

ECO-FRIENDLY HYDROMETALLURGY FOR RARE EARTH RECYCLING

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Rare Earth Elements (REEs): Key Points

• **REE abundance** Despite being labeled “rare,” REEs are relatively abundant in Earth’s crust:

- Cerium (Ce) $\approx$ 25th most common element
- Thulium (Tm) and lutetium (Lu) $\approx$ around 70th

• **Geographic distribution** Their uneven global distribution (see **Figure 1**) contributes to supply risk.

• **Role in green technologies** REEs are essential for emerging technologies supporting the green transition.

• **CRM classification** The European Commission identifies REEs as the most strategically important group of Critical Raw Materials (CRMs).

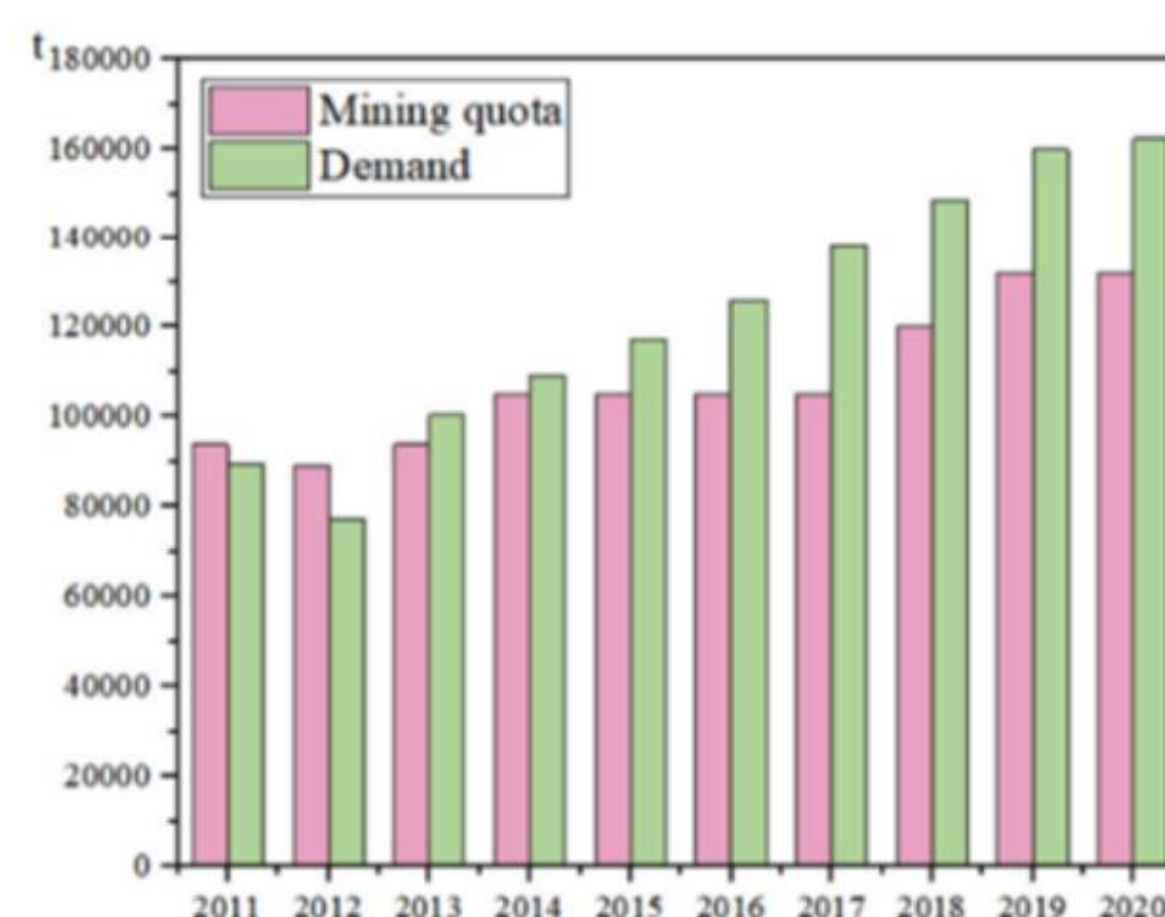
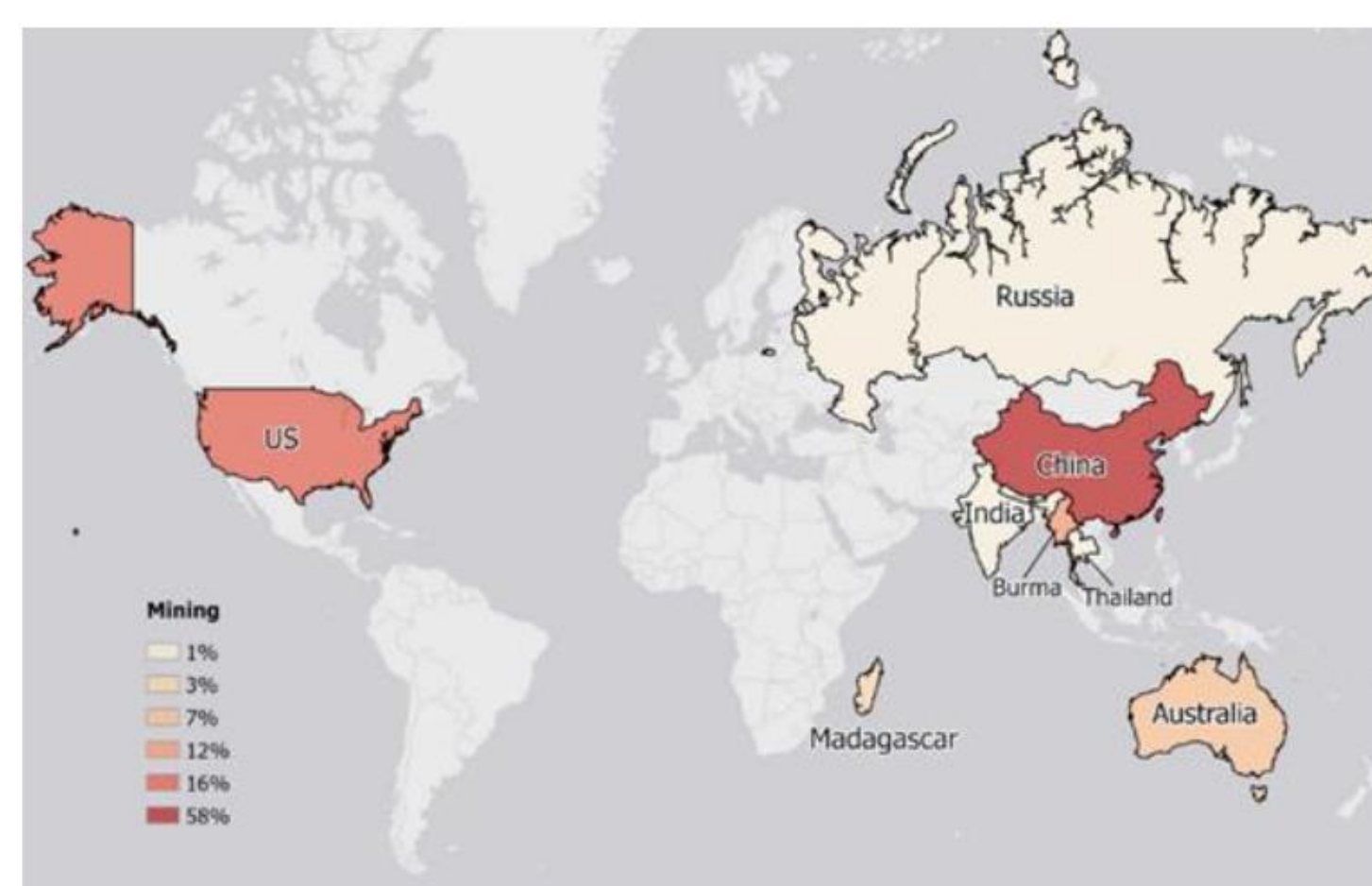


