

# An Unorthodox Method in the Extraction of REE

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# An Unorthodox Method in the Extraction of REE

Plasma Assisted Digestion (PAD™) + membrane extraction

International Plasma Research Institute



Geological Survey of Finland



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# Plasma Assisted Digestion (PADTM) + membrane extraction



- **Part 1** - Test an innovative method of processing REE bearing ore by putting it into a plasma furnace
- This alters the texture of the ore by destroying the crystal structure to become amorphous
- Ore becomes more amenable to hydrometallurgical acid extraction
  
- **Part 2** - Test the membrane separation solvent extraction system
- This would separate individual elements from the pregnant leach solution
- Characterize all feed and products
- Compare to conventional extraction systems

		Conventional REE Extraction	PAD <sup>TM</sup> & PertraX <sup>TM</sup>
CAPEX (Ratio)	Digestion	1.2	1
	Separation	15	1
OPEX (USD/kg)	Digestion	20	1.3
	Separation	10	6.6
		<b>30</b>	<b>7.9</b>

- Experimentally validate this table



# Plasma Assisted Digestion (PAD™)

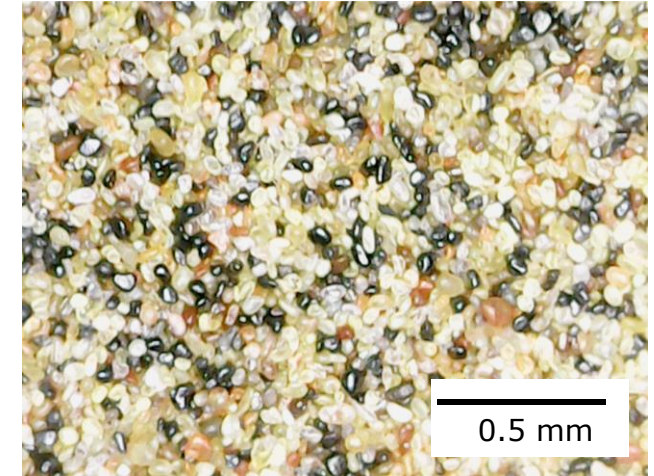
Lab scale plasma treatment unit, feed sample is passed through plasma state at 1 kg/h at 3000 °C+ for up to 10 minutes



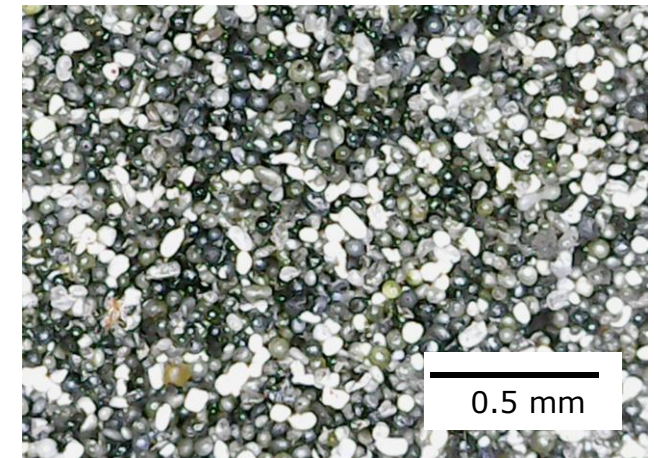
- 3500 kW Plasma furnace
- Operation @ 96% Conversion
- 578 kWh/kg or 0.162 J/(g.s)
- @5 cents a kWh
- 28.9 Euro per kg



