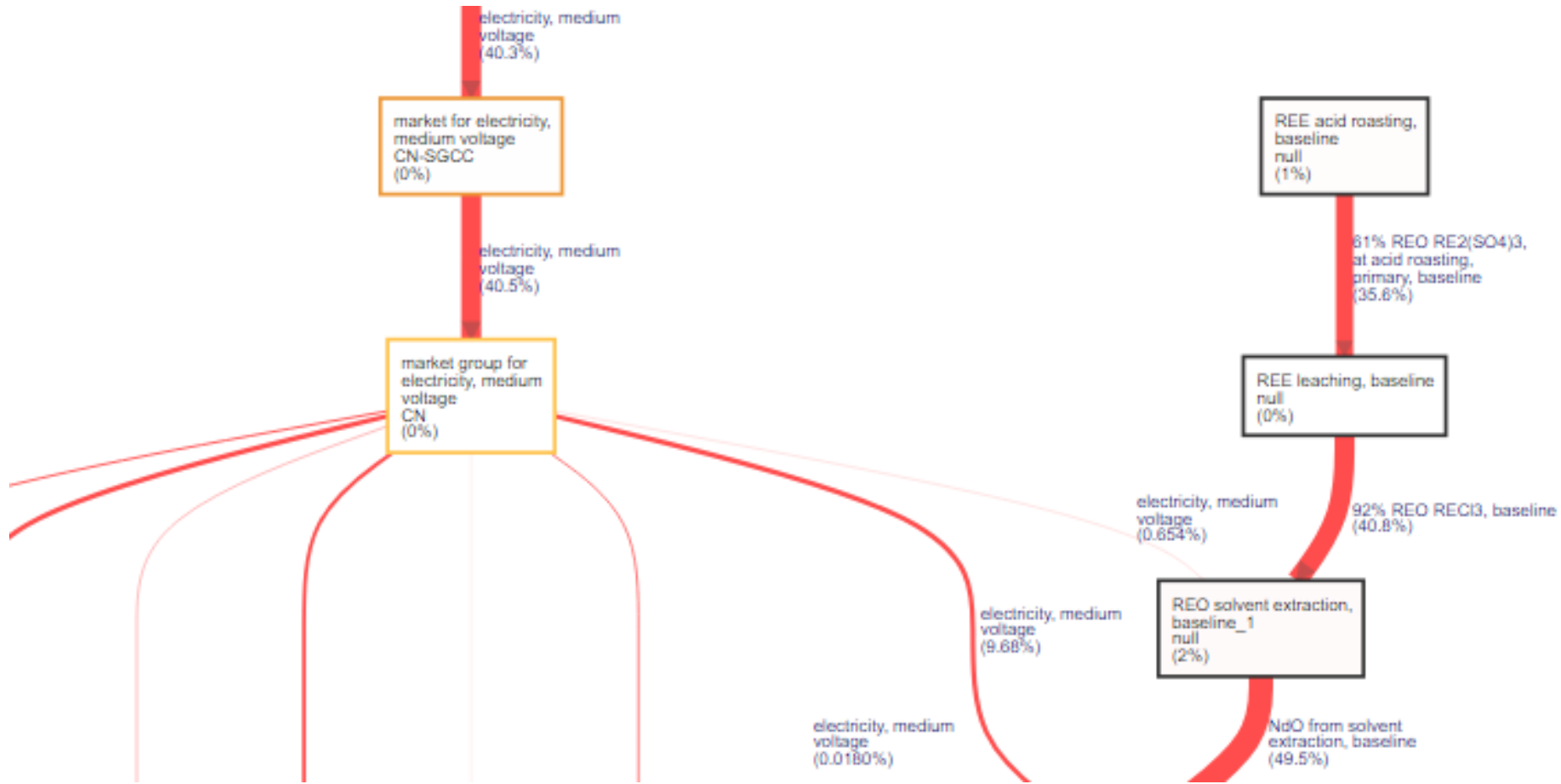
Baseline LCA – Processes of virgin Rare Earth Oxides production



