
崂山啤酒
LAOSHAN BEER
净含量:330ml


Bayan Obo Mining District　白雲鄂博礦區

Bayan Obo Mining District 白雲鄂博礦區

Bayan Obo mine tailing dumping site /
白雲鄂博鉱山 尾鉱処分場


TEREX MINING
709

Open-pit Bayan Obo Mine

露天掘りの白雲鄂博鉱山


Open-pit Bayan Obo Mine
露天掘りの白雲鄂博鉱山


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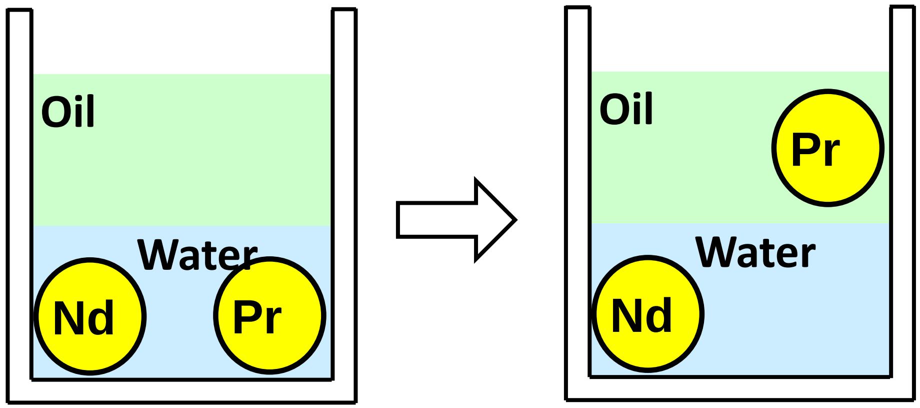
Open-pit Bayan Obo Mine
露天掘りの白雲鄂博鉱山

Open-pit Bayan Obo Mine
露天掘りの白雲鄂博鉱山

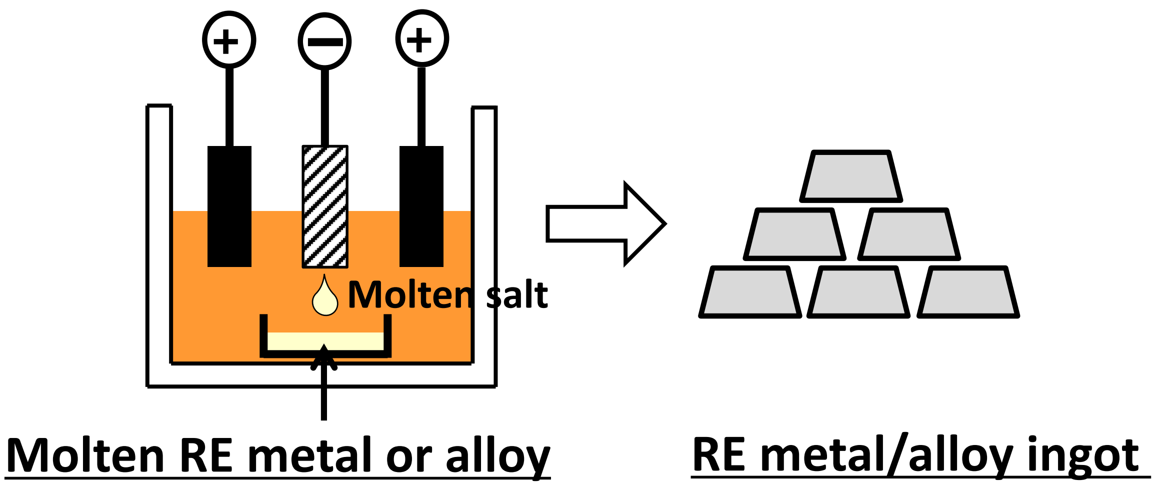
Huge tailing dumping site /
白雲鄂博鉱山 尾鉱処分場


Solvent extraction (SX) plant /
溶媒抽出工場
湿式製錬
→溶媒抽出
Hydrometallurgy
→Solvent Extraction

Separation / purification of rare earth



Metal production by molten salt electrolysis



東北大学大学院　工学研究科金属フロンティア工学専攻　竹田　修　博士　作成

参考）足立吟也編:「希土類の機能と応用」, CMC出版(2006); 足立吟也編:「希土類の材料技術ハンドブック」, NTS (2008); JOGMEC NEWS, Vol. 27 (2011)


Exchanging anode from molten salt electrolysis furnace /
溶融塩電解炉のアノードの交換作業
This process generates HF gas because it utilizes fluoride monten salt
Photo by Toru H. Okabe 2014.7, Baotou

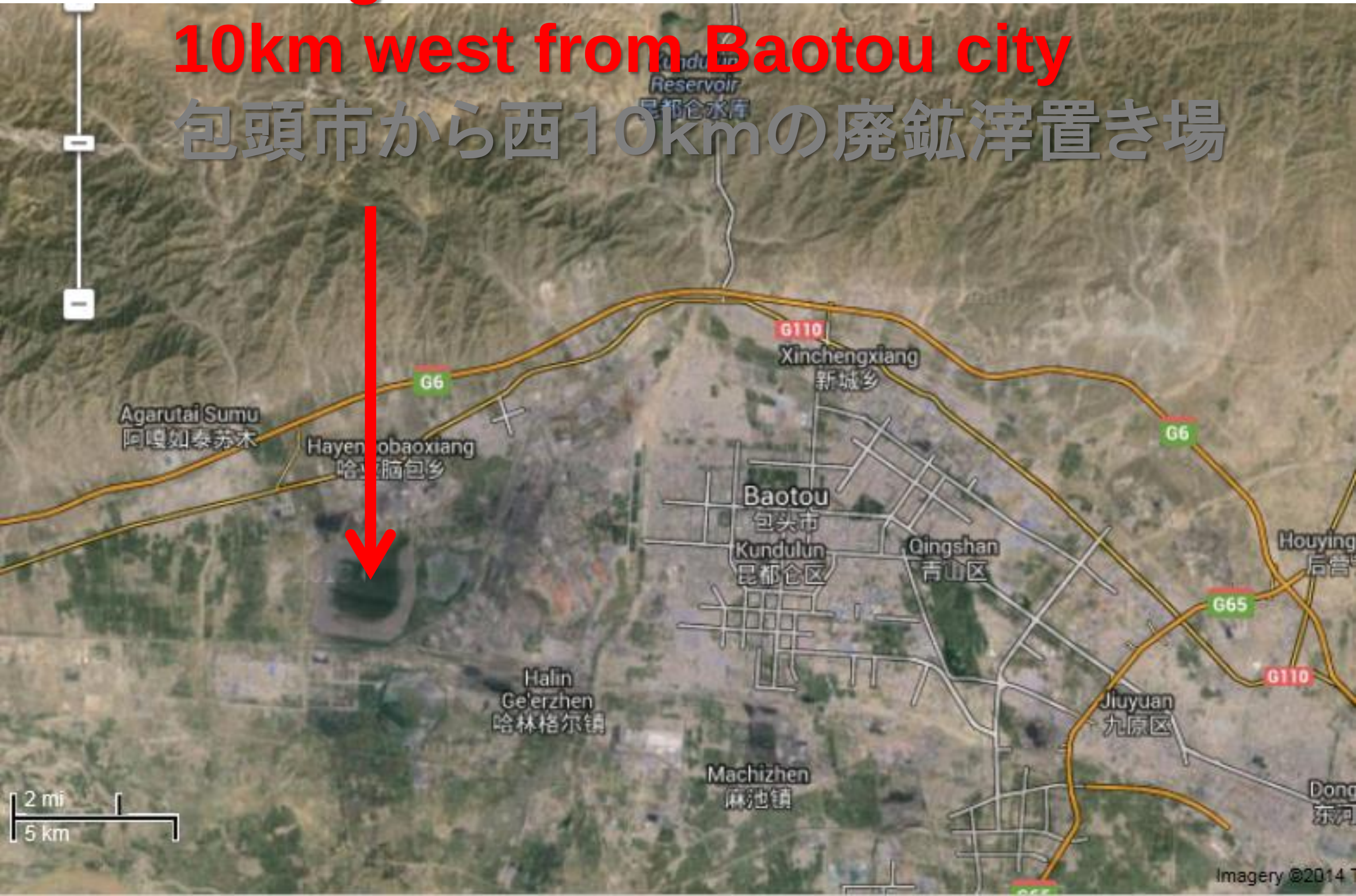
Molten salt electrolysis plant / 溶融塩電解工場

Photo by Toru H. Okabe 2014.7, Baotou

Tailing dam

10km west from Baotou city

包頭市から西10kmの廃鉱滓置き場




Tailing dam / 廃鉱滓処分場


Tailing dam / 廃鉱滓処分場

http://blogs.unimelb.edu.au/sciencecommunication/2013/09/08/whats-all-this-commotion-about-rare-earth-elements/

