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Future challenges in hydrometallurgy for critical metal recovery and recycling RadioChemistry and Processes Department CEA Marcoule

E. Andreiadis, V. Haquin, J. Serp, J.-P Dancausse, M. Miguirditchian, S. Bourg, F. Goettmann, J.-C Thieblemont, C. Poinssot

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E. Andreiadis, V. Haquin, J. Serp, J.-P Dancausse, M. Miguirditchian, et al.. Future challenges in hydrometallurgy for critical metal recovery and recycling RadioChemistry and Processes Department CEA Marcoule. ERES 2014 - the 1st conference on European Rare Earth Resources, Sep 2014, Milos Island, Greece. cea-02870005

HAL Id: cea-02870005

<https://cea.hal.science/cea-02870005>

Submitted on 16 Jun 2020

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Future challenges in hydrometallurgy for critical metal recovery and recycling

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The CEA : atomic energy and alternative energies



Created in 1945 to give nuclear capacity to France, in 2010 the CEA became :



energie atomique • energies alternatives

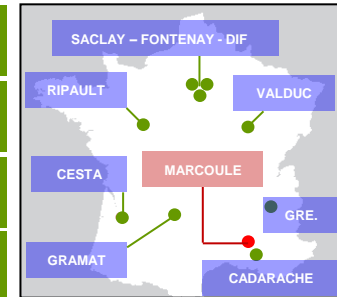
A change that **reflects the activities and potentials** of our organization.