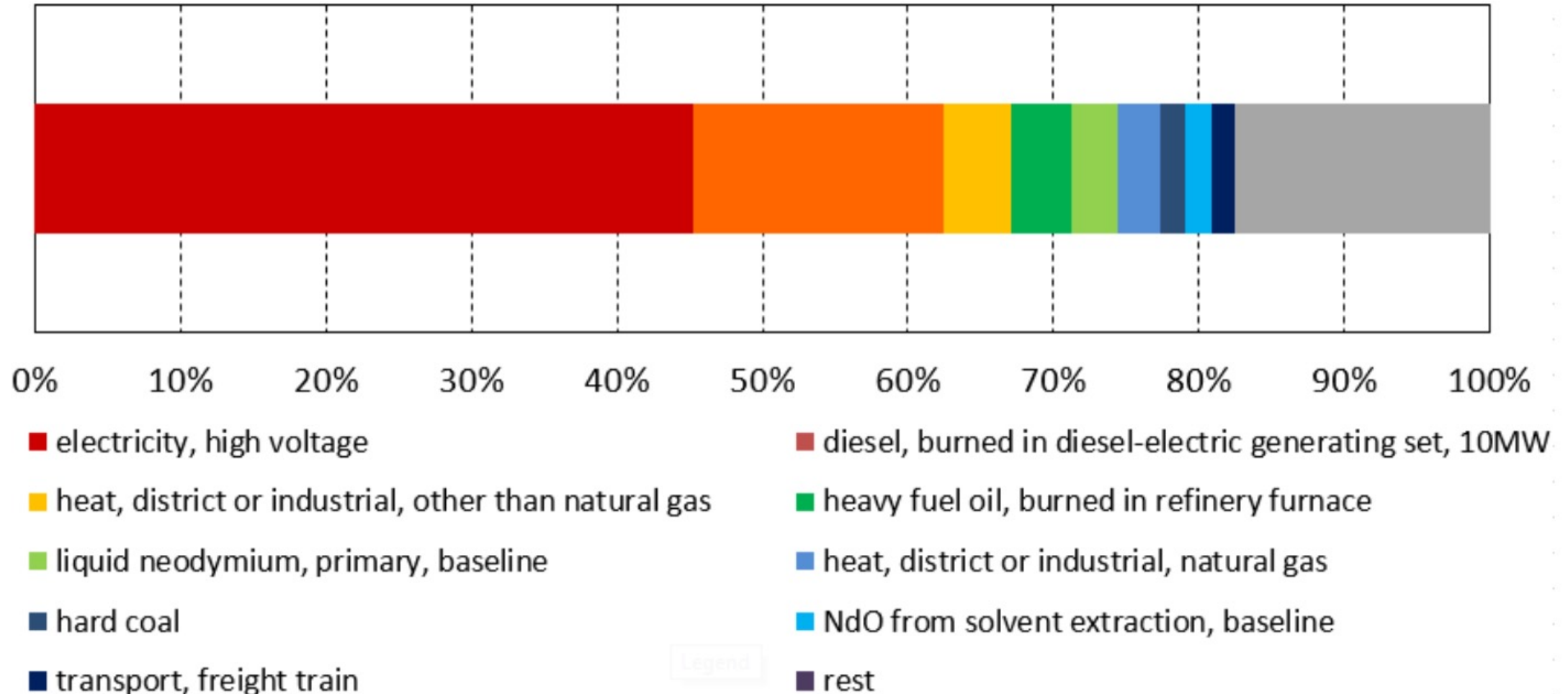
Baseline LCA – Processes from virgin REO to RE magnets



