Materials innovation institute

the innovation and valorization formula

Principle of LCA as applied to Processing and Recycling

Benjamin Sprecher

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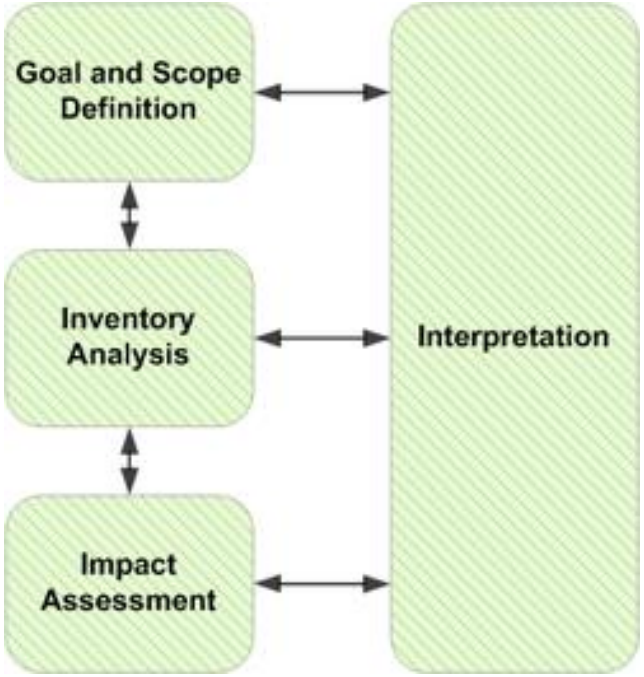
Contents

- Life Cycle Assessment: a quick primer
- An overview of an LCA of NdFeB magnets

LCA methodology

Necessary steps:

- Goal and scope definition
- Life cycle inventory
- Impact assessment
- Interpretation



Goal and scope definition

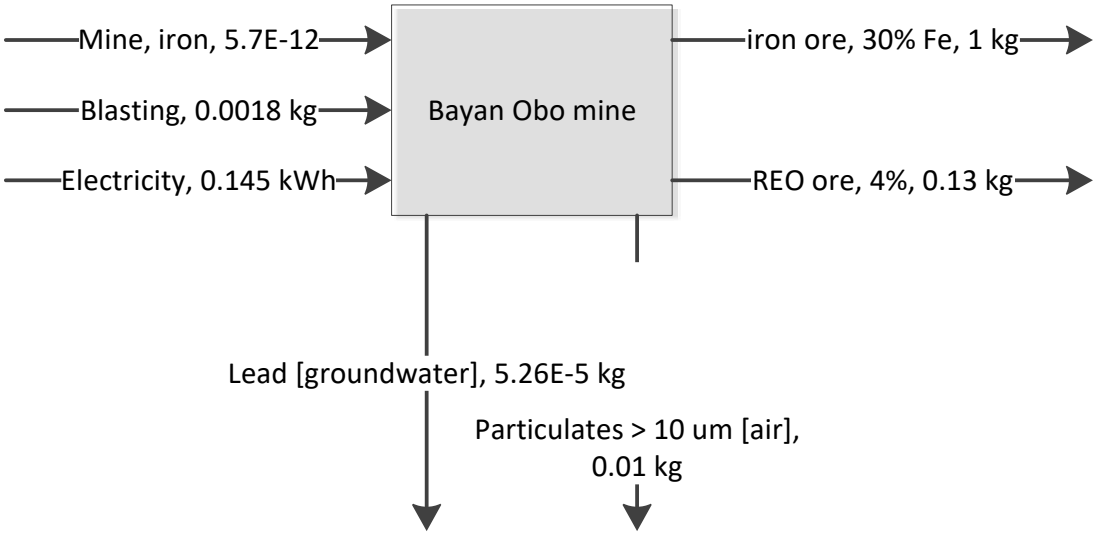
- Research question: what is the environmental impact of NdFeB magnets compared to…?