Low carbon energies

Defense and security

Information Technologies

Health technologies



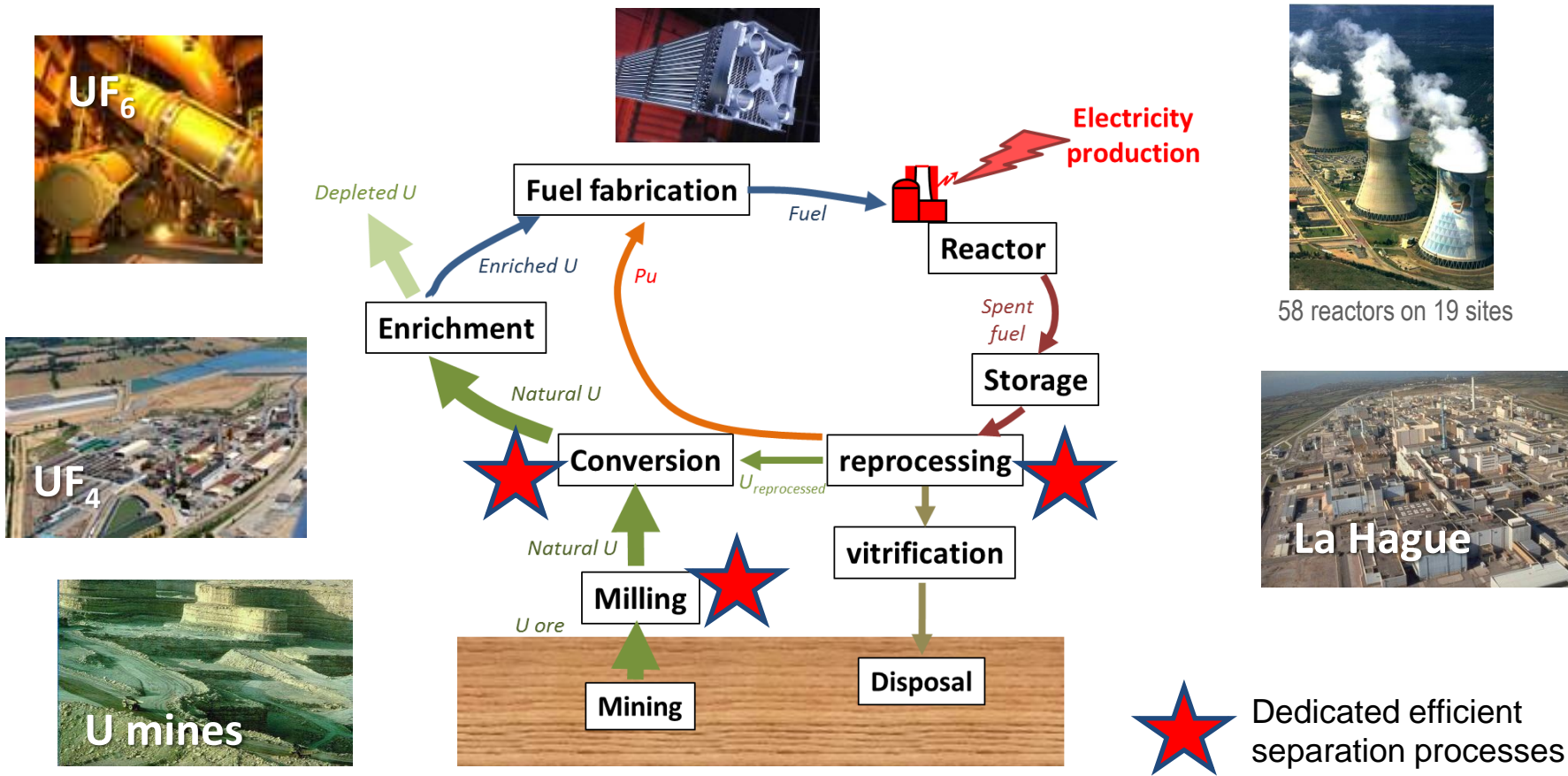
10 research centers

16 000 employees – Annual budget : 4,7 billions €

It filed **754 priority patent applications in 2013.**

Since 1984 it has created **120 companies** in the sector of innovative technologies.

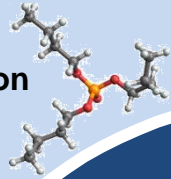
Separation processes along the nuclear fuel cycle



The skills developed in nuclear solvent extraction processes

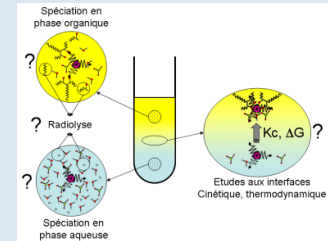
can be applied to the specific case of critical metal recovery and recycling

- Ligand design
- Synthesis and characterization of extracting molecules
- Optimization of extractant formulation



Extractant system selection

- Measurement of distribution coefficients
- Understanding of extraction mechanisms (affinity, selectivity)
- Structure-activity relations



Molecular scale chemistry

Specific objectives, D, SF, % Recovery

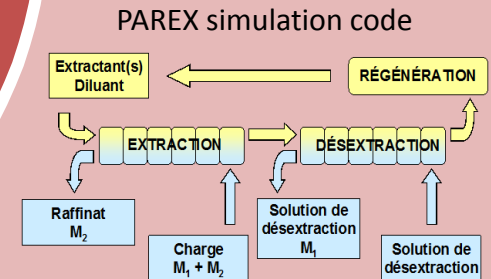


Integrated experiments

- Qualification of the process on real solutions
- Industrial extrapolation using simulation

