BRIN
BADAN RISET
DAN INOVASI NASIONAL

PERHIMPUNAN PERISET INDONESIA

Focus Group Discussion Seri #2, Dewan Pakar PPI

Inovasi dan Teknologi Pengolahan Limbah Elektronik (Logam Tanah Jarang)

Ratno Nuryadi
Kepala OR Nanoteknologi dan Material

12 September 2023

TODAY'S ELECTRONIC **GADGETS,**

TOMORROWS ELECTRONIC **WASTE....!!**

Outline

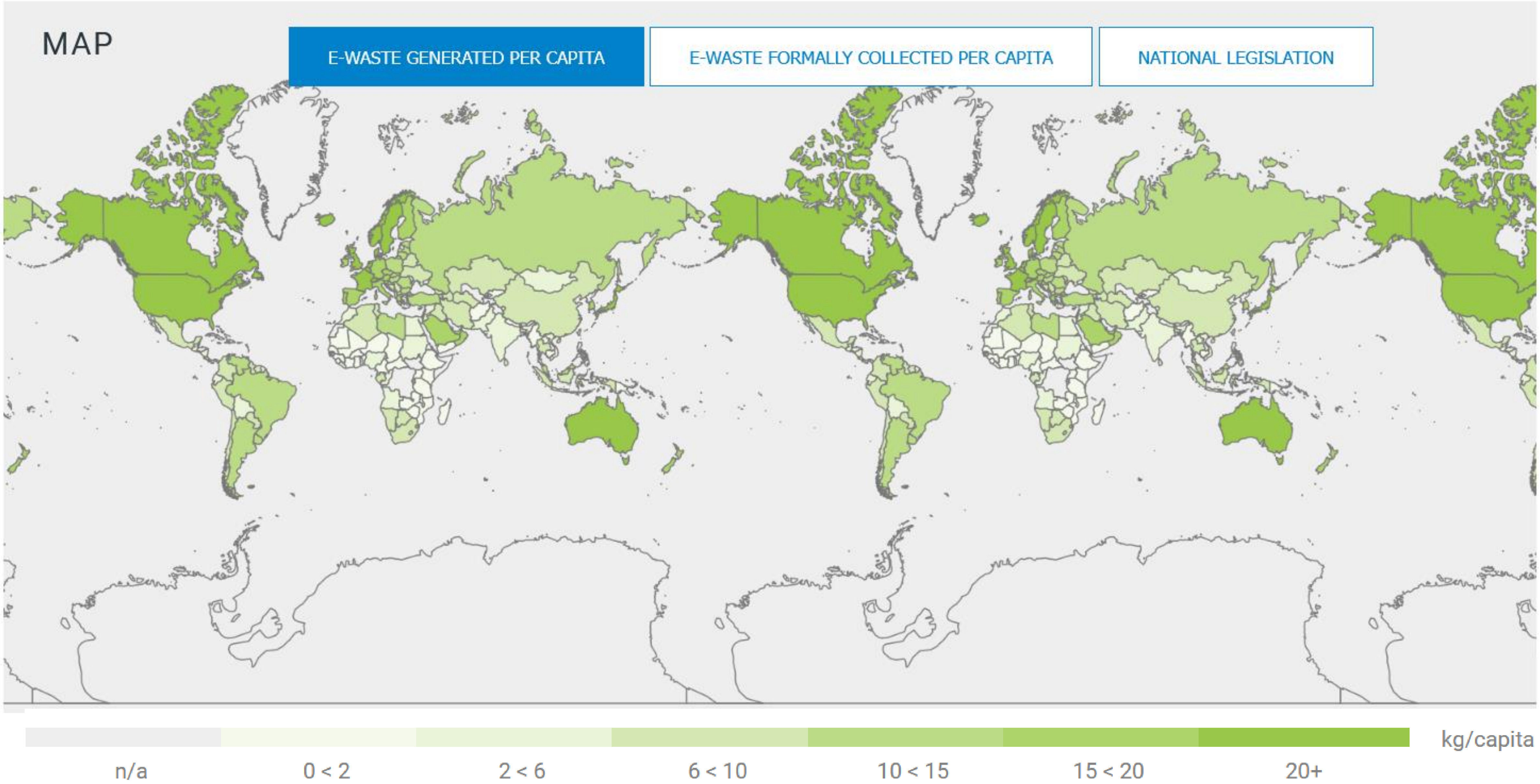
1. **Limbah Elektronik (Electronic Waste, E-Waste)**

2. **Logam Tanah Jarang (Rare Earth Elements, REE) dari Limbah Elektronik**

3. **Aktivitas Riset LTJ di BRIN**

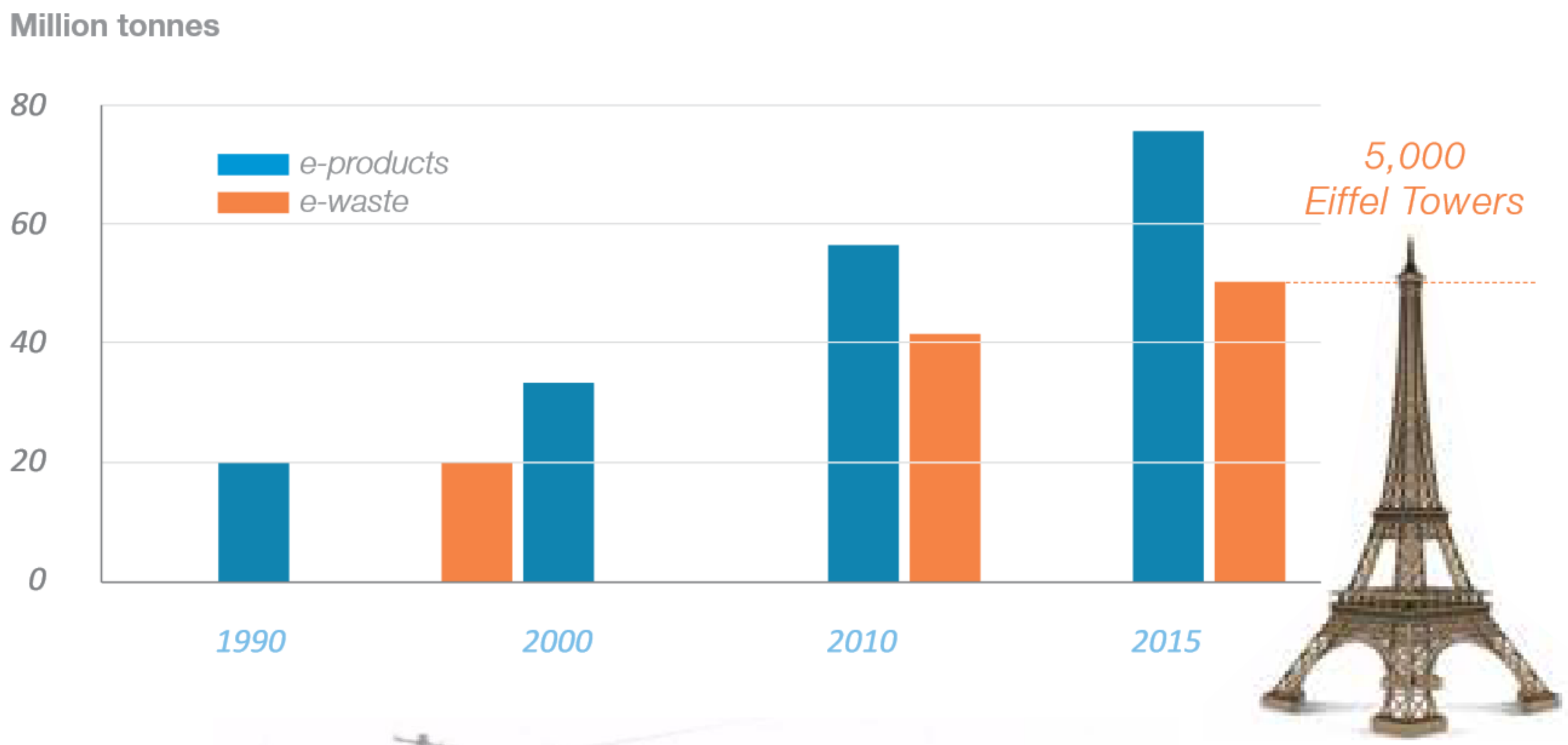
4. **Battery Recycling**

Distribusi Limbah Elektronik Global



Sumber : https://ewastemonitor.info/

Kenaikan Limbah Elektronik Global dari Waktu ke Waktu



StEP, UNU, and UNEP IETC have been working extensively on e-waste issues and made an attempt to look into the future of the problem in order to initiate policy level discussions on the challenges and opportunities ahead. Having insight into the future will help policymakers and industries, as well as other stakeholders, to make better strategic decisions. Forecasting is also necessary vis-à-vis strategic concepts towards sustainable development, such as circular economy and the UN's Agenda 2030.

We cannot expect immediate success with these concepts without an active search solutions. The complicated nature of production, use, and disposal of electronics require significant changes in order for the processes to become sustainable.

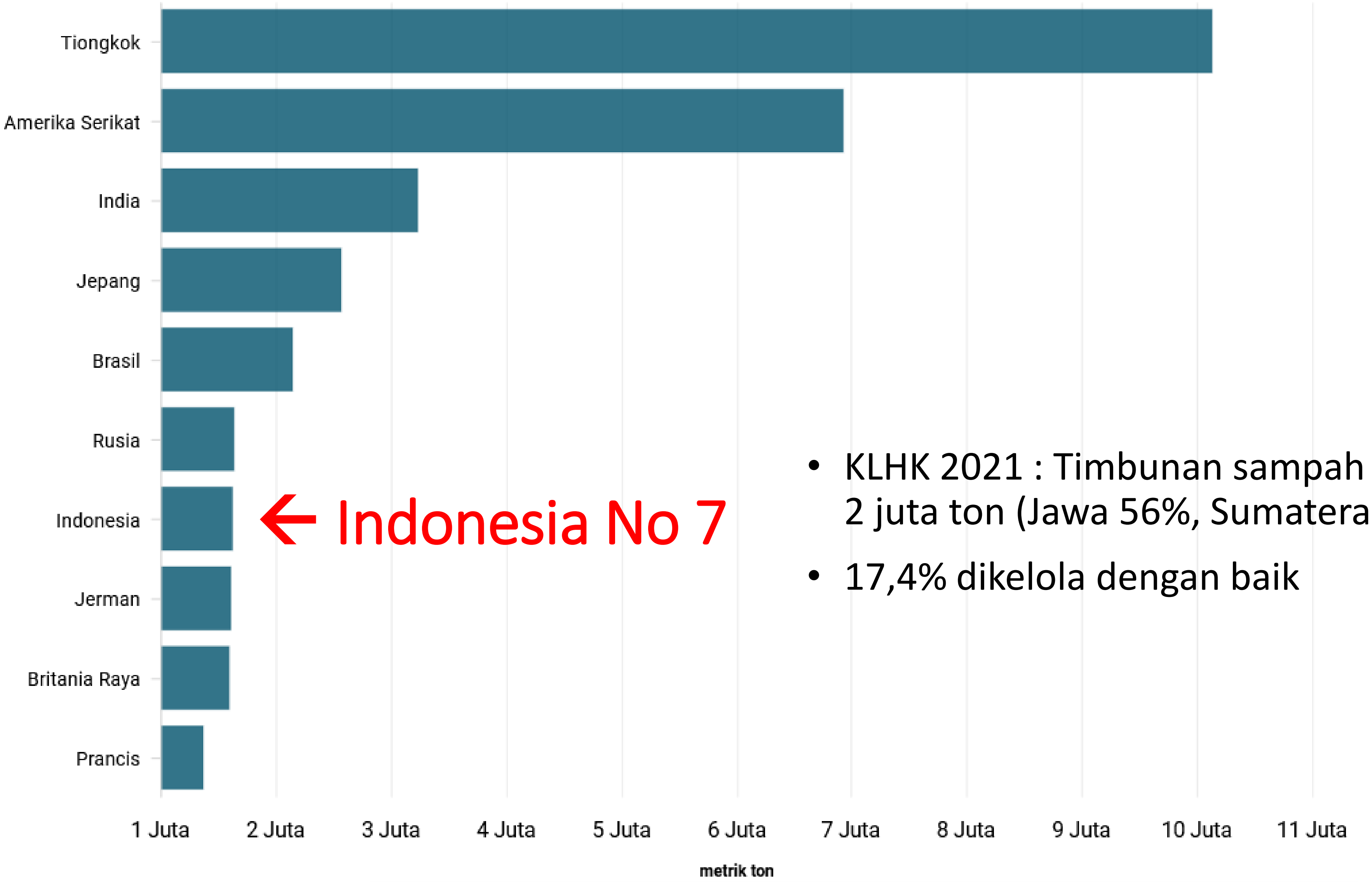
Efek E-Waste terhadap Lingkungan

- Emisi dari E-Waste menyebabkan kerusakan lingkungan.
- Bahan kimia beracun dari E-Waste memasuki "jalur pangan tanaman tanah".
- Ini tidak dapat terurai secara hayati dan menyebabkan polusi tanah.
- Tempat pembuangan sampah elektronik dan sebagian besar tempat pembuangannya tercemar dan menyebabkan bahaya kesehatan.