## Case Study 1

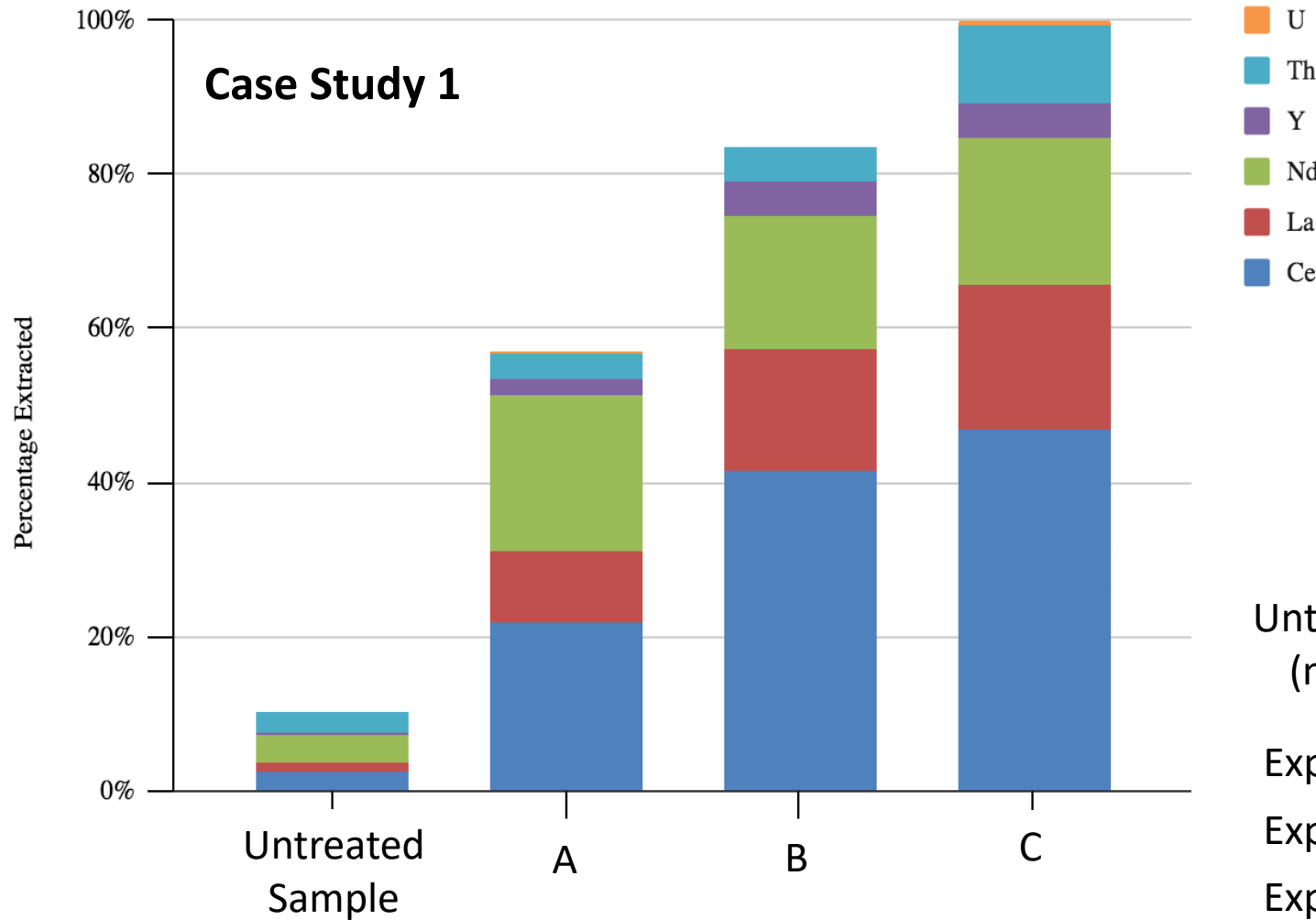


Ore feed (Mineral Sands)



Plasma Treated Product (PAD)

# Plasma Assisted Digestion (PAD™) results



PAD takes a complex mineral structure and breaks it into its own individual elements, then rapidly combines them into much simpler components, typically an oxide. This oxide is chemically easier to work with and process reducing operational costs downstream.

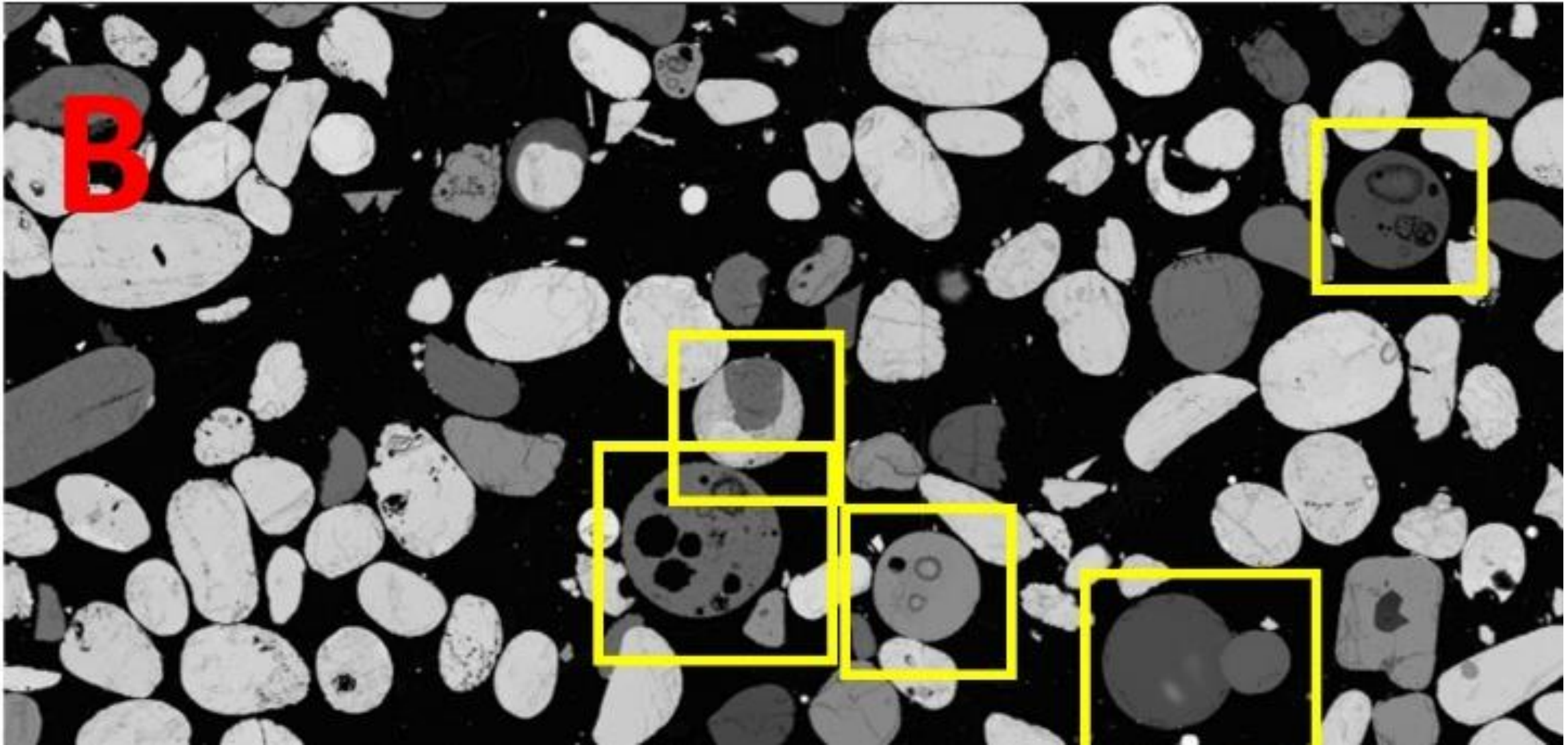
Untreated Sample = 1 hr, 12 Mol (32%) acid at 25°C  
(monazite sand)

Expt A = PAD + 5 min 1 Mol HCL acid at 25°C  
Expt B = PAD + 1 hr, 12 Mol (32%) acid at 25°C  
Expt C = PAD + 1 hr, 12 Mol (32%) acid at 80°C