Process modelling

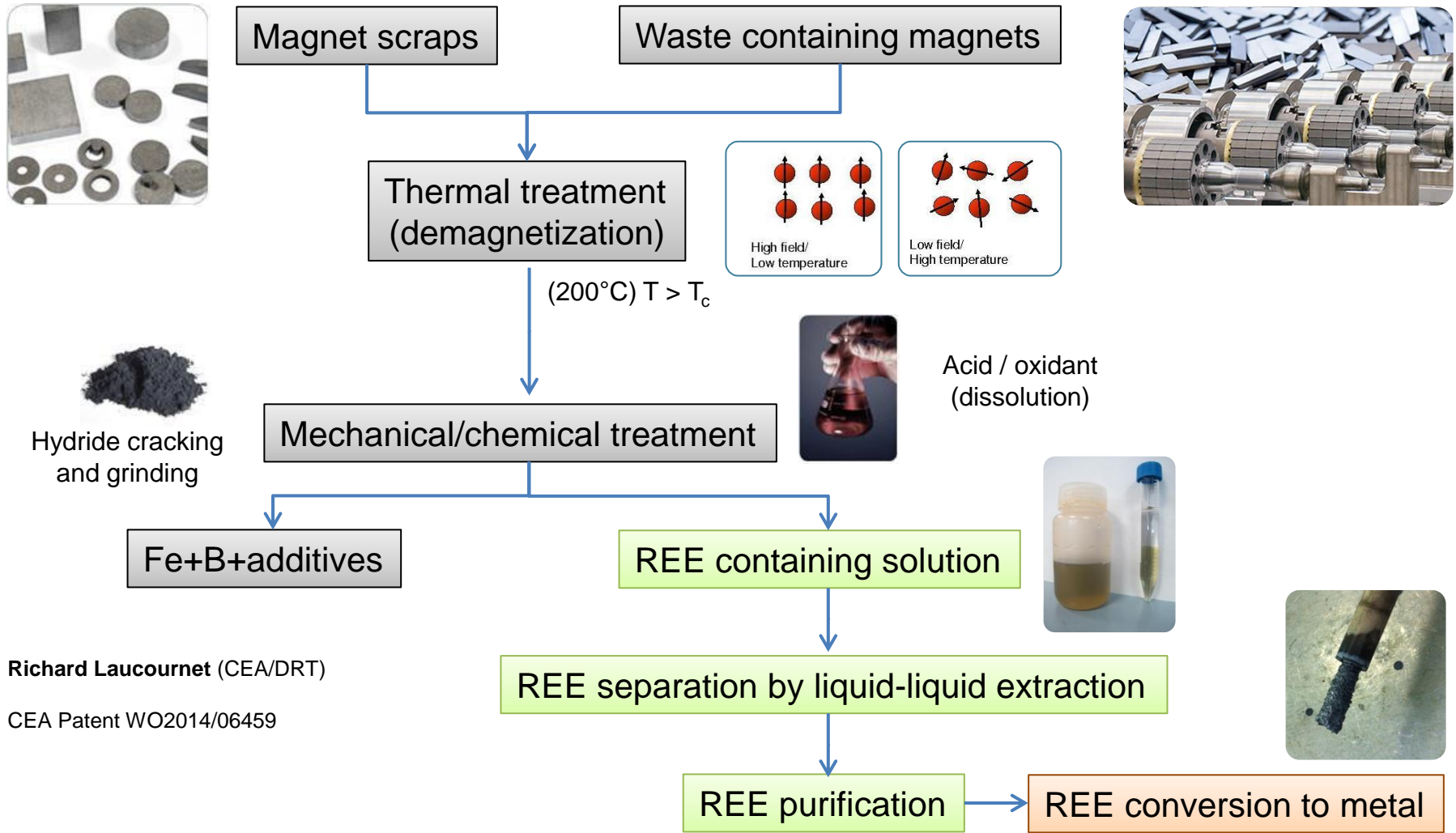
- Development of extraction models and specific flowsheet
- Optimization of the separation



