The Potential for Responsible Sourcing in the Magnet Value Chain: Strategies for the Future

Executive summary of study commissioned by Fairphone

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Reviewed by Fairphone

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Rare earths:
Supply and demand

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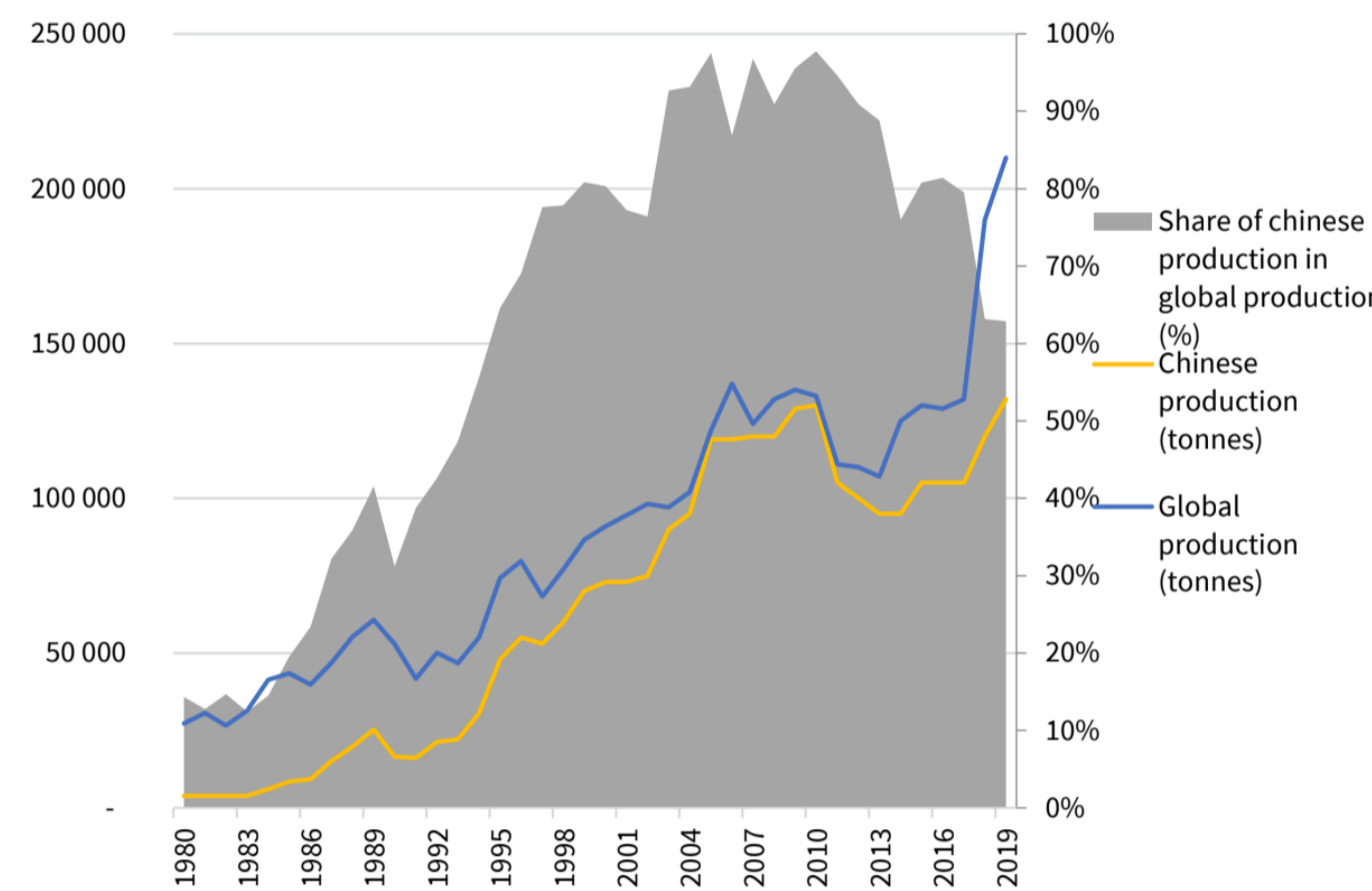
China: still the main actor in rare earth production

Despite the emergence of international competition for the production of rare-earth oxides (REO), China still produces the majority of the world's REO. Globally, more than 220,000 tons of REO is produced annually; in 2019, 63% of the global supply originated in China. Half of this originated in Baiyun Ebo.

This concentration is due to a number of competitive advantages that lead the Chinese production strategy:

- Lax environmental regulation
- Low prices (due to less demanding environmental regulation and low labor costs)
- Ability to complete separation of 17 different REO



Evolution of the production of rare earth oxides from 1980 to 2018. Source: Pigneur, 2019