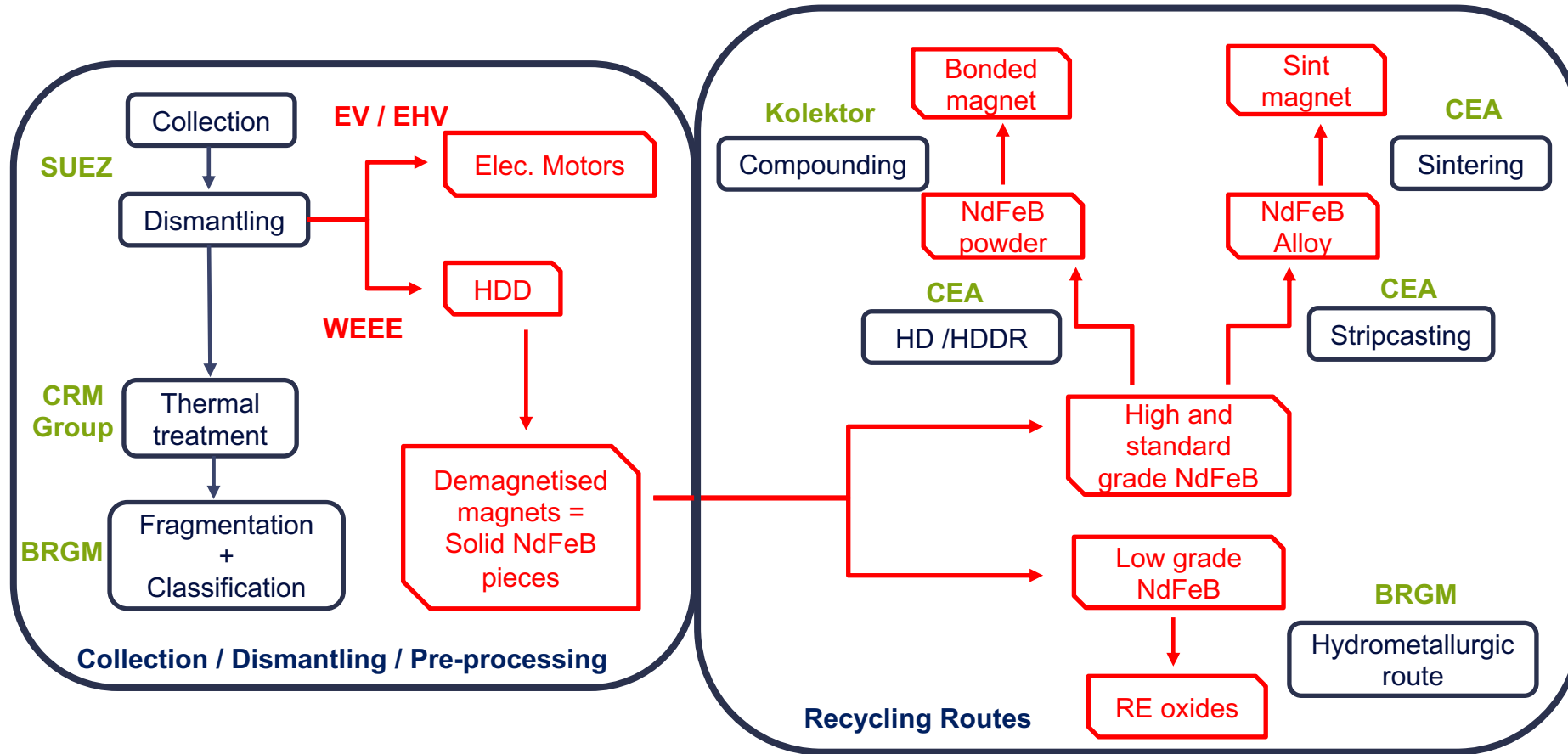
LCA results in Sankey diagram



LCA results of primary magnets: process contributions to climate change

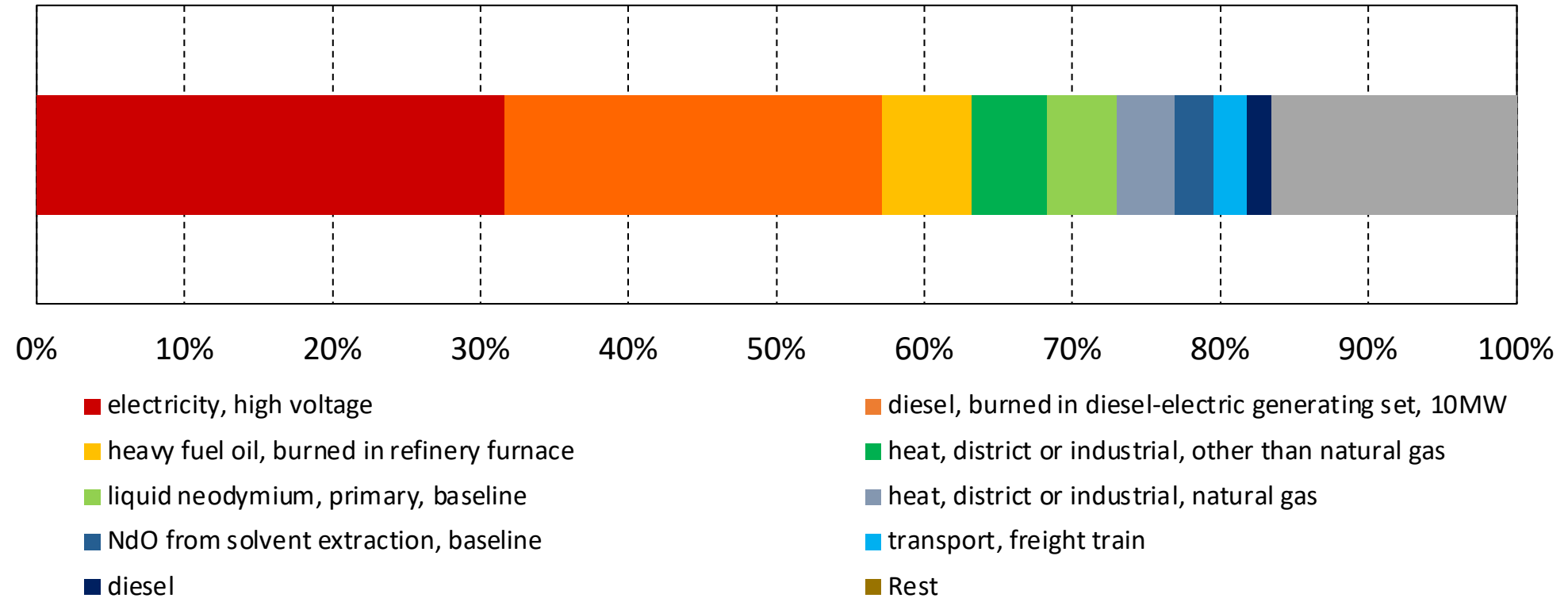


Recycling routes in VALOMAG