Efek E-Waste terhadap Tubuh Manusia

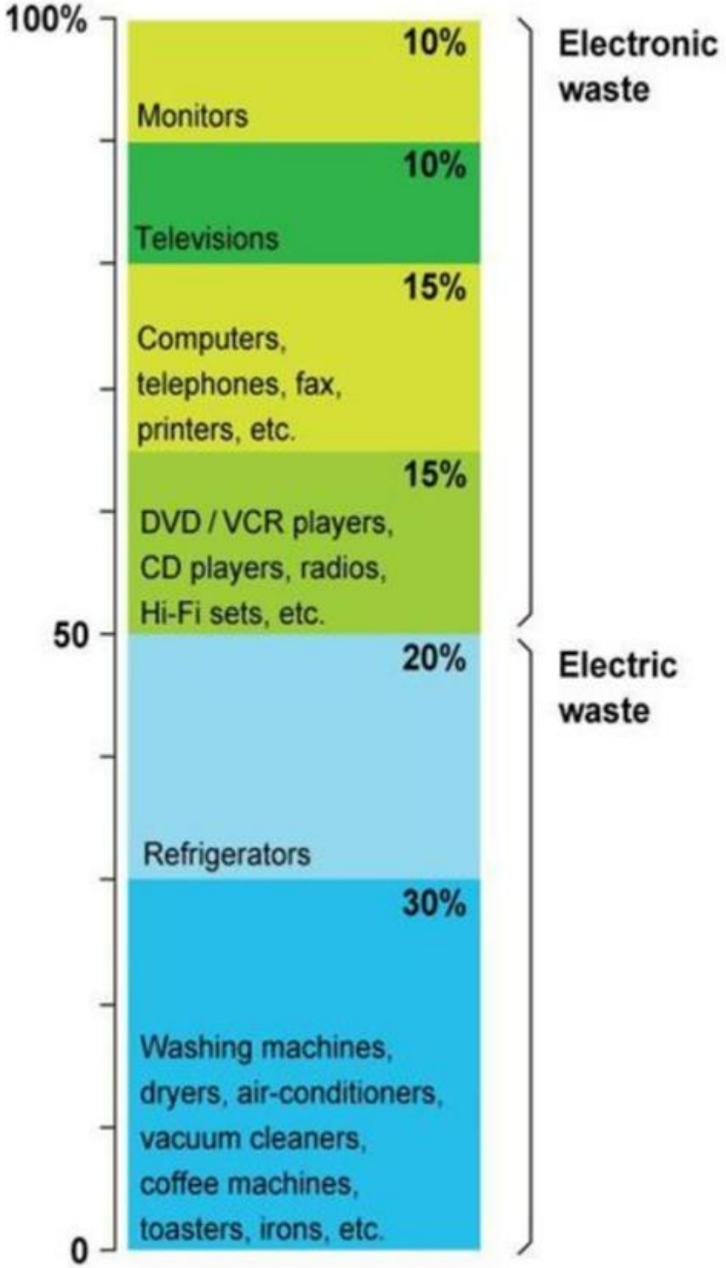
Elemen	Efek terhadap Tubuh Manusia
• Lead	: Kerusakan pada sistem saraf pusat dan perifer, sistem darah, dan kerusakan ginjal. Mempengaruhi perkembangan otak anak.
• Chromium	: Asma Bronkitis, kerusakan DNA
• Cadmium	: Racun yang tidak dapat diubah mempengaruhi kesehatan manusia. Akumulasi di ginjal dan hati. Menyebabkan kerusakan saraf.
• Mercury	: Kerusakan kronis pada otak dan sistem pernapasan.
• Plastic termasuk PVC	: Pembakaran menghasilkan dioksin. Bisa menyebabkan masalah reproduksi dan perkembangan: kerusakan sistem kekebalan tubuh, mengganggu regulasi hormon.

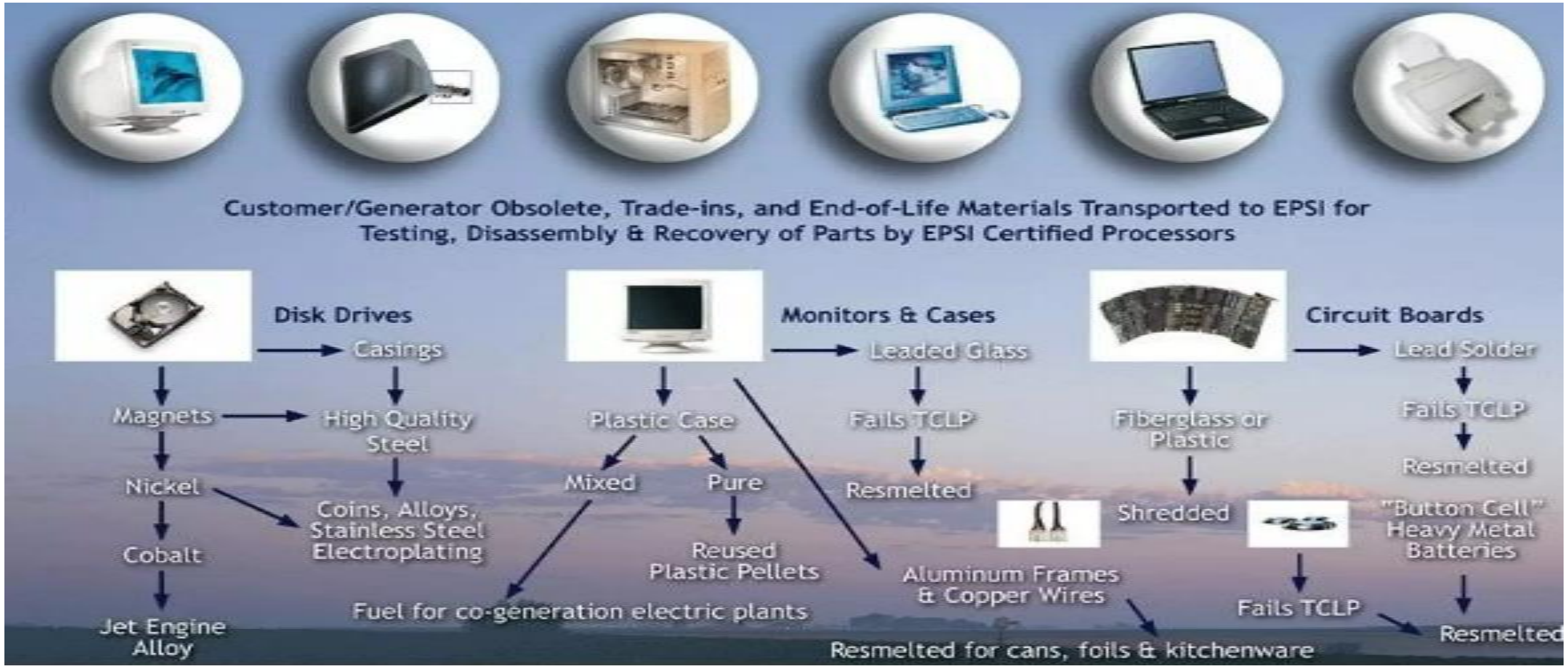
Limbah Elektronik Global per Negara



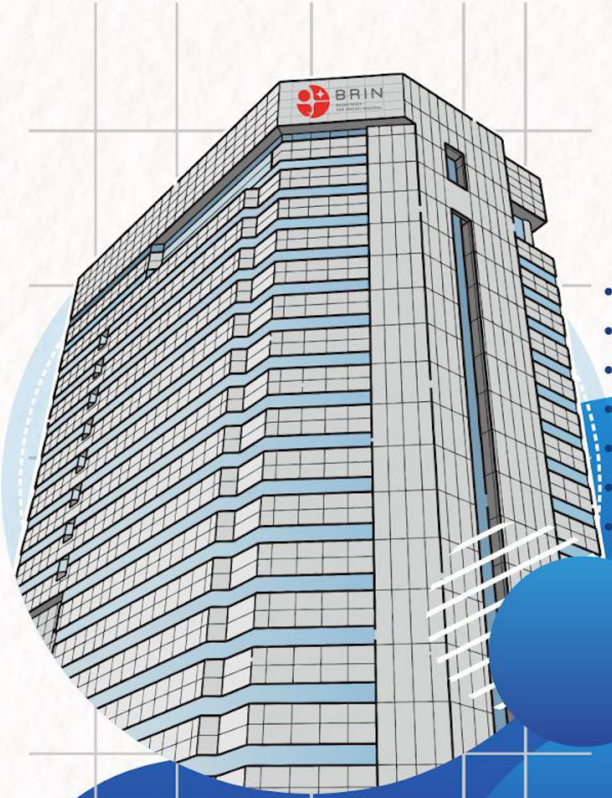
- KLHK 2021 : Timbunan sampah elektronik 2 juta ton (Jawa 56%, Sumatera 22%)
- 17,4% dikelola dengan baik

What is e-waste?





Rare Earth Elements from E-Waste



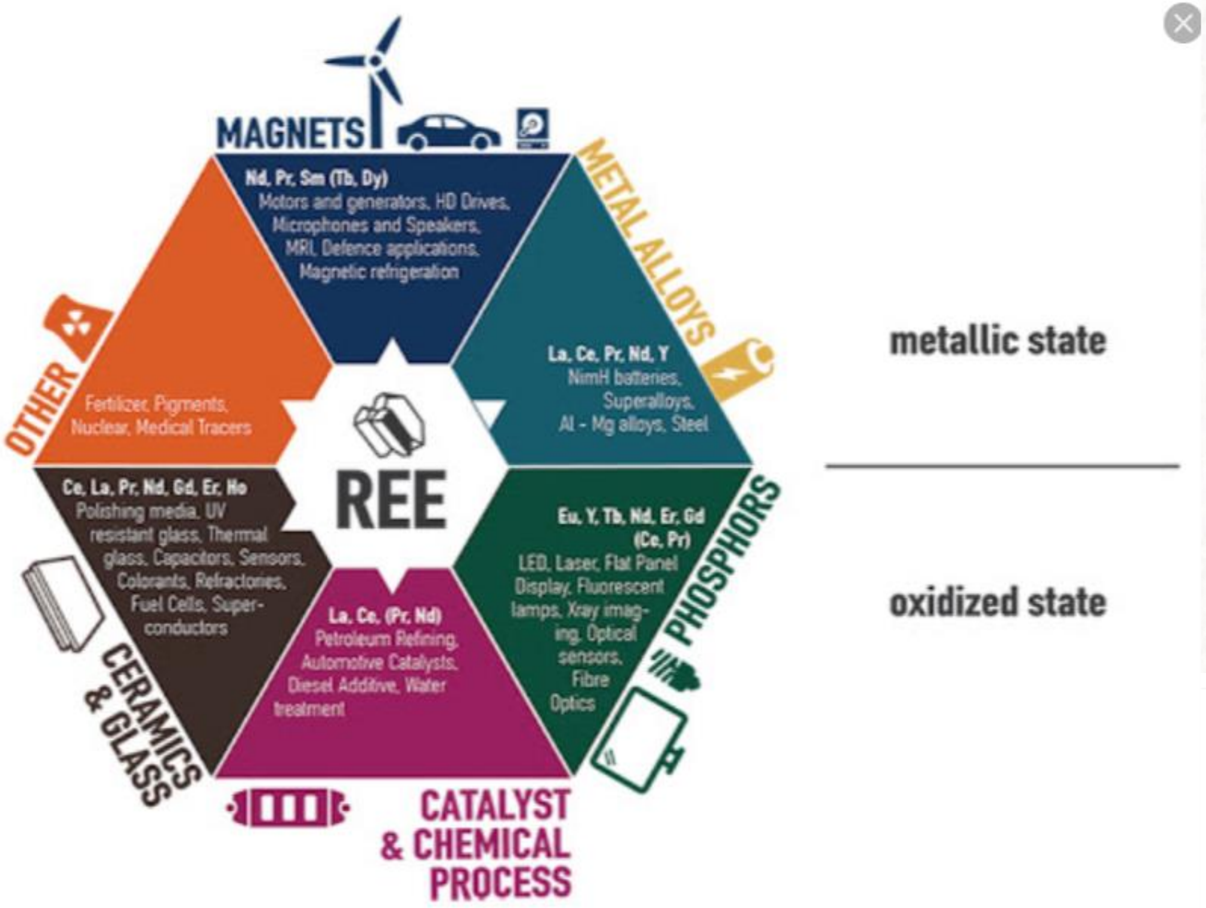
Rare Earth Element (Logam Tanah Jarang) di Periodik Unsur

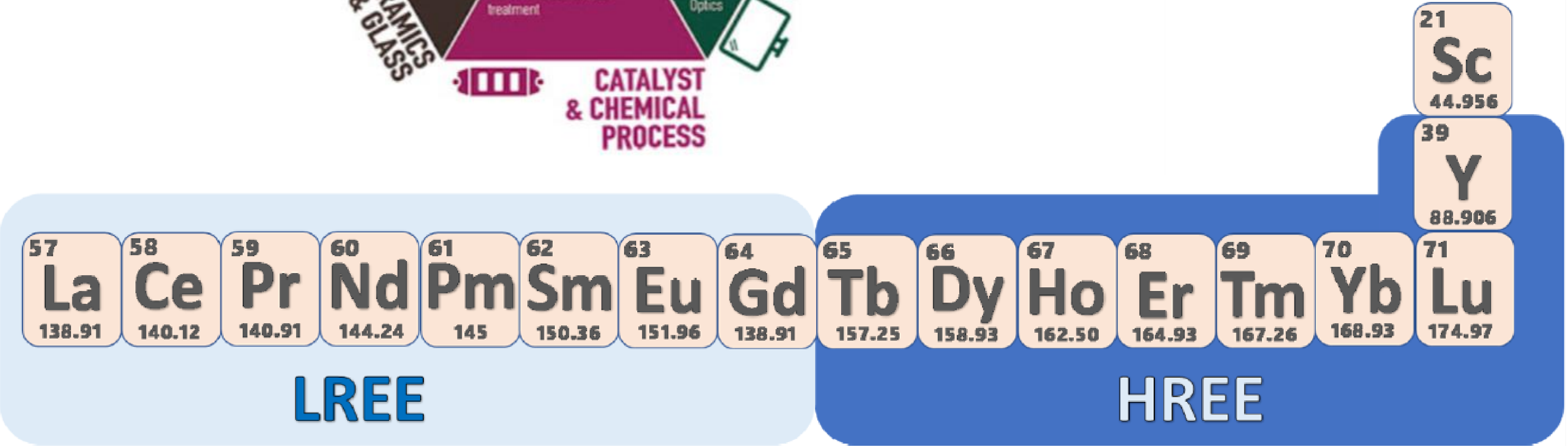
17 jenis LTJ :