- Assumptions
- Limitations
- Allocation method

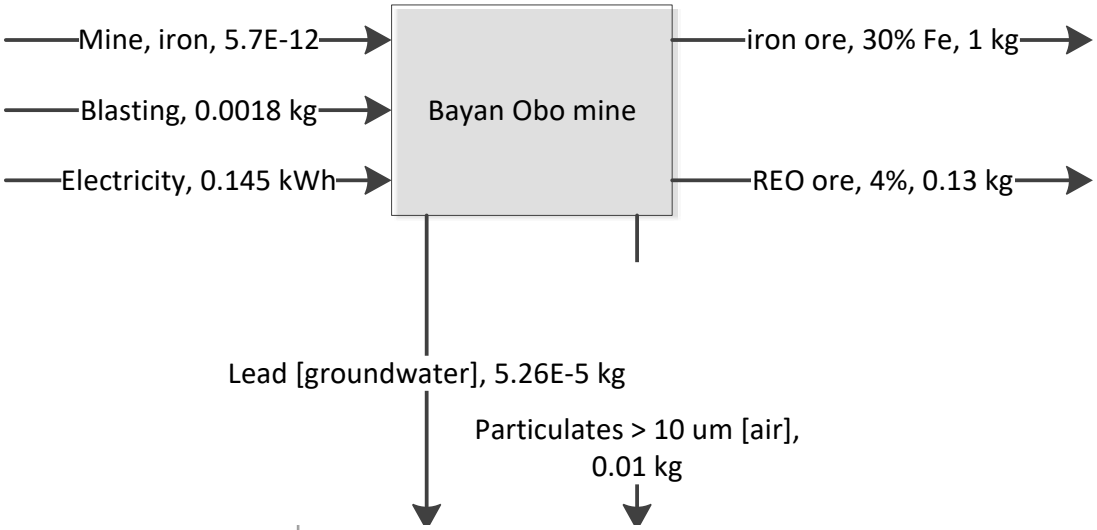
Life cycle inventory of the production of rare earths and the subsequent production of NdFeB rare earth permanent magnets.
Environmental science & technology 48.7 (2014): 3951-3958.

goal and scope – life cycle inventory – impact assessment – interpretation

Mining


Mine, iron, 5.7E-12
Blasting, 0.0018 kg
Electricity, 0.145 kWh
Bayan Obo mine
iron ore, 30% Fe, 1 kg
REO ore, 4%, 0.13 kg
Lead [groundwater], 5.26E-5 kg
Particulates > 10 um [air], 0.01 kg

