Life Cycle Sustainability Assessment for a Circular Resource Economy-

Comparing primary production of neodymium oxide against magnet scrap recycling using an LCA approach

9th scientific seminar of the PROMETIA association

31st August 2021

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The Materials Processing Institute is a not-for-profit research and innovation centre with a 75-year track record in developing new materials, processes, and technologies.

Minviro is a consultancy and technology company applying life cycle assessment approaches to quantify and mitigate environmental impacts for mining and metals projects.

Overview

- Circular economy, sustainability and life cycle assessment (LCA)
- Neodymium production
- Life Cycle Impact Assessment (LCIA)
- Opportunities, limitations, and collaborations

Circular economy, sustainability, and Life Cycle Assessment (LCA)

- Sustainable Development Goal 12 – Responsible Consumption and Production
- Life Cycle Assessment
  - Comprehensive and transparent methodology
  - Enables the identification of mitigation strategies
  - Identification of potential unintended consequences associated with a change

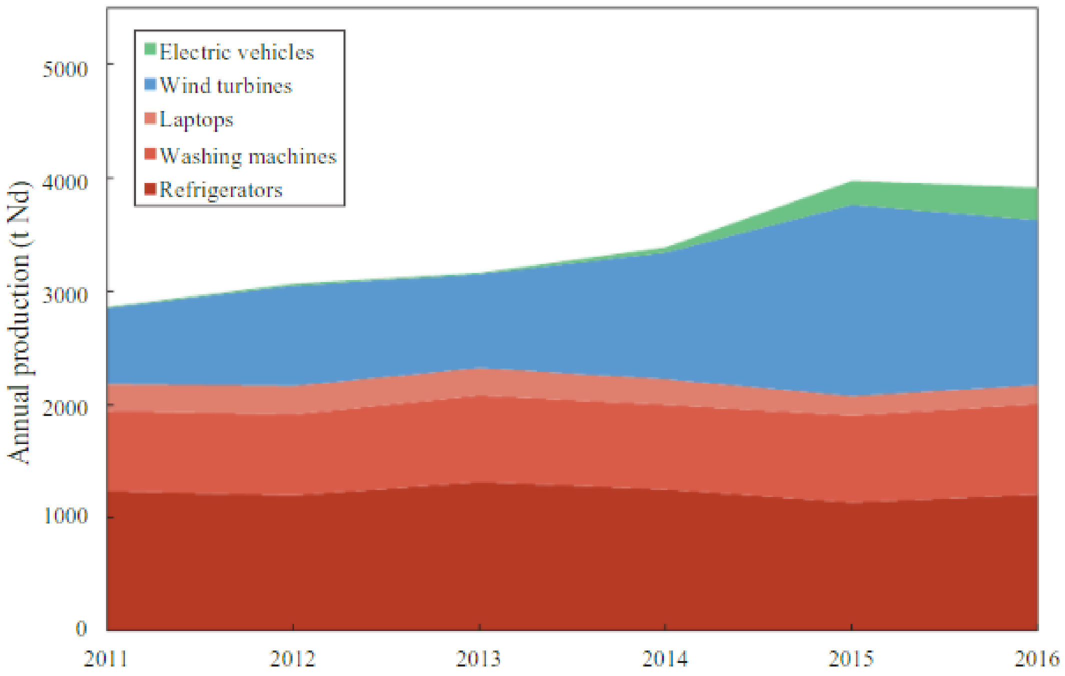
Neodymium use and production

Rare earth magnets are an essential part of translating electrical energy in EV's batteries to kinetic energy.

Magnets used in EV motors consist of a combination of neodymium and dysprosium.

Use of neodymium in sustainable applications, such as EVs and wind turbines, has been steadily increasing the last decade.

80% of neodymium is produced in China.