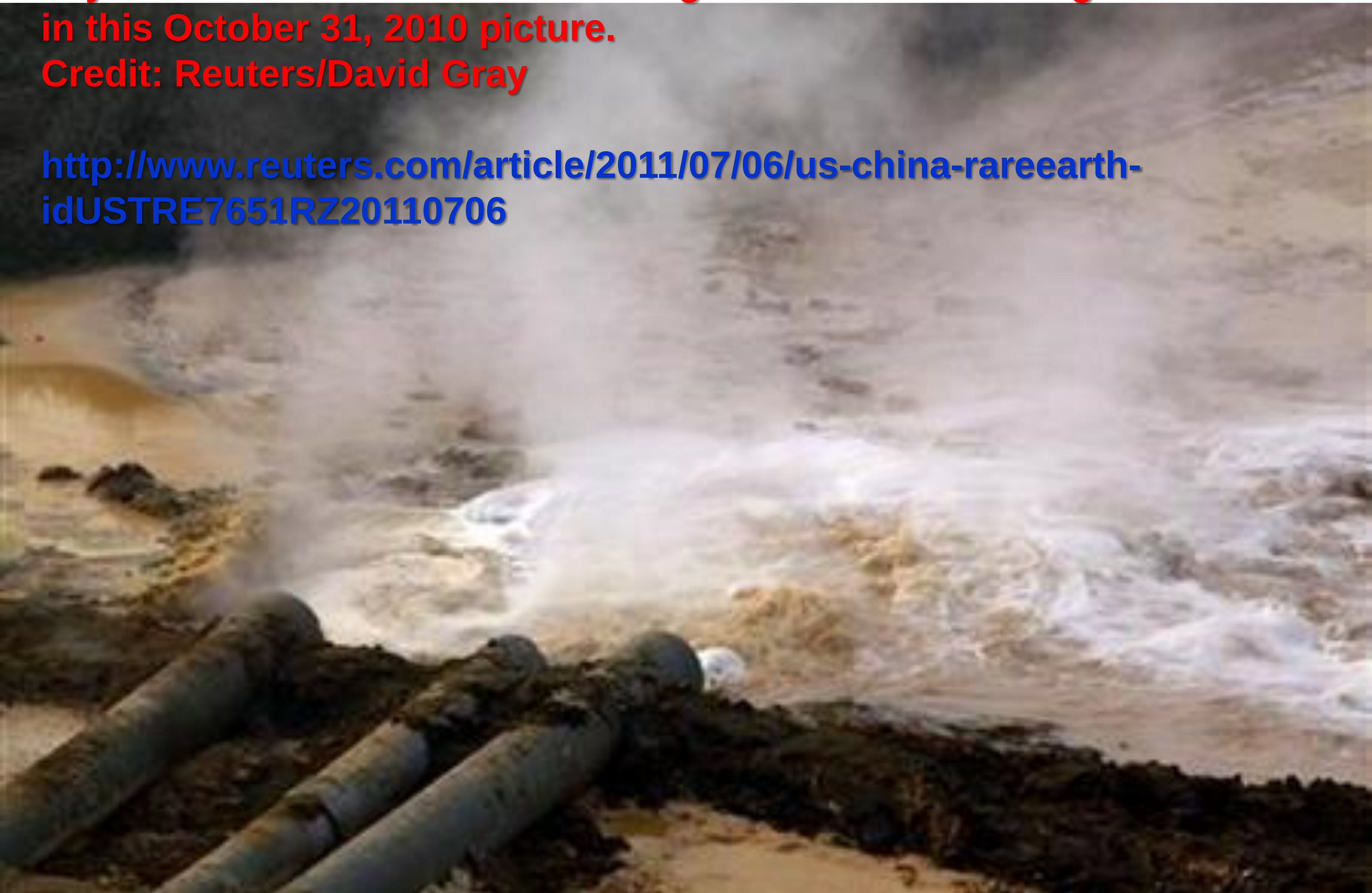
http://www.rootforce.org/2013/05/01/clean-and-green-rare-earth-elements-and-technology/

When googling "Baotou Tailing Dam" various images can be obtained

http://www.reuters.com/article/2010/11/21/us-climate-emissions-idUSTRE6AK1OU20101121

Pipes coming from a rare earth smelting plant spew polluted water into a vast tailings dam near Xinguang Village, located on the outskirts of the city of Baotou in China's Inner Mongolia Autonomous Region in this October 31, 2010 picture.
Credit: Reuters/David Gray

http://www.reuters.com/article/2011/07/06/us-china-rareearth-idUSTRE7651RZ20110706



Mountain Pass Mine (USA)

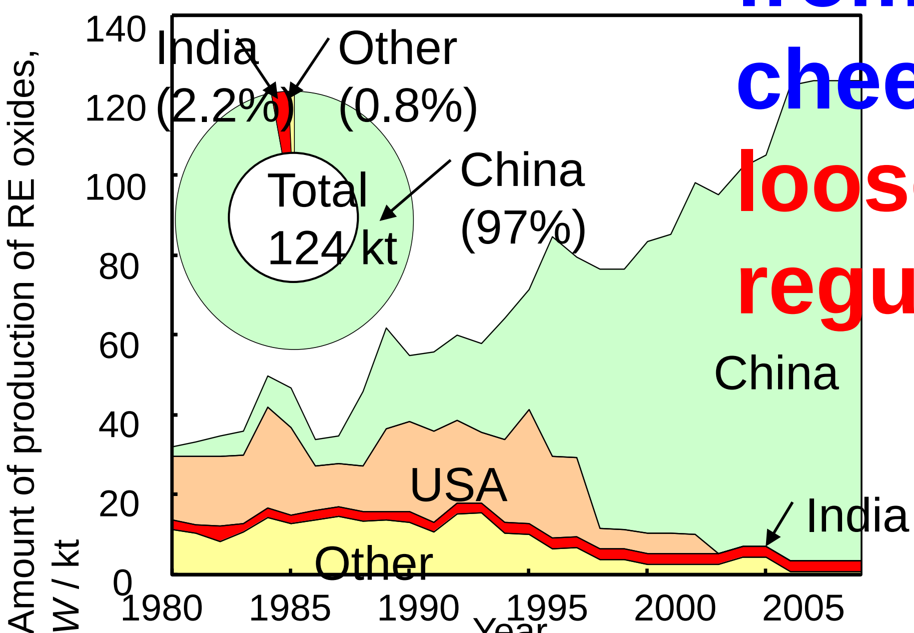
Re-stating mining operation?!

Mountain Pass Rare Earth Mine had been the largest mine in the past.

This mine also has NORM problems!

Supply risk of Rare earth:
⇨ 97% domination of China.

Rare earth resource market is dominated by China because of existence of high grade ore from large mine, cheep labor cost, and loose environmental regulations.

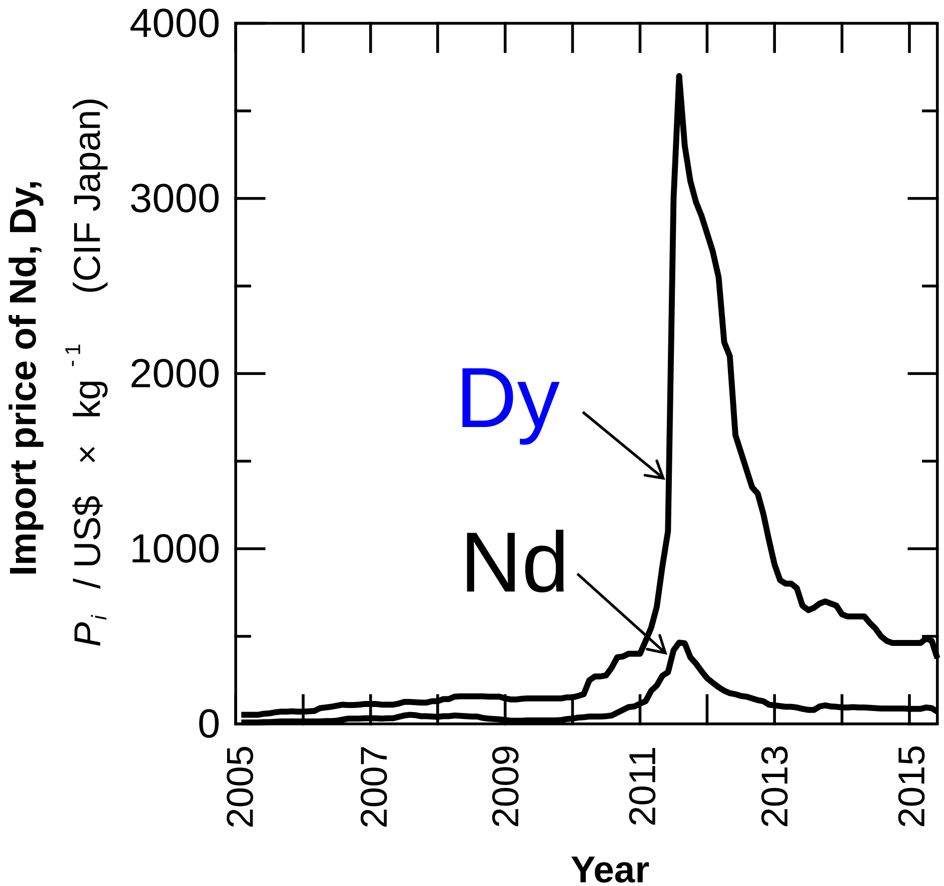


Change in amount of production of REE, and share in supply of REE in 2009

(USGS Mineral Commodity Summaries (2010))