Mining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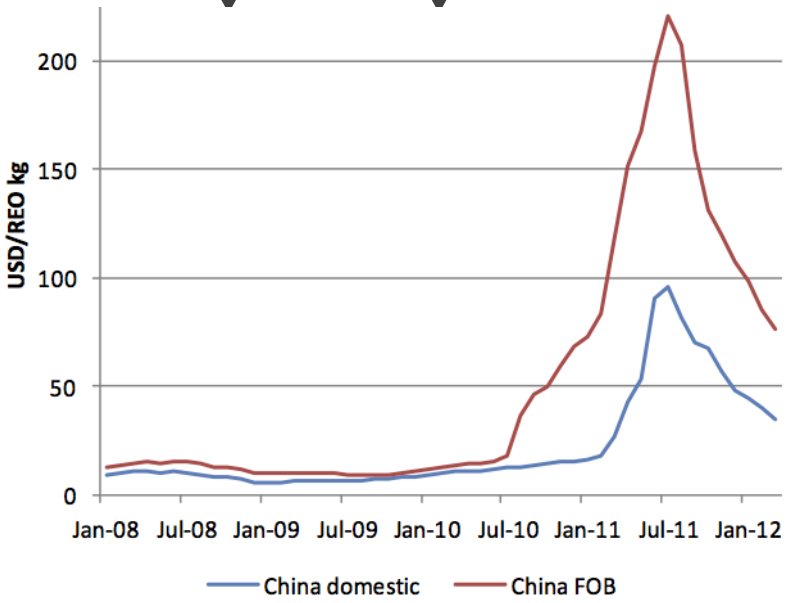
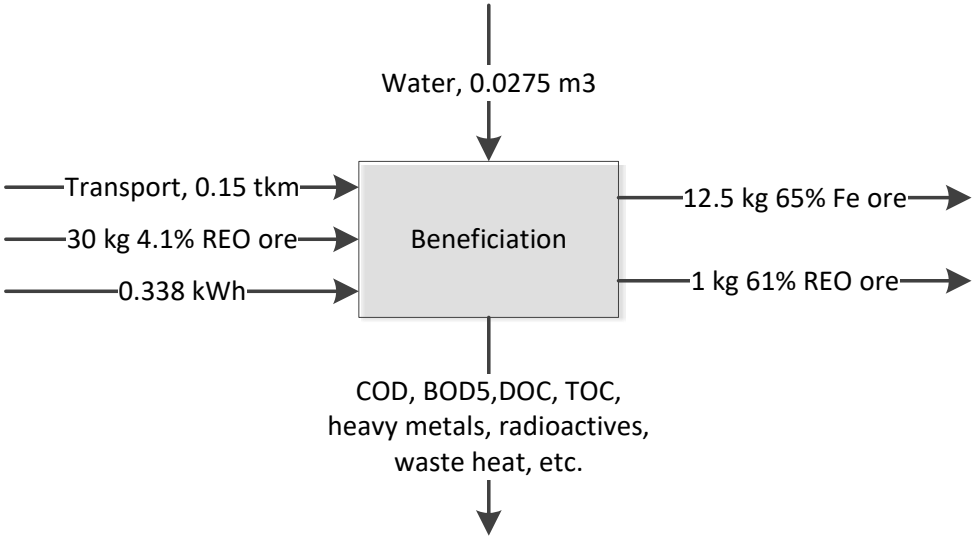
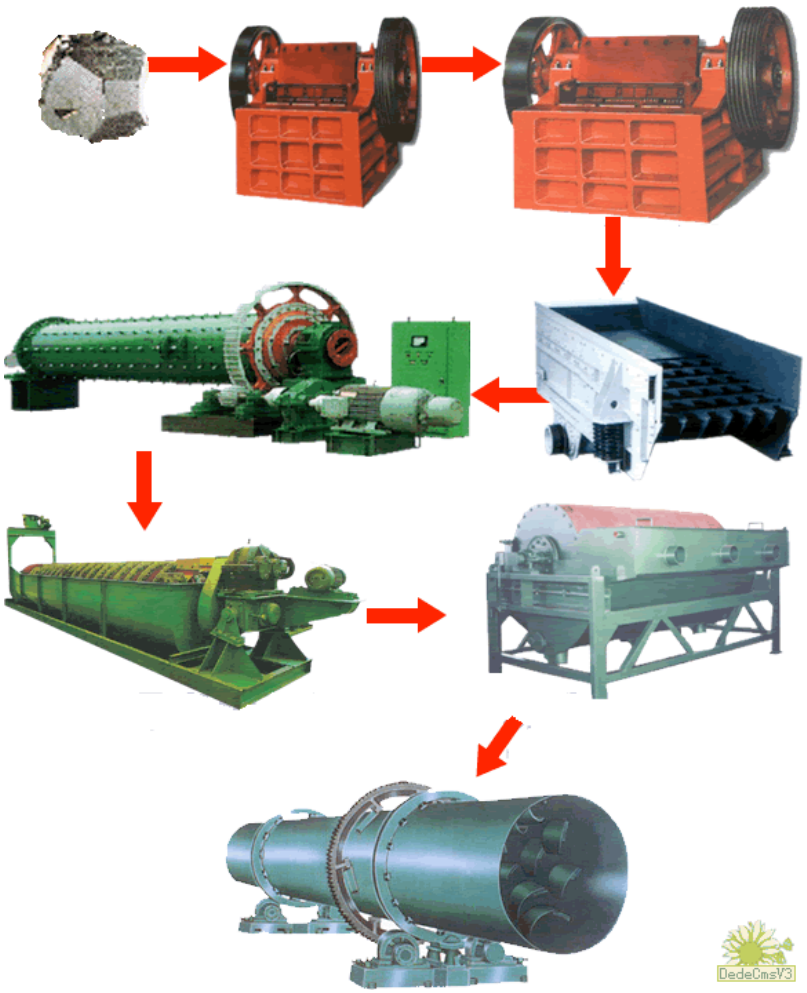