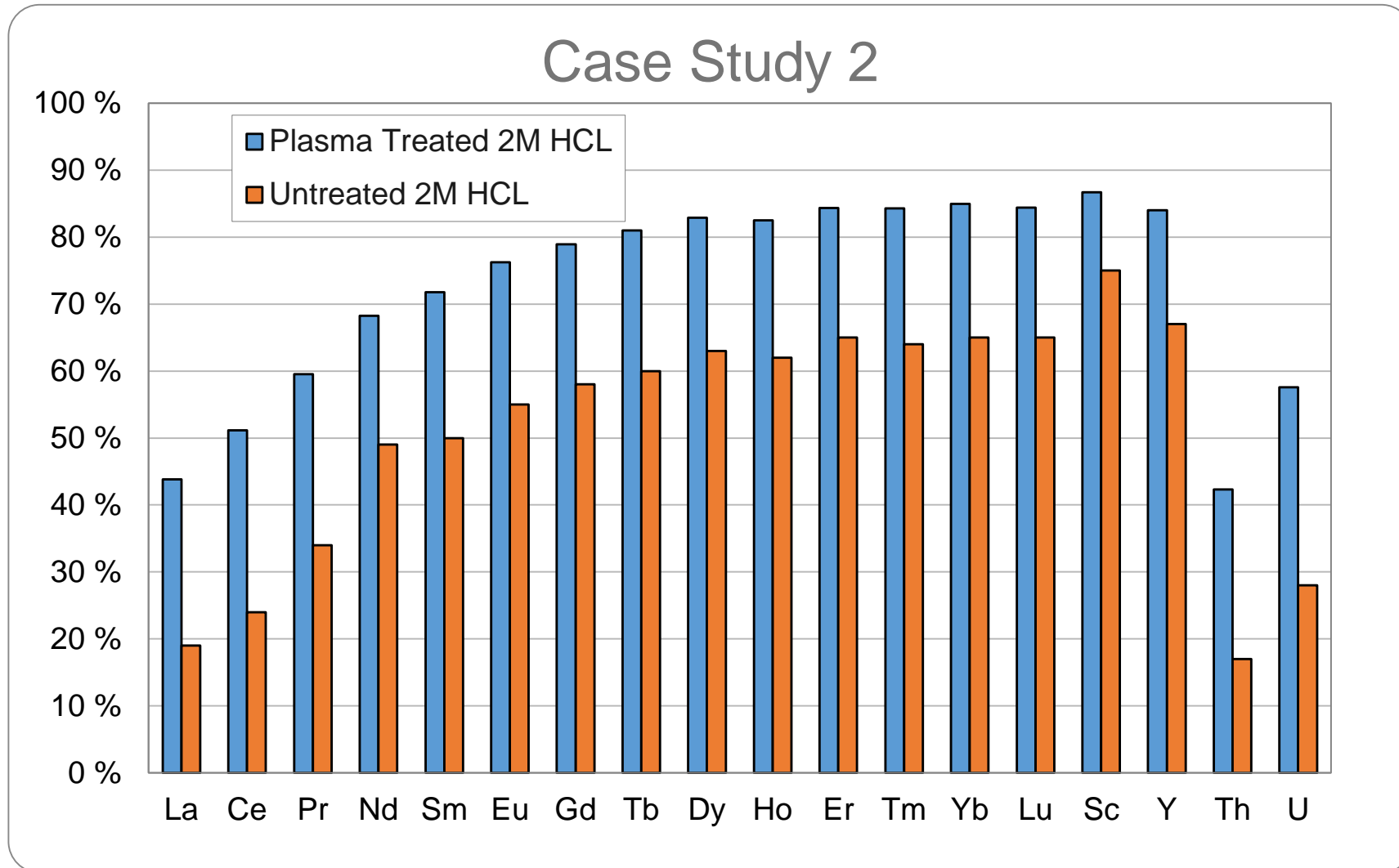
Expt A resulted in low cerium extraction but higher neodymium concentration. (Cerium is a low value REE and often discarded as the separation can often be too expensive)