Comparison of costs for producing metal and alloys of rare earth metals

	Japan	US	China	Australia
Feed cost	× high	× high	◎ very low	○ low
Energy cost	× high	○low	? low	○ low
Environmental cost	× very high	× high	◎ very low	× high
Employment cost	× high	× high	× low	× high



Dy: ~$ 50 /kg Dy metal

Nd: < $ 10 /kg Nd metal

⇩

Dy: ~$ 400 /kg Dy metal

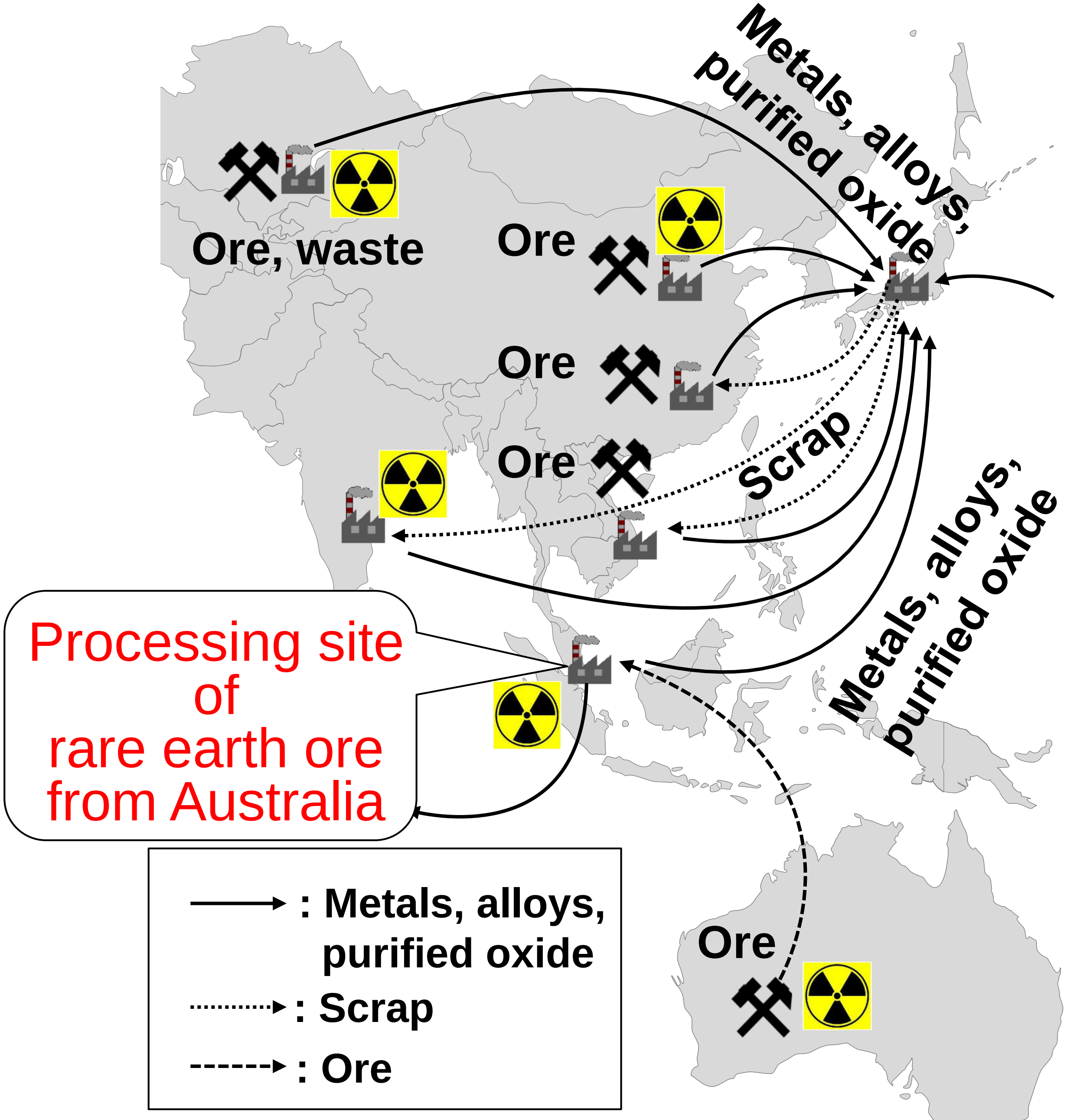
(max.> **$3500 / kgDy !**)

Nd: ~$ 100 /kg Nd metal

(max. **$450 / kgNd !**)

Price change of rare earth (Nd, Dy) from 2005 to 2015.

Change in amount of production of REE, and share in supply of REE in 20016.
(USGS Mineral Commodity Summaries (2016))



Material flow of rare earth metals and alloys in the world.

Japan imports only purified materials.

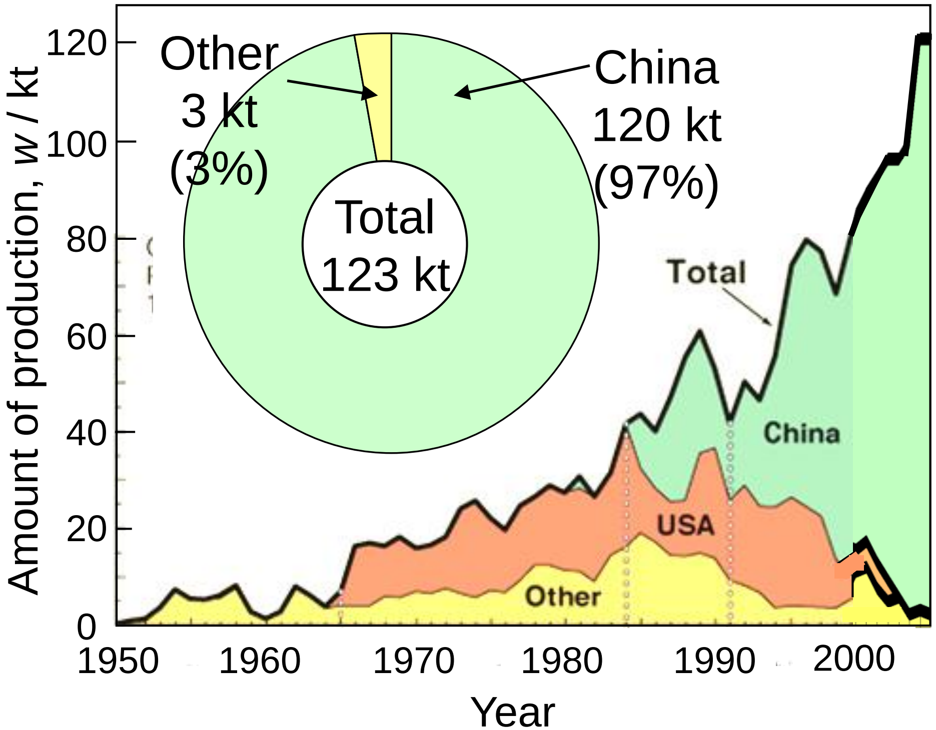
Practically, we can not import ore which contains radio active elements (NORM).

Fig. Global material flow for production of metals and alloys of rare earth metals and waste treatment of the scrap.

China has extremely high quality mineral resource and cheep labor.

Worlds' 97 % supply is dominated by China.

Problems in supply of REE



Dy: ~$ 50 /kg Dy metal

Nd: < $ 10 /kg Nd metal

⇩

Dy: ~$ 400 /kg Dy metal

(max.> **$3500 / kgDy !**)

Nd: ~$ 150 /kg Nd metal

(max. **$450 / kgNd !**)

Change in amount of production of REE, and share in supply of REE in 2006.

(USGS Mineral Commodity Summaries (2007))

Grade of Nd & Dy in the ore.

Ore		Ion cray	Bastnaesite		Monazite
Mining Site		Longnan (China)	Bayan Obo (China)	Mt. Pass (USA)	Mt. Weld (Australia)
REO grade in Ore (wt%)		0.05～0.2	6.00	8.90	11.20
Grade in REO (wt%)	Nd	3.00	18.50	12.00	15.00
	Dy	6.70	0.10	trace	0.20
Grade in Ore (wt%)	Nd	0.0015～0.006	1.11	1.068	1.68
	Dy	0.00335～0.0134	0.006	trace	0.0224

Dy grade in ore is very low, but
very easy to extract directly from ion clay...

(石原舜三，村上浩康:レアアース資源を供給する鉱床タイプ，地質ニュース624号，10 - 24. (2006))
(USGS Mineral Commodity Summaries (2010))

Table 4 Unit mass of rare earth used for industrial products (rough estimate).

