HAL
open science

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

To cite this version:

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

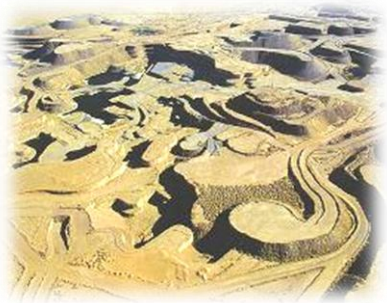
https://cea.hal.science/cea-02870005v1

Submitted on 16 Jun 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

DE LA RECHERCHE À L'INDUSTRIE



Future challenges in hydrometallurgy for critical metal recovery and recycling

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

eugen.andreiadis @ cea.fr

RadioChemistry and Processes Department
CEA Marcoule

www.cea.fr

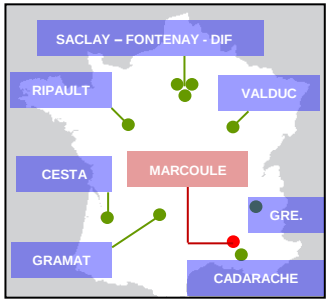
The CEA : atomic energy and alternative energies

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



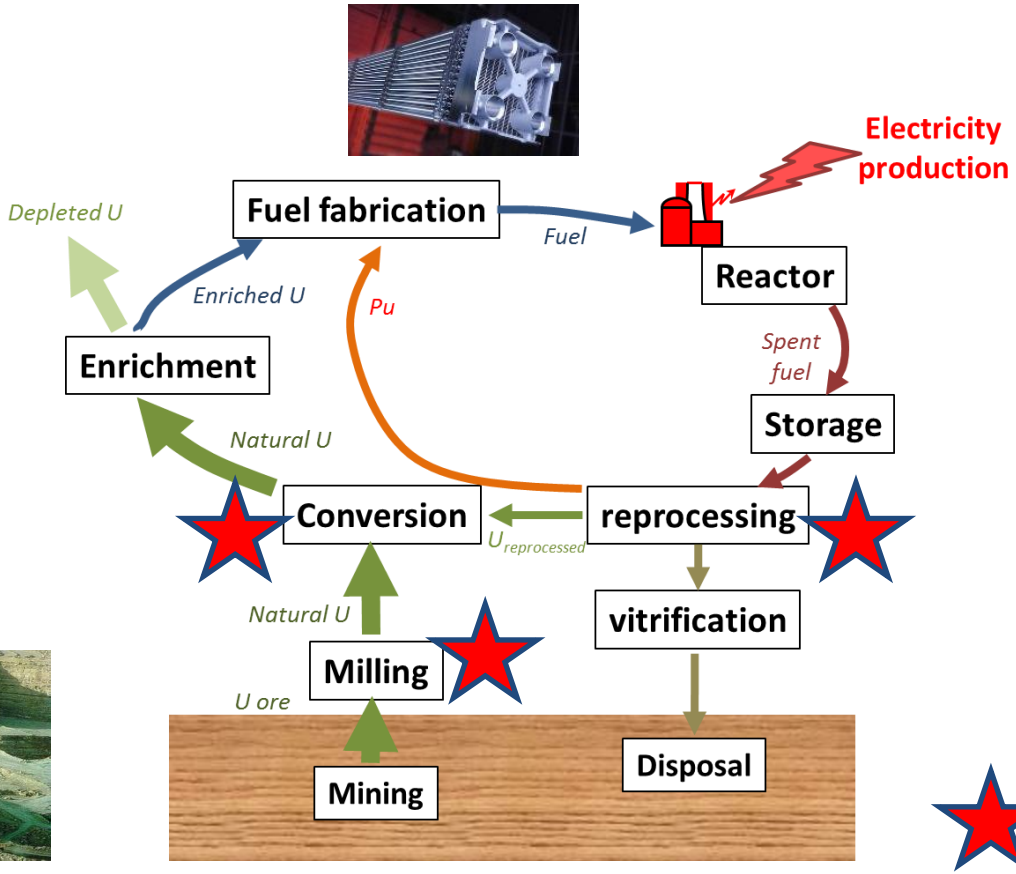
10 research centers

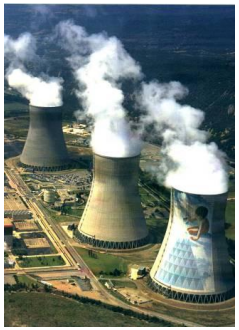
16 000 employees – Annual budget : 4,7 billions €