11 LTJ Berat

6 LTJ Ringan

* Sumber : Potensi Logam Tanah Jarang di Indonesia, ESDM, 2019

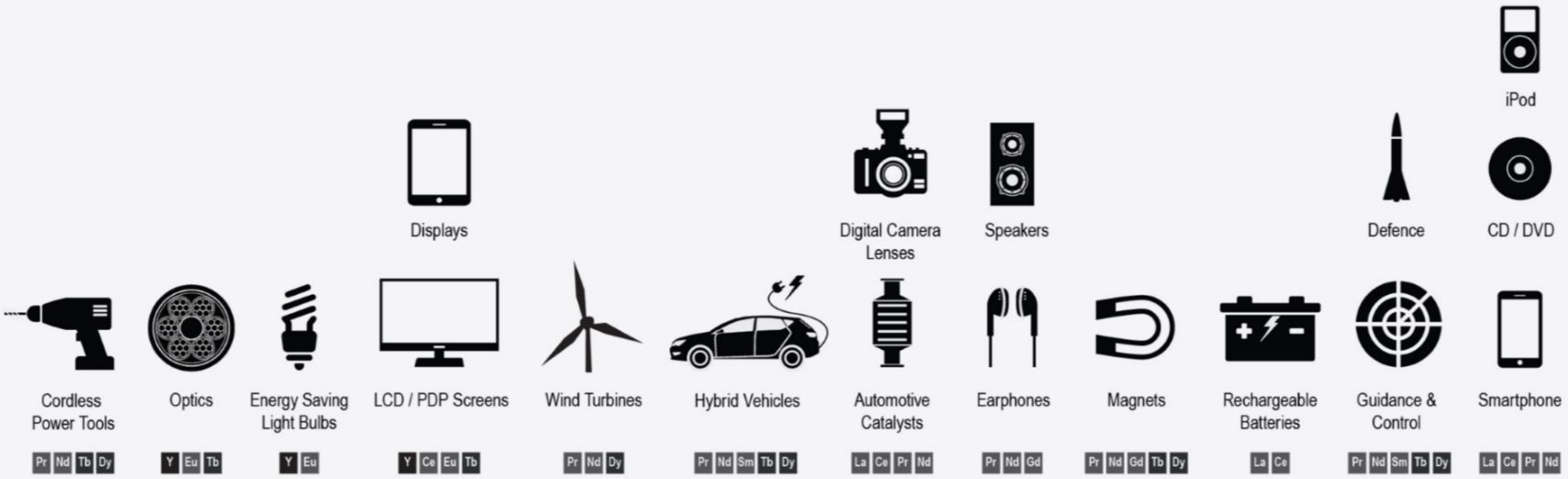




REE Classification (Light REE and High REE)

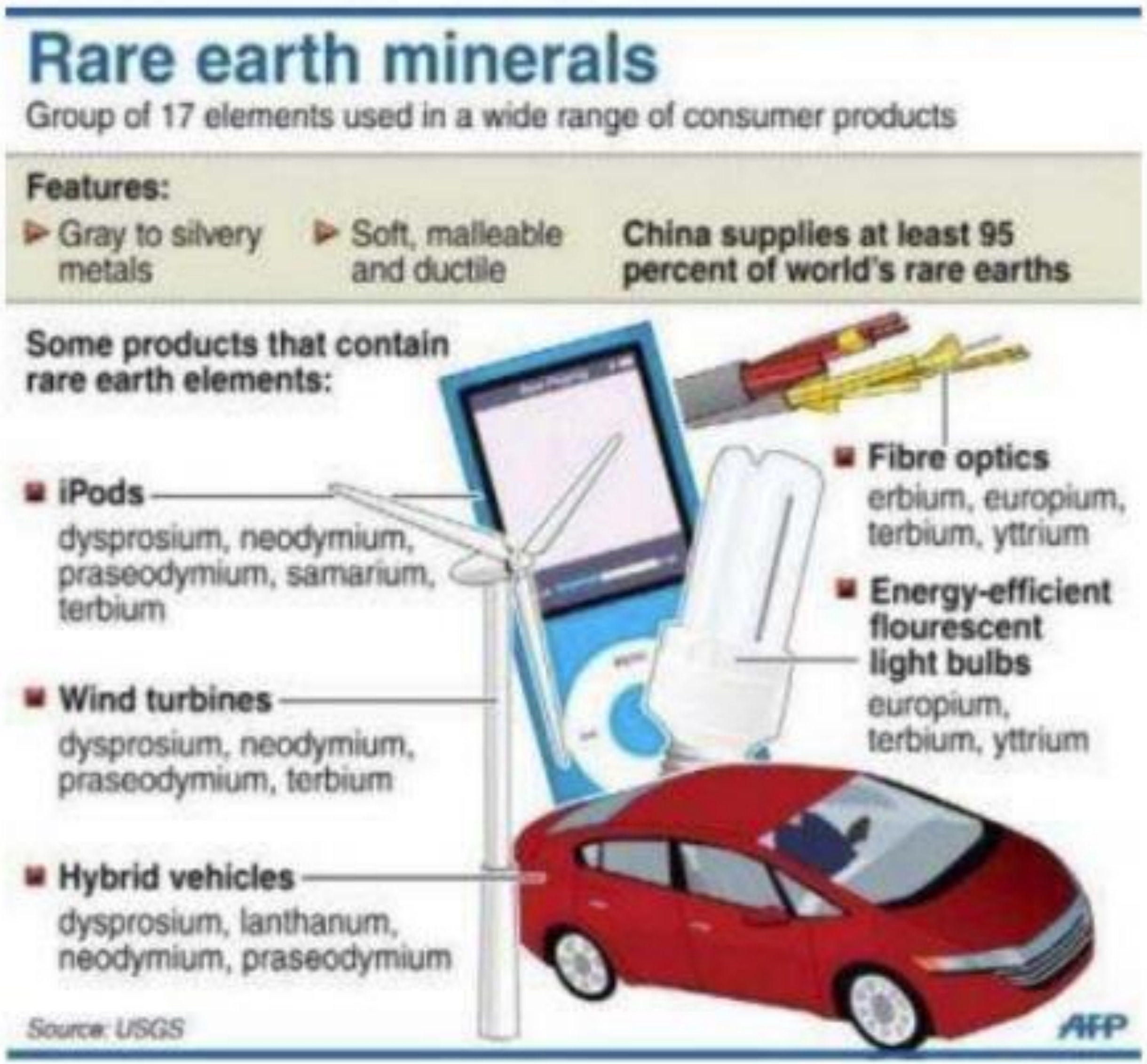
RARE EARTHS AT A GLANCE

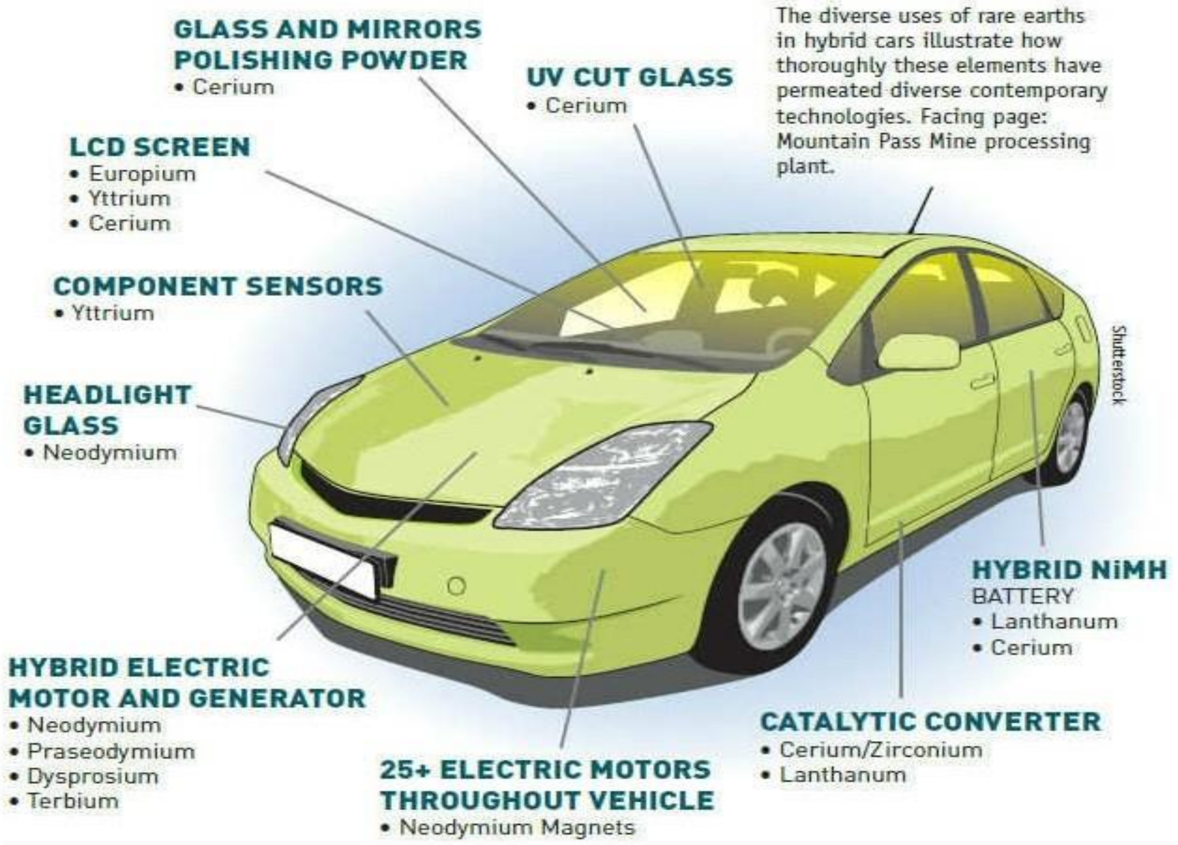
APPLICATIONS

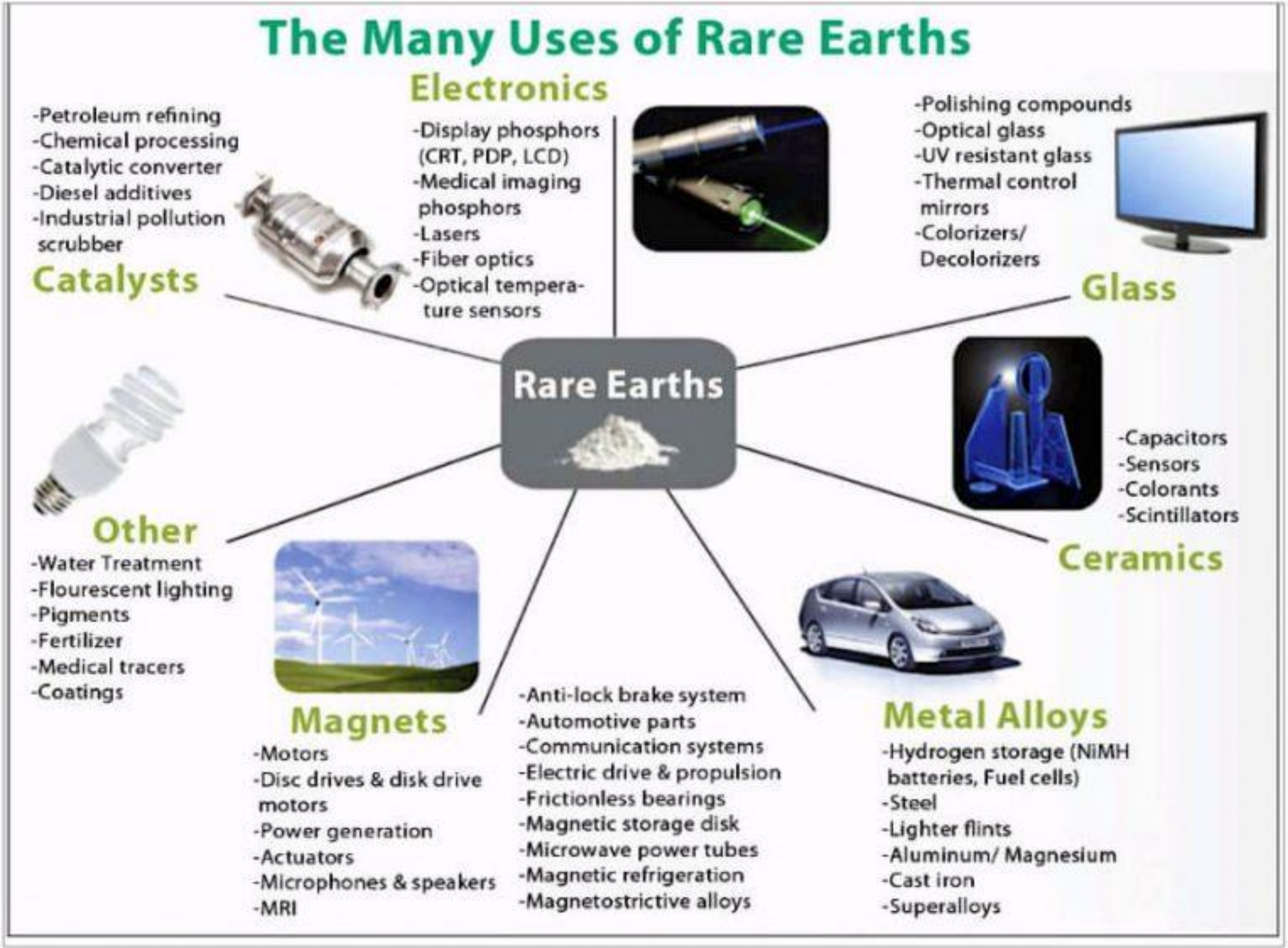


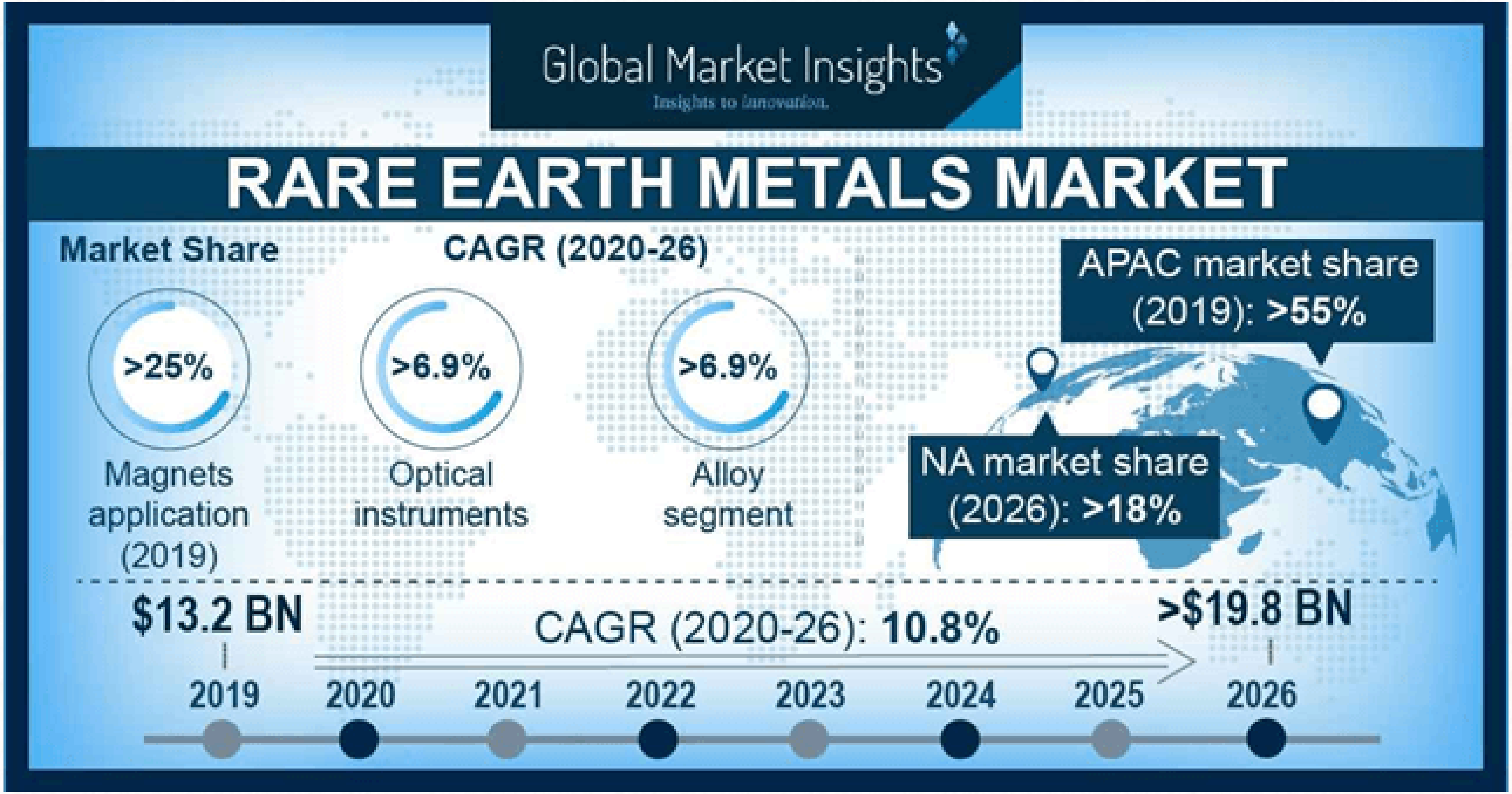
CLASSIFICATION

Source: UNCTAD Secretariat from Great Western Minerals Group Ltd, US Geological Survey, 2011, http://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/, Commodities at a Glance: Special issue on rare earths, UNCTAD 2014, http://projourno.org/elemental-table_610x2186-1/