Product	Unit mass of RE (kg RE / Unit)
Hybrid vehicle (HV)	0.25~1.25[a]
Electric vehicle (EV)	1.3~
Power steering	0.09
Air conditioner	0.12
Hard disk drive	0.01
Mobile phone	0.0005
MRI[b]	1500

1.3 kg RE magnet / EV

a: In the case of hybrid vehicles (HV) unit mass of RE varies with output power of motors.
Small HVs use about 0.25 kg/unit RE and large ones about 1.25 kg/unit.
b: Magnetic Resonance Imaging (MRI) units.

When producing high performance **motors for HEV or EV,** about 1.3 kg of Rare earth magnet (Nd-Fe-B) is necessary.

1.3 kg of Rare Earth magnet contains

21（～26）% of Neodymium (Nd)
10（ ～5）% of Dysprosium (Dy)
(Rest: Boron)
→ Magnet with high thermal stability requires large amount of Dy.

Ore grade of Nd is about 1% (Bastnaesite)
Ore grade of Dy is about 0.01%-0.003% (Ion cray)

When producing high perfomance motors:
about 0.27 kg of Nd (31 kg of Bastnaesite ore)

about 0.17 kg of Dy (1 to 4 tons of Ion cray)

are required.
For producing one motor, large amount of ore is required, and environment problems are induced when mining and refining.

Far larger mass of ore compared to the mass is automobile is consumed when producing high performance automobile.

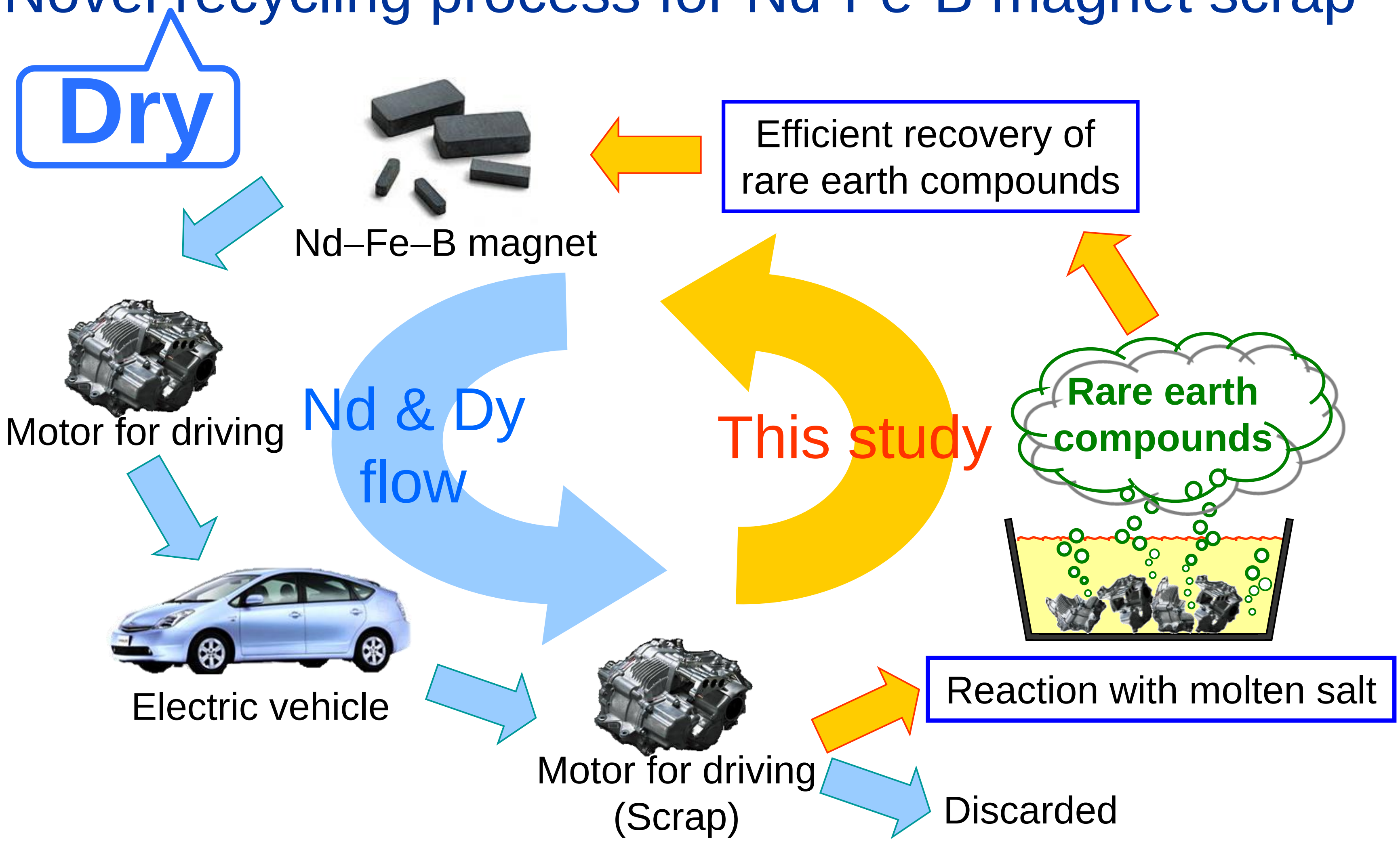
Key points:

- Production of Nd–Fe–B magnet for industrial motors will drastically increase in the future.
- Large amount of magnet scrap will be discarded.
- Resource of Dy (from ion cray) is scarce and limited (now available only from China).
- **Production of Nd from mineral ore induces environmental pollution.**
- Minerals for heavy REE, such as Dy, are unevenly distributed in the world.

Rare Metals

PGMs, REMs, Ga, Ta…

Novel recycling process for Nd-Fe-B magnet scrap



Development of effective recovery process
by utilizing molten salt as a rare earth extracting agent

Okabe's dream:

Development of efficient and environmentally sound recycling processes:

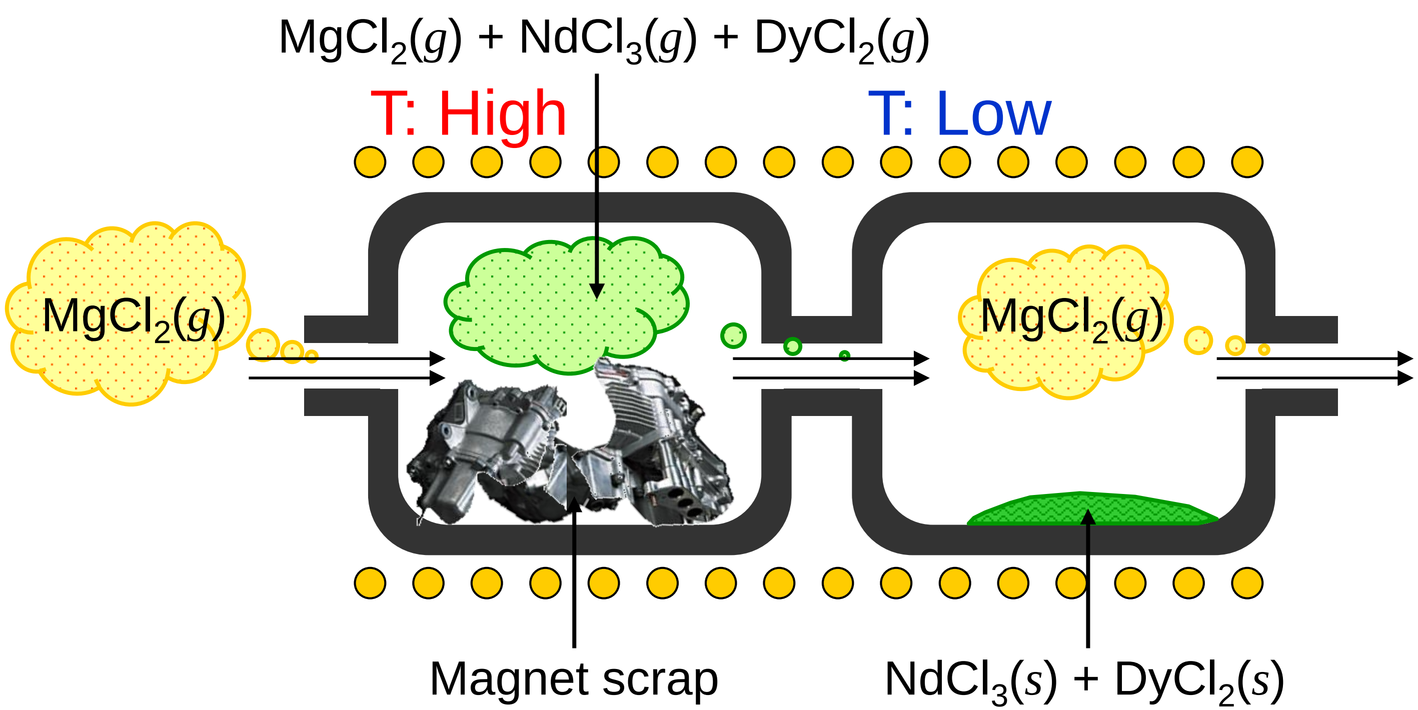


Fig. Schematic illustration of novel recycling process for magnet scrap.