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





58 reactors on 19 sites

Dedicated efficient separation processes

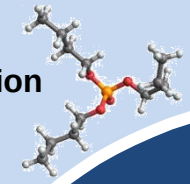
The skills developed in nuclear solvent extraction processes

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

A well-tried approach to process development

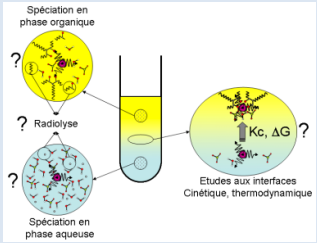
Extractant system selection

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



Molecular scale chemistry

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



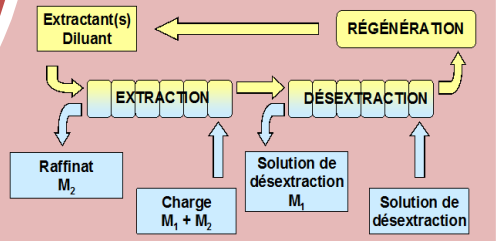
Specific objectives, D, SF, % Recovery

Integrated experiments

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

Process modelling

PAREX simulation code



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

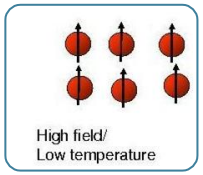
Example of a CEA patented technology for the separation of Dysprosium from permanent NdFeB magnets

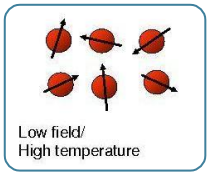
Scheme for REE recovery and purification

Magnet scraps

Waste containing magnets

Thermal treatment (demagnetization)





(200°C) $T > T_c$

Hydride cracking and grinding

Mechanical/chemical treatment

Acid / oxidant (dissolution)

Fe+B+additives

REE containing solution

REE separation by liquid-liquid extraction

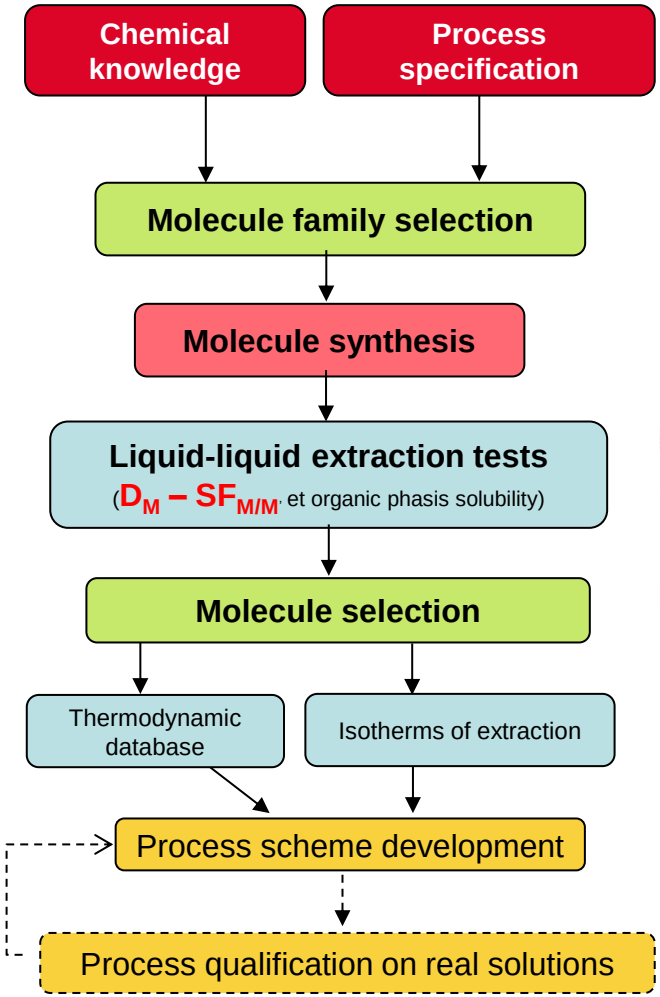
REE purification → REE conversion to metal