Rare earth minerals
Group of 17 elements used in a wide range of consumer products
Features:
Gray to silvery metals
Soft, malleable and ductile
China supplies at least 95 percent of world's rare earths
Some products that contain rare earth elements:
iPods
dysprosium, neodymium, praseodymium, samarium, terbium
Wind turbines
dysprosium, neodymium, praseodymium, terbium
Hybrid vehicles
dysprosium, lanthanum, neodymium, praseodymium
Fibre optics
erbium, europium, terbium, yttrium
Energy-efficient flourescent light bulbs
europium, terbium, yttrium
Source: USGS
AFP


GLASS AND MIRRORS POLISHING POWDER
• Cerium
UV CUT GLASS
• Cerium
The diverse uses of rare earths in hybrid cars illustrate how thoroughly these elements have permeated diverse contemporary technologies. Facing page: Mountain Pass Mine processing plant.
LCD SCREEN
• Europium
• Yttrium
• Cerium
COMPONENT SENSORS
• Yttrium
HEADLIGHT GLASS
• Neodymium
HYBRID NiMH BATTERY
• Lanthanum
• Cerium
HYBRID ELECTRIC MOTOR AND GENERATOR
• Neodymium
• Praseodymium
• Dysprosium
• Terbium
CATALYTIC CONVERTER
• Cerium/Zirconium
• Lanthanum
25+ ELECTRIC MOTORS THROUGHOUT VEHICLE
• Neodymium Magnets
Shutterstock

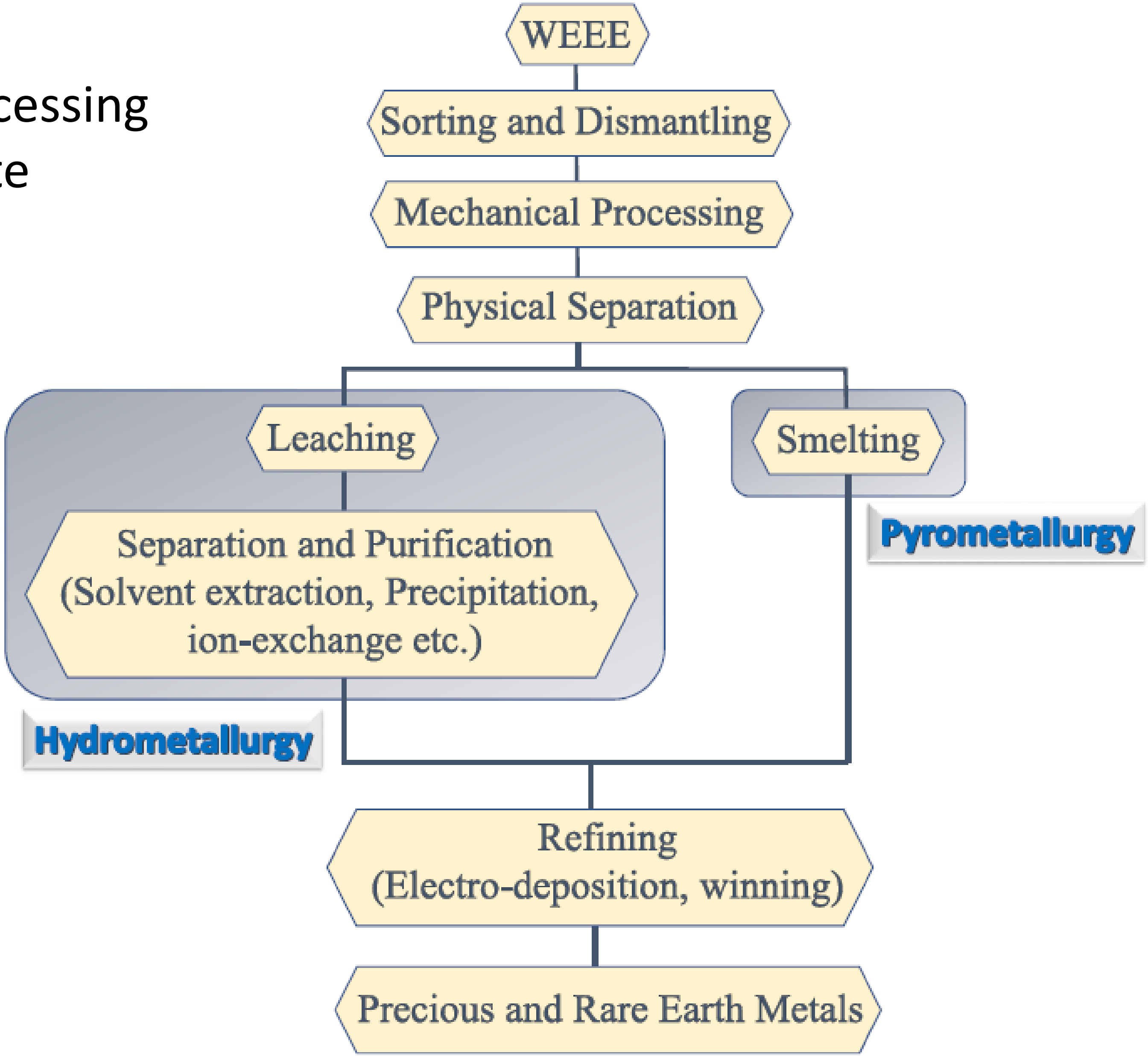

The Many Uses of Rare Earths
Rare Earths
Electronics
-Display phosphors (CRT, PDP, LCD)
-Medical imaging phosphors
-Lasers
-Fiber optics
-Optical temperature sensors
Catalysts
-Petroleum refining
-Chemical processing
-Catalytic converter
-Diesel additives
-Industrial pollution scrubber
Glass
-Polishing compounds
-Optical glass
-UV resistant glass
-Thermal control mirrors
-Colorizers/ Decolorizers
Ceramics
-Capacitors
-Sensors
-Colorants
-Scintillators
Other
-Water Treatment
-Flourescent lighting
-Pigments
-Fertilizer
-Medical tracers
-Coatings
Magnets
-Motors
-Disc drives & disk drive motors
-Power generation
-Actuators
-Microphones & speakers
-MRI
-Anti-lock brake system
-Automotive parts
-Communication systems
-Electric drive & propulsion
-Frictionless bearings
-Magnetic storage disk
-Microwave power tubes
-Magnetic refrigeration
-Magnetostrictive alloys
Metal Alloys
-Hydrogen storage (NiMH batteries, Fuel cells)
-Steel
-Lighter flints
-Aluminum/ Magnesium
-Cast iron
-Superalloys



Global Market Insights
Insights to Innovation.
RARE EARTH METALS MARKET
Market Share
CAGR (2020-26)
>25%
Magnets application (2019)
>6.9%
Optical instruments
>6.9%
Alloy segment
APAC market share (2019): >55%
NA market share (2026): >18%
$13.2 BN
CAGR (2020-26): 10.8%
>$19.8 BN
2019
2020
2021
2022
2023
2024
2025
2026