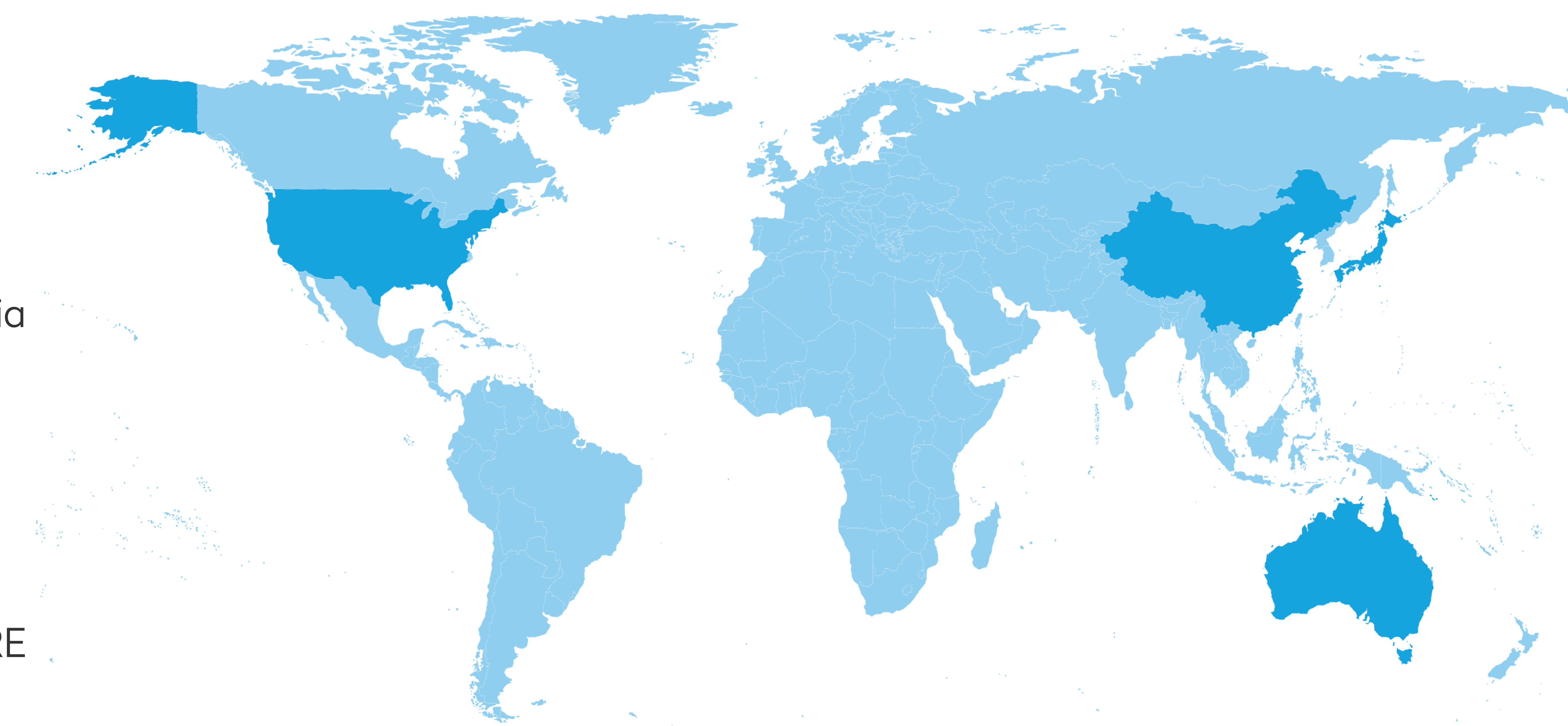
Other global actors in rare earth production

Japan

- Second in global NdFeB production - but first in terms of technologies relating to production capacity and recycling.
- 11% of NdFeB sintered magnet global production in 2015
- 10% of NdFeB bonded magnet global production in 2015
- Some REO separation

Emerging RE mining

- Mining projects are ongoing in Australia and the USA.
- Lynas Corporation Ltd. and MP Materials each produce about 10% of REO globally.
- Lynas transforms RE into REO (4 to 6 REO type), while MP Materials sends RE concentrate to China.



Trends in consumption of neodymium and NdFeB magnets

- 30% of REO produced globally is used in NdFeB magnets.
- Approx. 28,000 tons of REO today is required to meet demand for NdFeB magnets.
- Large information gaps on NdFeB consumption per sector exist, particularly in relation to military and industrial machinery uses.
- Today's main NdFeB users are industrial machinery, the automotive industry, electronics and electric equipment.

Because China is the main actor in REO production, it is also the leader in the supply of rare earth-derived NdFeB magnets. In 2015, 88% NdFeB sintered magnets came from China, a growth of 12% per year from 2005 - 2015.

Neodymium and NdFeB magnet consumption predicted to double by 2030

The consumption of Nd oxide in magnets is expected to double by 2030 to 60,000 tons. While the demand for electronic and medical application is expected to remain stable, it appears future demand will be driven by:

- Automotive industry
- Electric vehicles
- Wind turbines (depending on what technology becomes dominant within the sector)

	2010	2020	2030
Global demand for Nd oxide (t)	20 000	28 000	60 000
Wind turbines	3-4%	10%	↗
Automotive (includes automation and appliance)	30-45%	42%	↗
Electrified vehicles	5-15%	10%	↗
Electronic and medical	30-37%	19%	↘
Others (includes compressors)	13-17%	19%	↘

Estimates of consumption of NdPr for magnets in different sectors. Without general industrial engines and magnetic separation. Source: Constantinides, 2012 ; Lynas, 2019