Richard Laucournet (CEA/DRT)

CEA Patent WO2014/06459

CEA/DEN Patent application filed 2014

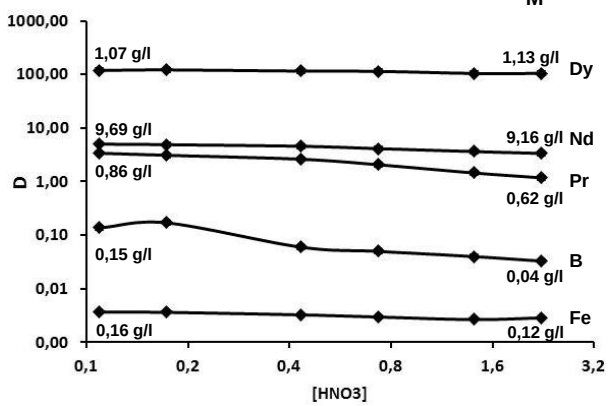
Selection and evaluation of the extractant system



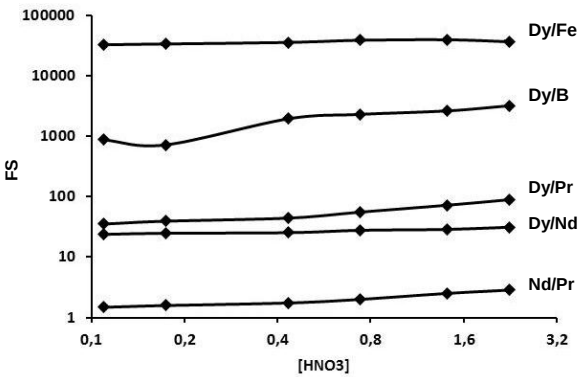
- ✓ Tests on synthetic and real dissolution solutions
- ✓ **Efficient separations** of REs / transition metals and RE / RE in a large range of acidity (0,4 to 5 M)
- ✓ **No third-phase** formation (phase modifier)