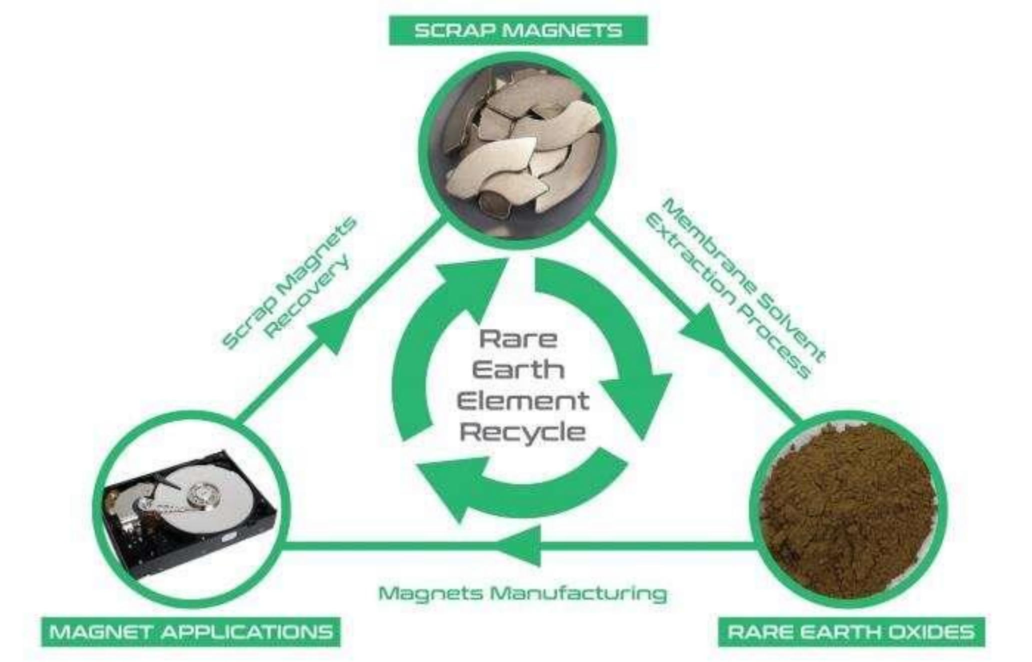
Extraction of REEs from E-waste

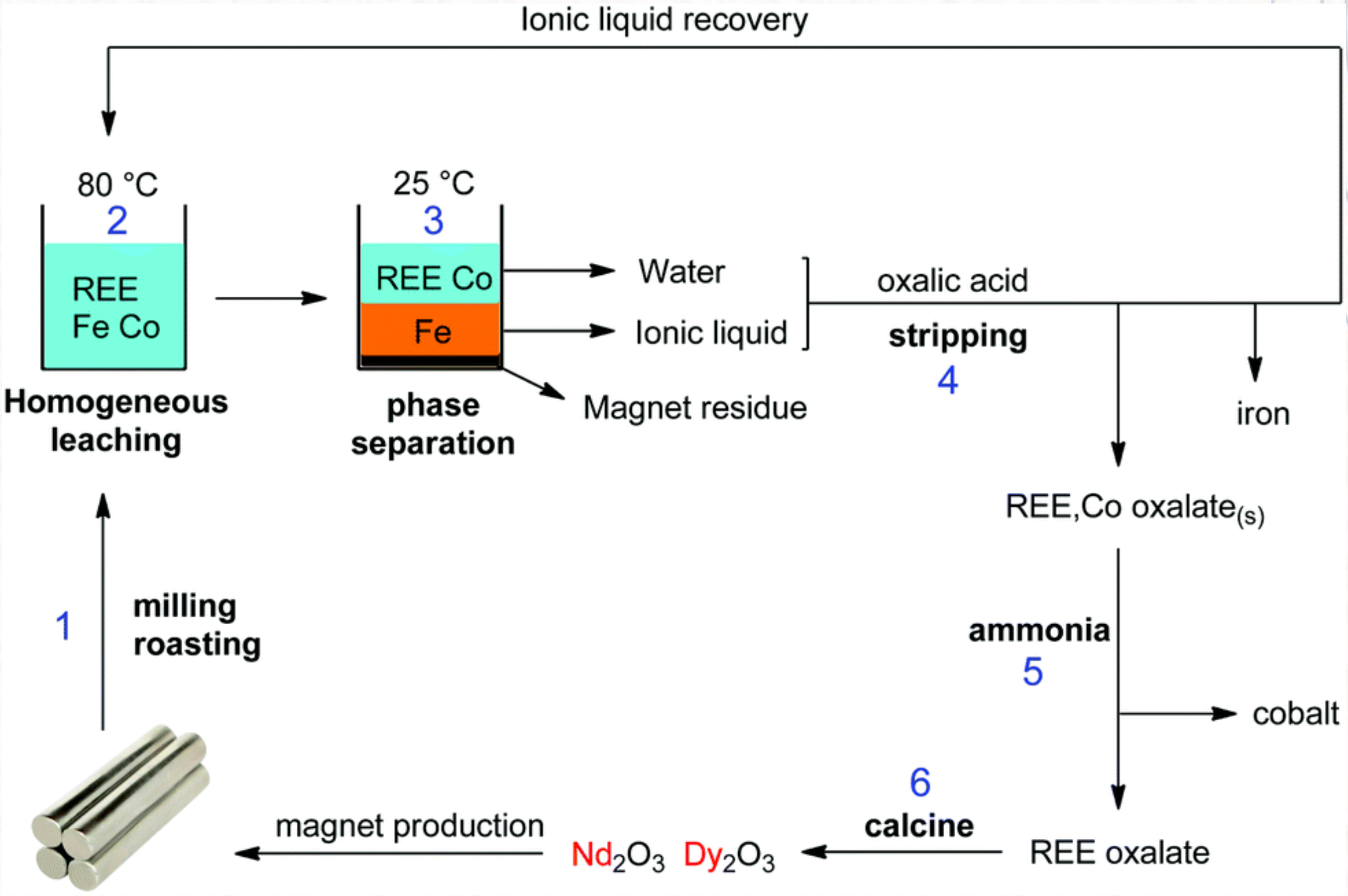
General REEs Processing from E-Waste



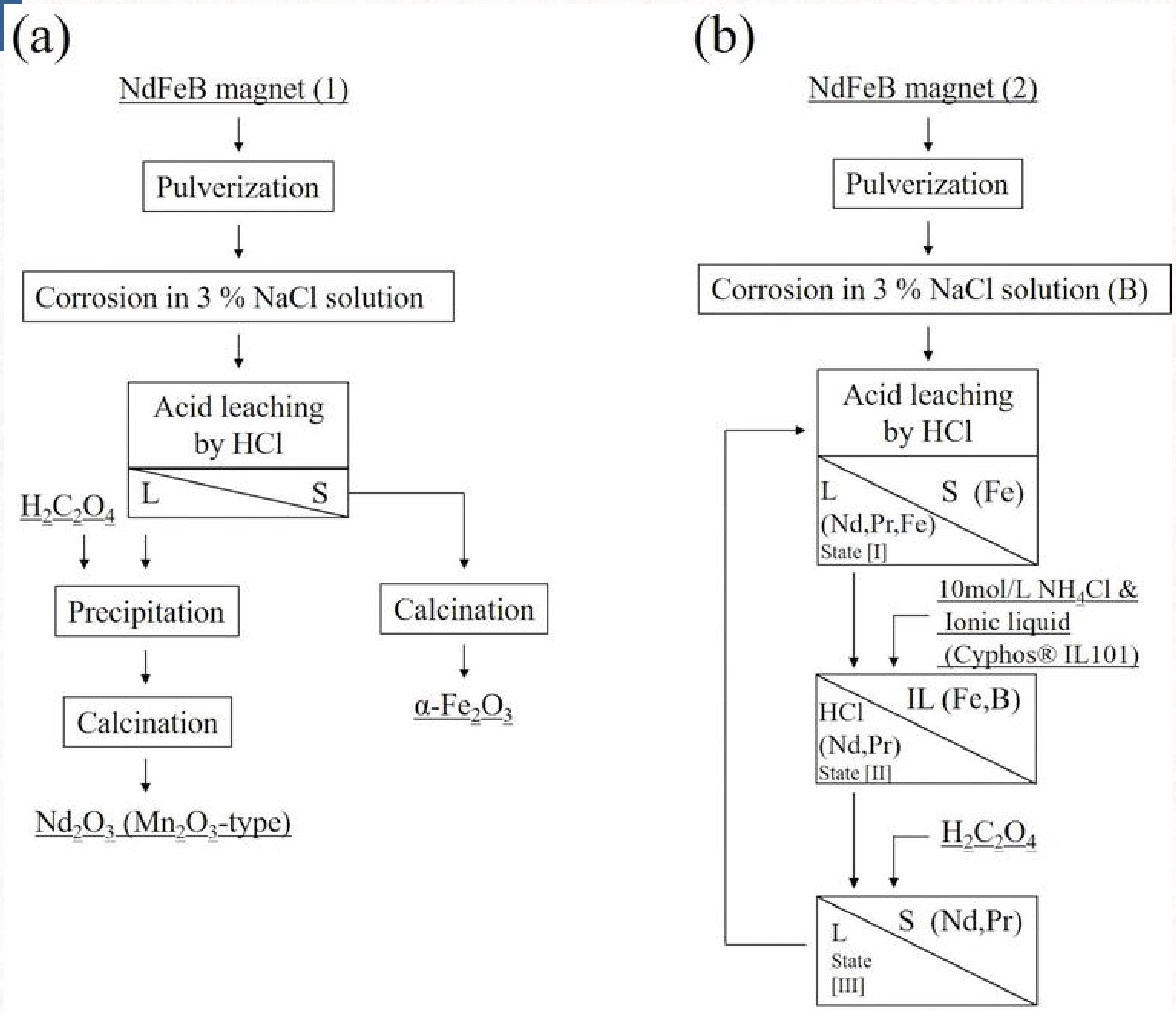
Flowchart of WEEE (Waste of Electrical and Electronic Equipment) Processing to Extract REEs

REEs Processing from Permanent Magnets





REEs Processing from Permanent Magnets



REEs Processing from Fluorescent Lamp (after powdering)

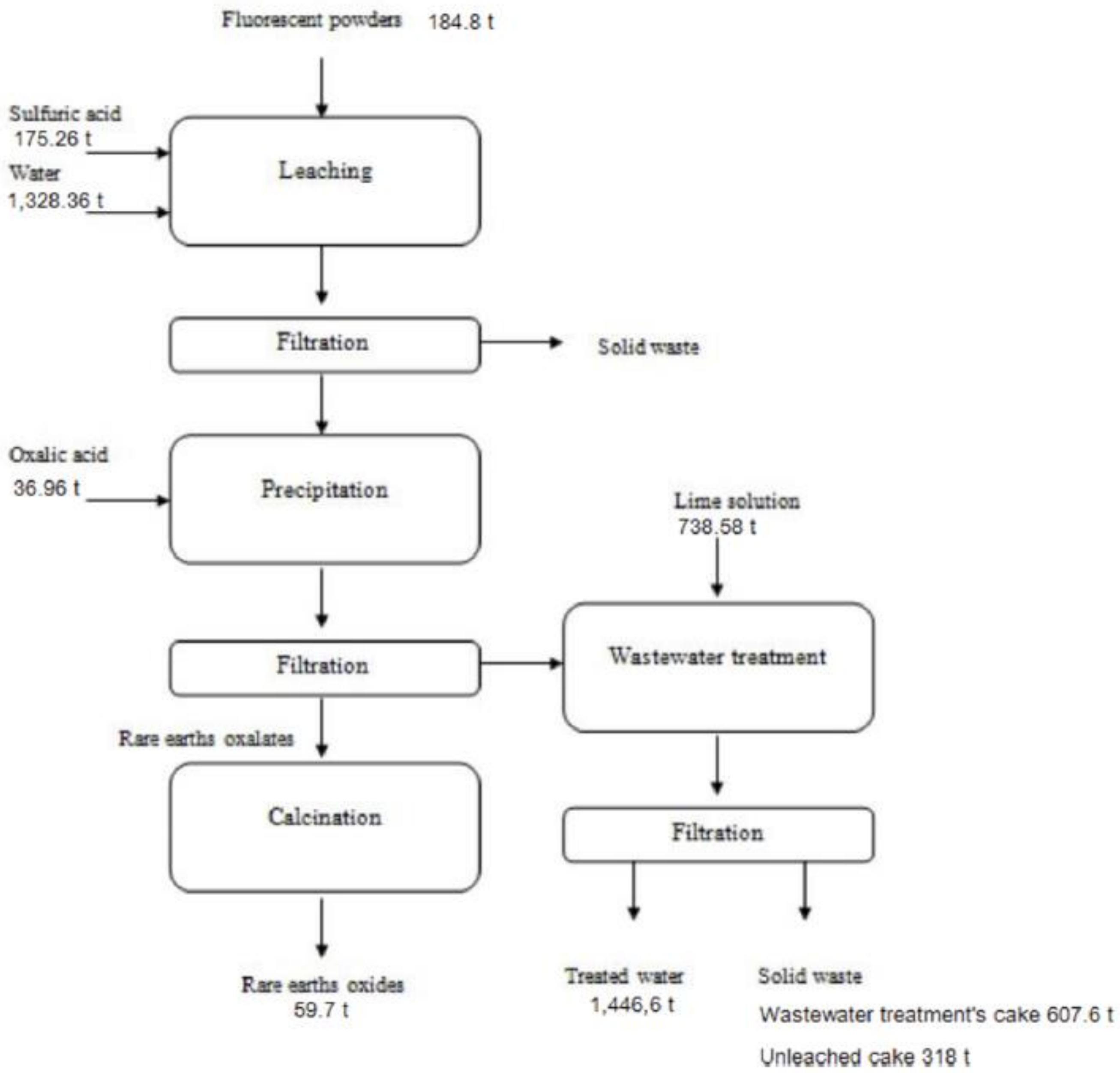


Fig. 2. The process developed in the HydroWEEE project and the total annual mass balance Source: Innocenzi et al. (2016a).

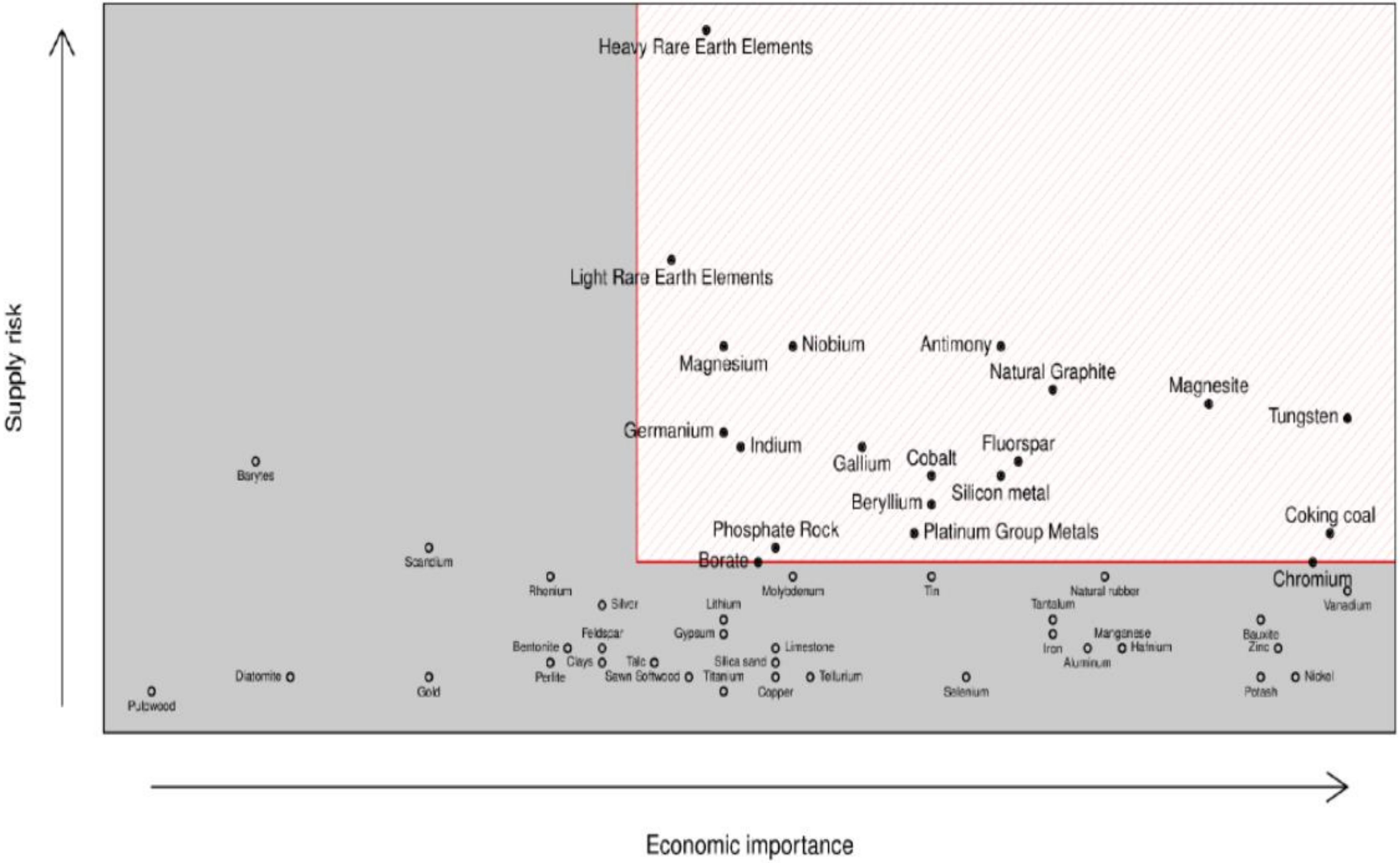
Table 5: Review of existing REEs recovery technologies

Source of REEs	Technology/ method	Stage of technology	Existing at industrial scale
Lamp phosphors (Ey,Terbium, Yt)	Chemical attack of phosphors and recovery of REEs from the solution by precipitation or solvent extraction	Mature (but still developing)	Yes (Rhodia)
Cathode Ray Tube phosphors (Ey)	Chemical attack and solvent extraction	Limited research (declining interest)	NO
Permanent Magnets	Hydrometallurgy	Mature generally but still in lab scale	Investment project

Source of REEs	Technology/ method	Stage of technology	Existing at industrial scale
(Neodymium,Dispr osium, Samarium)		in relation to REE	(Rhodia)
	Pyrometallurgy	Mature generally but not in relation to REE	NO
	Gas-phase extraction	Lab scale	NO
	Reprocessing of alloys to magnets after hydrogen decrepitation	Lab scale	NO
	Biometallurgical method	Lab scale	Planned pilot in 2014
Nickel metal-hydride batteries (lanthanum cerium, praseodymium and neodymium)	Combination of Ultra High Temperature smelting and hydrometallurgy/pyrometa-llurgy	Mature	Yes (Umicore & Rhodia)
Optical glass (Lanthanum)	Hydrometallurgy process	Lab scale	NO
Glass polishing powder (Cerium)	Chemical process	Lab scale	NO

Source : Binnemans et al. (2013) and own elaboration

Figure 1: Criticality assessment for the EU



Source: European Commission, (2014).