NdFeB magnet value chain

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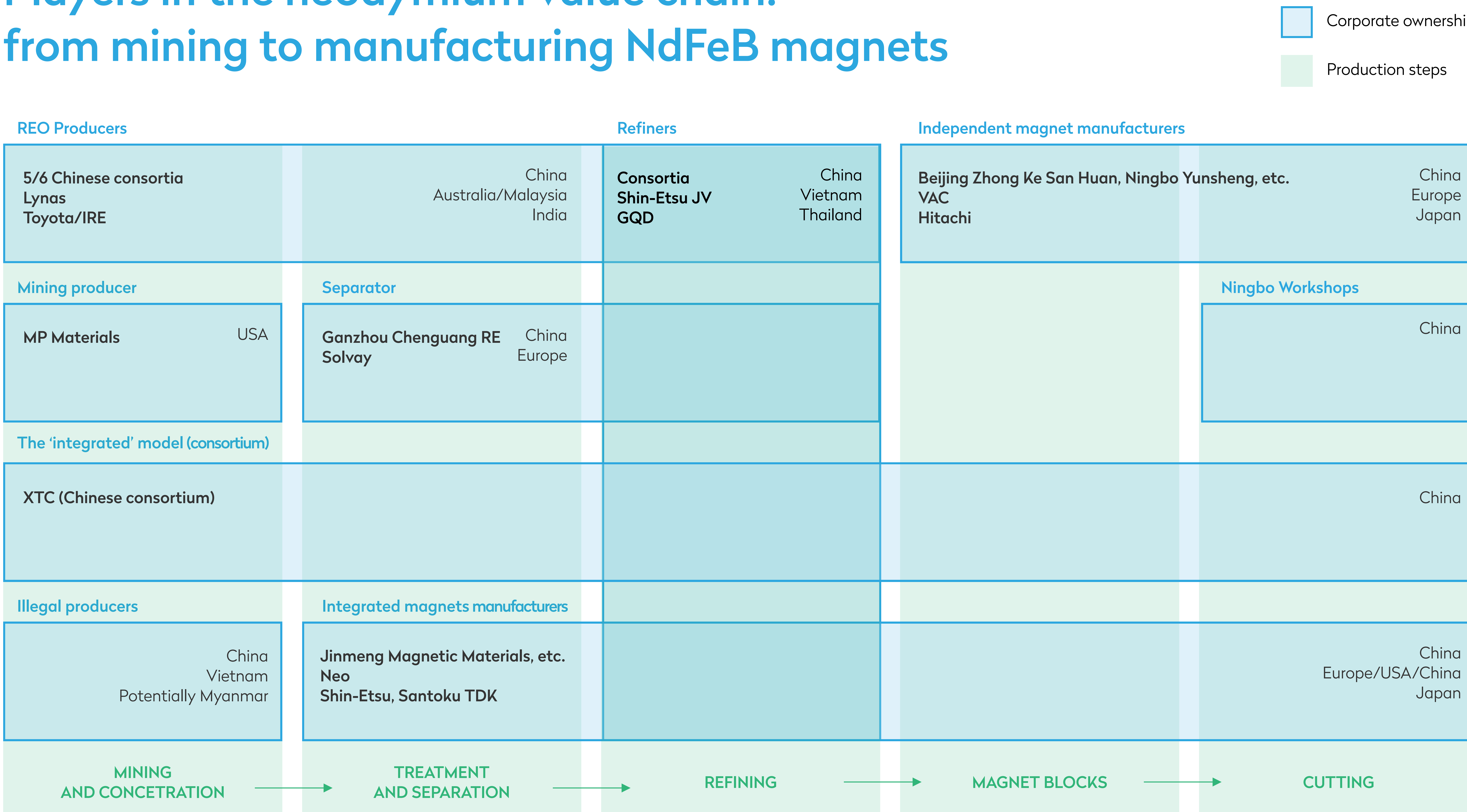
Players in the neodymium value chain: from mining to manufacturing NdFeB magnets



Company name mentioned is an indication of the type of supply chain action and doesn't imply the actual supply chain relationships.

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Mining and metallurgical actors

The vast majority of RE production happens in China. The Chinese state has shares in all production stages based in the country. Few separators are independent of mine production.

In 2014, six consortia were launched to shut down illicit production, but in some (southern) regions, illegal production remains a problem that requires further engagement from both government and industry. Over 80% of participants in the consortia were related to the mining and metallurgical stages of production. While an "integrated" model gained some interest, in reality there is buying and selling at all production stages.

Other countries

- There are some RE refining players in Vietnam and Thailand.
- Australian-based Lynas transforms RE into REO and has a tolling agreement for refining. The majority of their customers are Japanese.
- As previously mentioned, MP Materials currently sends RE concentrate to China for processing.

Magnet manufacturers: informal or integrated?

Apart from Xiamen Tungsten Co. Ltd. (XTC), most Chinese magnet manufacturers are independent and therefore reliant on RE producers. On average, Chinese production remains "low quality" mass production; workshops in Ningbo are an example of this. Pricing pressure and frequently required shape changes have created an “informal workshop” environment.

Japanese legislation places responsibility for recycling of magnets on the industries using them. JinMeng, Santoku and ShinEtsu are integrated manufacturers of magnets, enabling the recycling of magnets at the end of their life.

Automotive sector as magnet consumer
Patent requirements by the automotive sector have created an entry barrier for magnet manufacturers. However, the industry has a more stable relationship with magnet manufacturers than the electronics industry, opening up more opportunities for collaboration and engagement on recycling.

Main recycling routes: defective magnets, scraps, and end-of-life magnets

The current value chain system requires change to drive impact

Despite the establishment of consortia in China, illegal mining and the mindset of overproduction at low prices persists. This hinders the implementation of more efficient processes and recycling.

Recycling legislation can be a tool to change this.