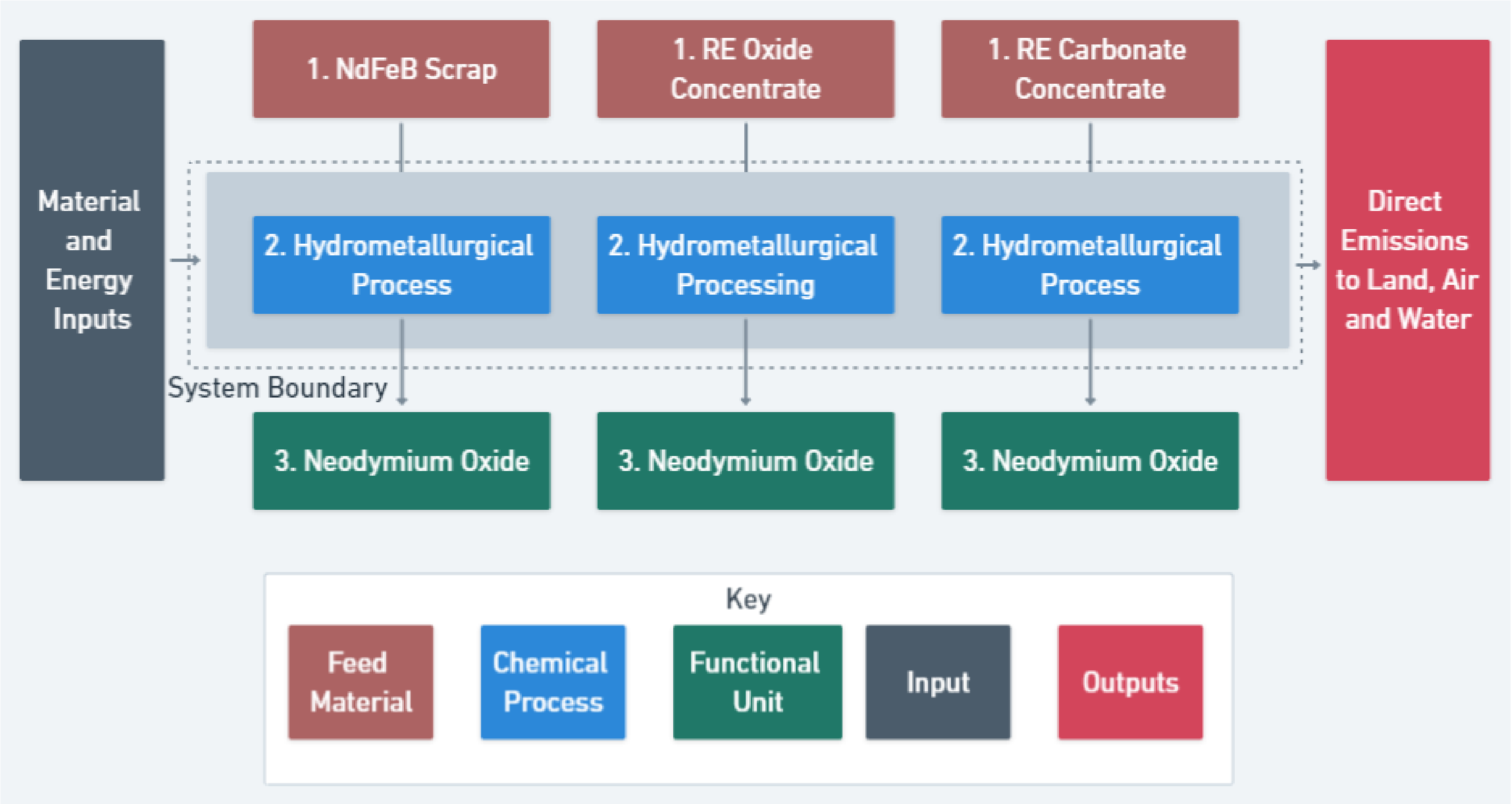
System Boundary

Functional unit:

1 kg of neodymium oxide

Processed through three different routes, all assumed to be based in China:

- Hydrometallurgical recycling of NdFeB magnet scrap (gate to gate)
- Production from rare earth oxide concentrate (Bayan Obo mine, cradle to gate)
- Production from rare earth carbonate concentrate (leaching of ion adsorption clays, cradle to gate)



Methodology

- LCI for neodymium oxide produced through primary production from rare earth oxide and rare earth carbonate from Ecoinvent 3.7.1
- LCI for neodymium oxide produced from the recycling of NdFeB magnets scrap collected from operational facility
- LCIA methodology used Environmental Footprint 2.0
- For simplicity, mass-based allocation is used
- Today only the global warming potential impact category is discussed
- Transport of consumables and final products not included