# Case Study 1 – MLA BSE images

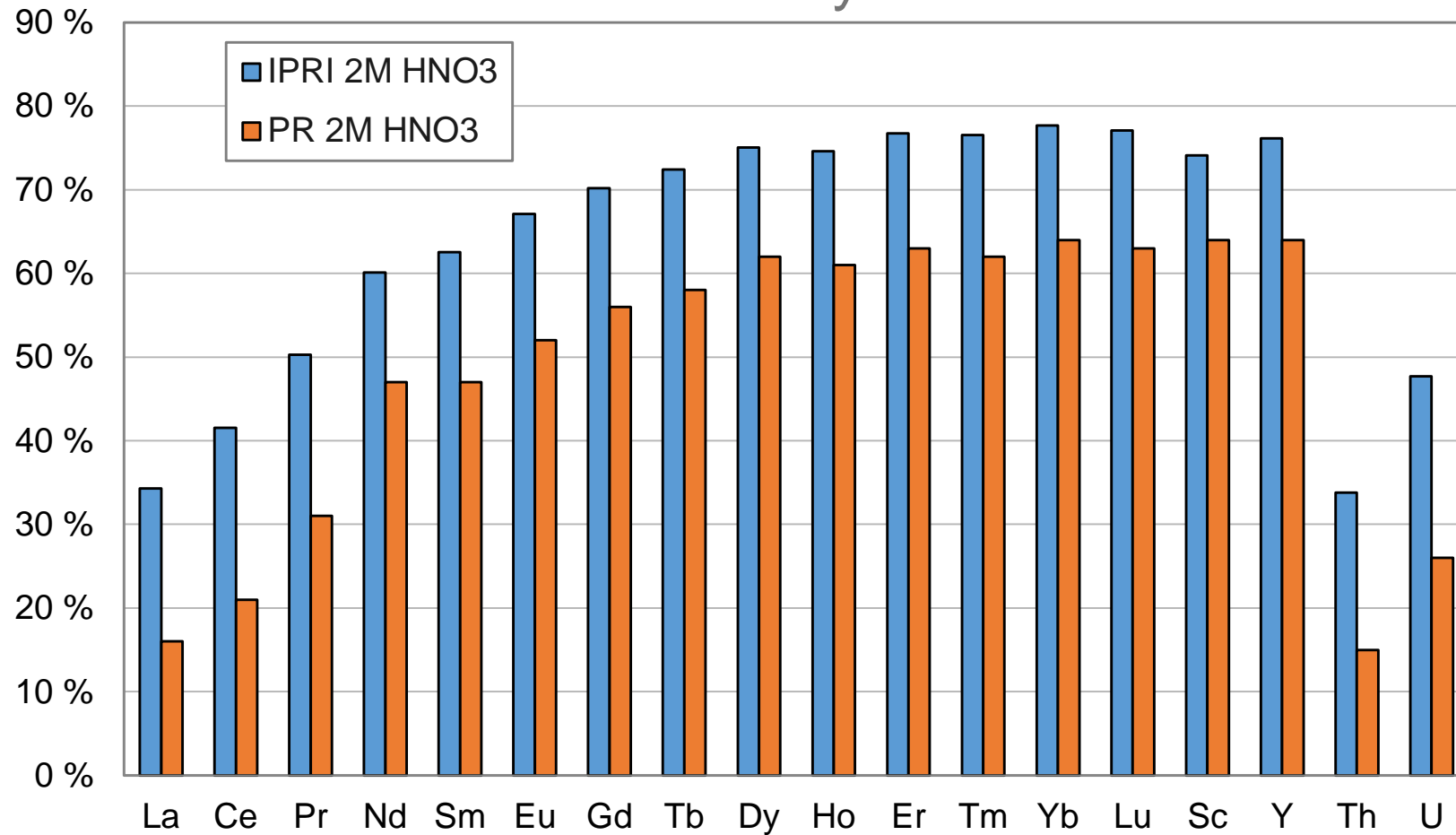


# Case Study 2



Hydrochloric acid (HCl) at 2 molar concentration,  
at room temperature and pressure on a drum roll for 5 minutes

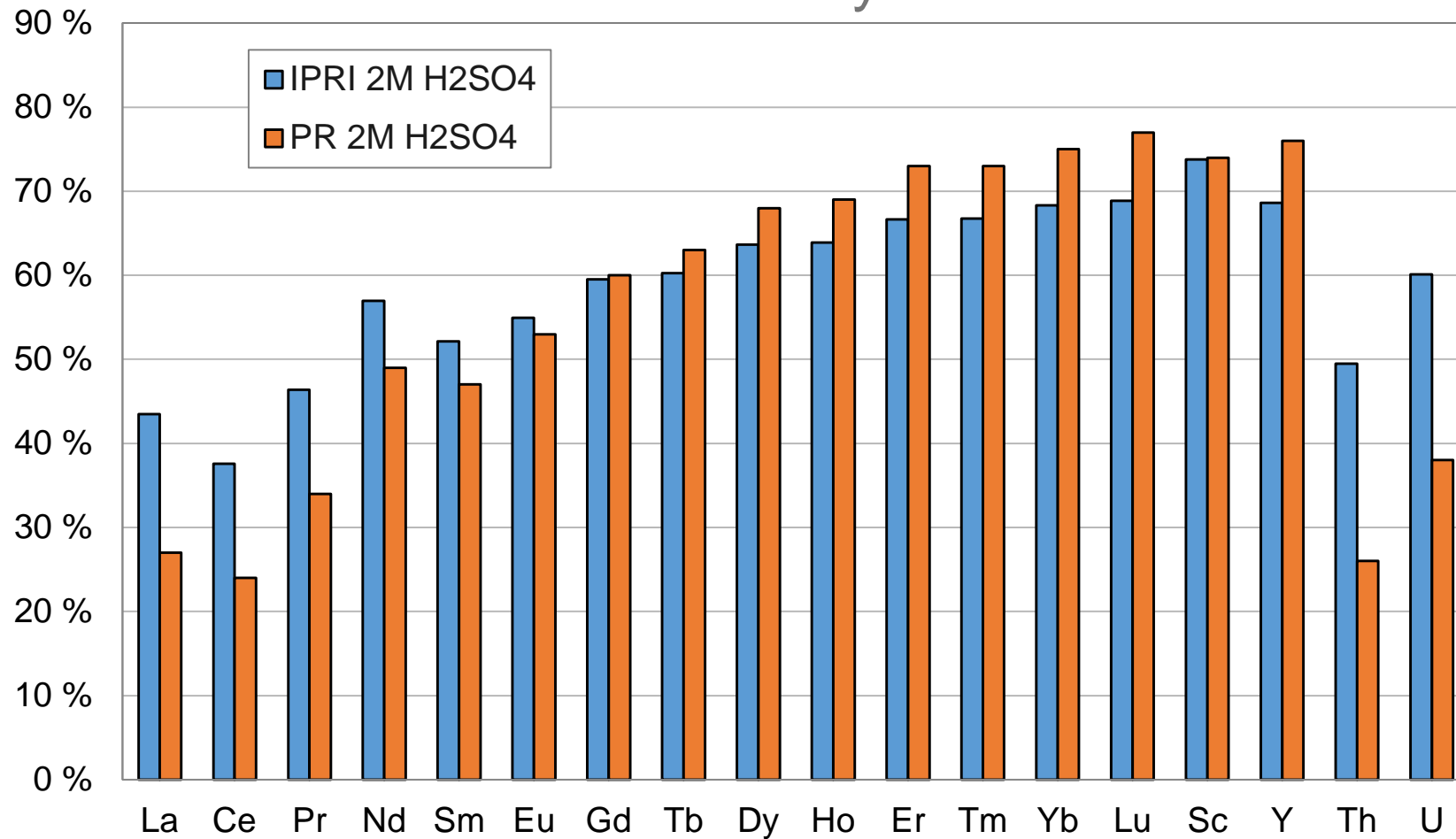
## Case Study 2



Nitric acid (HNO<sub>3</sub>) at 2 molar concentration,  
at room temperature and pressure on a drum roll for 5 minutes