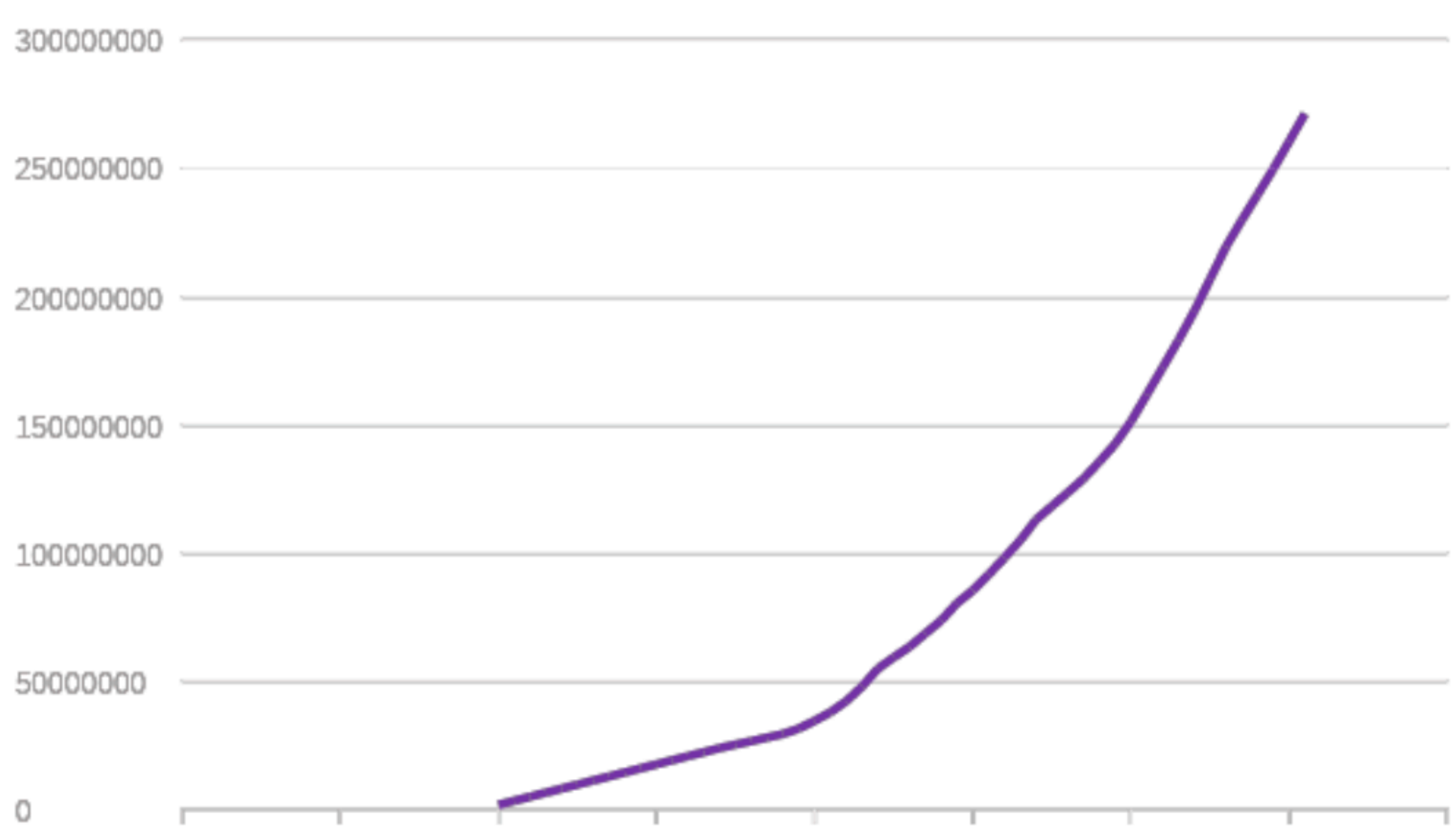
Key social and environmental issues

1. Mining waste
2. Radioactivity
3. Inefficient processes
4. Lack of recycling
5. Problematic dysprosium supply
6. Significant energy and water consumption
7. Outsourcing and informal workshops
8. Poor working conditions and human rights

1. Mining waste and 2. Radioactivity: a long-term health and environmental issue

Mining waste is a major challenge when considering the impacts of mining production. The maintenance needed for tailing facilities is literally endless.

Radioactivity: naturally occurring in tailing ponds, leading to huge amounts of low-level radioactive waste.



Cumulative production of tailings dumped in the Baiyun Ebo tailing pond since its creation in 1965 (tonnes). Source: Pigneur, 2019]

Case Study: Baiyun Ebo 2016: Main tailing pond
The Baiyun Ebo tailing pond is huge: in 2016 it contained 271 million tons of tailings (4% of all Chinese iron tailings), and its size has been rapidly increasing. The mine footprint itself is approximately 108 km2. It poses significant risks to local people and the environment. Related contamination of water and land affects more than seven villages - over 3,000 people.