**Example of a CEA patented technology
for the separation of Dysprosium from
permanent NdFeB magnets**



Scheme for REE recovery and purification

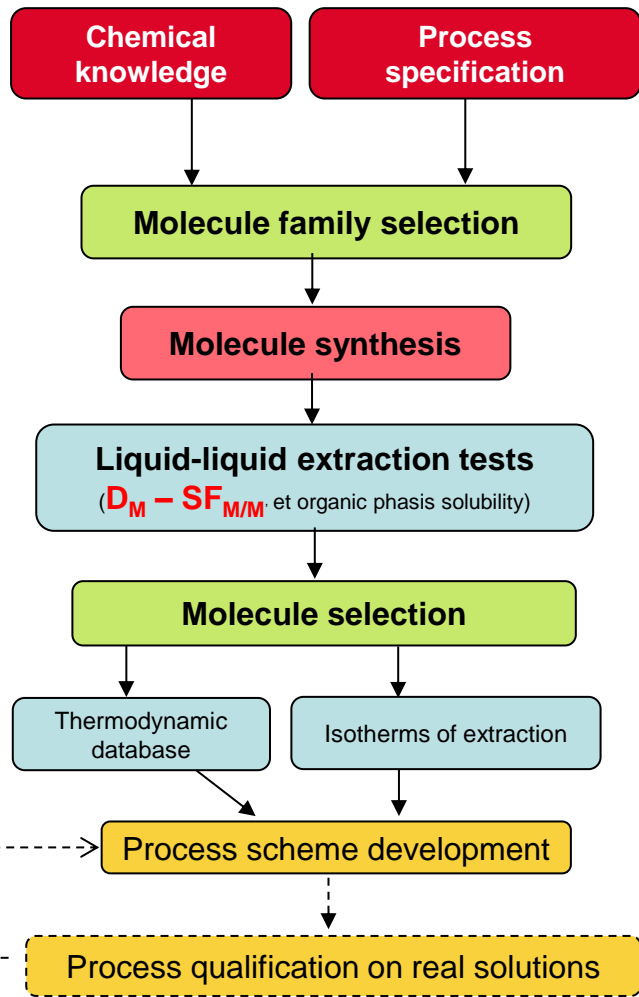


Richard Laucournet (CEA/DRT)

CEA Patent WO2014/06459

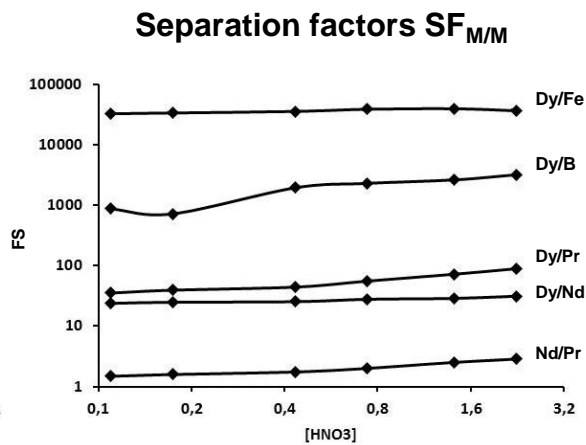
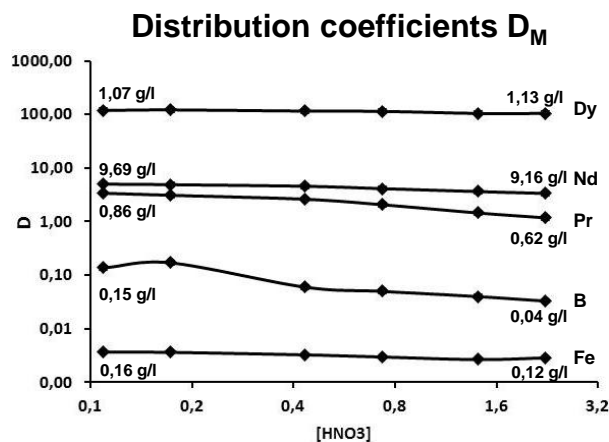
CEA/DEN Patent application filed 2014