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

Distribution coefficients D_M

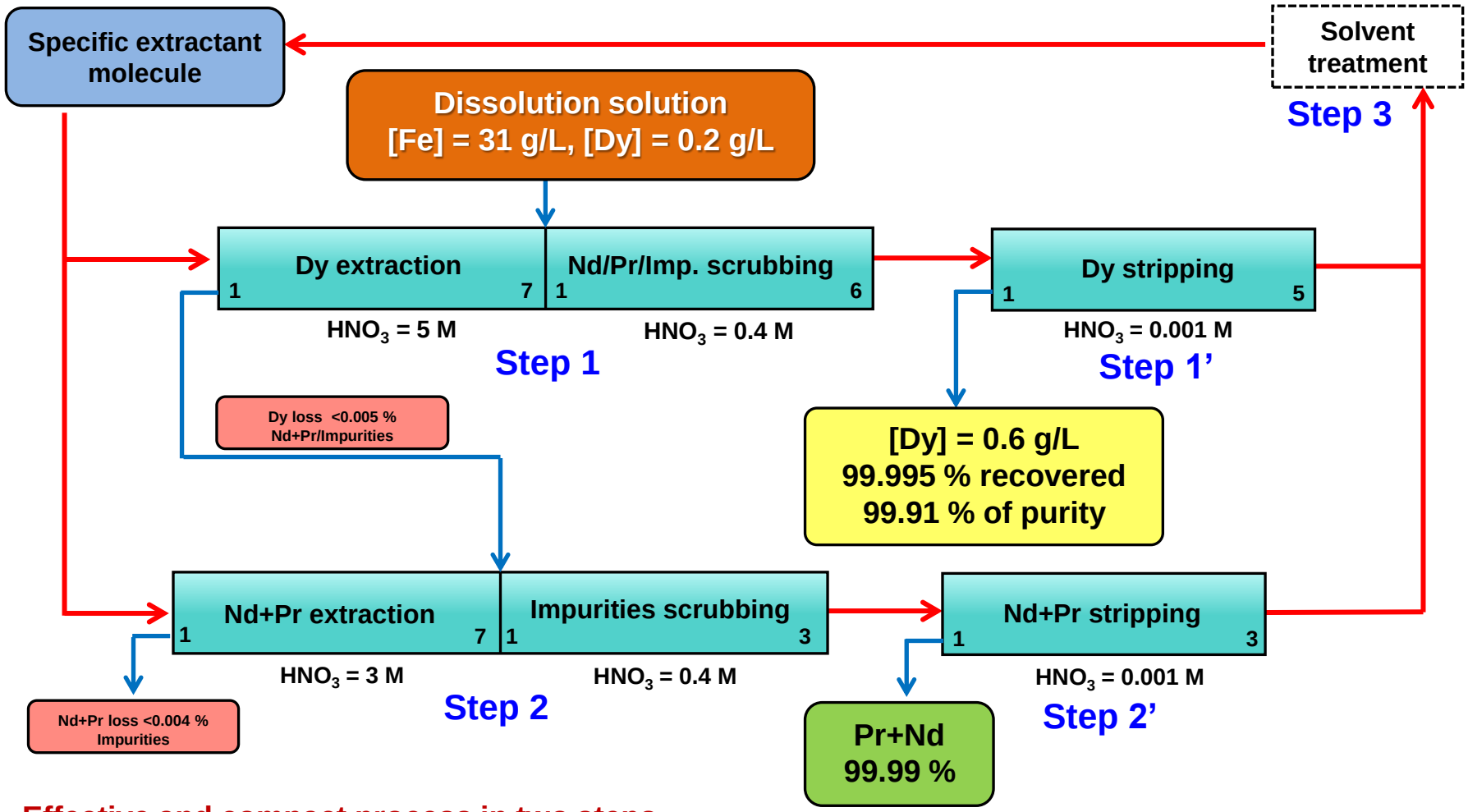


Separation factors $SF_{M/M}$



- ✓ 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

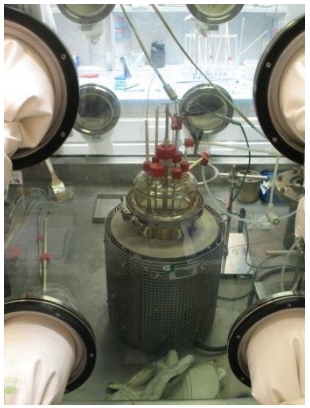
Pyrometallurgical process for metal elaboration