Current status of rare earth production in China and recycling in Japan

Institute of Industrial Science, The University of Tokyo
Toru H. Okabe

'Current status of rare earth production in China and recycling in Japan',
Toru H. Okabe:
REE4EU Project
REE4EU Exploitation Workshop
Presentation in the exploitation workshop with external industry and EU-policy participation, Wednesday 24th April, (45 min)
[April 22-25, 2019, Stakeholders workshop, 24 April 2019, Avenue de la joyeuse Entrée 1, 4thfloor, 1040 Brussels, Belgium] (2019. 4. 24).
[Invited presentation]

Development of new recovery process of rare metals from scraps

Rare Metals

Environmentally sound technology for producing and recycling less-common metals

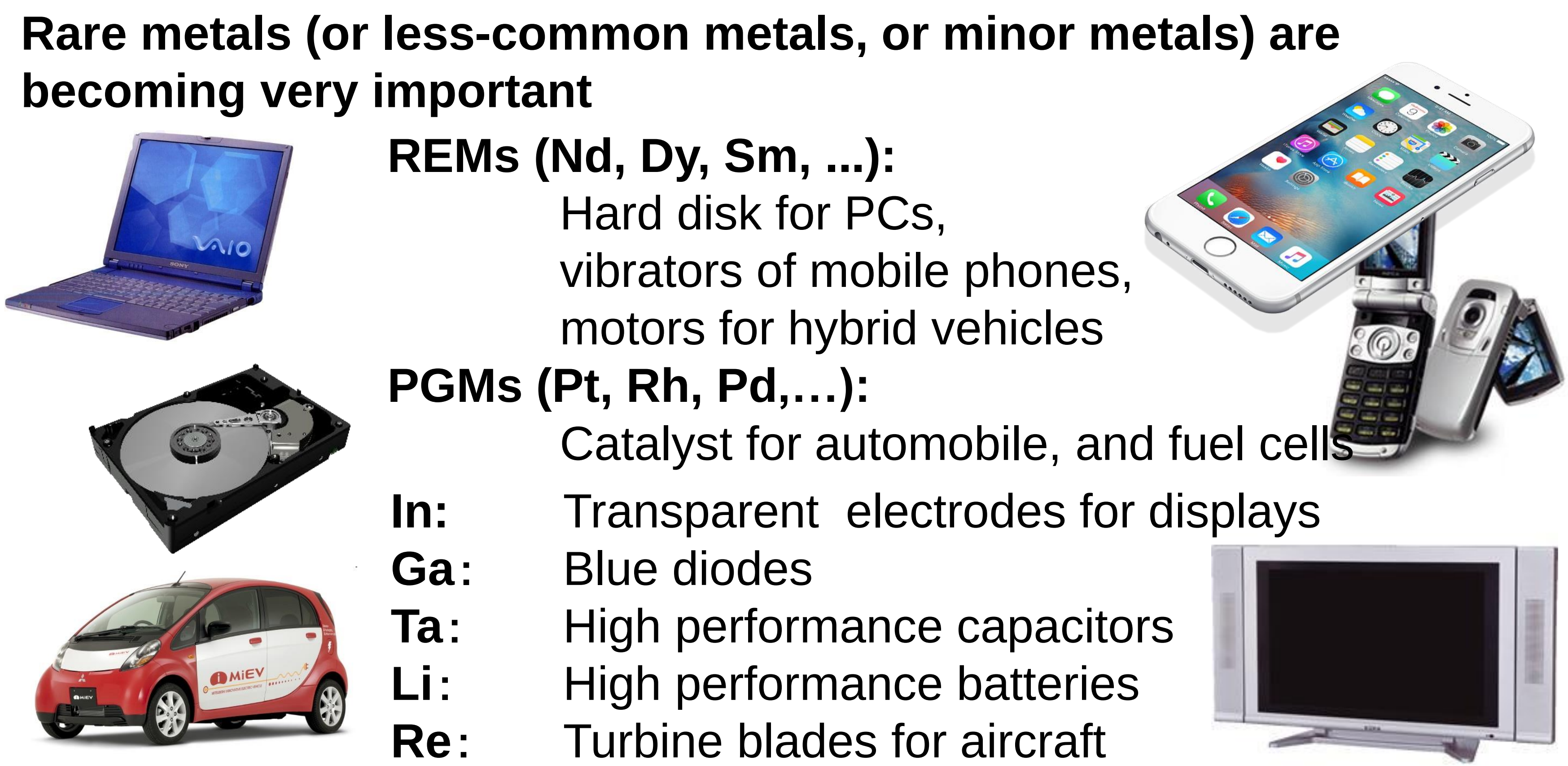


Fig. 1
Rare metals (or less-common metals, or minor metals) are becoming very important materials for ensuring a high-quality lifestyle in advanced countries. These metals are essential for producing high-tech industrial products, which will be "scrap" after their lifetime of usage.

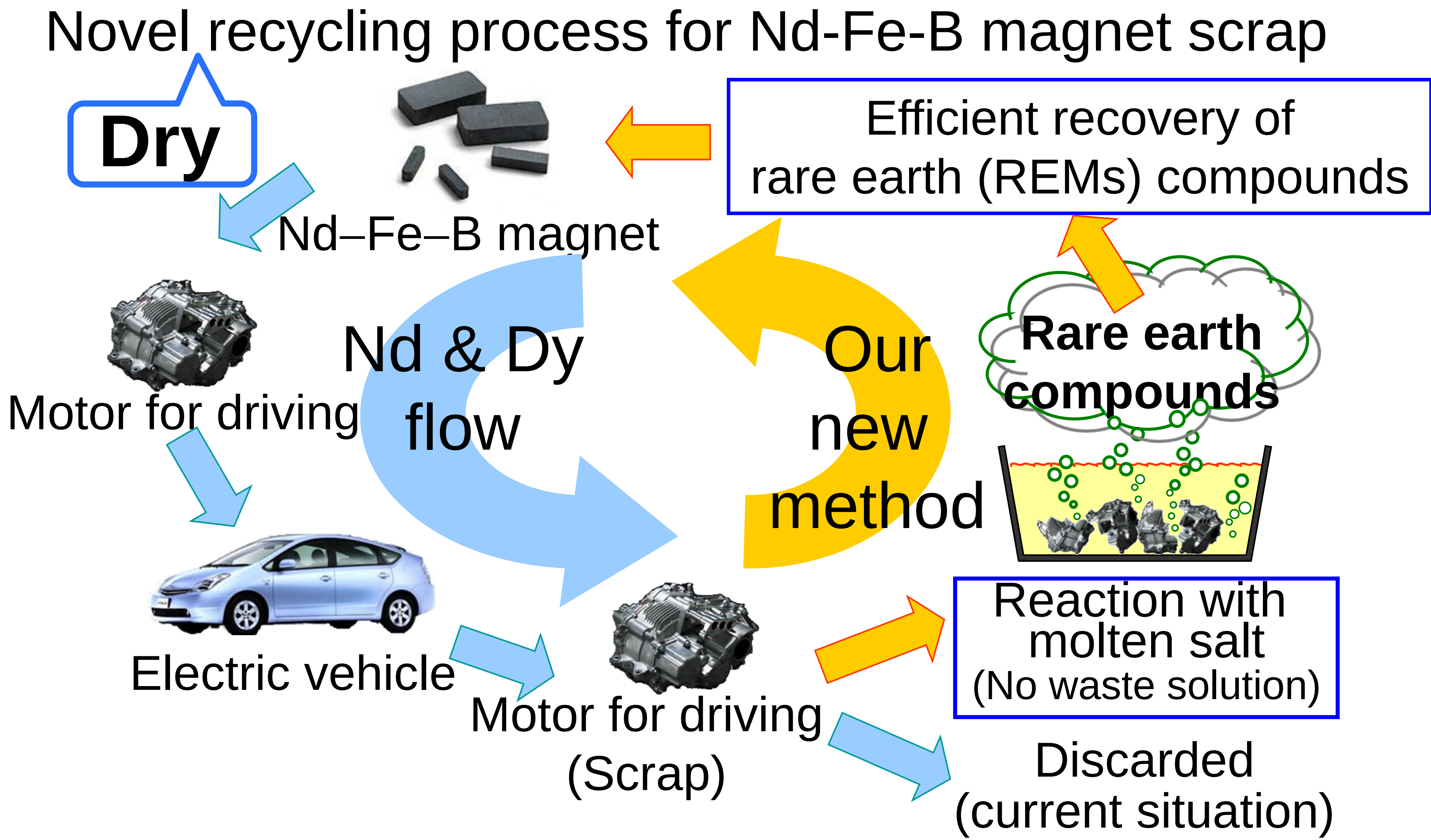


Fig. 3

A representative scheme for the development of an effective recovery process by utilizing molten salt as a rare-earth extracting agent. A novel environmentally sound recycling process for Nd–Fe–B magnet scrap, which does not generate any waste aqueous solution, is currently under development. This research won many awards.

Recycling process of REM magnet scrap

- Oxidation / Hydrometallurgical separation process → Current major process

- Molten salt electrolysis
  - → Santoku, AIST, Osaka Univ., Kyoto Univ.,
  - → Tohoku Univ., etc.