There are other serious issues for long term management of the waste

- Radioactive waste: 119 thousand tons of thorium in the tailing pond, including pollution from historical processes
- Risks of dam failure and catastrophic contamination of the Yellow River
- High dust exposure

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Potential solutions

Improved production efficiency

- Reuse of products
- Recycling to curb growth
- R&D and investment in waste management and recycling

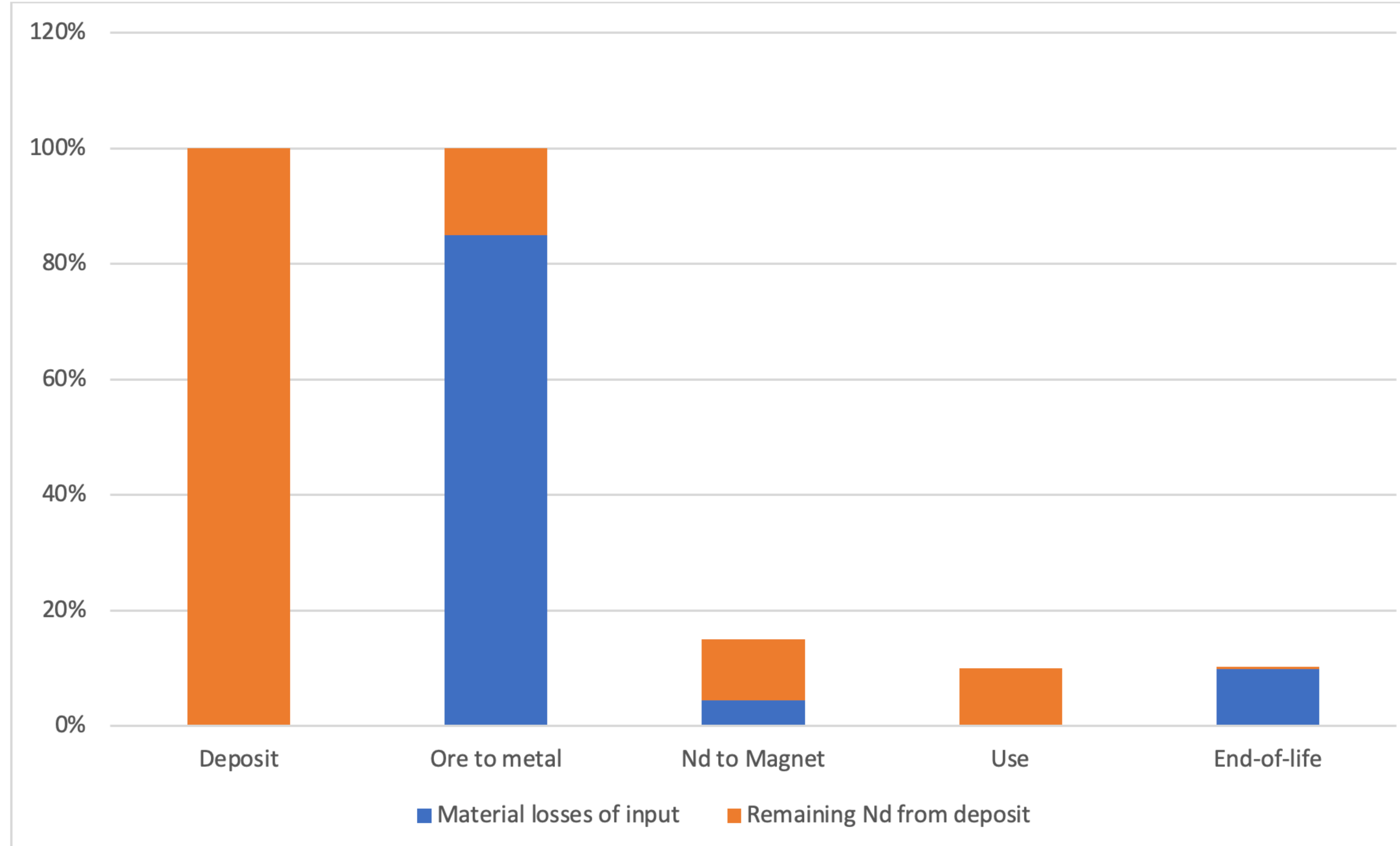
It should be kept in mind that these solutions don't necessarily help to manage the historical pollution created by past mining activity.

NASA satellite photography, June 30, 2006

3. Inefficient processes show a loss of rare earth, leading to depletion

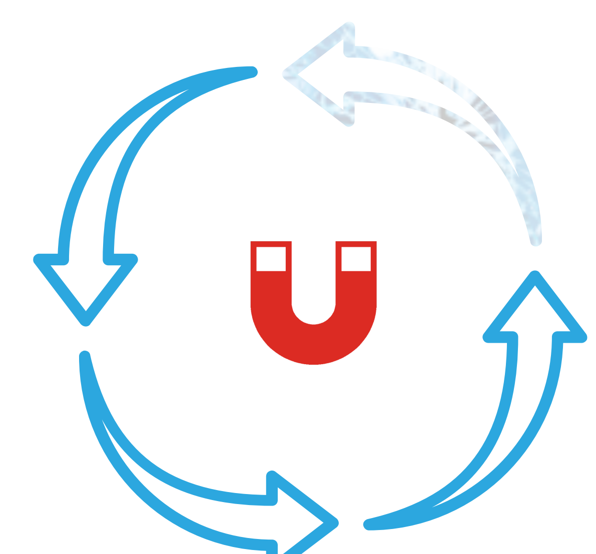
Inefficient mining steps at Baiyun Ebo are contributing to the rapid depletion of rare earth resources. Another identified inefficiency is in the first step of the concentrate production process: separating iron ore from rare earths minerals.