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

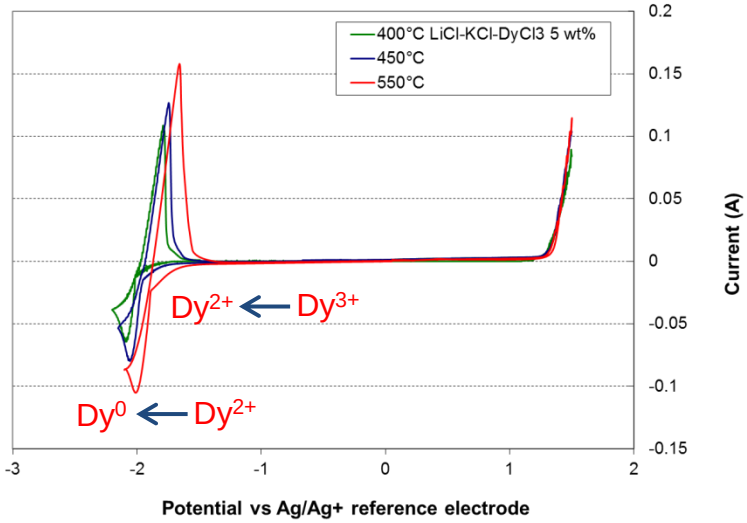
Glovebox setup



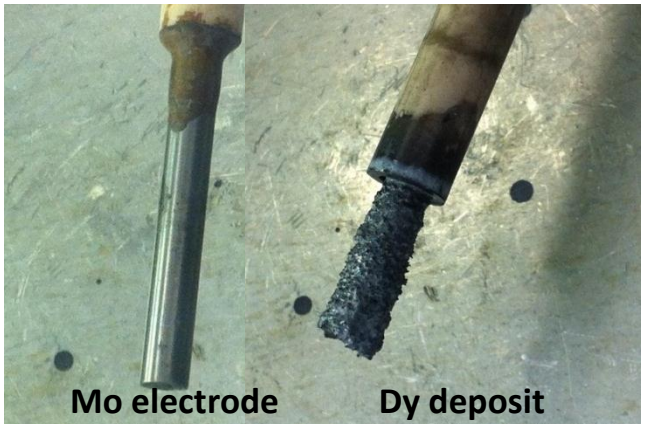
Metal deposition tests to evaluate the process efficiency:

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

Cyclic voltammetry in molten chloride salt



Metal deposition tests on the gram scale

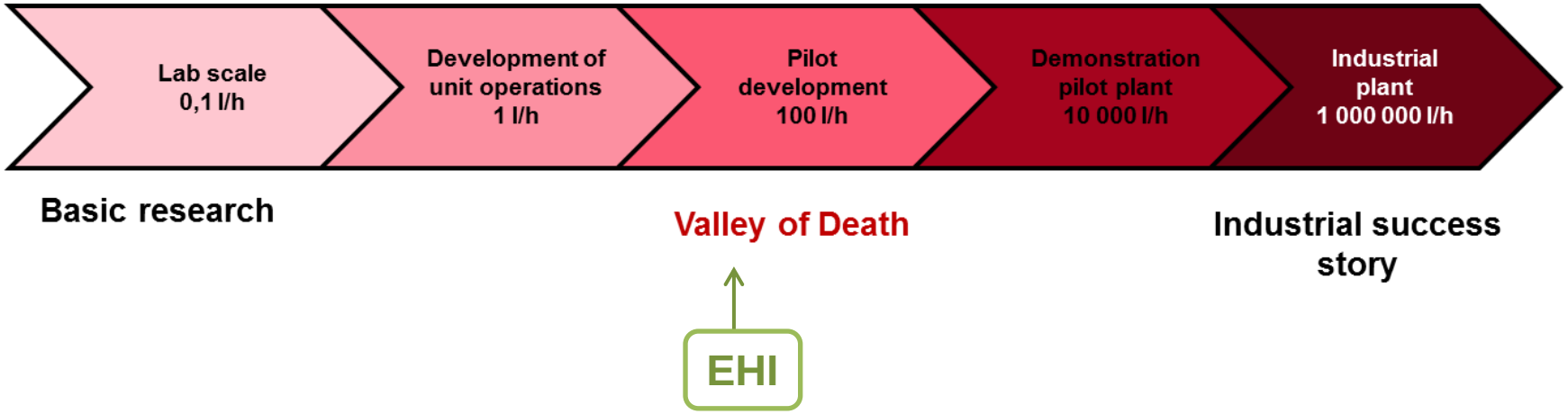


Demonstration platform
EHI
European Hydrometallurgical Institute

Why a European Hydrometallurgical Institute?