- Slag / Metal separation
  - → Shinetsu, Santoku, Tohoku Univ.,
  - → Akita Univ.

Currently, various recycling technologies are being investigated

- Other pyrometallurgical processes

→ Univ. Tokyo, Kyoto Univ. etc.

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- Other pyrometallurgical processes

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Recycling process of REM magnet scrap

- Oxidation / Hydrometallurgical separation process → Current major process

In Japan, waste water treatment containing heavy metals and organic compounds is costly, and we are trying to develop new environmentally sound processes which does not produce any waste solutions.

→Dry pyrometallurgical process will be one of the key processes

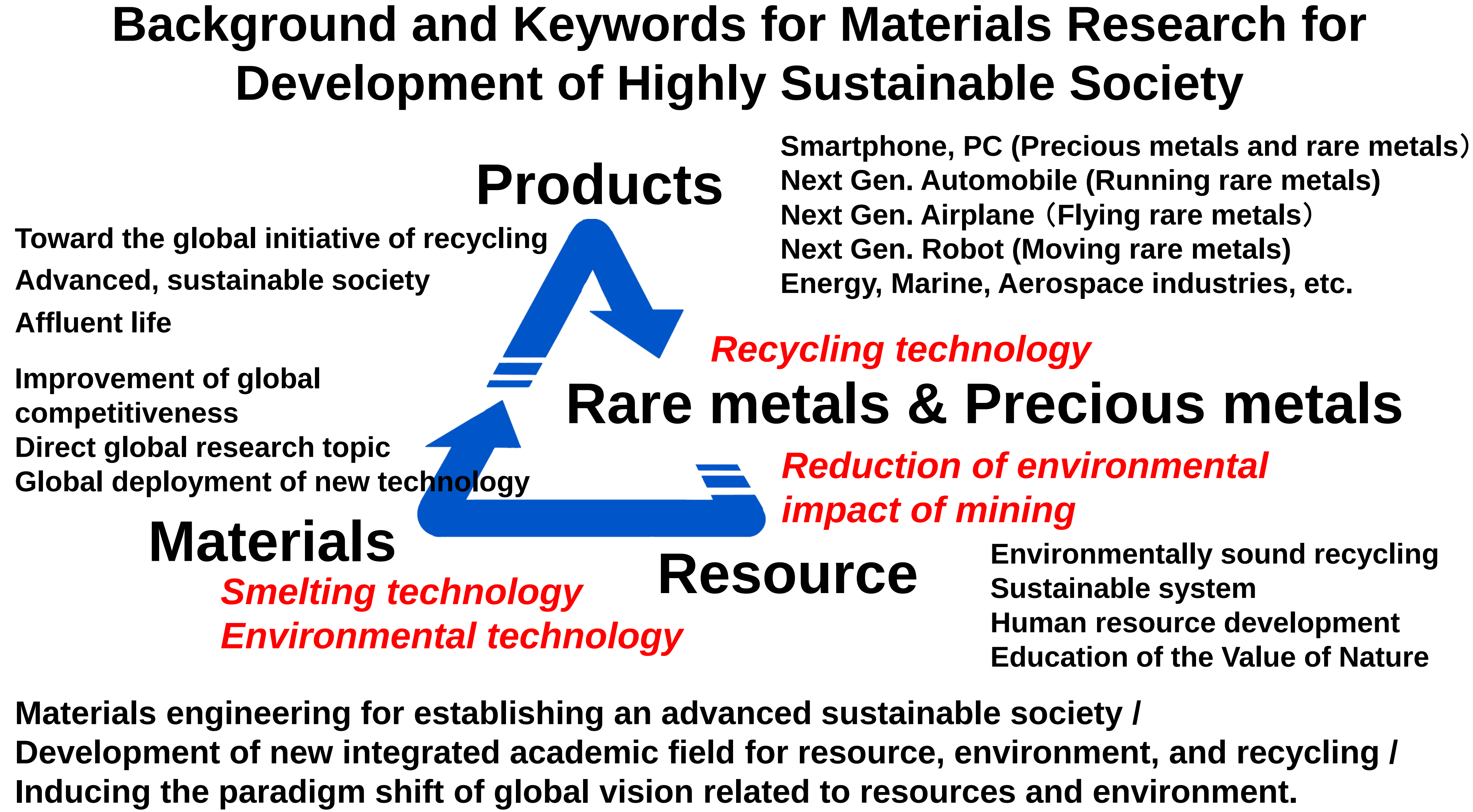

Fig. 1
Aiming to establish an advanced recycling society through various approaches, the pivotal items necessary to realize a materials recycling society (rare metals and precious metals are shown as representatives) are listed. In the future, recycling and environmental technologies for rare metals and precious metals will be key for a highly sustainable society.

Development of new recovery process of rare metals from scraps

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Comparison of costs for producing metal and alloys of rare earth metals

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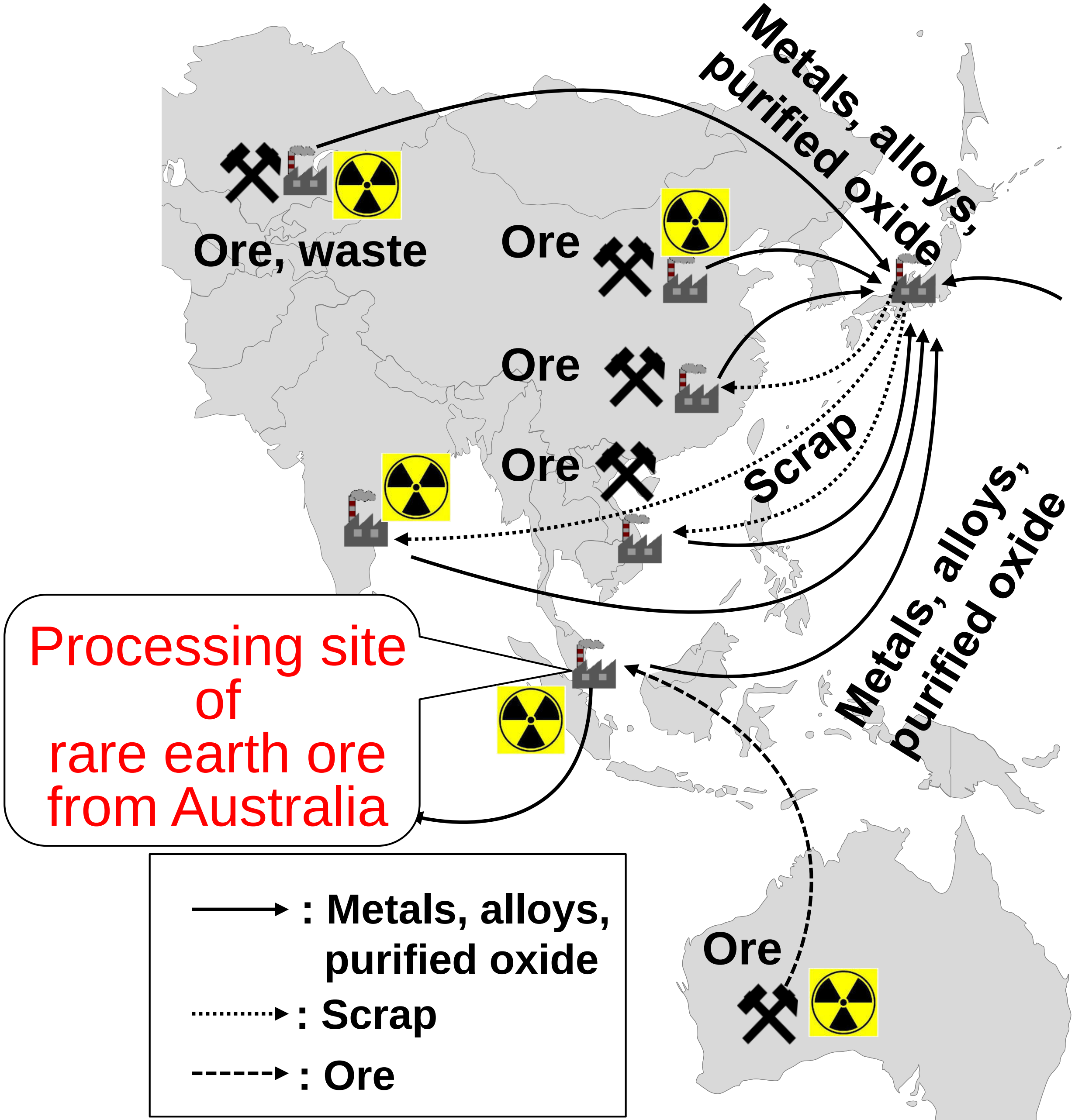