Image: Neodymium losses in percentage through global value chain from Baiyun Ebo to magnet recycling. Source : author



4. No end-of-life recycling, leading to further resource depletion

Currently, the end-of-life recycling of magnets outside of China and Japan is limited.



5. The dysprosium supply chain is a hotspot for non-traceability, pollution and deforestation

Dysprosium (and all heavy rare earths) are mainly sourced from ionic clays in southern China. It is difficult to find alternative sources of supply. 10% to 40% of Chinese production is still linked to illegal and informal production. Traceability remains difficult to guarantee.

Attempt to rehabilitate mining waste left over from rare earth heap leaching. Orange trees are planted to prevent landslides, but the pollution is not being addressed.
Changpu Village, Xunwu County, Cr. Dongjiang Expedition Report.

Producing one ton of REO has major impacts

- 2,000 tons of waste rocks
- 1,000 tons of wastewater containing ammonium sulphate and heavy metals
- 300m2 of vegetation and topsoil removed

In China's southern region, the Ganzhou district alone has seen huge impacts from RE mining

- 302 abandoned mines and 191 million tons of waste rock
- Deforestation was estimated to have increased from 23 km2 in 2000 to 153 km2 in 2010
- 100 landslides related to RE mining

6. Energy and water consumption is significant

Overall, separation of rare earths by solvent extraction is the most impactful step of production.

Climate & energy issues

12-16 kg CO2-Eq/kg REO

Global warming potential (GWP) of production Baiyun Ebo

27.5 kg CO2-Eq/kg REO

Global warming potential (GWP) of production at Lynas

Direct water consumption issues

Chemical treatment and separation are the production steps using most water - more than 400 m3 water/hour for Lynas alone.

Share of GWP from mine to REO:

49% Separation of rare earths by solvent extraction

36% Finishing (preparation and packaging of REO for clients)

13% Chemical treatment

Reducing oxides to metals (refining) also has high energy consumption

7. Outsourcing of cutting and informal workshops in Ningbo, China

When the cutting is not made by magnet producers there are increased risks of links with the informal sector and precarious work.

8. Working conditions and human rights

It is difficult to assess actual working conditions in RE mines and industry, but we do know there is precarious work, especially in illegal mines:

- Labor rights generally not respected
- No worker representation
- Lack of access to contracts and social insurance

To the author's knowledge there is no known social conflict about labor rights in the chain of NdFeB magnets outside China, even if there are socio-environmental conflicts (Lynas in Malaysia for instance).

Strategies to drive positive change in the rare earth value chain

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Building proofs of concept: greater integration of recycled materials and greater traceability of supply

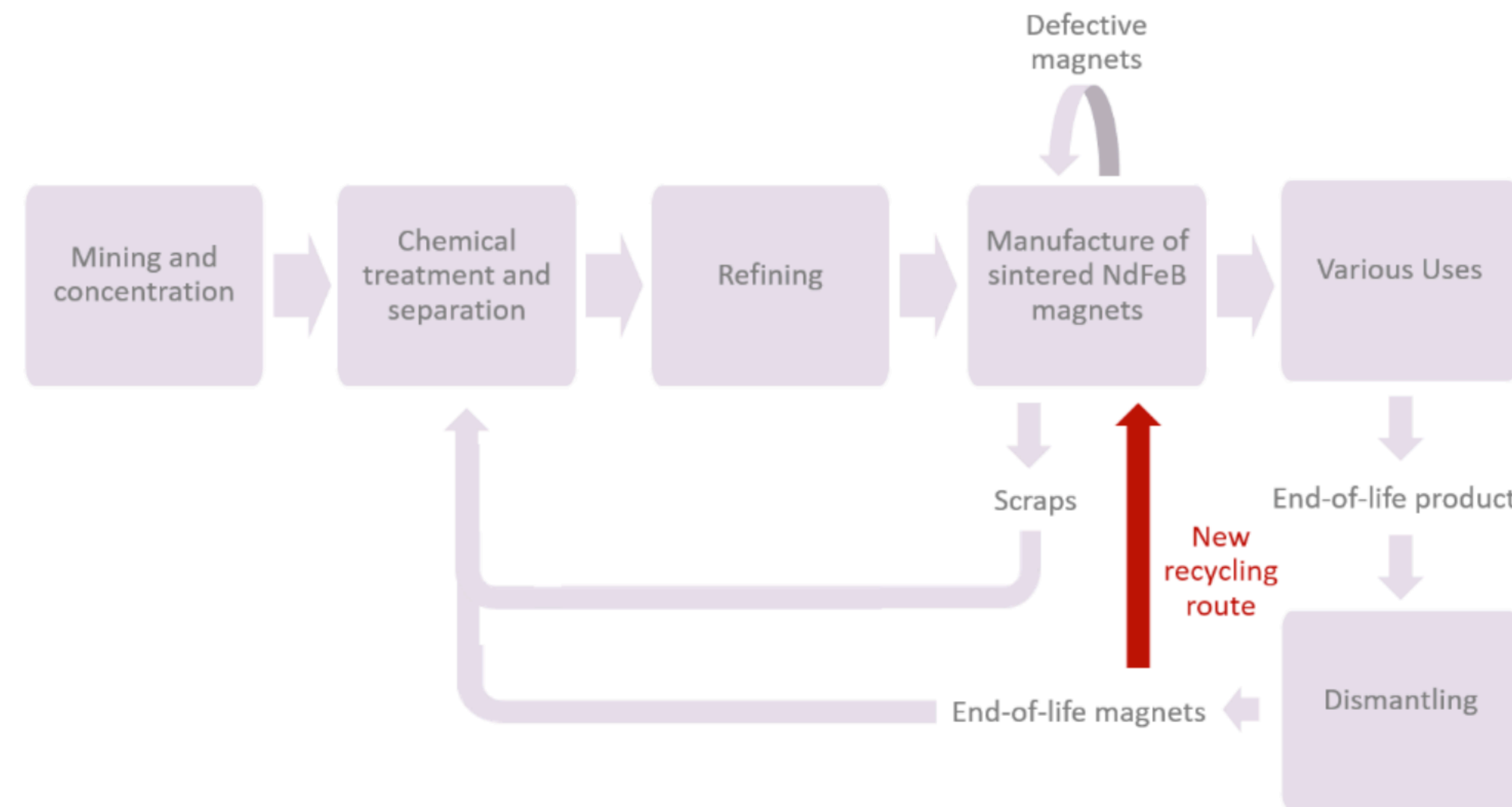
Considering the depletion of RE and the desire to transition to a circular economy, there are a number of potential strategies to avoid social and environmental problems (although not completely, as can be seen below):