USD/REO kg
200
150
100
50
0
Jan-08
Jul-08
Jan-09
Jul-09
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
China domestic
China FOB

Beneficiation of REO containing ore





Process = [P4098] beneficiation of REE ore, baseline

Economic inflows

Label	Name	Value	Unit
[G83]	soda, powder, at plant[RER]	0.09	kg
[G101]	transport, lorry >16t, fleet average[RER]	0.021	tkm
[G133]	transport, freight, rail[RER]	0.378	tkm
[G507]	sodium silicate, spray powder 80%, at plant[RER]	0.09	kg
[G526]	fatty acids, from vegetarian oil, at plant[RER]	0.03	kg
[G538]	heavy fuel oil, burned in industrial furnace 1MW	0.97	MJ
[G551]	steam, for chemical processes, at plant[RER]	2.7	kg
[G2938]	electricity, medium voltage, at grid[CN]	0.338	kWh
[G3919]	transport, coal freight, rail[CN]	0.15	tkm
[G4100]	ore, 30% fe 4.1% REO, baseline	30	kg

Economic outflows

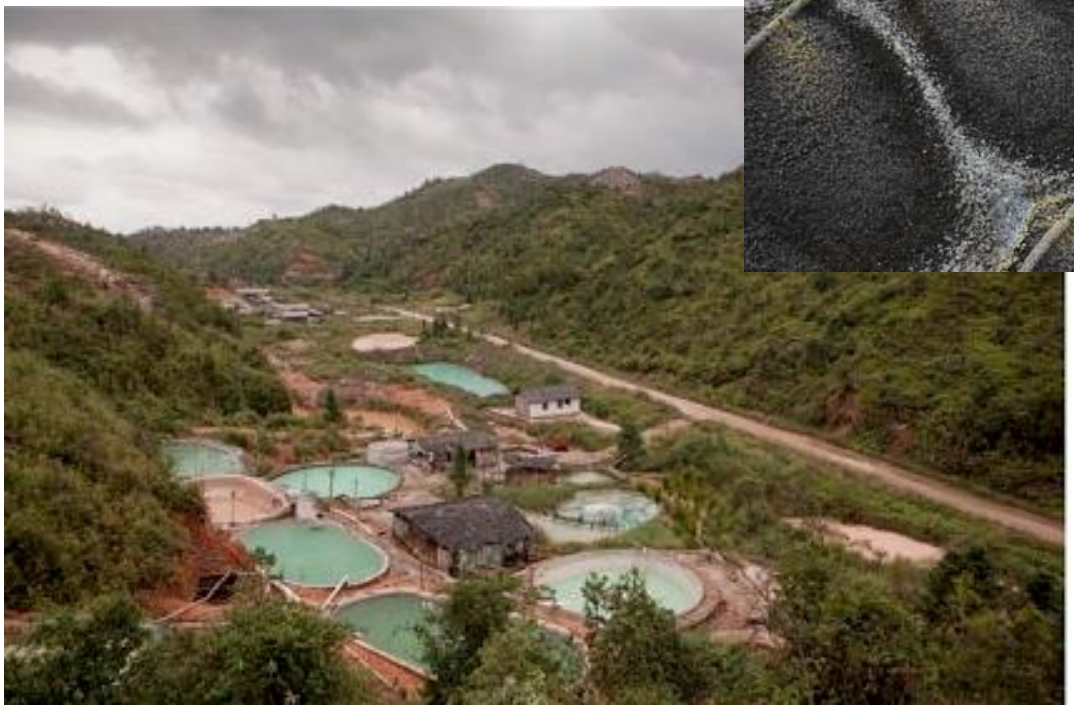
[G4099]	61% REO concentrate from beneficiation, primary, baseline	1	kg
[G4106]	65% iron ore, from Bayan Obo mine, baseline	12.5	kg