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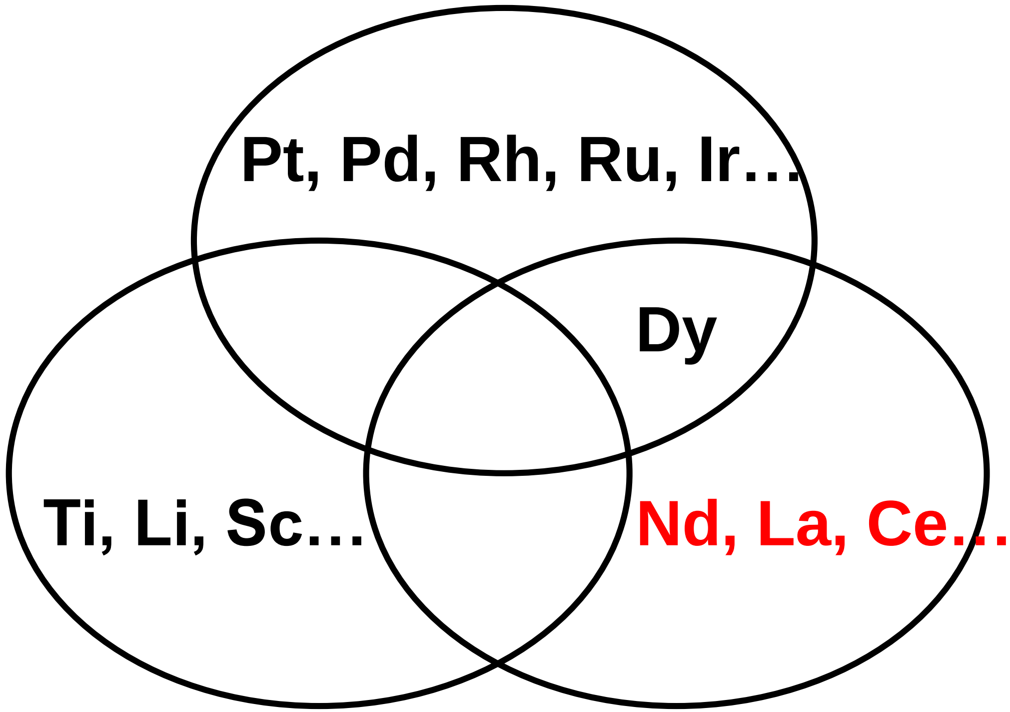
Fig. Global material flow for production of metals and alloys of rare earth metals and waste treatment of the scrap.

A: Resource Supply Restriction



B: Technological Restriction

C: Environmental Restriction

Fig. Key factors that determine rare metal supply. Environmental and technological restrictions are the major practical constraints, not the resource supply restriction, especially for rare earth metals.

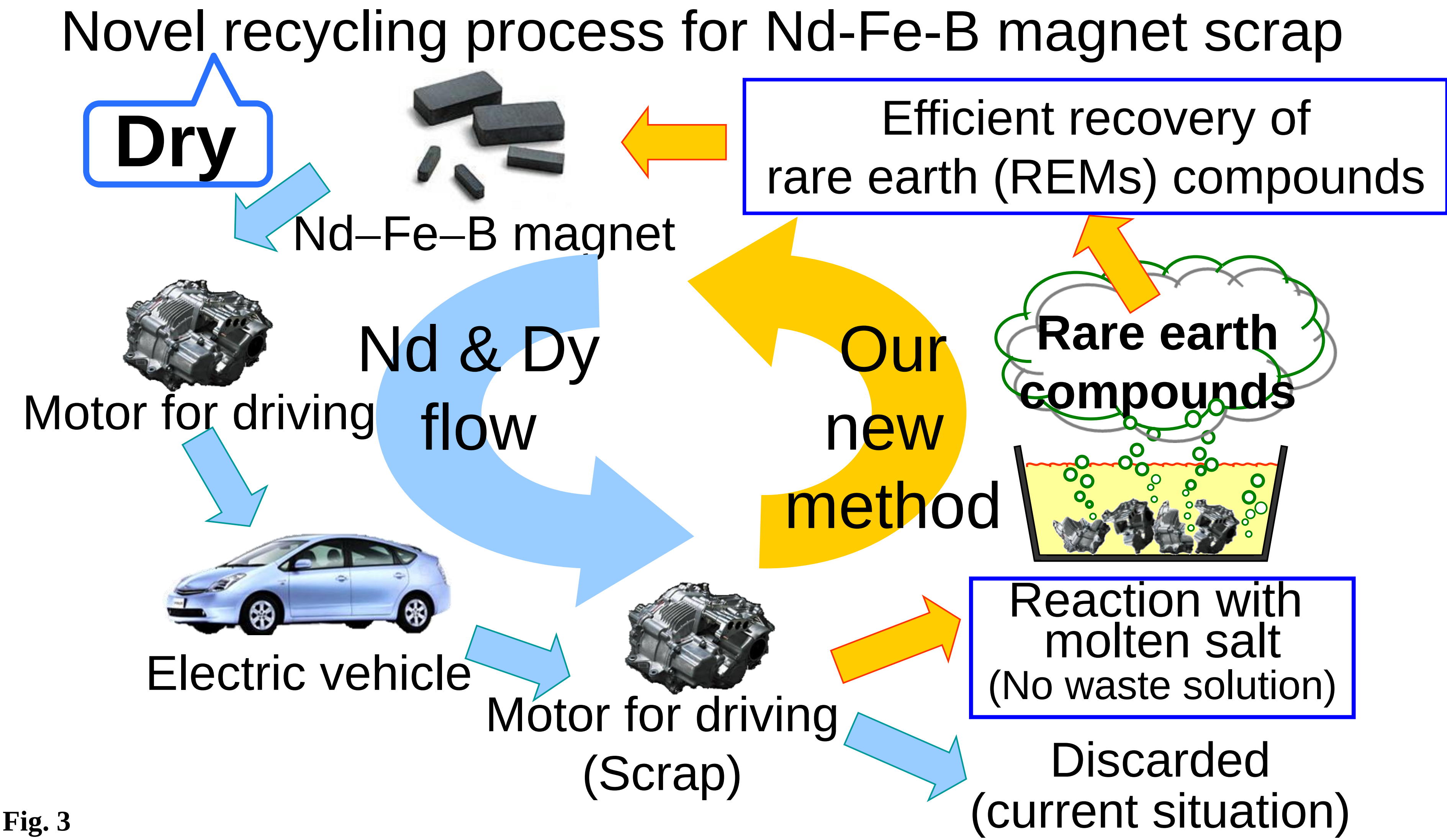


Fig. 3

A representative scheme for the development of an effective recovery process by utilizing molten salt as a rare-earth extracting agent. A novel environmentally sound recycling process for Nd–Fe–B magnet scrap, which does not generate any waste aqueous solution, is currently under development. (T. H. Okabe, S. Shirayama: International patent PCT/JP2009/056079 (2009.3.26), US Patent No. 8323592 (2012.7.19), Chinese Patent No. ZL200980119301.3 (2013.7.10), German Patent No. 60329388.3 (2009.9.23), British Patent No.1512475 (2009.9.23), Japanese Patent No. 5424352 (2013.12.6), Y. Miyamoto, T. Okamoto, T. H. Okabe: Japanese Patent No. 5709164, International patent PCT/JP2012/056032 (2012.3.8), etc.) **This**

When considering the bottlenecks of supply of rare metals (including REMs), many people put heavy weight on the resource constraints of rare metal supply.

However, in practice, environmental and technological constraints are the major bottlenecks, rather than any problem with shortage of resources.