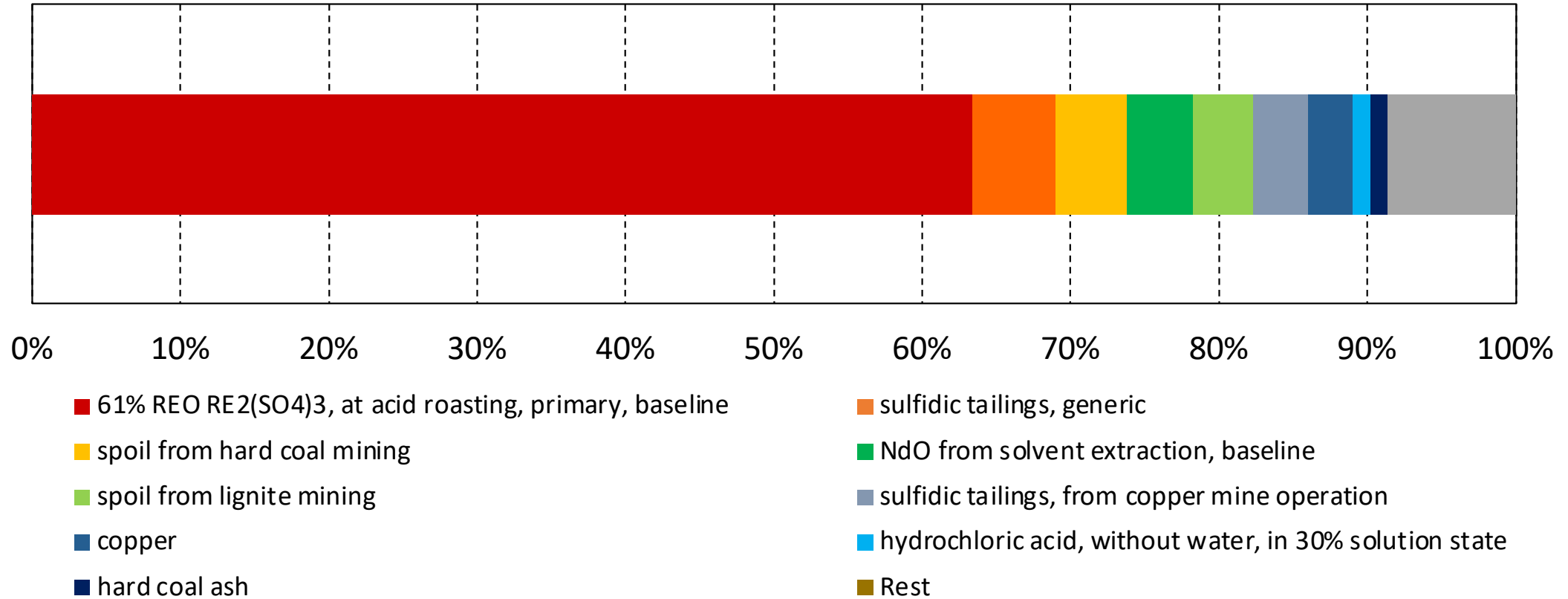


Legend: Partner involved (green text), Materials (red box), Process step (black box)

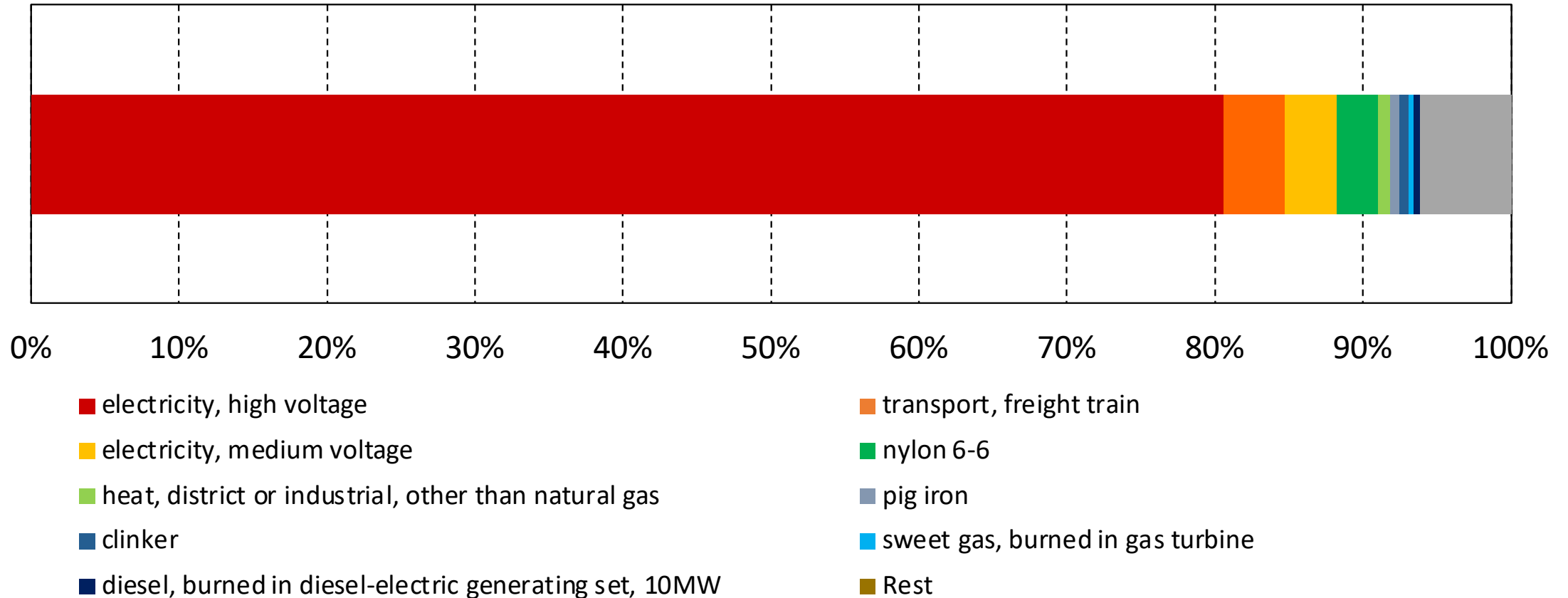
LCA results of VALOMAG sintered magnet route: process contributions to climate change