LCIA Results - Global Warming Potential

Total impact of recycling process is 31.8 kg CO_2 eq. per kg Nd_2O_3

Thermal energy input from combusting coal has an impact of 9.7 kg CO_2 eq. per kg Nd_2O_3

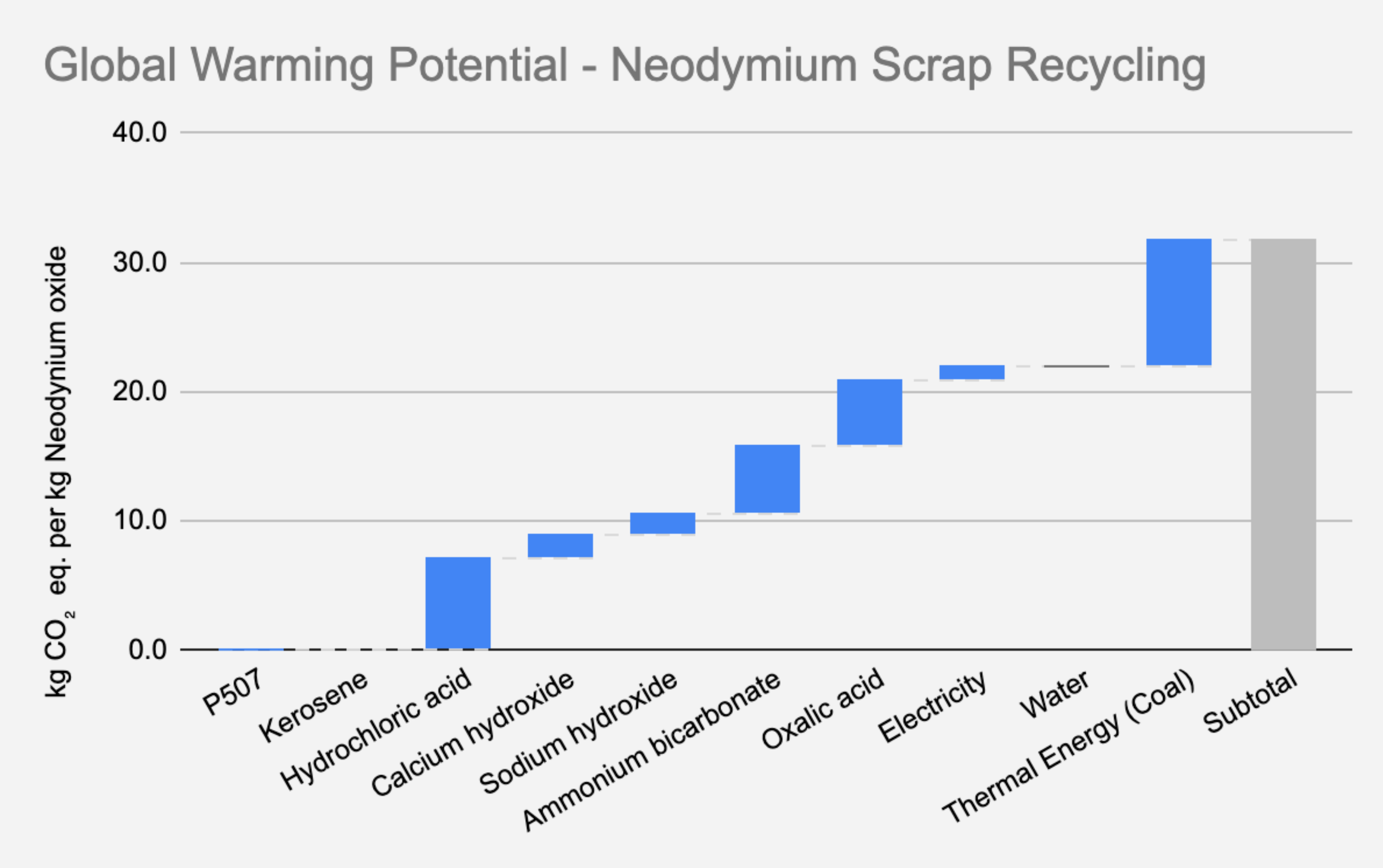
Embodied impact of hydrochloric acid consumed in the process contributes 7.1 kg CO_2 eq. per kg Nd_2O_3

Oxalic acid and ammonium bicarbonate each contribute 5.1 kg CO_2 eq. per kg Nd_2O_3

Consumption of calcium hydroxide and sodium hydroxide in the process each contribute 1.7 kg CO_2 eq. per kg Nd_2O_3

Use of electricity has an impact of 1.1 kg CO_2 eq. per kg Nd_2O_3

Kerosene, P507 and water are minor contributors.