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

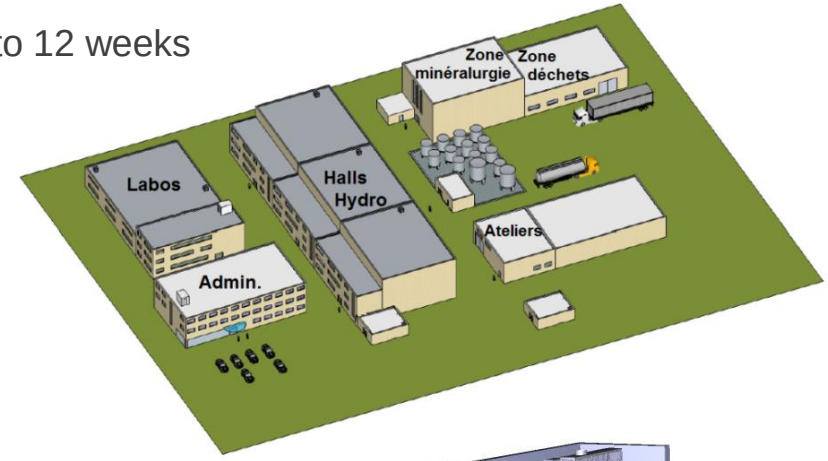
- **New mineral resources** (from mines or urban mines) are essential for **Europe's raw material supply**
  - low grade and polymetallic resources ➔ need for **new extraction processes**
  - social acceptance ➔ **eco-conception** and **sustainability** are key issues
- **Hydrometallurgy** is one tool 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

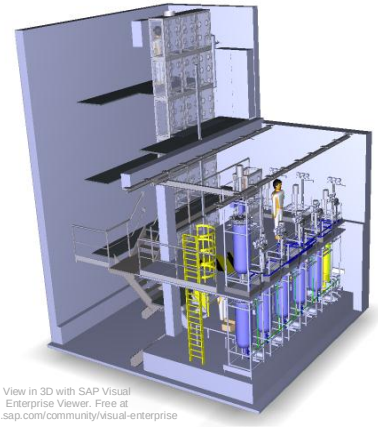


The goals of the EHI

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

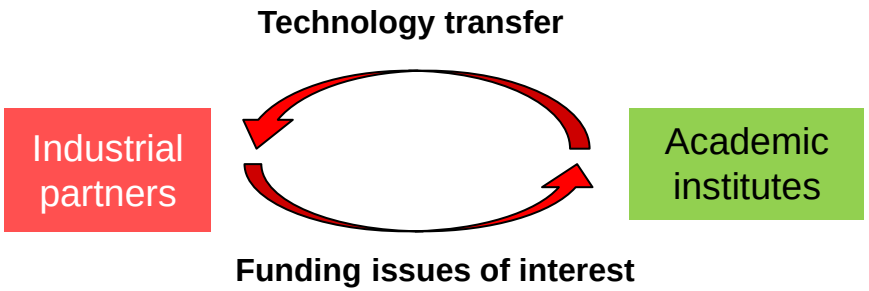
PROMETIA -
mineral processing and extractive metallurgy for mining and recycling innovation association