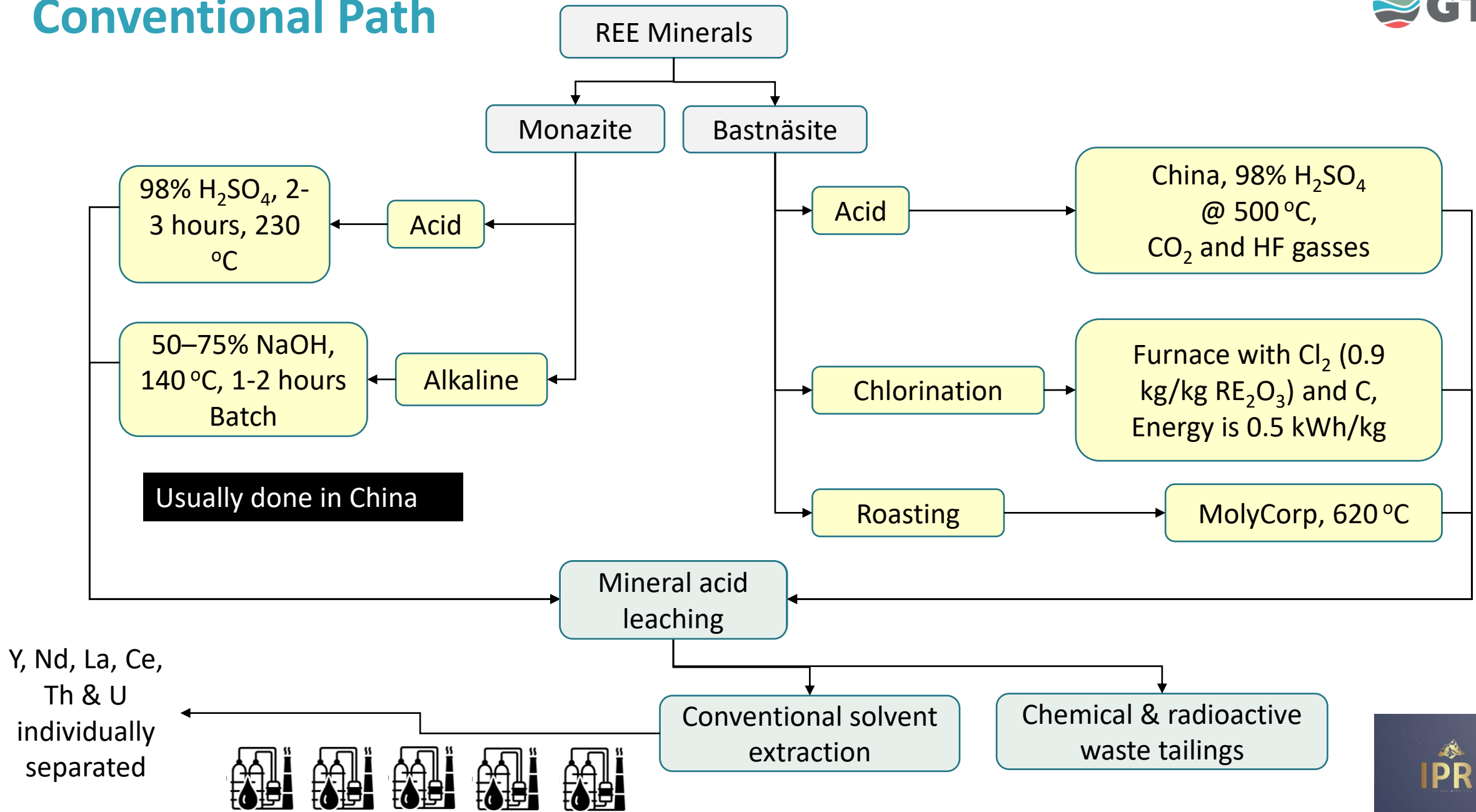


## Case Study 2



Sulfuric acid (H<sub>2</sub>SO<sub>4</sub>) at 2 molar concentration,  
at room temperature and pressure on a drum roll for 5 minutes