Selection and evaluation of the extractant system



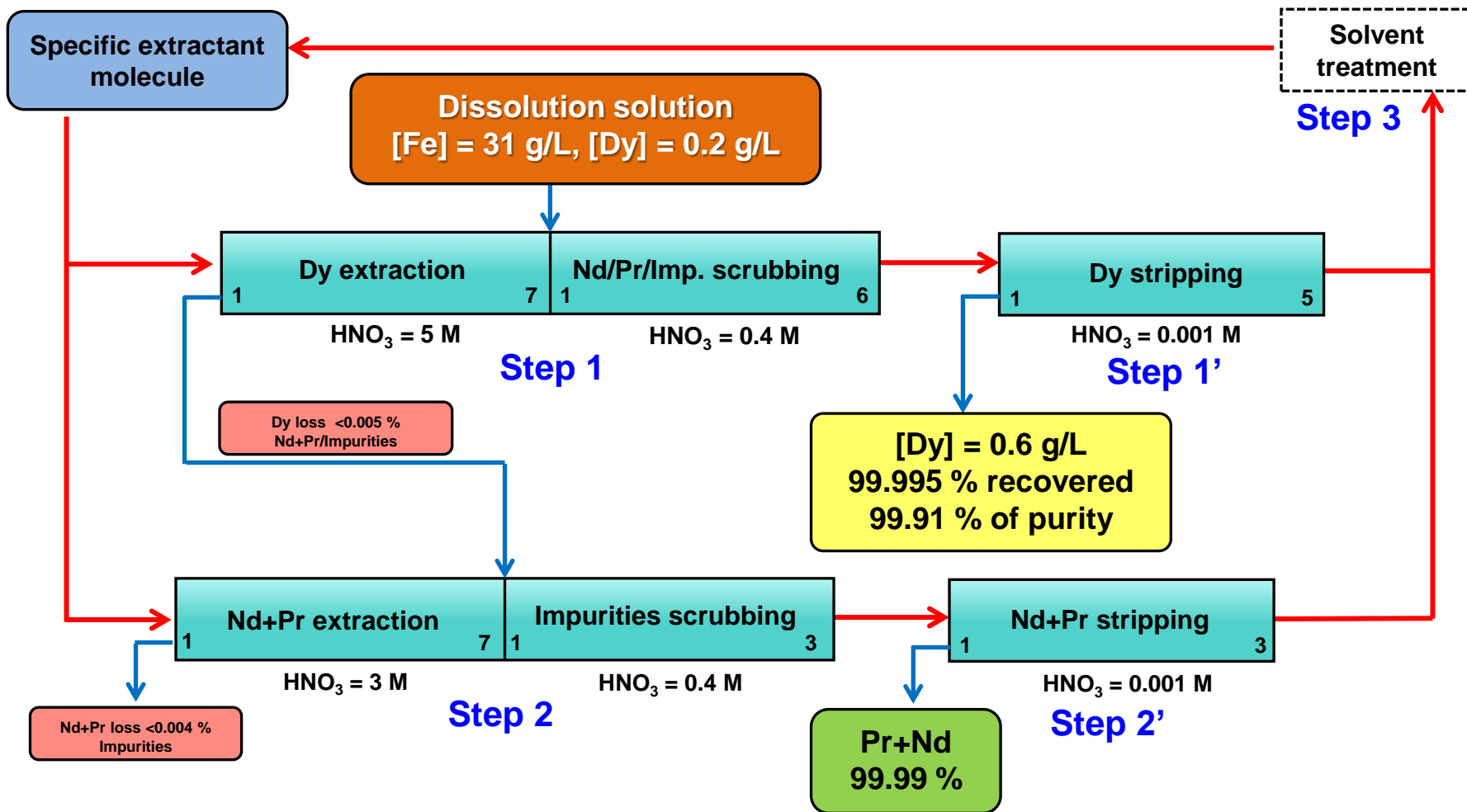
- ✓ Tests on synthetic and real dissolution solutions
- ✓ **Efficient separations** of REs / transition metals and RE / RE in a large range of acidity (0,4 to 5 M)
- ✓ **No third-phase** formation (phase modifier)

Élément	B	Fe	Co	Ni	Cu	Pr	Nd	Dy
g/l	0.4	31	0.2	0.8	0.5	2.7	11	0.2



- ✓ Development of a chemical model and calculation a flow sheet of the process using the **CEA's PAREX simulation code**
- ✓ **Good agreement** between extraction experiments and calculated values for both synthetic and real solutions

Development of the separation process flowsheet



**Effective and compact process in two steps
for Dy (step 1) and Nd+Pr (step 2) separation from REE solutions**

Patent application filed

Objective: pyrometallurgical conversion of the separated REE into high purity RE metals.