Roadmap and Research Facilities in BRIN

ROADMAP: Extraction of REEs from Primary and Secondary Sources (Monazite, Xenotime, Coal Fly Ash, Lateritic, Redmud, Urban Mining, E-Waste, Lapindo mud, Granitic Stone etc)

(For development of advanced and functional materials)

SP 1 – Exploration Characterization Identification
- PRTPB
- PRSDG
- PRTDBBNLR
- DIRI
- Dir. PLFRKST
- DFRI

SP 2 – Metallurgical Test of REEs Processing
- PRTPB
- PRTDBBNLR
- DIRI
- Dir. PLFRKST
- DFRI

SP 3 – Beneficiation and Extraction of REEs
- PRTPB
- PRM
- PRTDBBNLR
- DIRI
- Dir. PLFRKST
- DFRI – Dir. PRI

SP 4 – Synthesis of REE material from the REEs product of extraction and Application for energy, medical, defense etc.
- PRTPB
- PRM
- PRMM
- PRKM
- OREM
- PRTDBBNLR
- DIRI
- Dir. PLFRKST
- DFRI – Dir. PRI

SP 5 – Study of techno-economic and supply chain
- PRTPB
- PRMM
- DPRI
- DIRI

Technology Transfer
- Dir MKI DFRI
- Dir PRI DFRI

License

2023 | 2024 | 2025 | 2026 | 2027

2023 – Sources and Reserves of REEs
- KESDM

2024 – Research Collaboration Center of REEs
- UNIVERSITY
- INDUSTRY

2025 – Research Collaboration Center of REEs
- UNIVERSITY
- INDUSTRY

2026 – Scale-up and demo plant in industries
- Mining Industry
- PT. Mineral Industri Indonesia (MIND ID)
- Industry of Energy, Medical, Defense
- KESDM
- Kemenperin

2027 – Adoption of technology to industry
- Mining Industry
- PT. Mineral Industri Indonesia (MIND ID)
- Industry of Energy, Medical, Defense
- KESDM
- Kemenperin

Facilities: Integrated Mineral Processing Laboratory

https://elsa.brin.go.id/ **Locations: LAMPUNG**

- Mineral Characterization Lab.
- Hydroelectrometallurgy Lab. & Pilot Plant
- Pyrometallurgy Lab. & Pilot Plant
- Biometallurgy Lab.
- Non-Metal Processing Lab. & Pilot Plant
- Comminution & Beneficiation Lab.
- Heat Treatment Lab.

REEs Pilot Plant Facility in Yogyakarta

Leaching and Precipitation Equipment

Reagent Input

Mixer Settler

Ion Exchange Column

- REEs extraction from REOH (from monazite and xenotime sand)
- Capacity: 10 kg product of REEs

Y2O3 > 95%

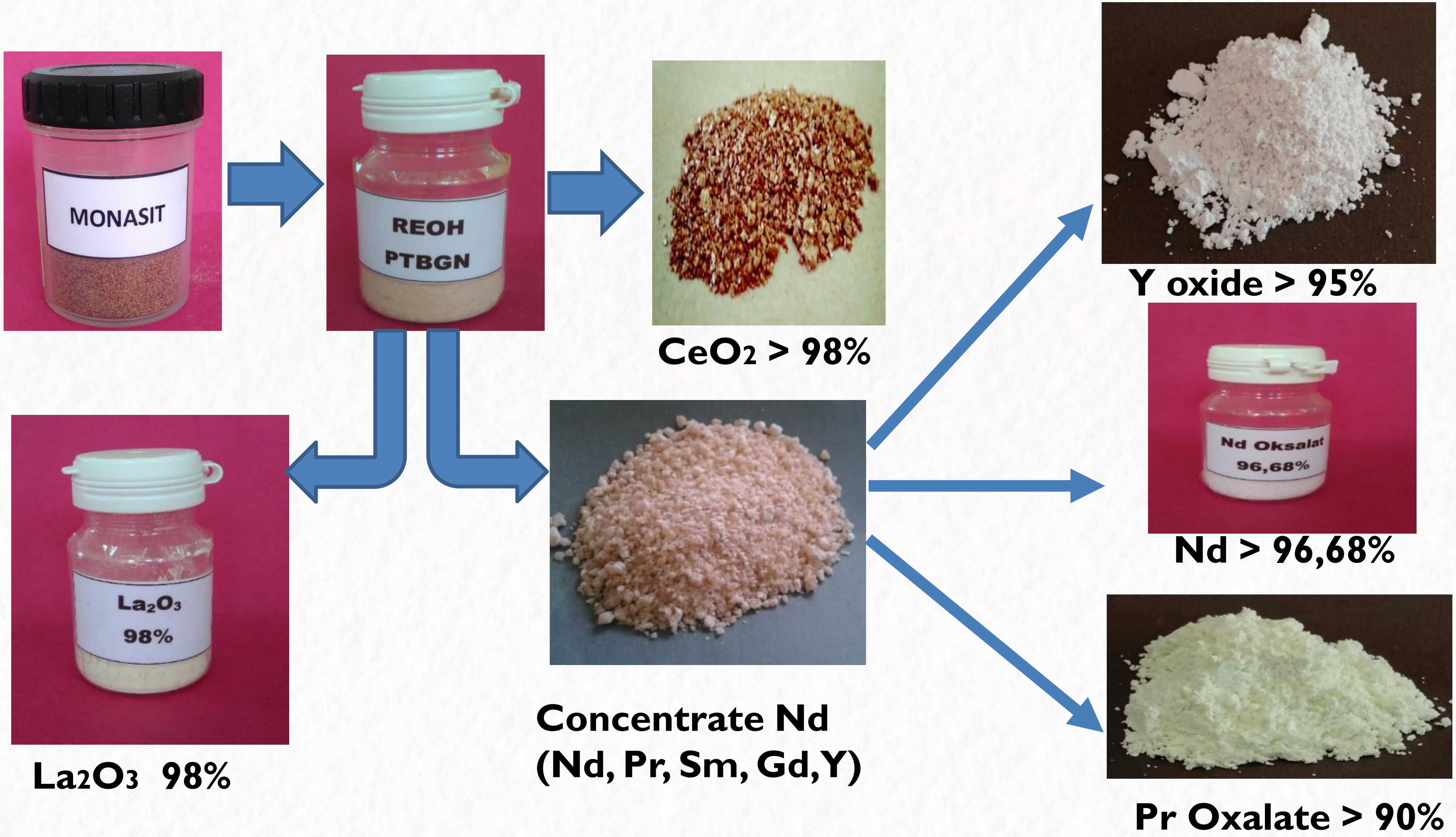
Nd(OH)3 > 60%

Pr Oksalat > 90%

Nd > 95%

Research Products in BRIN

REEs Extraction from REOH of Monazite



REEs, Th, U, Fe, Ti, P extraction from Monazite Sand (Tailing's Tin Ore Processing)

Monazite: **Rp. 10.000-13.000/kg**

Tin Slag: **Rp. Rp.3.000/kg**

U3O8 :
Rp. 1.890.000/kg
Source: Cameco

Thorium oxide:
Rp.6.500.000/kg
Source : USGS 2022

Certified Reference Material Radioactive and REE:
Rp. 2.000.000/100 gram
Source : Oreas

LTJ hydroxide/carbonate:
Rp. 82.000.000/ton

REEs oxide:
Cerium **Rp. 9.300.000/ton**
Neodymium **Rp. 1.000.000.000/ton**

Metal REEs:
Cerium **Rp. 52.000.000/ton**
-
Neodymium **Rp. 1.258.000.000/ton**

Source : metal.com

Wardana et al., 2023

CRM Products of REEs

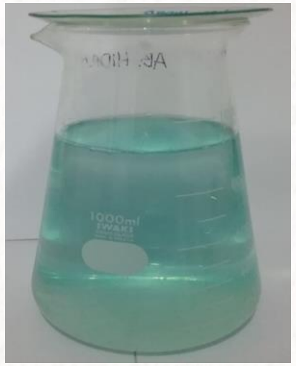
		
CRM Monazite sand	CRM La_2O_3	CRM REOH

		
CRM CeO_2 from monazite sand	CRM CeO_2	CRM ZrO_2

Extraction of Lanthanum from Spent Catalysts

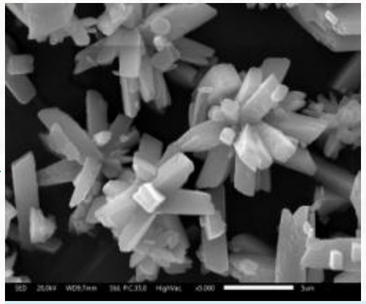
Spent Catalyst from Petroleum industry

Leaching



Filtrate

Precipitation



La Oxalate from spent catalyst

Solid residues

Geopolymer (material construction)

https://www.mdpi.com/2073-4344/10/9/1090

https://iopscience.iop.org/article/10.1088/1757-899X/285/1/012007/meta

https://iopscience.iop.org/article/10.1088/1757-899X/742/1/012025/meta

https://link.springer.com/article/10.1007/s43615-022-00183-9

https://www.scientific.net/AMM.898.23

https://ejurnalmaterialmetalurgi.lipi.go.id/index.php/metalurgi/article/view/437

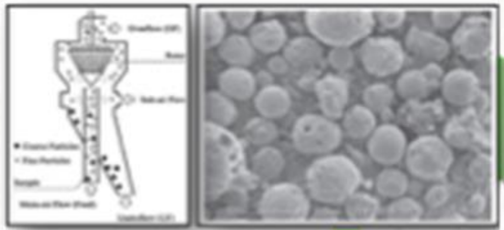
https://ejurnalmaterialmetalurgi.lipi.go.id/index.php/metalurgi/article/view/572

https://journal.ugm.ac.id/jrekpros/article/view/69723

REEs from CFA

Estimated Production
49.3 million tonnes (2050)

Fly ash



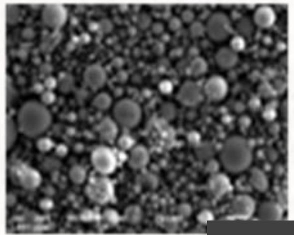
- **Filler for light-weight material**
- **Biomaterial**

Cenospheres Recovery

Hollow particle of silica alumina

REE extraction

Material Konstruksi
1. **Pozzolanic**
2. **Bellite**



Adsorbent (PRB)

- The highest composition → **Silica and Alumina**
- Other valuable compounds aside REY, i.e. **Cenospheres**
- **TOTAL EXTRACTION** is the best approach → **COMPREHENSIVE**

Bottom ash

Adsorbent (PRB)

REE Extraction

Geopolymer

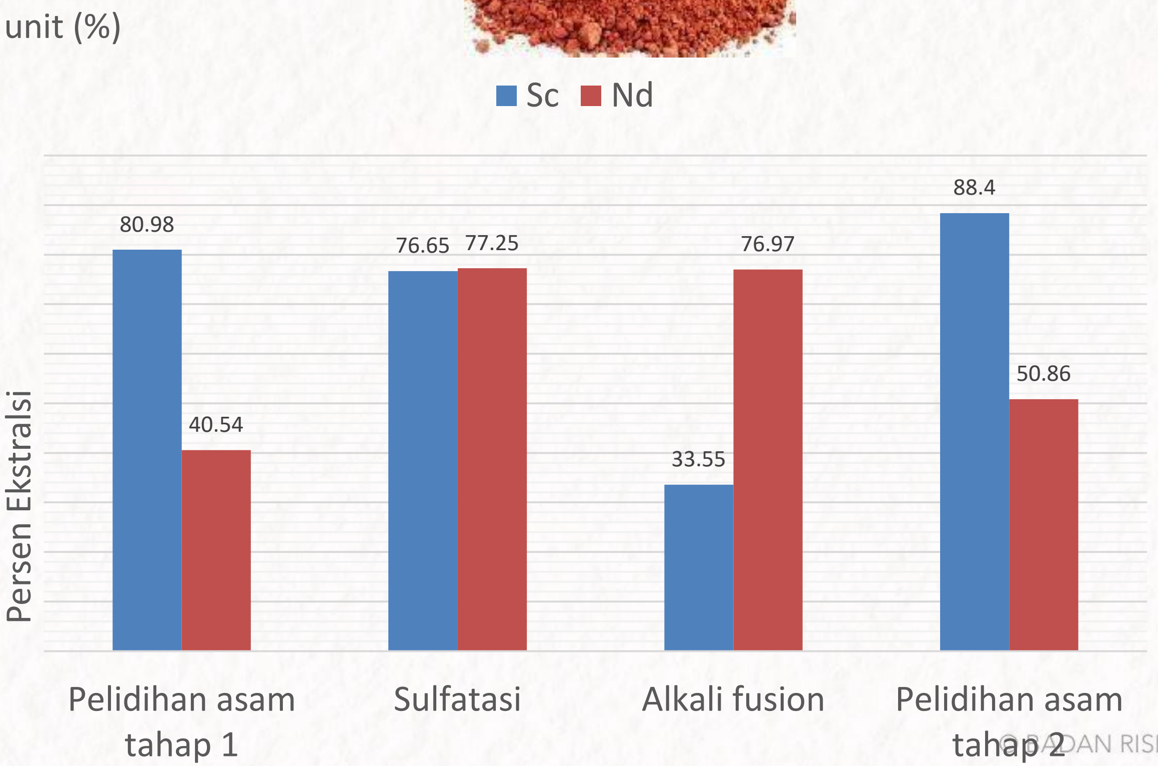
- **Passivication of heavy metals**
- **Material construction for extreme conditions**

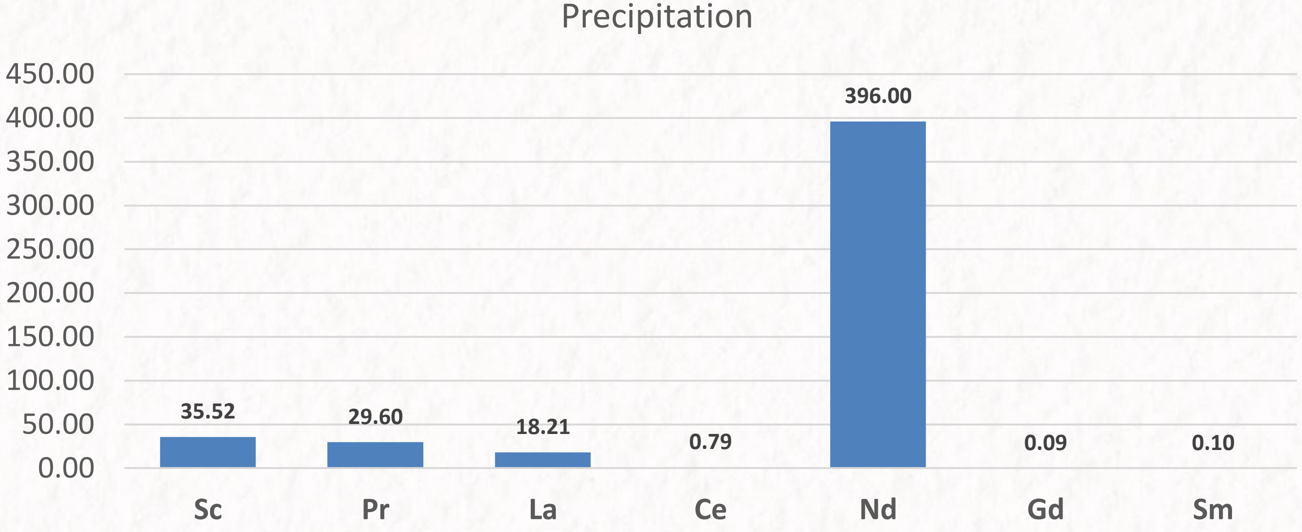
https://link.springer.com/article/10.1007/s40789-022-00476-2
https://www.sciencedirect.com/science/article/abs/pii/S0959652621003632
https://link.springer.com/article/10.1007/s40831-021-00414-7
https://aip.scitation.org/doi/abs/10.1063/5.0066649
https://www.mdpi.com/2310-2861/8/4/233
https://www.sciencedirect.com/science/article/abs/pii/S0301751610001183
https://ijog.geologi.esdm.go.id/index.php/IJOG/article/view/418
https://www.scientific.net/KEM.849.102
https://iopscience.iop.org/article/10.1088/1757-899X/532/1/012001/meta
https://iopscience.iop.org/article/10.1088/1757-899X/742/1/012042/meta
https://www.sciencedirect.com/science/article/abs/pii/S2213343720304644
https://www.jstage.jst.go.jp/article/journalofmmij/124/12/124_12_878/_article/-char/ja/
https://www.sciencedirect.com/science/article/abs/pii/S0301751610000402
http://jurnalmetal.or.id/jmi/article/view/194
https://iopscience.iop.org/article/10.1088/1755-1315/851/1/012039/meta