# Conventional Path

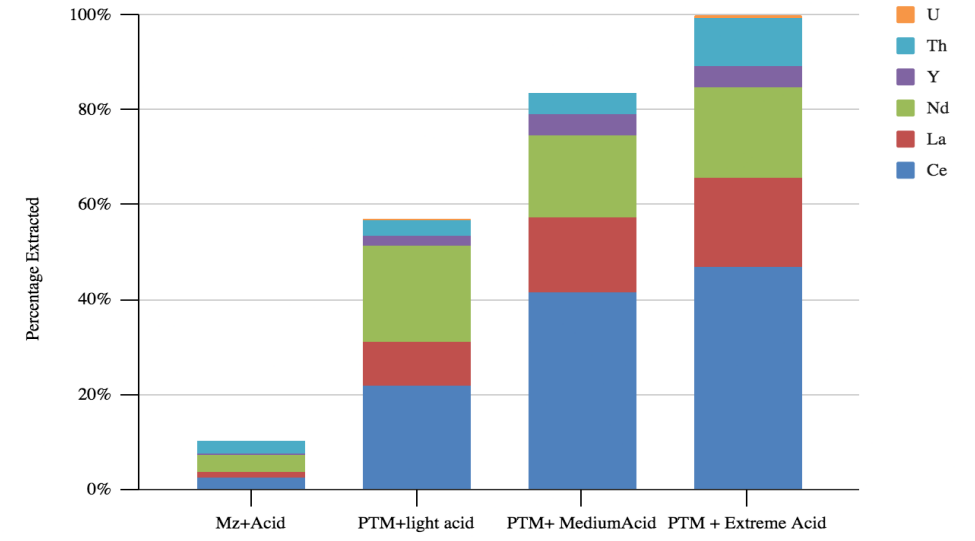
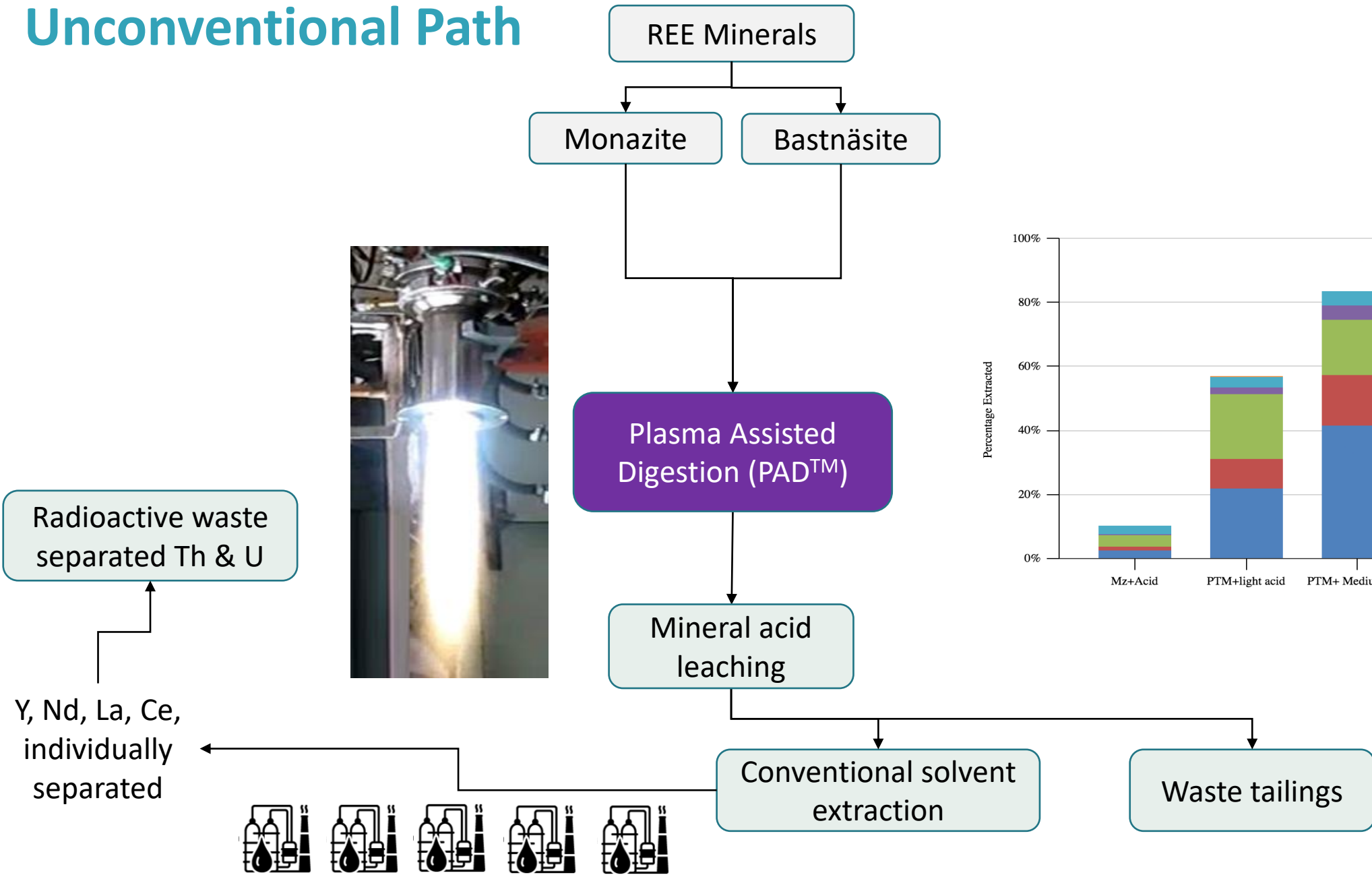


Usually done in China

Y, Nd, La, Ce,  
Th & U  
individually  
separated



# Unconventional Path





# Membrane Separation (PertraX™)

- Membrane separation is an advanced solvent extraction
- Target elements are removed individually
- It replaces the inefficient conventional mechanism of using traditional mixer/settlers and simplifying it
- This results in a faster, smaller process consuming less chemicals and offering better alternative separation capabilities