1.	**USE 100% RECYCLED MAGNETS BY DIRECT RECYCLING (MAGNETS TO MAGNETS)**	Dismantling of end-of-life sintered magnets followed by the introduction of magnets at the level of decrepitation. Same process used than for defective magnets. Today, there are no 100% recycled magnets produced in this way, but does not seem to be any technological impediment to implementing this recycling. Though this method is subject to quality losses.
2.	**USE RECYCLED DY AND TRACED ND**	Sourcing NdPr outside China with guaranteed traceability to avoid the social and environmental problems associated with Baiyun Ebo and the mines in southern China. As traceability cannot be ensured for Dysprosium, this strategy could be coupled with a supply of recycled Dysprosium.
3.	**USE PRIMARY AND SECONDARY RE**	Estimate/acknowledge with the magnet manufacturers the recycled content already in magnets. Setting up traceability of the recycled content and pushing to increase this recycled content. The strategy is based on the reintroduction of scraps or magnets at the end of their life in the chemical treatment of rare earths, mixed with ore. There is no loss of quality in the NdFeB magnets produced.

Difference between strategy 1 and 3: direct and indirect recycling

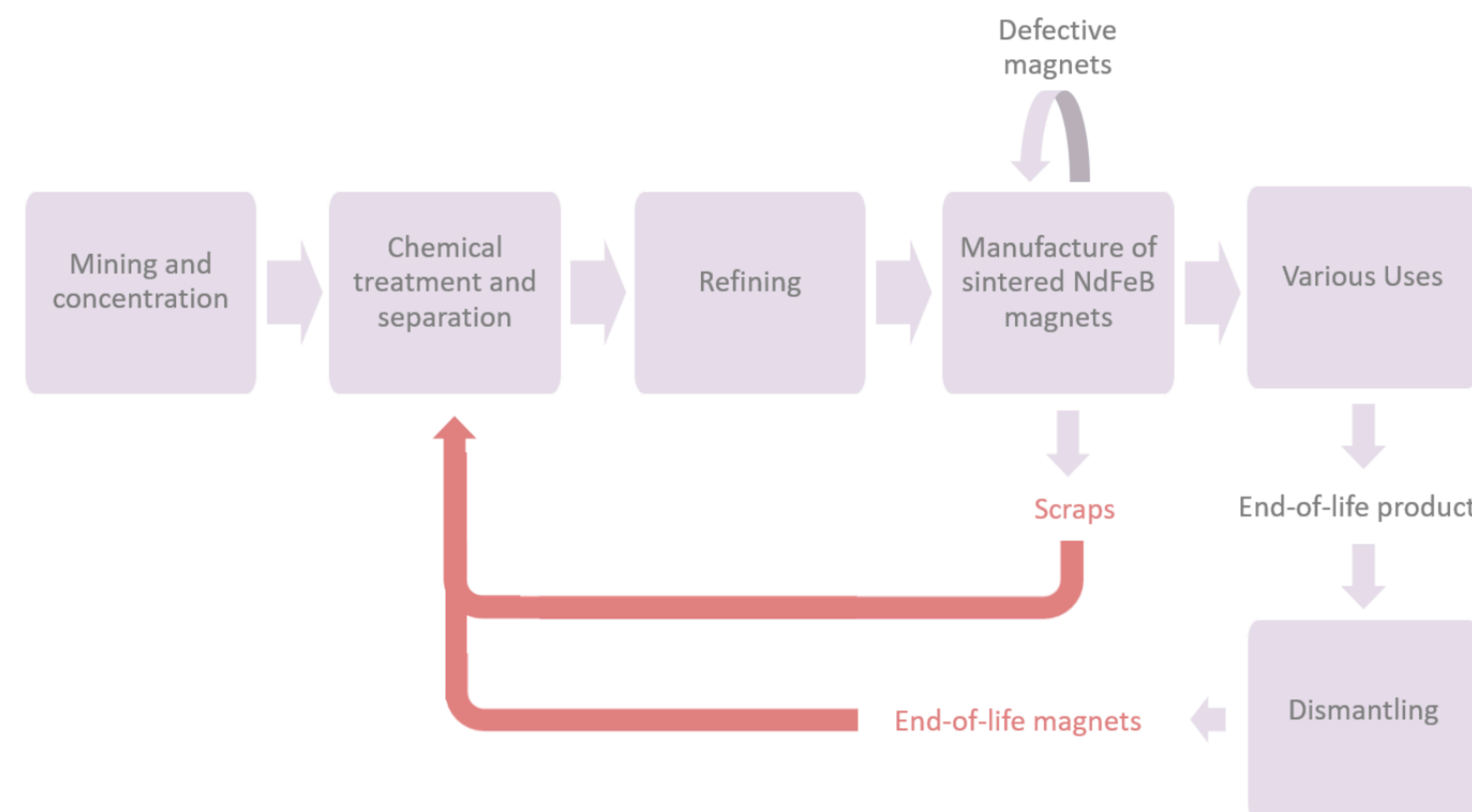
Strategy 1

USE 100% RECYCLED MAGNETS
BY DIRECT RECYCLING
(MAGNETS TO MAGNETS)



Strategy 3

USE PRIMARY AND
SECONDARY RE



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Strategies tackling specific social and environmental issues for a more sustainable NdFeB value chain

4.	**USE MAGNETS WITHOUT HRE**	Nd permanent magnets have been made without heavy rare earth through hot deformation method. This method is different from the typical sintering production method for neodymium magnets. Technical feasibility for use in Fairphone remains unsure.
5.	**RESEARCH FOR WASTE MANAGEMENT**	Creating a joint-funded research project on long term management of rare earth mining wastes.
6.	**BETTER PROCESSING OF RE**	Improving the production process of rare earths at concentration, chemical treatment, separation and refining steps, which could have a significant impact on the environmental impacts of production and material losses.
7.	**STOP SMUGGLING OF RARE EARTHS**	Pushing international actions against smuggling of rare earths to support Chinese national effort on shutting down the illegal mining : standards for traceability (ISO/TC 298), classify rare earths smuggling as a cross-border organized crime by the UNODC, traceability requirement for rare earth purchases, as it has been done with conflict minerals in the United States (Dodd-Frank Act) or in Europe.

Overall of risk factors and strategies

	1	2	3	4	5	6	7