REEs Extraction from Red mud of bauxite

- Production of 1 ton Alumina produces 1 to 1.5 ton of redmud.
- Redmud contains 20-60% of Fe, REEs, and ferrotitanates /(REE,Ca,Na)(Ti,Fe)O_3, calcium- natrium ferrotitanates / (Ca,Na)(Ti,Fe)O_3

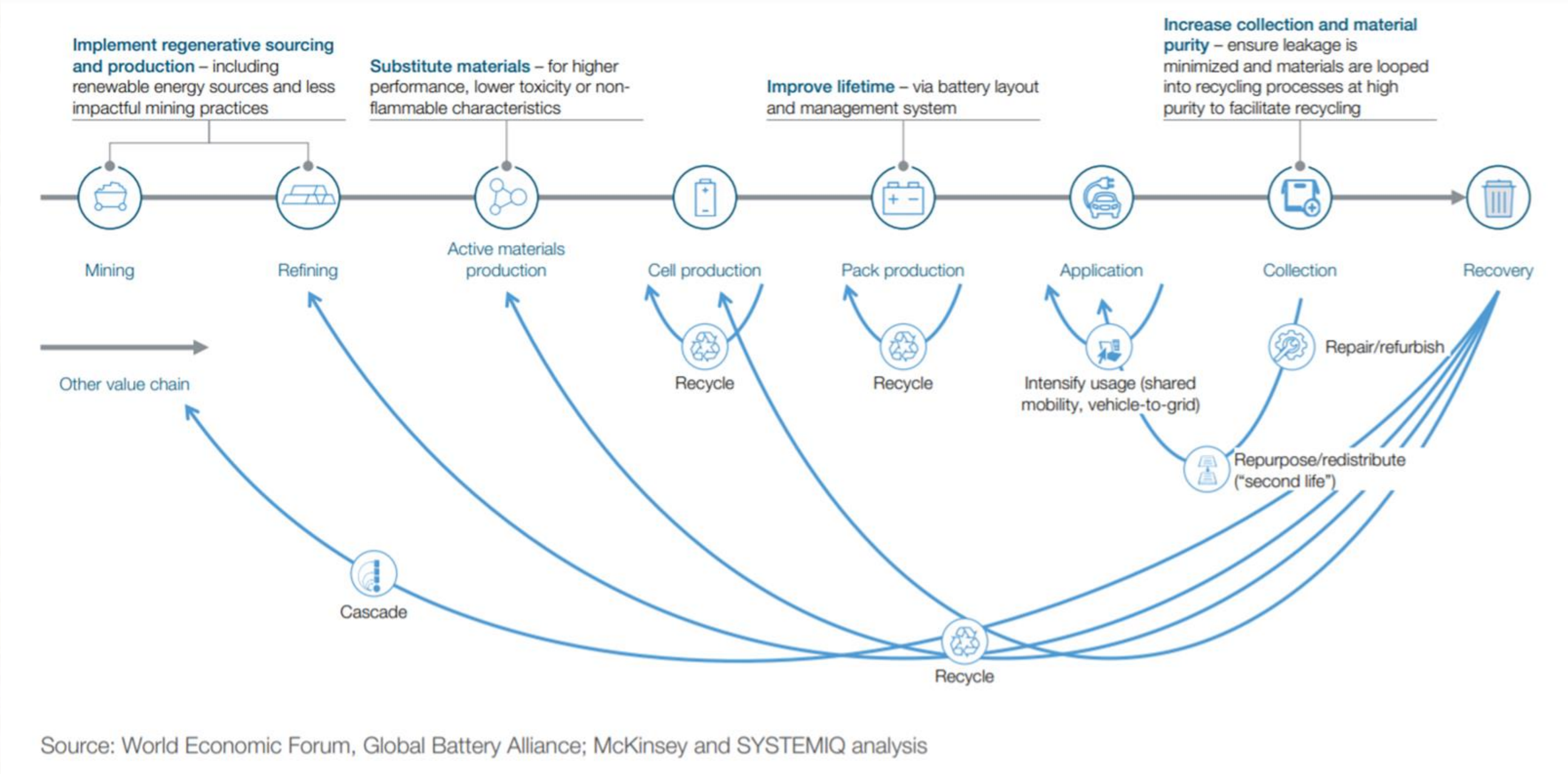
REEs extraction from redmud is conducting by researchers in Bandung.





Battery Recyling

CIRCULAR ECONOMY FOR BATTERIES

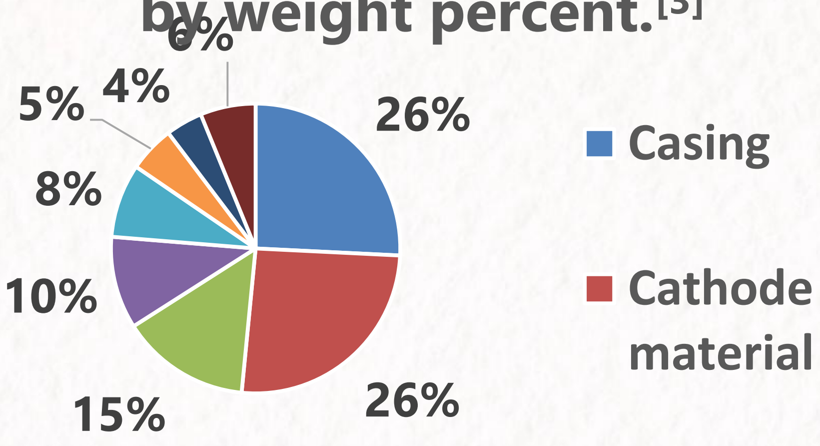


Why recycle?

Li-ion batteries (LIBs) has become the most popular secondary battery and are utilized in wide-ranging applications, from portable electronic devices to stationary and renewable energy storage, as well as electric vehicles (EVs).
With the massive growth, the LIBs market is expected to exceed 6,000 GWh or 6 TWh by 2030[1]

LIBs can run between 1700 – 5300 cycles before reaching its end-of life, which puts the operating lifetime of LIBs at 4.5 – 14.5 years.
It is predicted that there are up to 4 billion LIBs that is reaching their end-of-life in 2040[2]
Those LIBs will eventually become waste and need to be treated carefully.

Li-ion battery components by weight percent.[3]

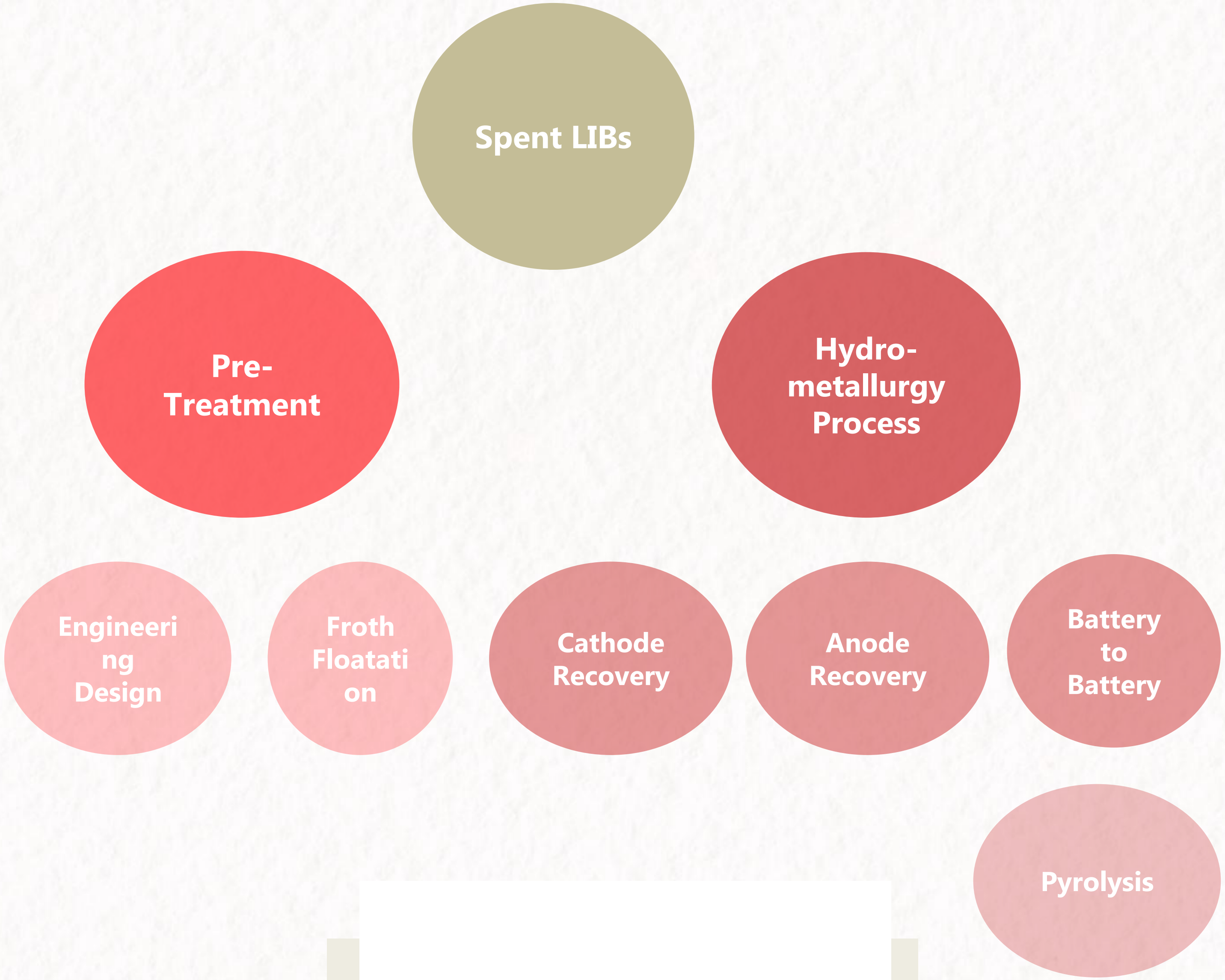


LIBs contain electrode materials that can be recovered through recycling process to create a circular economy and sustainable LIBs production

Without recycling, LIBs can be a threat due to toxic organic chemicals in the electrolyte that can cause hazard to environment

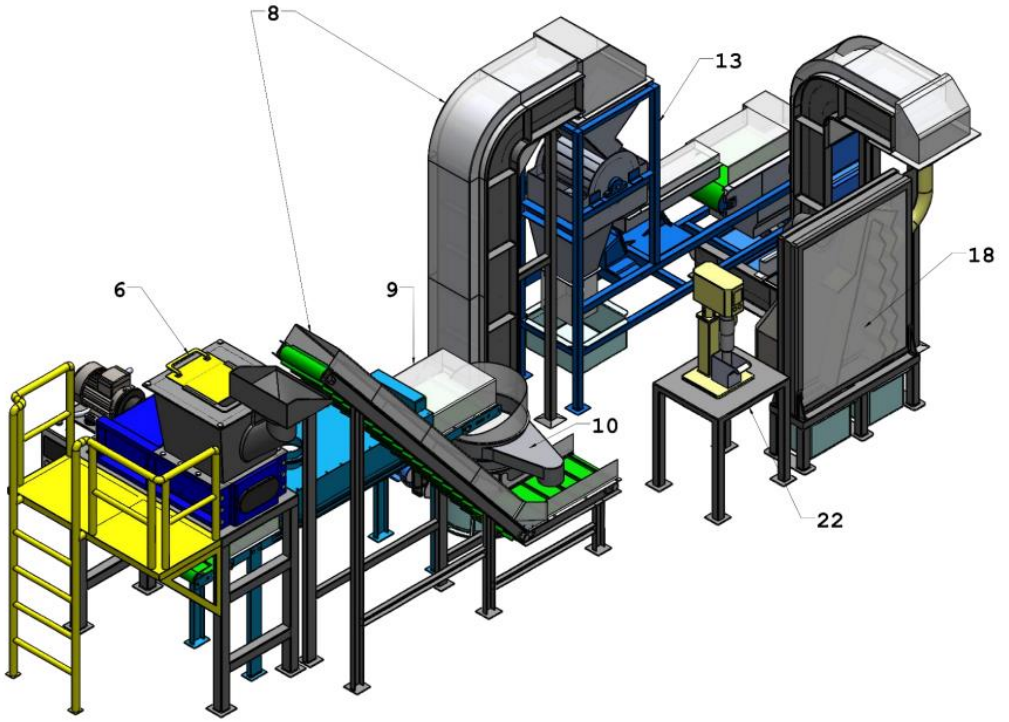
[1] Benchmark Mineral Intelligence
[2] K. Richa, et al., "A future perspective on lithium-ion battery waste flows from electric vehicles", *Resources, Conservation, Recycling*, vol. 83, pp. 63-76, 2014.
[3] T. Georgi-Maschler, et al., J. Power Sources 207 (0) (2012) 173e182.

Our Research



Engineering Design

Designing the pre-treatment prior to hydrometallurgy process, which has a scalability and ready to be scaled up.