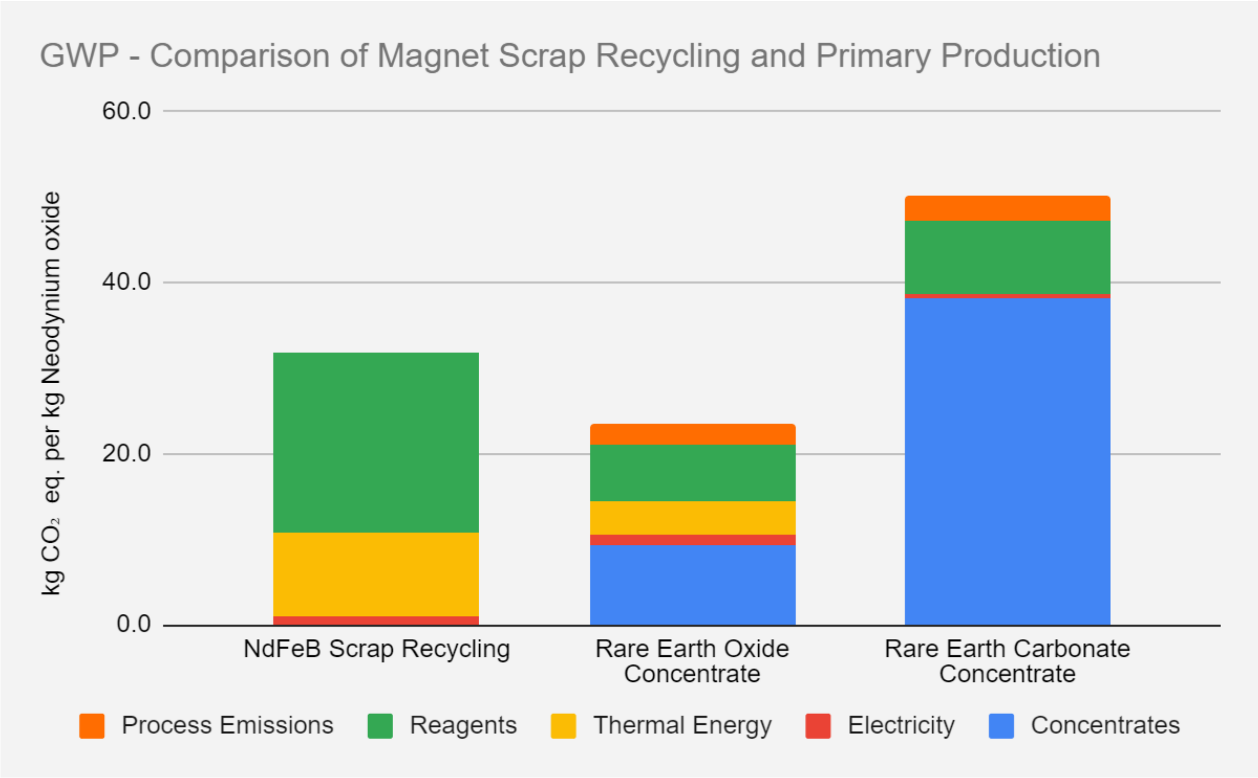


LCIA Results - Global Warming Potential

GWP of NdFeB magnet scrap (31.8 kg CO_2 eq.) recycling is higher impact than the REO route (23.5 kg CO_2 eq.) but lower than the RE Carbonate route (50.2 kg CO_2 eq.)

For the rare earth carbonate route, the upstream production of producing rare earth carbonate concentrate is the largest impact driver: 38.1 kg CO_2 eq.

Relative contriubtion of process inputs (materials and concentrates) the largest GWP driver for each route.