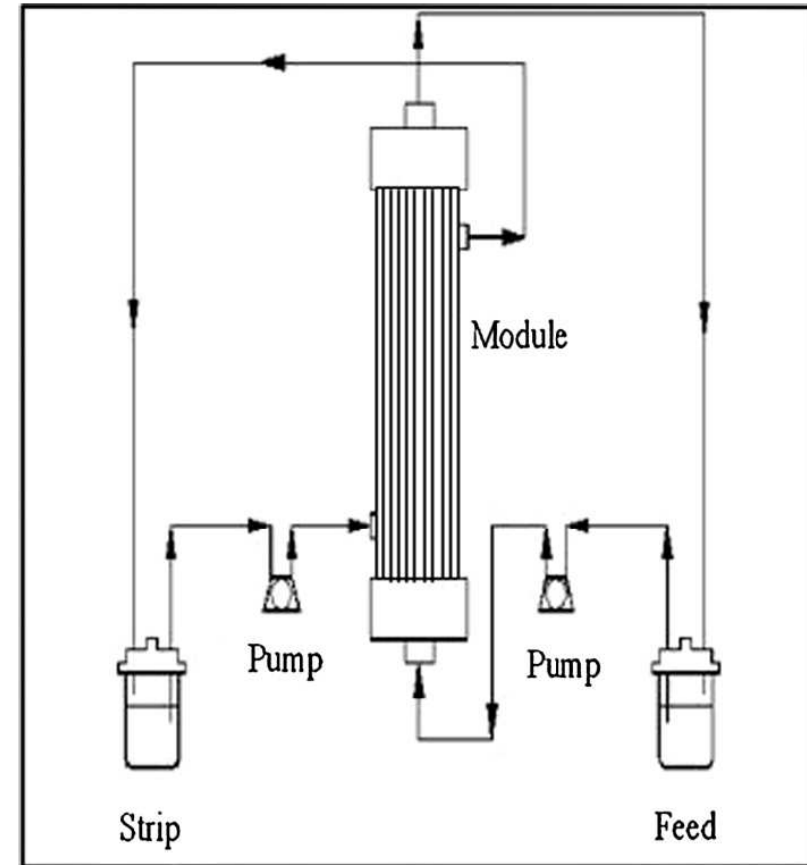
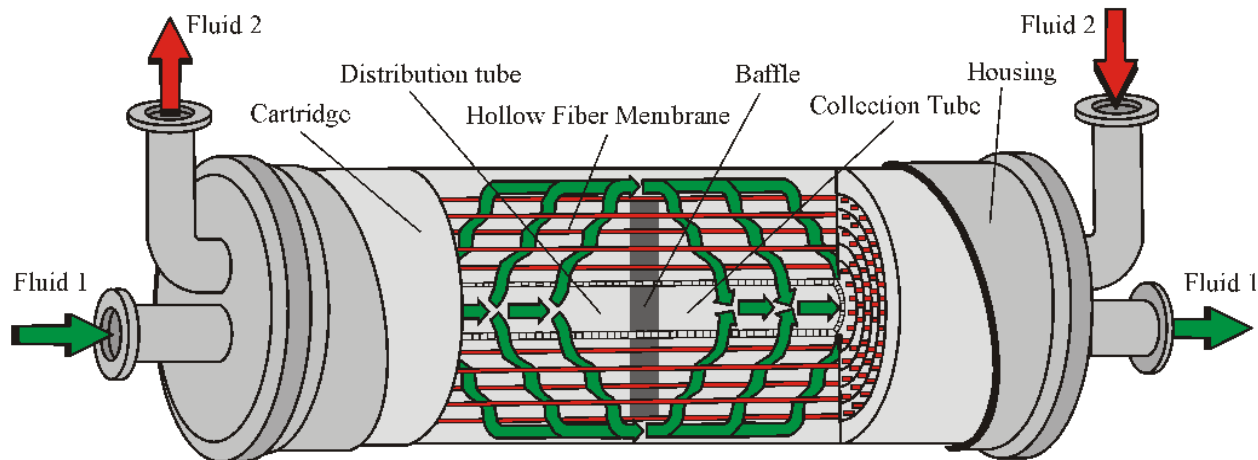
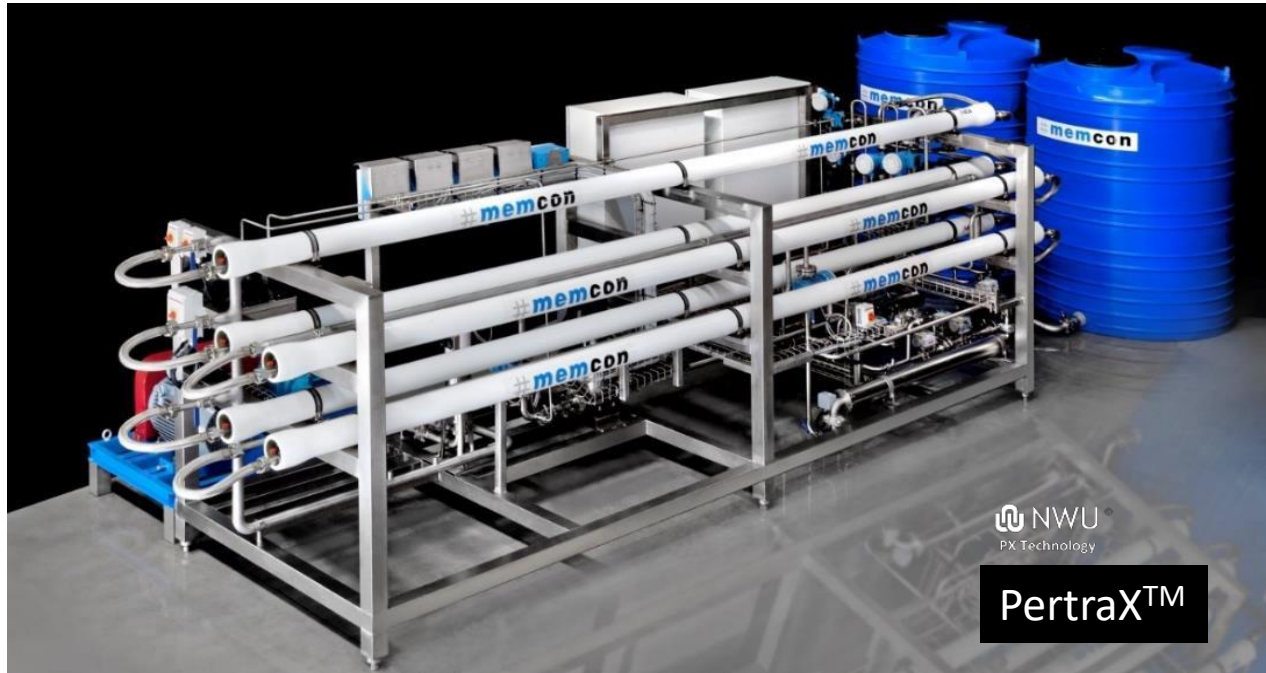