Current status of rare earth production in China and recycling in Japan

NORM：
Naturally Occurring Radioactive Materials

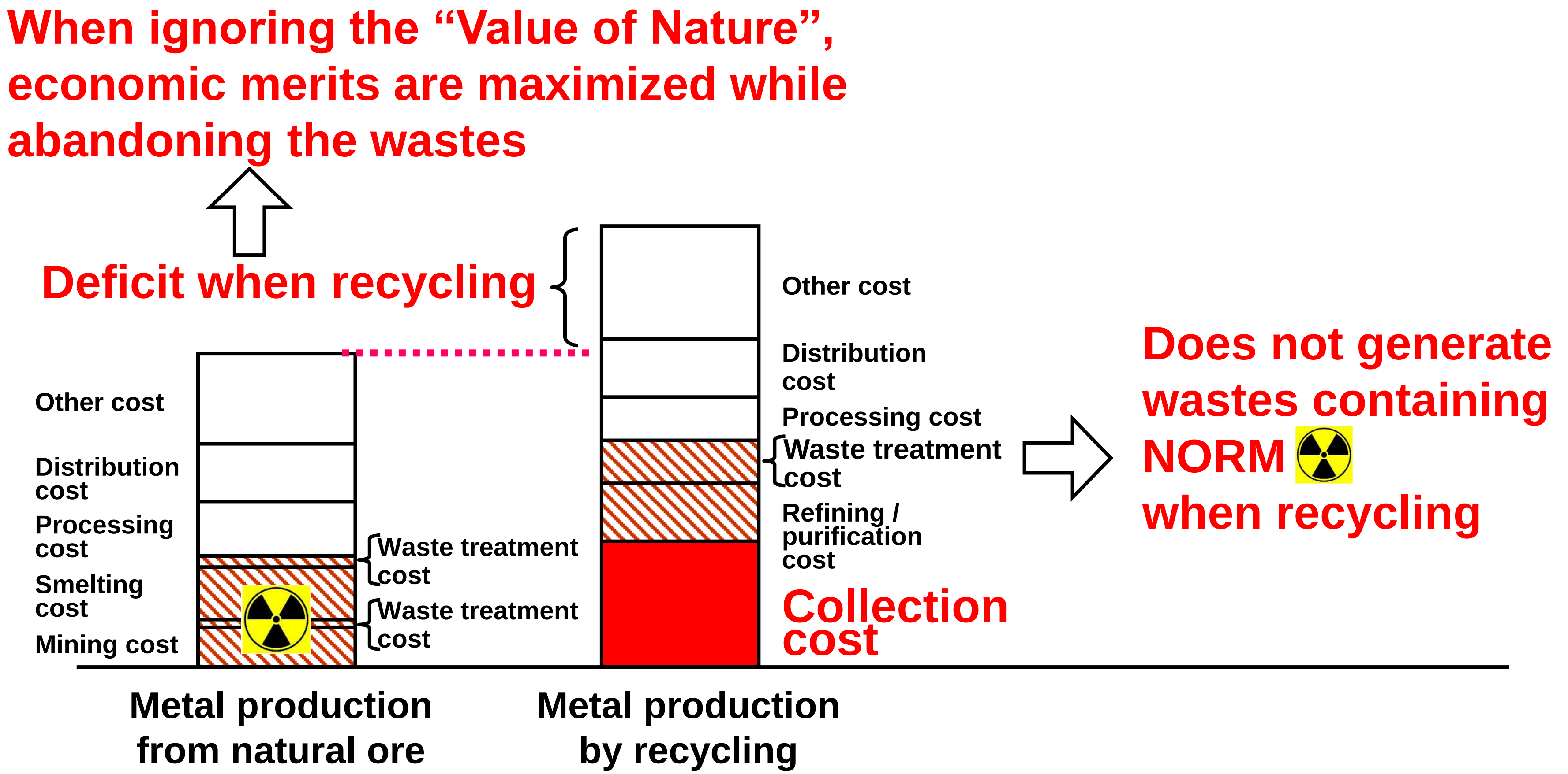
Goldschmidt's classification of elements

Relationship between main products and by-products.

Value of nature

Value of nature

(a) Nominal value of rare metals based on the current economic principles



※ Hatched parts in the figure are often carried out in mining countries or regions.

Fig. 9 The concept for evaluating the value of metals. In the current societal system, the value of nature is not considered. Recycling prevents consumption of natural resources and suppresses loss of the value of nature.

Value of nature

(a) Nominal value of rare metals based on the current economic principles

(b) Real value of rare metals counting the value of nature.

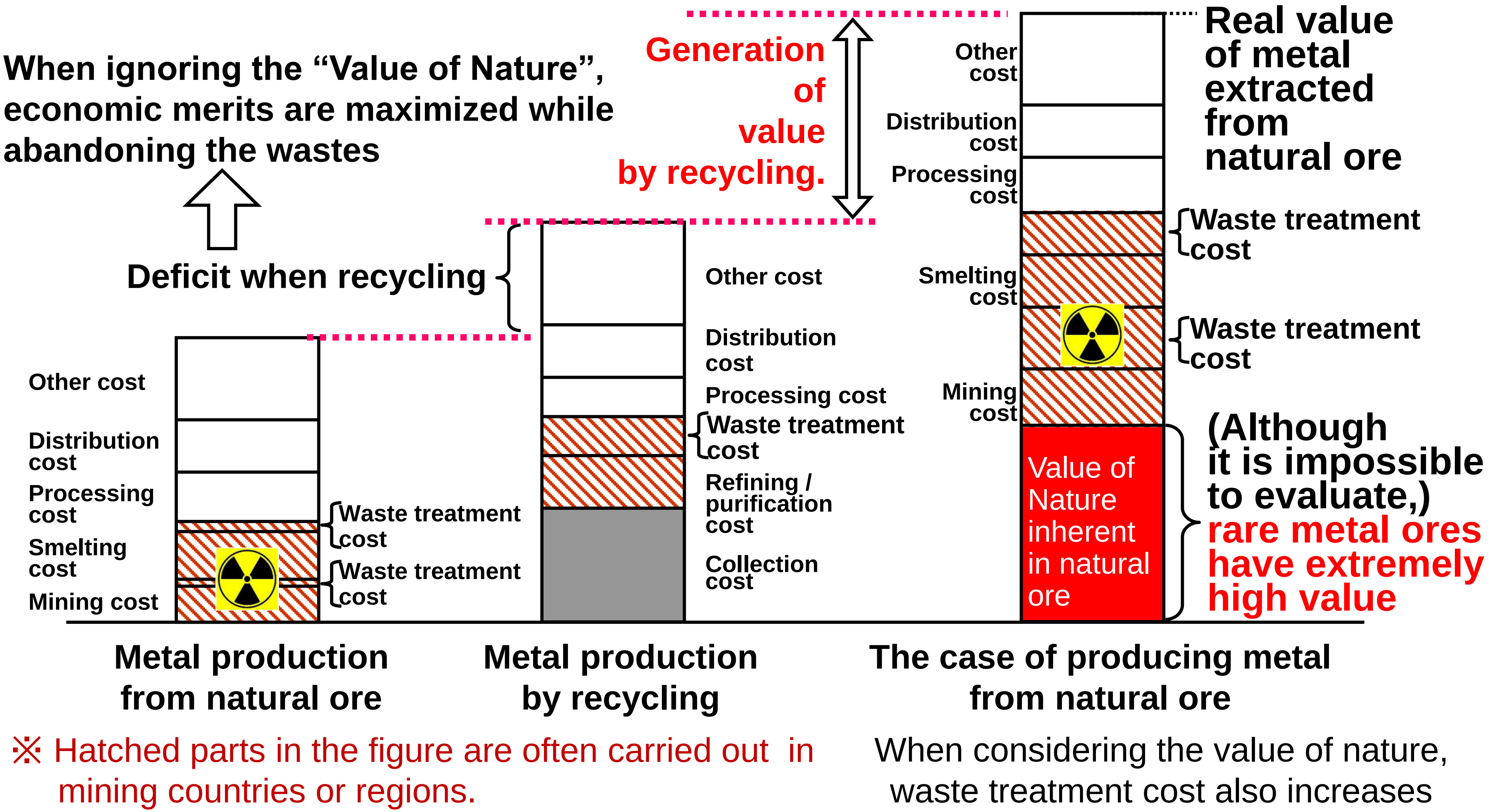


Fig. 9 The concept for evaluating the value of metals. In the current societal system, the value of nature is not considered. Recycling prevents consumption of natural resources and suppresses loss of the value of nature.

When extracting rare metals from recycled feed material, harmful wastes generated from natural ore processing can be avoided.

This is the primary advantage of the cyclical use of rare metal resources.

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IOM3 The Institute of Materials, Minerals and Mining
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Bottlenecks in rare metal supply and the importance of recycling – a Japanese perspective

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ABSTRACT

Rare metals are less common metals that are generally perceived to be scarce. The media often presents one-track thinking on the depletion of mineral resources. Despite this common notion, the supply of most rare metals – including rare earth metals (REMs) – in terms of the amount of minerals available in known deposits is not a serious problem. Key factors that determine the supply of rare metals are the costs of mining and smelting and related environmental destruction. These are the major practical constraints, rather than the amount of mineral deposits in the earth. When extracting rare metals from recycled feed material, harmful wastes generated from natural ore processing can be avoided. This is the primary advantage of the cyclical use of rare metal resources. In this article, bottlenecks of rare metal supply, and the importance of recycling, are discussed, using REMs as an example.

ARTICLE HISTORY
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KEYWORDS
Rare metals; REMs; bottlenecks; supply chain; recycling; environmental destruction

'Bottlenecks in Rare Metal Supply and the Importance of Recycling - a Japanese Perspective', Toru H. Okabe:
Mineral Processing and Extractive Metallurgy, vol.126, no.1-2, (2017) pp.22-32.

1. Introduction

Most of the things that generate wealth, including rare metals, have good and bad aspects: light and shadow.

2. Misconceptions of the general public about rare metals

From the words 'rare metals', the majority of the public

Rare metals are less common metals that are generally perceived to be scarce. The media often presents one-track thinking on the depletion of mineral resources.

Despite this common notion, the supply of most rare metals — including rare earth metals (REMs) — in terms of the amount of minerals available in known deposits, is not a serious problem.

Key factors that determine the supply of rare metals are the costs of mining and smelting, and related environmental destruction. These are the major practical constraints, rather than the amount of mineral deposits in the earth.

Development of new recovery process of rare metals from scraps

Rare Metals

Environmentally sound technology for producing and recycling less-common metals

Innovation Changes
Rare Metal to be recycled efficiently

(Carnegie Museum of Art, Pittsburgh, Pennsylvania, cover page of JOM, Nov. 2000)

Environmentally sound metal production / recycling technology has to be developed

Current status of rare earth production in China and recycling in Japan

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