Figure 1. Geographic REEs distribution (2020),⁵ and (right) annual REEs mining production and demand in China.

In few words...

What the FREECOVER project does

- **Eco-friendly recycling** FREECOVER develops a *green* chemical process to recover valuable metals from old magnets.
- It uses **natural materials** instead of harsh chemicals, making the process safer and more sustainable.
- It focuses on recovering **rare earth elements (REEs)** — Nd, Pr, Dy, Sm — from **NdFeB** and **SmCo** waste magnets.
- It also recovers **transition metals** like cobalt (Co) and copper (Cu), and **reuses water**, reducing waste.

How the FREECOVER process works, more details

1) Dissolving the magnets and removing iron

- Old magnets are broken down using **natural acids** (acetic and citric acid). These acids come from biomass and are much gentler than industrial acids.
- Iron is then removed by forming a solid that can be separated (precipitation).

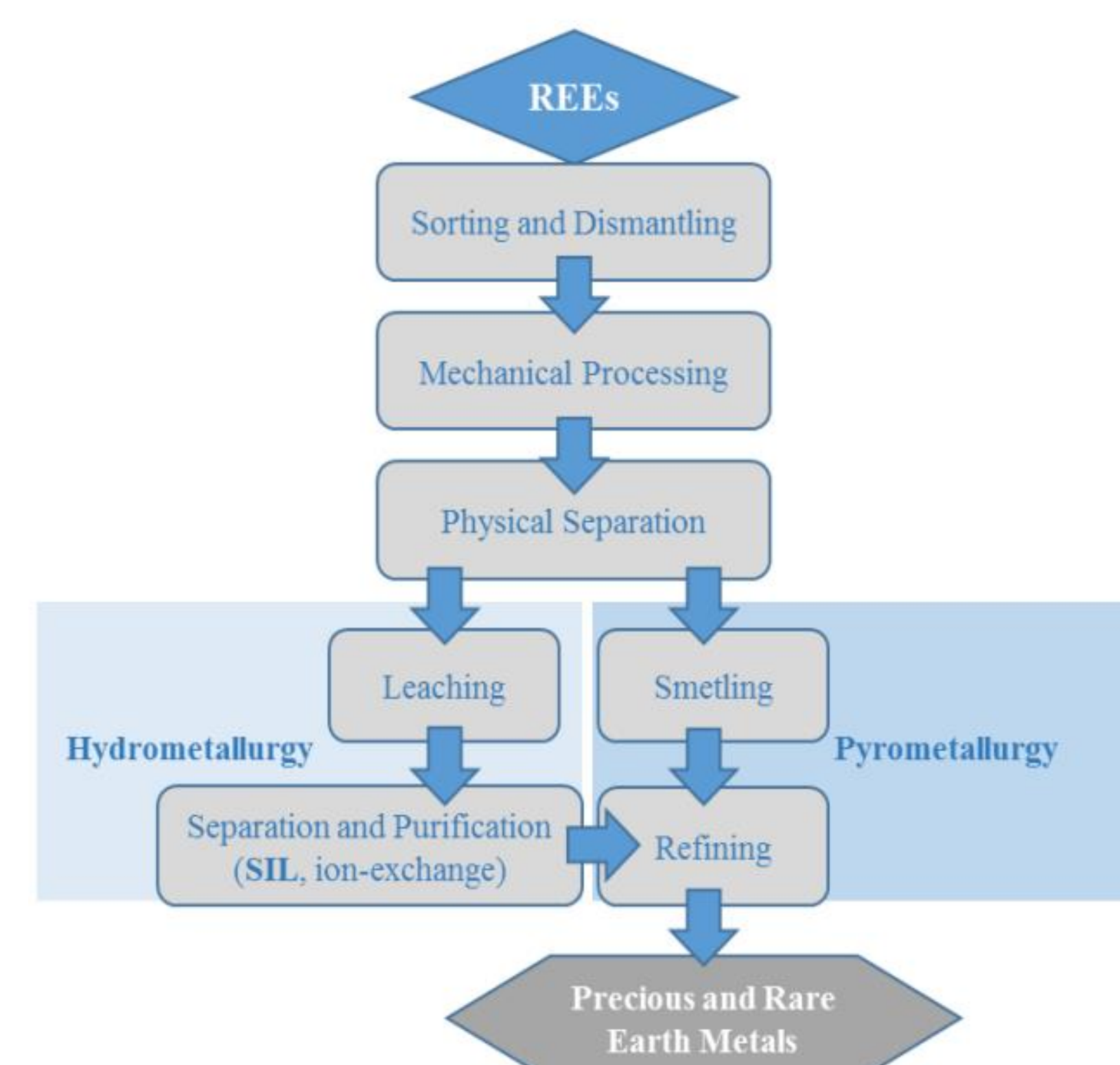
2) Extracting rare earth elements (REEs)

- The dissolved metals include REEs (Nd, Pr, Dy, Sm) separated using **eco-friendly ionic liquids (ILs)** placed on a polymer support. they form **Supported Ionic Liquid Membranes (SILMs)**.
- Natural minerals like **pyrophyllite (PYP)** and **zeolites (ZEO)** are added to make composite membranes.

3) Recovering transition metals and recycling water

- Natural adsorbents (**PYP** and **ZEO**) capture leftover metals such as Co, Ni, and Cu.
- The cleaned water is reused to dissolve new magnet waste, reducing water consumption.
- Once the adsorbents are full, they can be cleaned and reused

Hydrometallurgical and pyrometallurgical processes are currently considered the main methods for recovering valuable materials (see **Scheme 1**).



Scheme 1. Flowchart of REEs recovery through hydro/pyrometallurgical routes.

FREECOVER thrives on research staff exchanges among the participating units. It's honestly the most effective, and the most fascinating, way to build quick, engaging, and truly meaningful mutual growth.

Emanuele is heading off to Barcelona, where he'll be spending three months. Silvia will start her adventure in 2027, travelling to Ljubljana for a one-month stay.



Silvia Ruggieri and Emanuele De Rienzo (UniVr)

We're sorry we couldn't be there...we hope the poster speaks for itself! In the meantime, we're in Kyoto (Japan), presenting FREECOVER's results at the prestigious ICL 2026 conference. Feel free to reach out if you need any information.