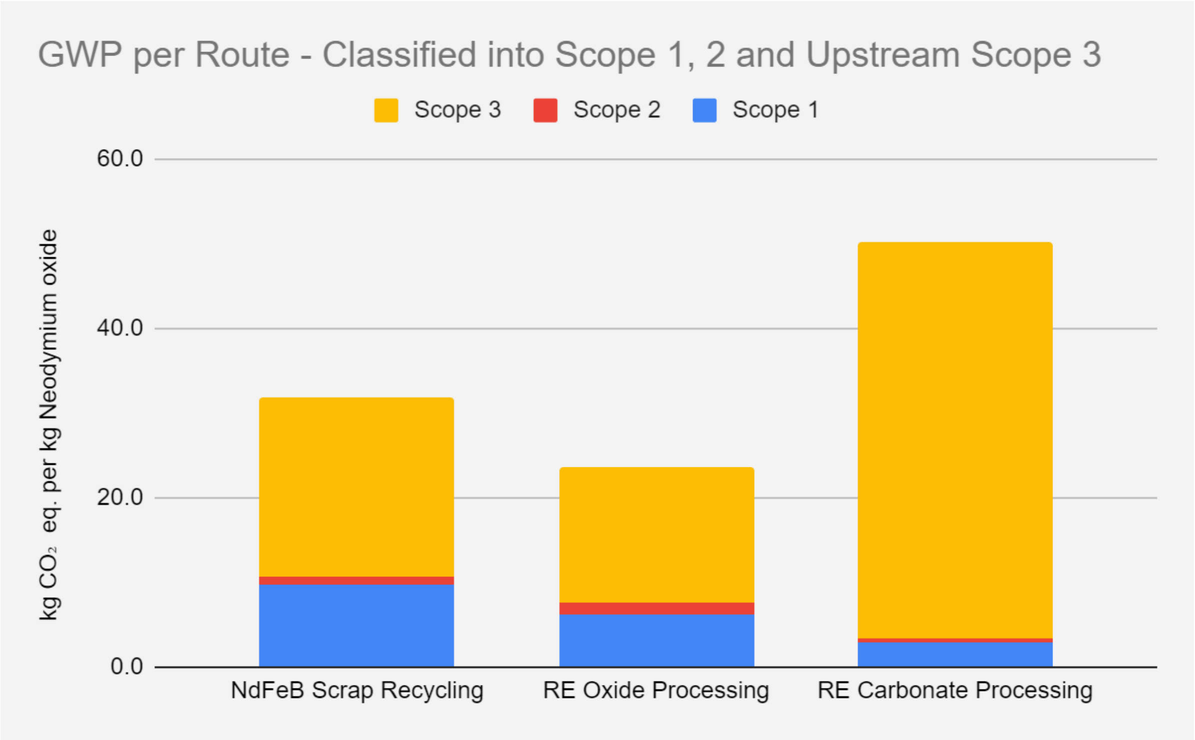
LCIA Results - Global Warming Potential by Scope

GWP for each production route is classified into scope 1, scope 2 and upstream scope 3 emissions.

Upstream scope 3 emissions (embodied impact of materials used) causes more than half of the impact for each route, ranging from 16 to 47 kg CO_2 eq. per kg Nd_2O_3

Scope 1 emissions (process emissions or from combusting fuels on site) range from 2.9 to 9.7 kg CO_2 eq. per kg Nd_2O_3

Scope 2 emissions (embodied impact of energy imported to site) contribute between 0.5 to 1.1 kg CO_2 eq. per kg Nd_2O_3



Opportunities for Impact Reduction

For both the recycling and primary production routes there are a number of opportunities for impact reduction for the discussed production routes

- Decarbonisation of the Chinese grid. Currently, electricity is generally produced from fossil fuels.
- Use natural gas as the thermal energy source rather than coal.
- Collaborate with suppliers of materials to minimize contribution of the embodied impact of required reagents.
- Mitigate process emissions by utilising carbon capture and storage.

Opportunities, limitations, and collaborations

- LCI
  - Robust data collection
  - High quality data
- Communication
  - Not “green washing”
  - Enable informed decisions to be made
- Data automation
  - Blockchain technology
  - Machine learning

Thank you.

Any questions?

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