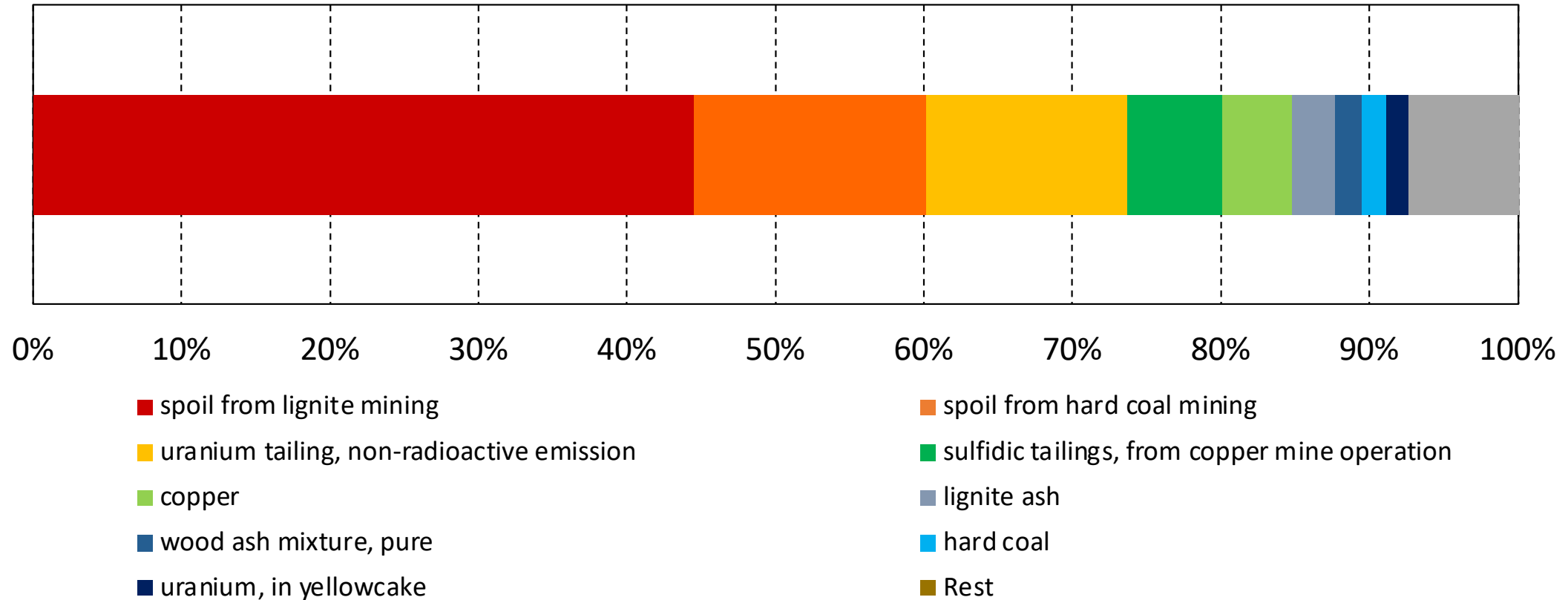
LCA results of VALOMAG sintered magnet route: process contributions to human toxicity