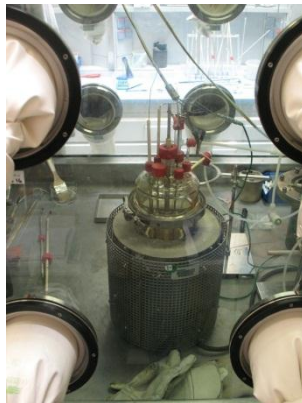
Use of **transient electroanalytical techniques**

(voltammetry reversal chronopotentiometry, chronoamperometry...)

to optimize the experimental condition:

- Salt composition
- Temperature
- Dy concentration
- Current and current density

Glovebox setup

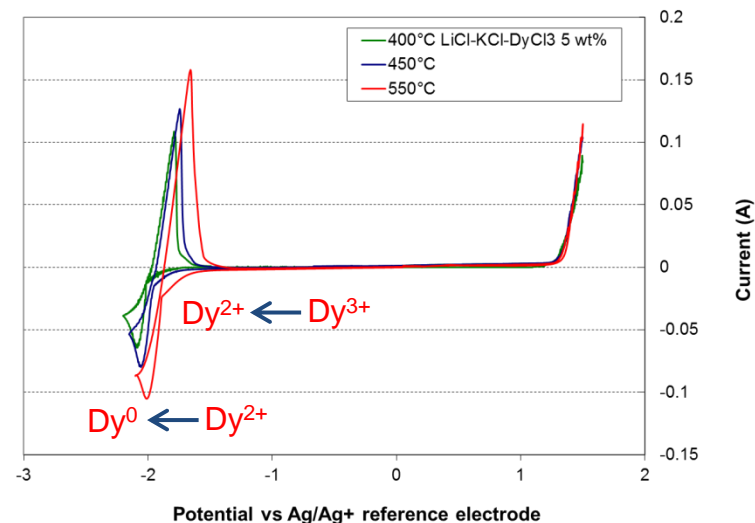


Metal deposition tests to evaluate the process efficiency:

- Metal adherence
- Faradic yield
- Product purity
- Cell materials compatibility



Cyclic voltammetry in molten chloride salt



Metal deposition tests on the gram scale



Mo electrode

Dy deposit

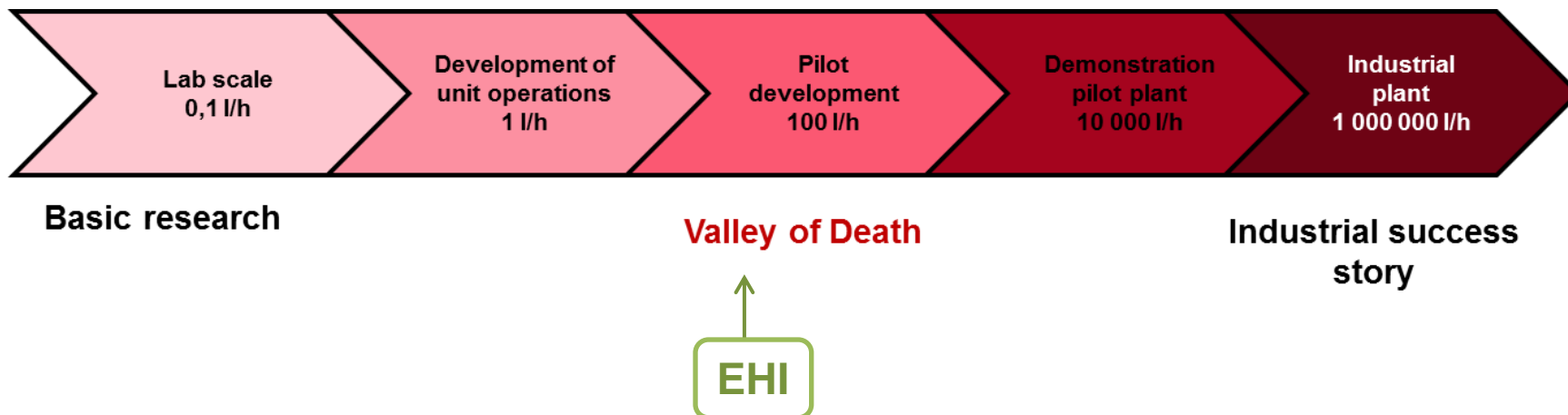
**Demonstration platform
EHI
European Hydrometallurgical Institute**