Discharging
↓
Crushing/Shredding
↓
Drying
(tunnel conveyor)
↓
Screening
(vibratory screen)
↓
First Separation
(magnetic separator)
↓
Second Separation
(eddy current
separator)
↓
Third Separation
(zigzag separator)
↓
Froth Flotation
↓
Hydrometallurgy Process

1 patent submitted

Froth Flotation

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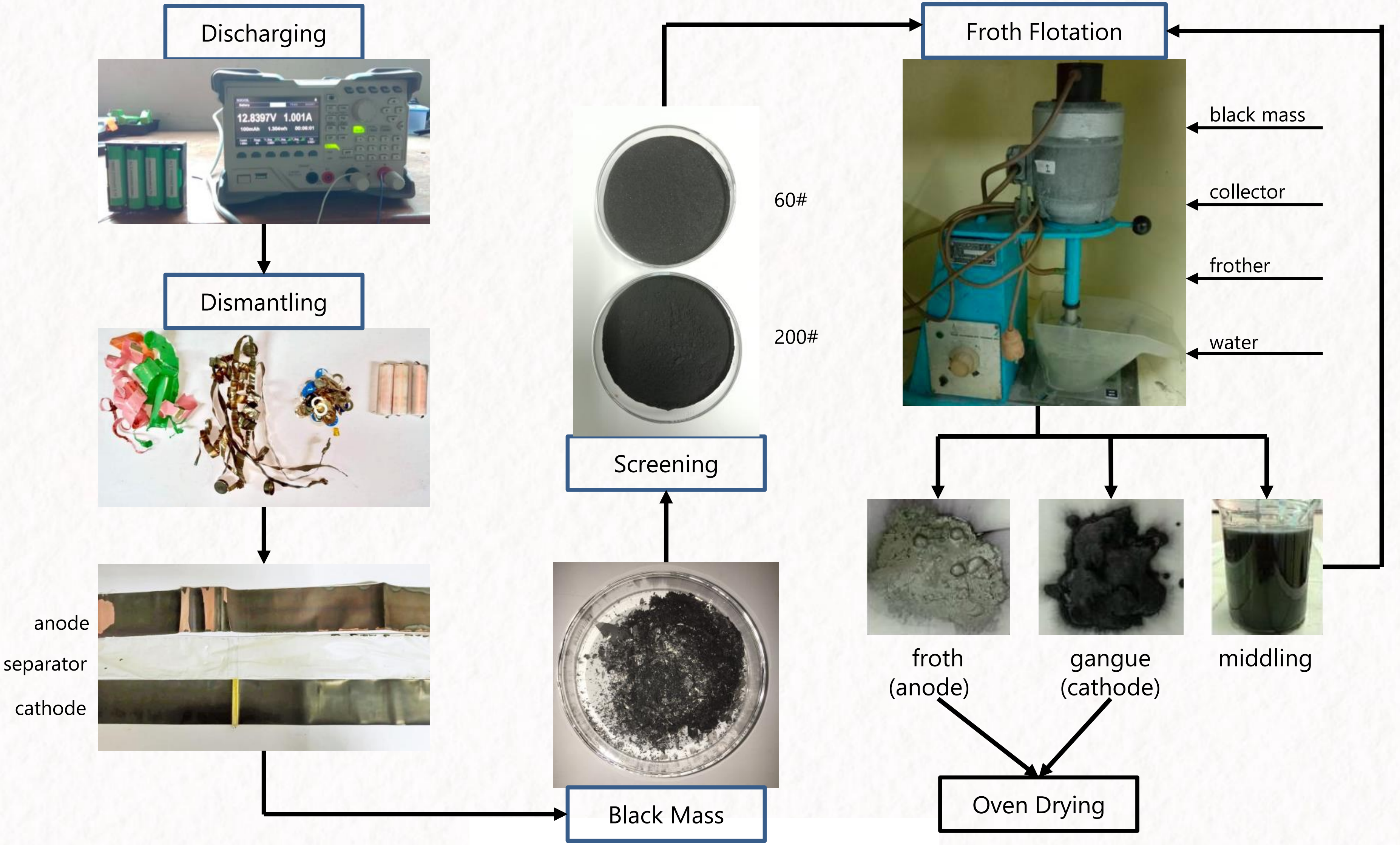
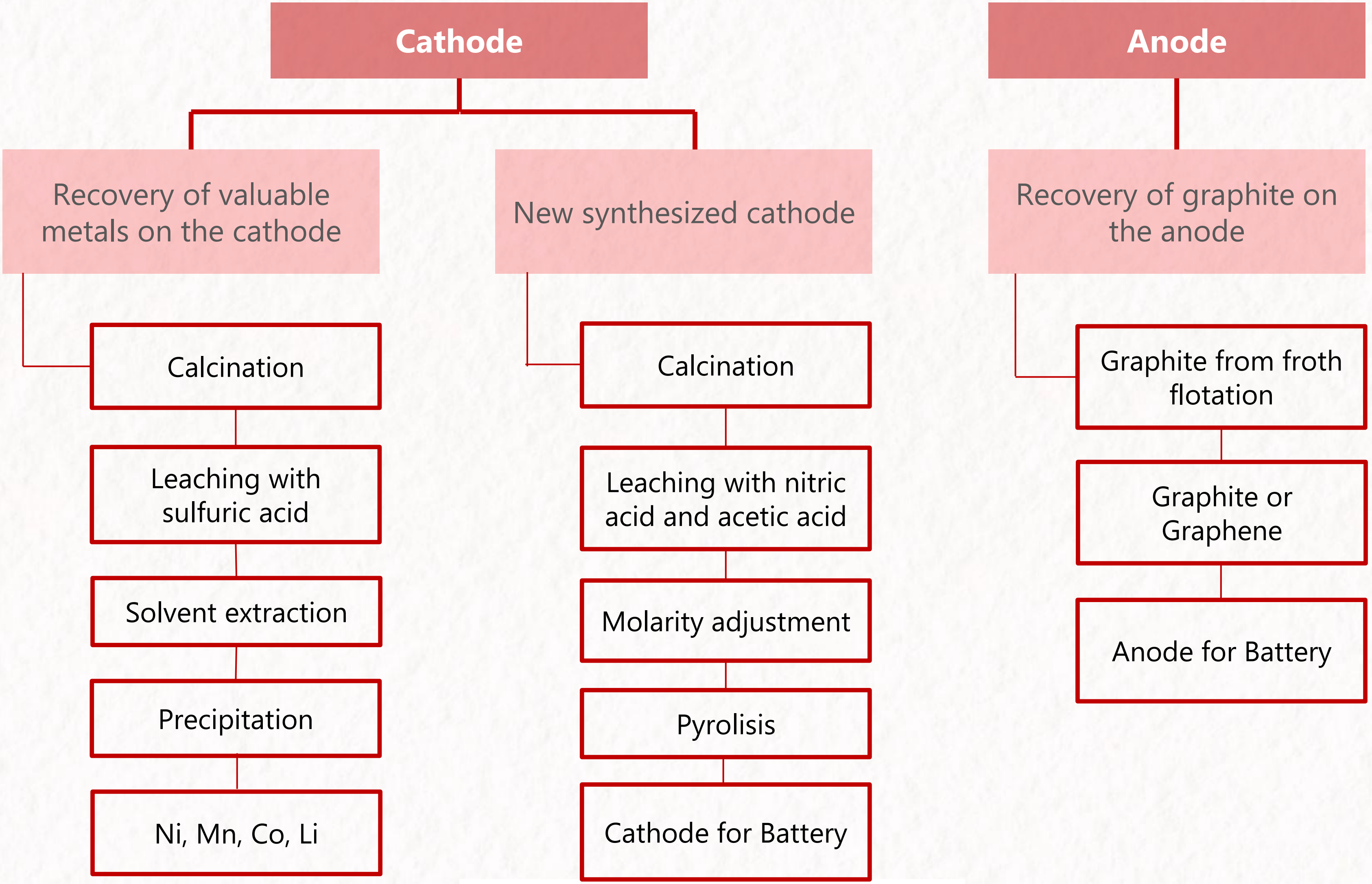
DAN INOVASI NASIONAL



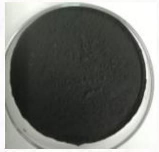
1 patent submitted

Hydrometallurgy Process

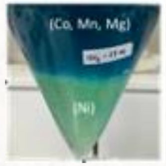


Cathode Recovery

- Calcinated Spent Cathode Powder

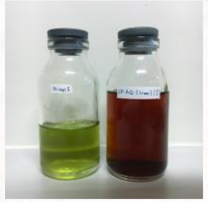


- Leaching
- Solvent Extraction



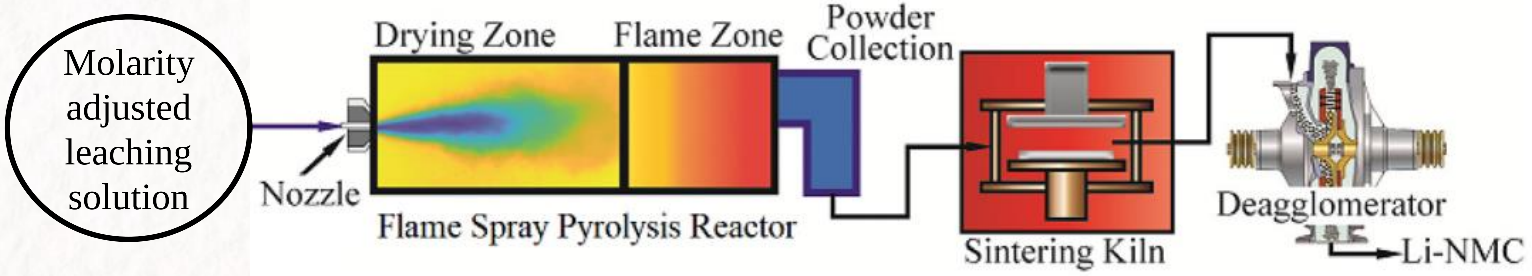
- Co and Mn
  - Solvent Extraction

  - Co
    - Chemical Precipitation
      - Co hydroxide
  - Mn
    - Chemical Precipitation
      - Mn hydroxide
- Ni and Li
  - Selective Precipitation



  - Ni (sulfate)
    - Chemical Precipitation
      - Ni hydroxide
  - Li
    - Saturated Na_2CO_3
      - Li carbonate

Pyrolysis


Molarity adjusted leaching solution
Drying Zone
Flame Zone
Powder Collection
Nozzle
Flame Spray Pyrolysis Reactor
Sintering Kiln
Deagglomerator
Li-NMC


FLAME SPRAY PYROLYSIS

Economics Overview

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- **Battery Waste** — 2-15 DR/Kg
  - **Other**
    - Alumunium (Average Price) — 2-4.5 USD/Kg
    - Copper (Average Price) — 7-11 USD/Kg
  - **Cathode**
    - Nickel Salt (Average Price) — 8-31 USD/Kg
    - Cobalt Salt (Average Price) — 42-62 USD/Kg
    - Mangan Salt (Average Price) — 4-11 USD/Kg
    - Lithium Salt (Average Price) — 58-75 USD/Kg
  - **Anode**
    - Graphite (Average Price) — 0.5-3 USD/Kg
    - Graphene (Average Price) — 10-200 USD/Kg

Source :
Trading Economics, 2021
Plastic Markets, 2020
Recycler's World, 2020
Argonne National Laboratory, 2020

Research Collaboration

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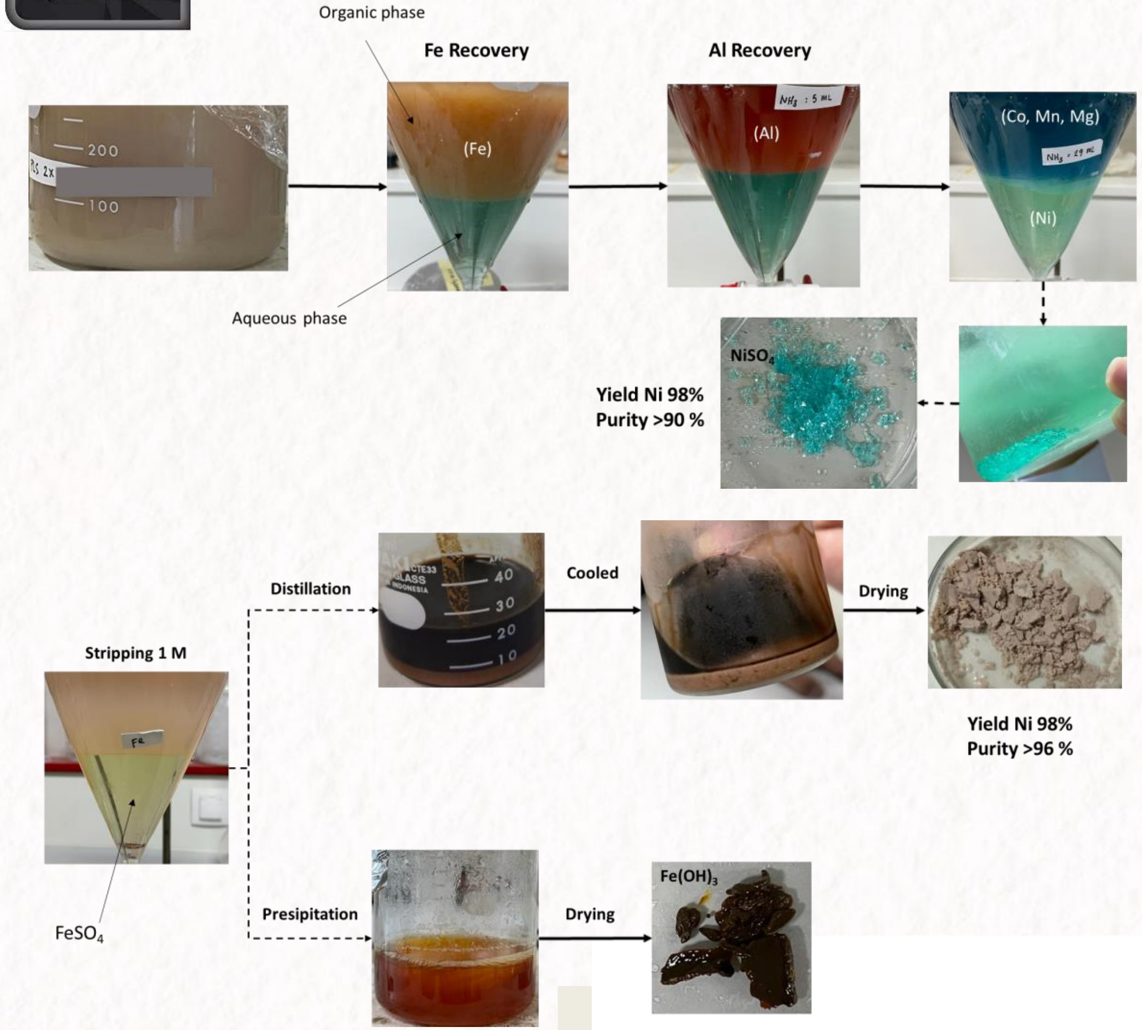
Hm
Hydrotech Metal

METALS EXTRACTION FROM *PREGNANT LEACH SOLUTION*



THANK YOU

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