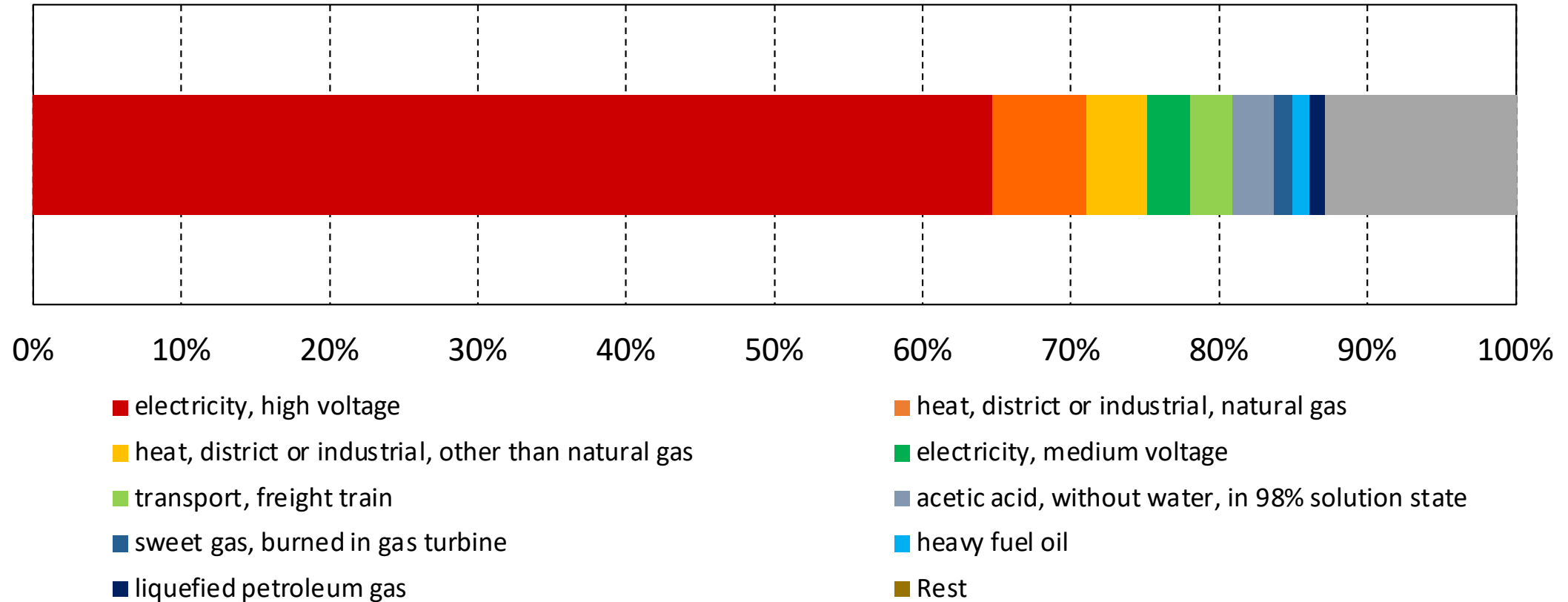
LCA results of VALOMAG bonded magnet route: process contributions to climate change



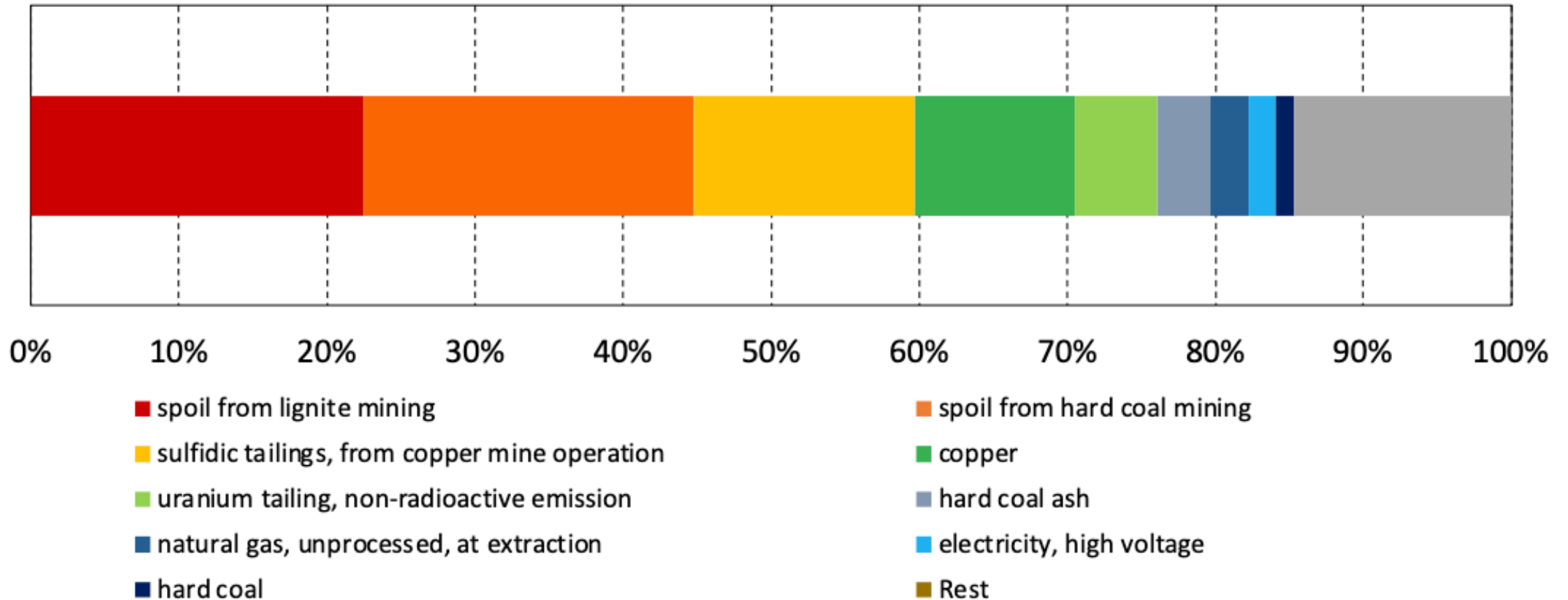
LCA results of VALOMAG bonded magnet route: process contributions to human toxicity