RISK FACTORS	**Use 100% recycled magnets**	**Use recycled Dy and traced Nd**	**Use primary and secondary RE**	**Use magnets without HRE**	**Research for waste management**	**Better processing of RE**	**Stop smuggling**
5.1.1 MINING WASTE LONG-TERM MANAGEMENT	✓ (orange)	✓ (orange)	✓ (orange)	✗ (red)	✓ (green)	✓ (green)	✓ (orange)
5.1.2. RADIOACTIVITY	✓ (green)	✗ (red)	✓ (orange)	✗ (red)	✓ (green)	✓ (green)	✗ (red)
5.1.3. LOSS OF RARE EARTHS AT CONCENTRATION STEP	✓ (green)	✓ (green)	✓ (orange)	✗ (red)	✗ (red)	✓ (green)	✗ (red)
5.1.4. DYSPROSIUM	✓ (green)	✓ (green)	✓ (orange)	✓ (green)	✗ (red)	✗ (red)	✓ (green)
5.1.5. ENERGY AND WATER CONSUMPTION	✓ (green)	✗ (red)	✗ (red)	✗ (red)	✗ (red)	✓ (green)	✗ (red)
5.1.6. OUTSOURCING OF CUTTING	✓ (orange)	✓ (green)	✓ (orange)	✓ (orange)	✗ (red)	✗ (red)	✗ (red)
5.1.7. NO END-OF-LIFE RECYCLING	✓ (green)	✓ (orange)	✓ (orange)	✗ (red)	✗ (red)	✗ (red)	✗ (red)
5.1.8. WORKING CONDITIONS AND HUMAN RIGHTS	✓ (orange)	✓ (green)	✓ (orange)	✓ (orange)	✗ (red)	✗ (red)	✓ (green)
IMPACT ON QUALITY	✗ (red)	✓ (green)	✓ (green)	Unkown	✓ (green)	✓ (green)	✓ (green)
IMPACT ON PRICE	✗ (red)	✗ (red)	✓ (orange)	Unkown	✗ (red)	Unknown	✗ (red)

Recommendations for short and longer-term strategies

Longer-term strategy

Develop the production for recycled magnets through decrepitation process (strategy 1).

Otherwise, implement strategy 2, while providing support on the question of long-term management of mining waste and the improvement of production processes.

Short-term strategy

Environmental level
Creating partnerships with magnet producers already engaged in the use of recycled material (Strategy 3)

- Shin-Etsu, Santoku, TDK, Baotou Jinmeng Magnetic Materials Co. Ltd.
- Shenyang General Magnetic Co. Ltd.

The technical implications - and limitations - of this type of recycling have yet to be fully understood. The quality of the product can be maintained, but there is a risk of a lower recovery rate that requires further research.

Social level
Set up the measures of strategies 2 and 7 concerning the traceability of materials.

- Engage Lynas, which offers to ensure traceability from the rare earth mine to the manufacture of magnets.
- Support the measures to combat illegal mines: ISO standardization and international measures to combat smuggling.

Fairphone investigated, and now integrated 90% recycled Neodymium in motor and 100% in speakers

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Join us in creating a more sustainable magnet value chain

We're seeking partners to help further the strategies outlined in this document.
If your organization wants to help make positive change in the NdFeB value chain, please contact Tirza Voss: **tirza@fairphone.com**

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