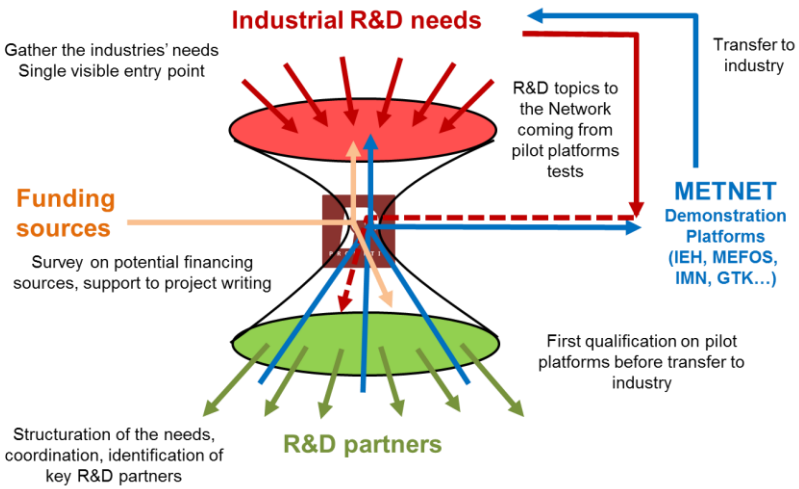
PROMETIA

The PROMETIA association

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





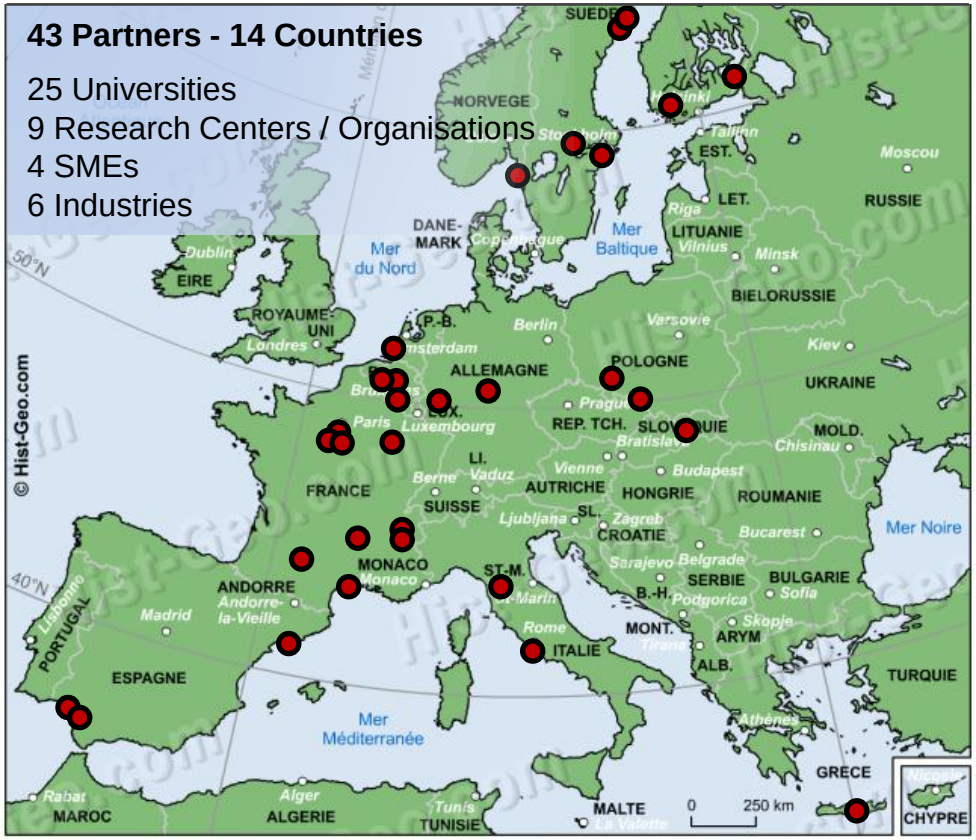
Purpose of the network

- **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**")

Members of the PROMETIA network

Open to any partners willing to join

Stephane.Bourg @ cea.fr
Christophe.Poinssot @ cea.fr



Univ Loraine (FR)	CEA (FR)
INP GRENOBLE (FR)	MEFOS (SE)
INP-TOULOUSE (FR)	GTK (FI)
ENSCP (FR)	IMN (PL)
ENSCM - ICSM (FR)	VTT (FI)
CNRS Grenoble	BRGM (FR)
TU LULEA (SE)	ENEA (IT)
TU Crete (GR)	VITO (BE)
WrocL.Univ.Tech (PL)	
CHALMERS (SE)	IDENER (SP)
POLIMI (IT)	AMPHOS 21 (SP)
TU Kosice (SK)	TASMAN (SE)
RWTH Aachen (GE)	IEH (FR)
TU DELFT (NL)	
KU Leuven (BE)	
UNI SEVILLE (SP)	AURUBIS (GE)
Univ Regensburg (GE)	BOLIDEN (SE)
Univ Cyprus (CY)	ERAMET (FR)
KIT (GE)	UMICORE (BE)
JUELICH (GE)	ELKEM (NO)
Lappeenranta UT (FI)	KGHM (PL)
Aalto University (FI)	Stenna Metal (SE)
Univ. Manchester (UK)	

Conclusions

- 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