Environmental emissions

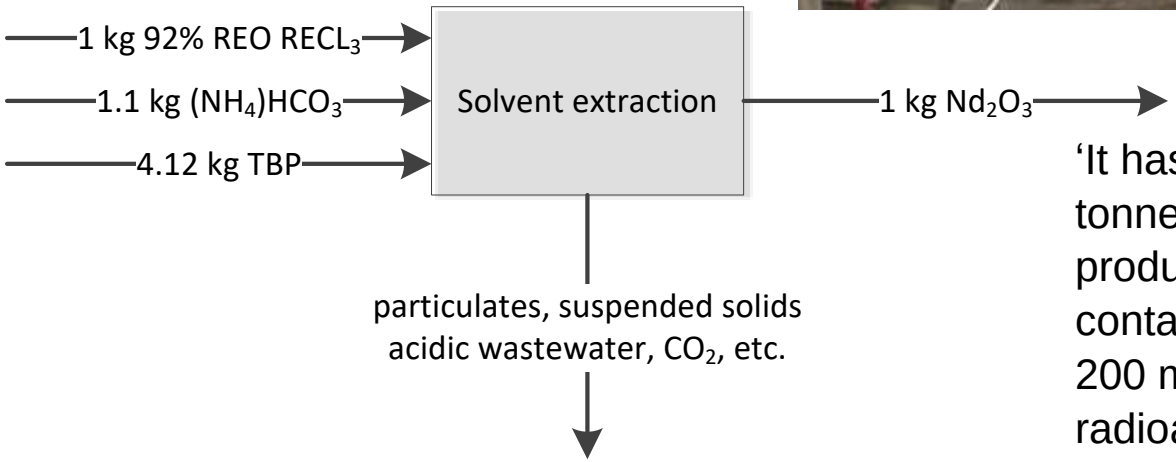
[E1]	Occupation, industrial area, built up[resource_land]	1	m2a
[E281]	COD, Chemical Oxygen Demand[water_unspecified]	0.00157	kg
[E457]	Uranium-234[air_low population density]	0.022	kBq
[E459]	Thorium-232[air_low population density]	2.90E-03	kBq
[E1146]	Chromium VI[water_unspecified]	1.05E-06	kg

goal and scope – life cycle inventory – impact assessment – interpretation

Leaching

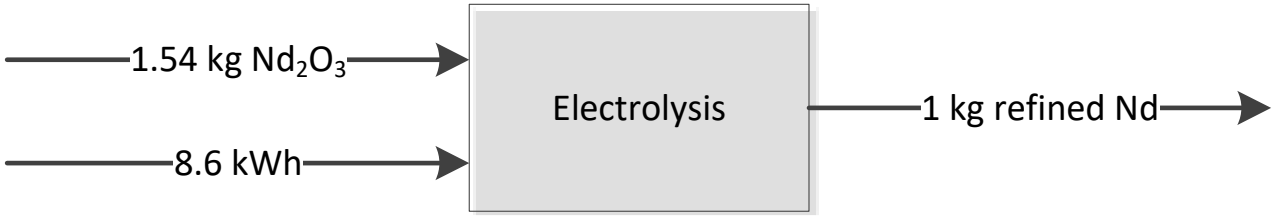


Solvent extraction



'It has been reported that refining one tonne of REE oxide can potentially produce 60 000 m3 of waste gas containing sulphuric and hydrofluoric acid, 200 m3 of acidic water and 1.4 tonnes of radioactive waste' (China Daily 2010).