Why a European Hydrometallurgical Institute?

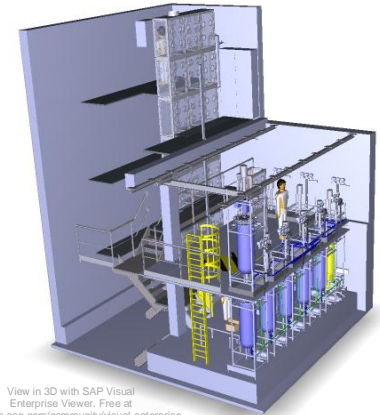
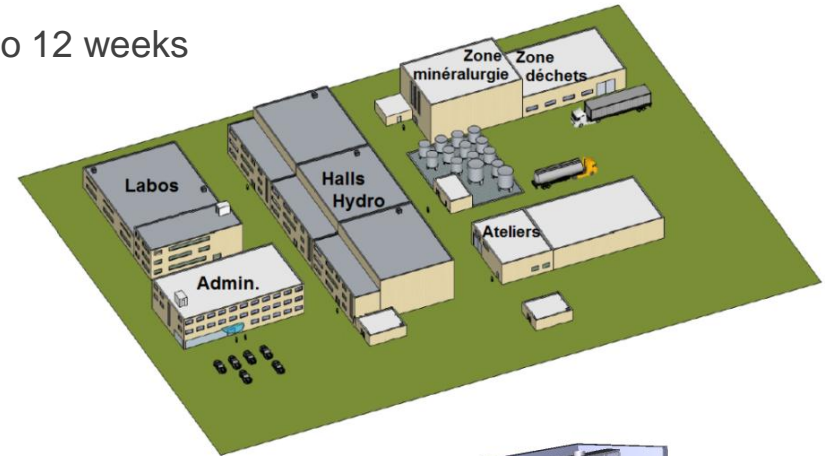
Process development at pilot scale; a key step towards industrial achievements

- **New mineral resources** (from mines or urban mines) are essential for **Europe's raw material supply**
 - low grade and polymetallic resources → need for **new extraction processes**
 - social acceptance → **eco-conception** and **sustainability** are key issues
- **Hydrometallurgy** is one tool to achieve these goals
- **Pilot scale development** is essential to enhance and validate extractive processes, contributing to a better **risk management**.
- There is no **large scale open tool** to conduct such pilot tests in Europe today



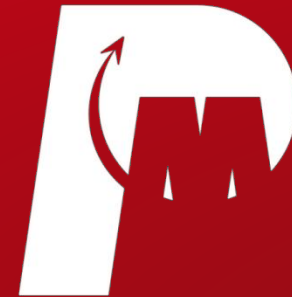
Technological and business aspects

- The facility must be able to work **24/7** for periods from 1 to 12 weeks
- Processing flow expected are typically **from 1 to 50 L/h**
- Extension: **1000 m² of labs & 2000 m² of testing halls**
- Covered technological steps include
 - Leaching (acidic, basic, pressurized)
 - Bioleaching
 - Precipitation
 - Solvent extraction
 - Electro-winning
 - Limited minerallurgical treatment and (reactive) roasting
- Dedicated **analytical and development laboratories**
- Two technological platforms
 - **Low through put platform** (1 L/h)
for pilot testing of (small) recycling processes
 - **High through put platform** (up to 50 L/h)
for pilot testing of larger hydrometallurgical extraction processes
- **Confidentiality** of the projects must be granted (no IP)