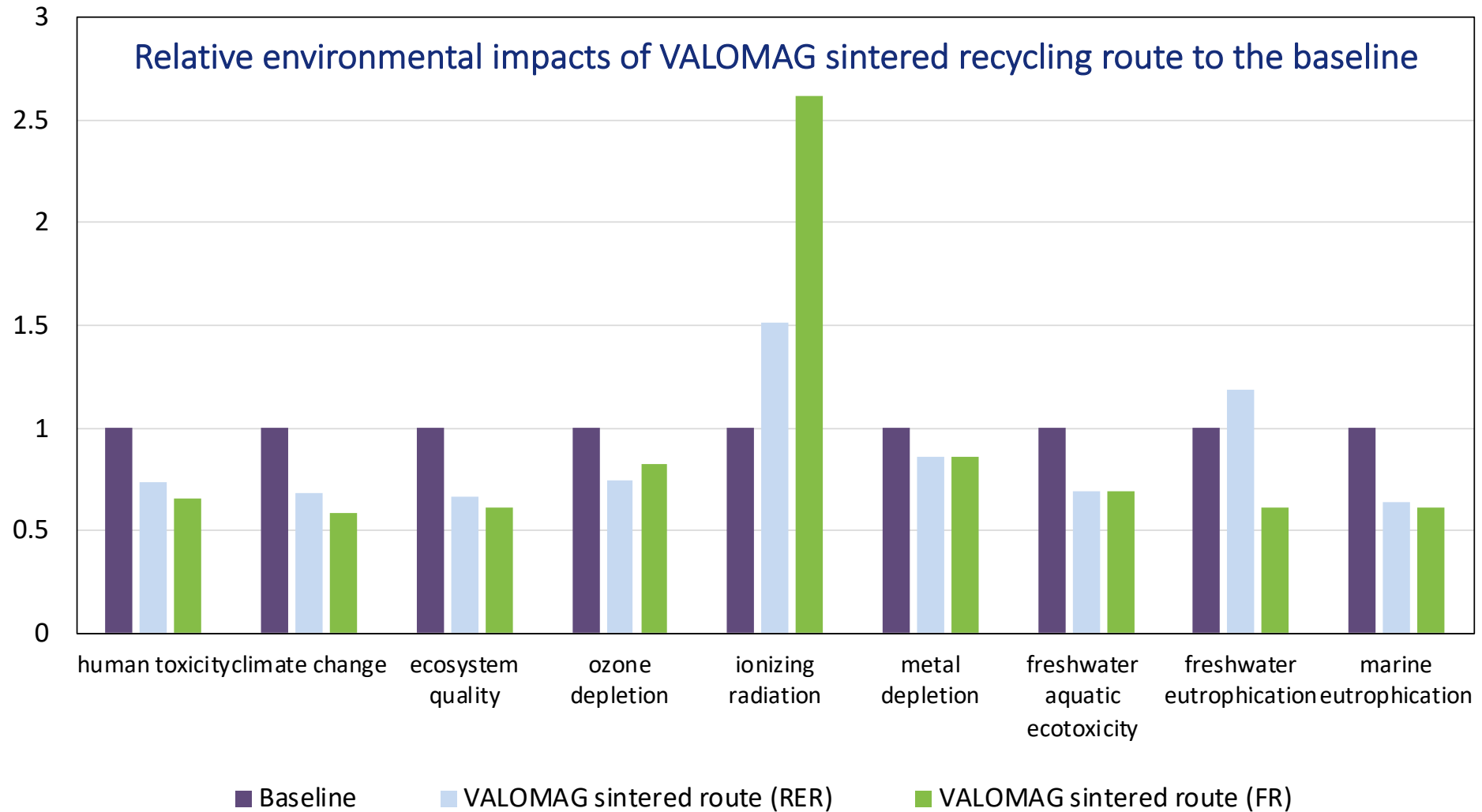
LCA results of VALOMAG hydrometallurgical route: process contributions to climate change