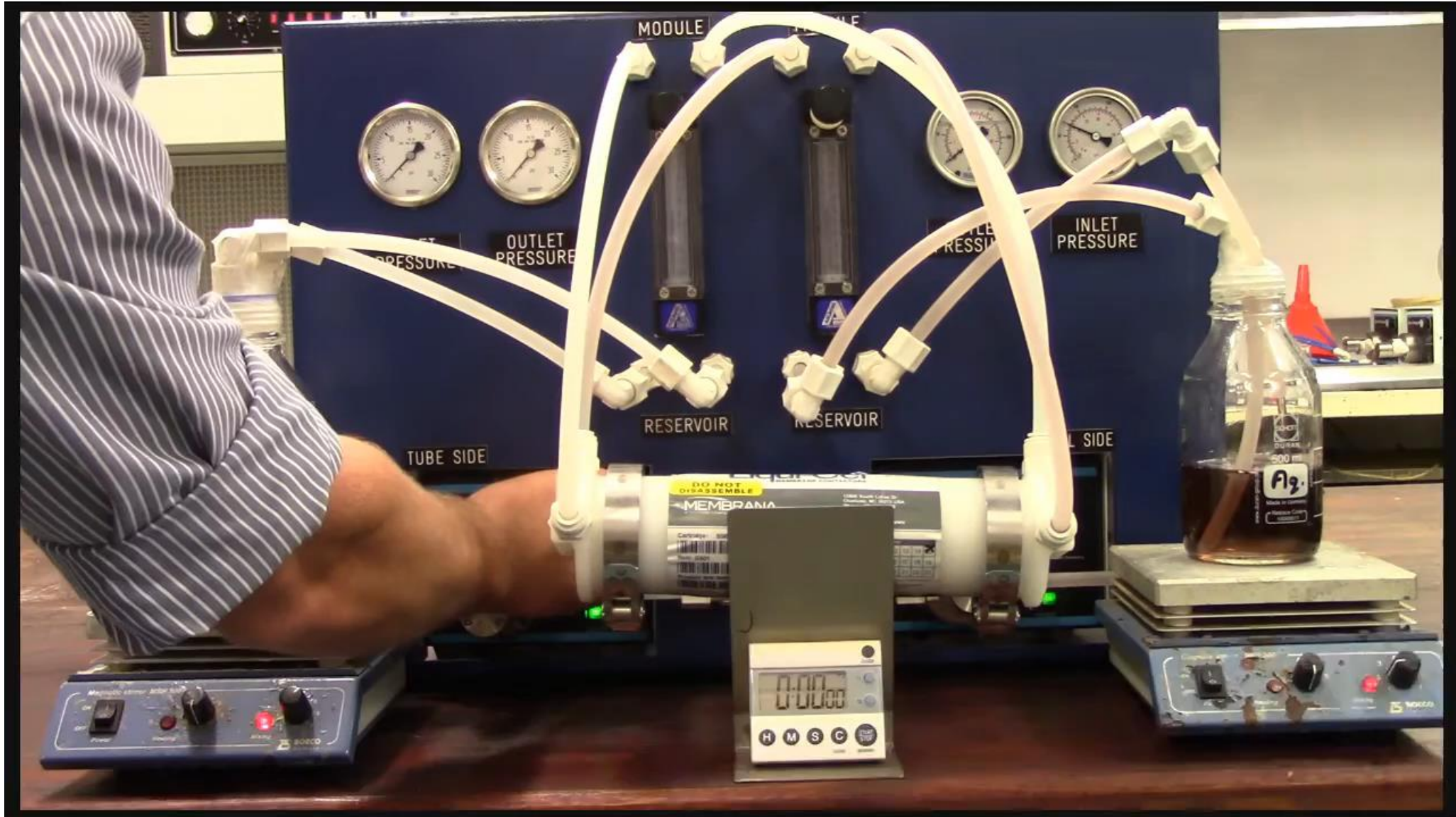
Fig. 1. Schematic diagram of experimental setup.

Rout P.C. and Sarangi K. (2014): Separation of vanadium using both hollow fiber membrane and solvent extraction technique – A comparative study, Separation and Purification Technology 122 (2014) 270–277

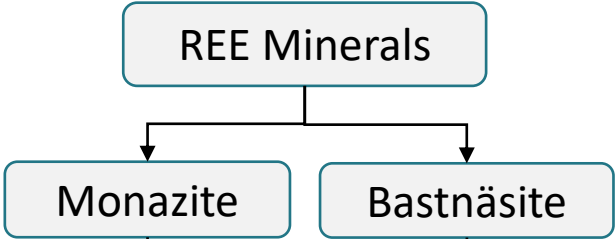
# Membrane Separation



Solvent extraction of Cobalt (Blue) and Nickel (Green)







Plasma Assisted Digestion (PAD™)

Mineral acid leaching

Membrane Separation

A much shorter value chain

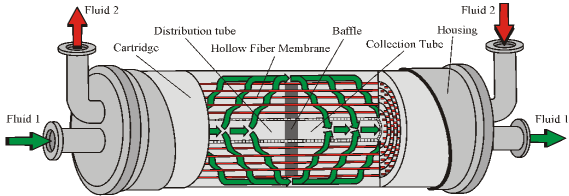
Could be done in Finland

Many of the existing hazards are now gone

Less toxic waste tailings

Radioactive waste separated Th & U

Y, Nd, La, Ce, individually separated



# Plasma Assisted Digestion (PAD™) + membrane extraction



- Conventional Rare Earth Element (REE) extraction is expensive and difficult.
- Due to the nature of the chemicals used in the conventional extraction process, most Western nations are not prepared to do industrial scale refining of REE
- This unorthodox approach requires 40-80% fewer chemical quantities.
- Individual REE products could be produced at the mine site
- Extraction of individual REE can be done in Finland, no need to send concentrate to China

		Conventional REE Extraction	PAD™ & Pertract™
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- Strategic Fit

Rare Earth Elements no longer need to be “rare” or expensive



# Oils ain't oils....

## Target groups who might benefit

- REE mining operations
- Technology groups that need REE metals
- Capital investment groups that are dependent on value chains that need REE

## How could these target groups benefit?

- A way of separating REE into individual products
- Shorter value chain, with less complex chemical requirements
- Could be done locally at the mine site, with no need to send concentrate to China
- Lower CAPEX and lower OPEX
- Many smaller scale operations easy to do
- Can be custom fit to specific ores at a pilot scale



# Uniqueness and novelty

The science of the plasma is mature, but the application is unusual. The chemistry is new but extremely simple. The literature is also extremely limited as the kinetics chemistry etc. is so simple it's not worth it to publish it, till now. The only thing that may have been mentioned is as a note somewhere that they attained the oxide and dissolved in acids as it was easier. This process path has been rejected in the past due to the perception of high energy cost. This was done without considering the footprint of the whole value chain.



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**Kiitos & Thank you**