For more information:
Frederic.Goettmann @ cea.fr

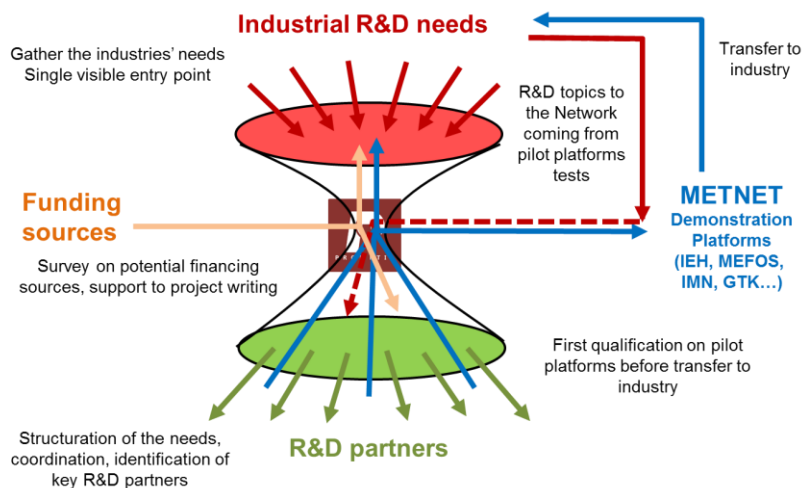
**PROMETIA -
mineral processing and extractive
metallurgy for mining and recycling
innovation association**



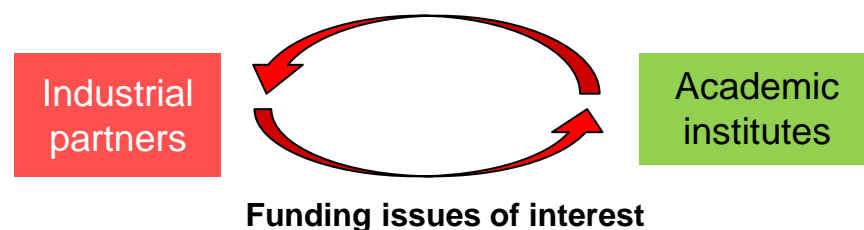
P R O M E T I A

Main objectives of the network

- Develop **innovative technological solutions** to optimize raw materials & waste treatment
- Enhance **EU skills** in mineral processing and extractive metallurgy of ores and industrial residues
- In the longer term, **boost the innovation capacity** of the EU raw materials related sectors



Technology transfer



Purpose of the network

- Create **links** between academic research and industry
- Gather the **competences** in mineral processing and extractive metallurgy in Europe to
- Provide the industrials with a **single entry point** for answering **R&D needs**
- Coordinate the **R&D needs** (“translation” between industry and research)
- Ease the access to **pilot platforms** for R&D
- Help members to **answer H2020 calls**
- Help members to **get funding** from various sources (lobbying) (“**labelization**”)

- **CEA developed historical skills in recycling processes for the nuclear industry**
 - CEA and France developed efficient and industrially-mature separation processes in very demanding conditions (highly active environment)

- **Requirements of nuclear safety lead to develop specific skills to understand any of the actual mechanisms involved in the separation processes**
 - Very specific to nuclear industry: no possibility to only rely on empirical approach
→ High-level skills and very robust processes

- **CEA develops new processes to improve the recovery of critical materials from primary or secondary mines**
 - Specific in-house developments: Dy recycling processes from magnets
 - Numerous industrial contacts
 - Demonstration platforms: European Institute of Hydrometallurgy EIH
 - European network of extractive metallurgy: PROMETIA

CEA is committed to support the development of mining and recycling industry