Electrolysis

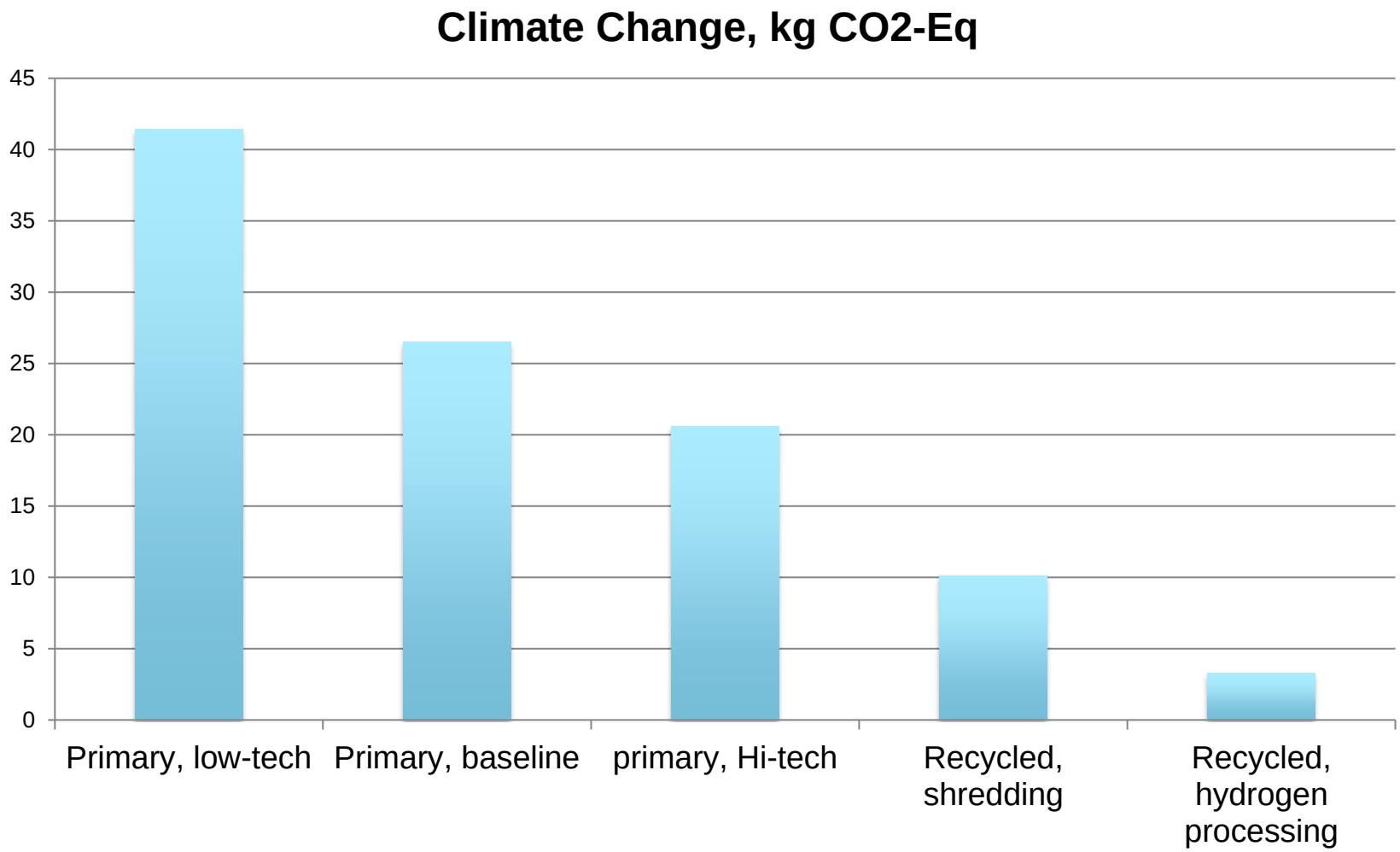


Waste disposal

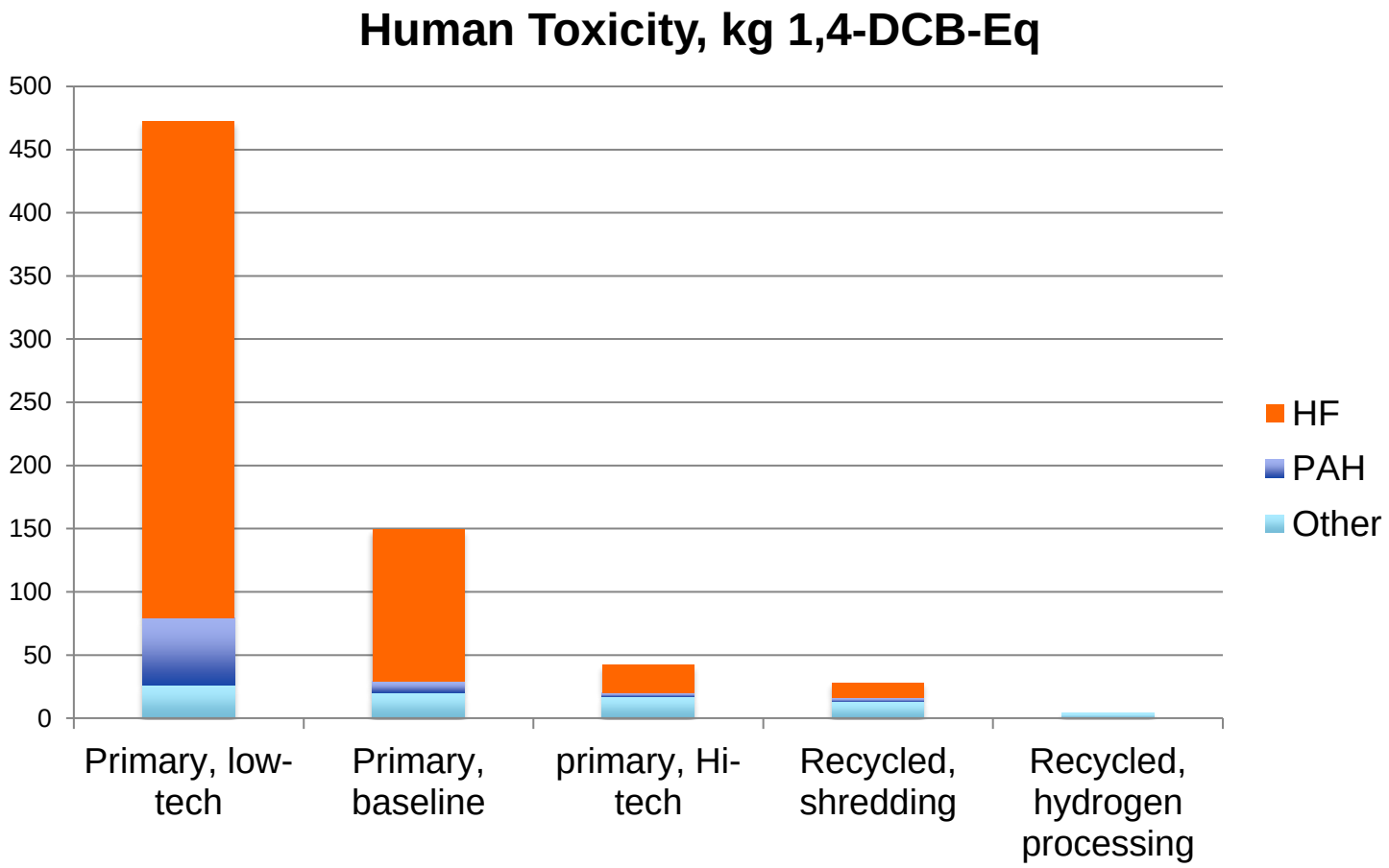
‘It is estimated that within the whole rare earth refining industry approximately 20.000 – 25.000 thousand t of waste water are generated per year.

The NH3/NH4+-content of waste water ranges roughly between 300 and 5000 mg/litre.’ (Schüler et al., 2011)