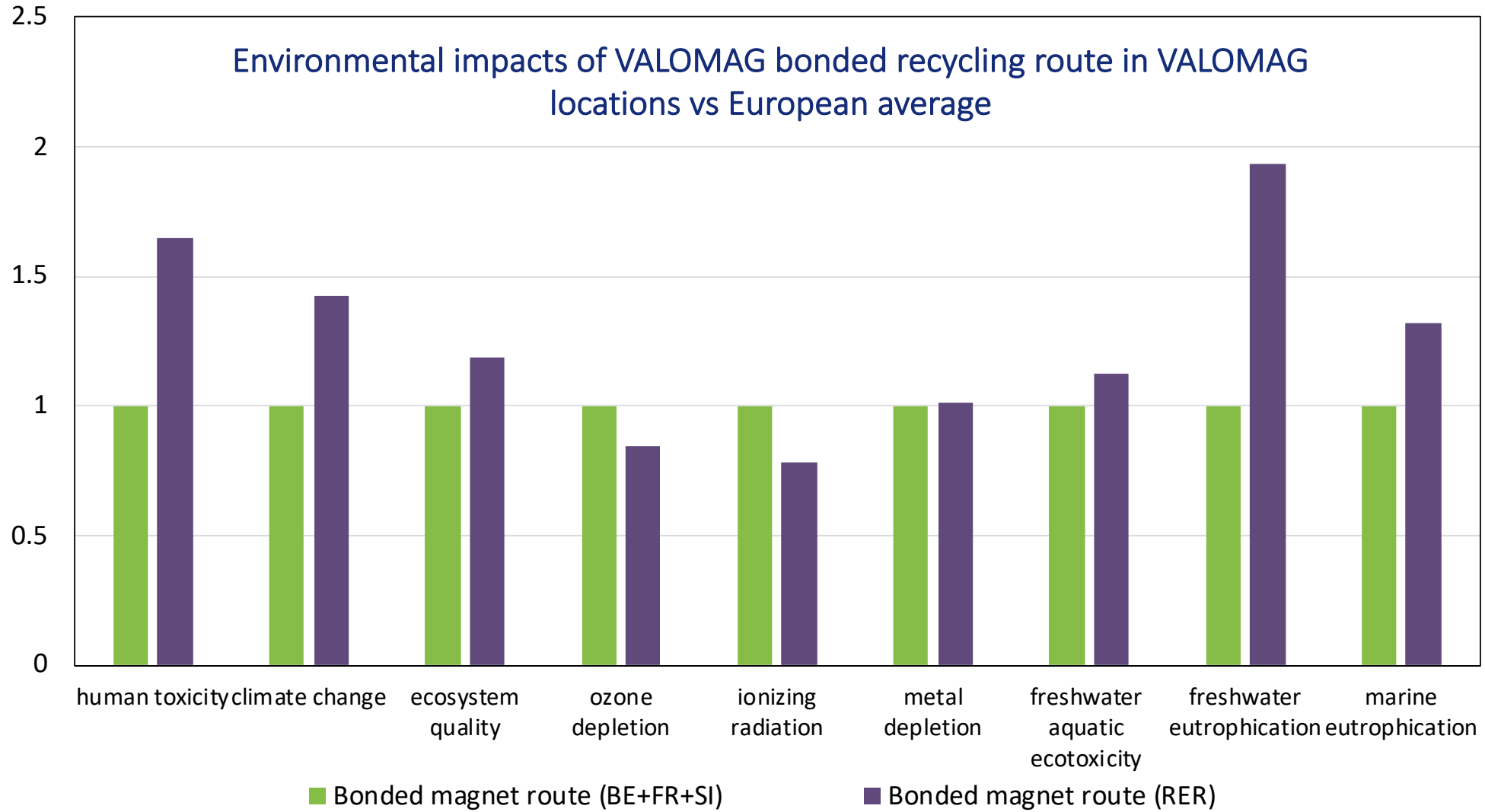
LCA results of VALOMAG hydrometallurgical route: process contributions to human toxicity



Relative impacts of VALOMAG sintered magnet recycling technology



Environmental impacts comparison between locations-Bonded magnet route



Future recycling of rare earth magnets

- Recycling helps to
 - strengthen the RE supply chain resilience.
 - lower the potential environmental impacts of primary RE magnet production.
- RE products call for more attention to “design for recycling”.
- Further technology upscaling can expect even better environmental performance.



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