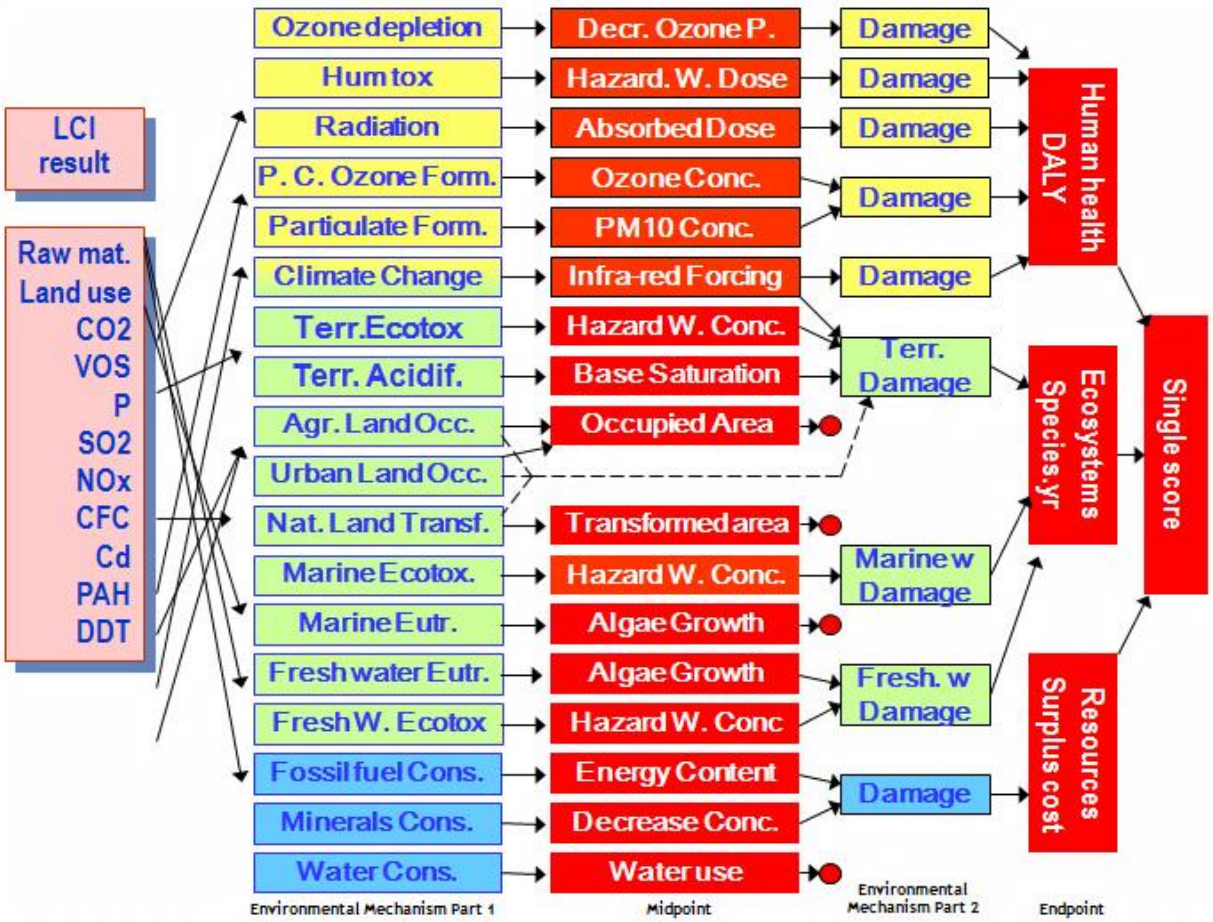
Results: GWP


Climate Change, kg CO2-Eq
45
40
35
30
25
20
15
10
5
0
Primary, low-tech
Primary, baseline
primary, Hi-tech
Recycled, shredding
Recycled, hydrogen processing

Results: human toxicity



Life cycle impact assessment



goal and scope – life cycle inventory – impact assessment – interpretation

Interpretation of results

Examples of conclusions that could be drawn

- Recycling not always better!

(really dependent on recycling parameter assumptions)

- The nickel coating is very important!

(do I know anything about how nickel is modelled in the background database?)

- Electricity > mining!

(what electricity source is your LCI database using?)

goal and scope – life cycle inventory – impact assessment – interpretation

Overall takeaway message

- LCAs of mining and heavy industry are particularly susceptible to the uncertainties and methodological choices inherent to LCA.

- LCAs are nevertheless great for understanding the structure of your environmental impacts

Questions ?

b.sprecher@tudelft.nl