REE4EU: Integrated High Temperature Electrolysis (HTE) and Ion Liquid Extraction (ILE) for a Strong and Independent European Rare Earth Elements Supply Chain

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REE4EU – Rare Earth Recycling for Europe

REE4EU, funded in the frame of Horizon 2020 TOPIC SPIRE-07-2015 and started in October 2015, is now focusing on the High Temperature Electrolysis (HTE) Engineering Strategy for analysis and design of the HTE reactors to be built at Elkem's (Norway) and LCM's (UK) premises.

The HTE reactor in the REE4EU project will afford the direct conversion of RE oxide mixtures, derived from a variety of RE-containing wastes, into RE alloys in a cost and environmental friendly way. This will allow a closed recycling loop of critical RE elements for permanent magnets and Ni metal hydride battery electrodes. Europe then could be fully independent of imports of the specially critical and costly dysprosium alloys used in special applications such as permanent magnets for offshore windmills.

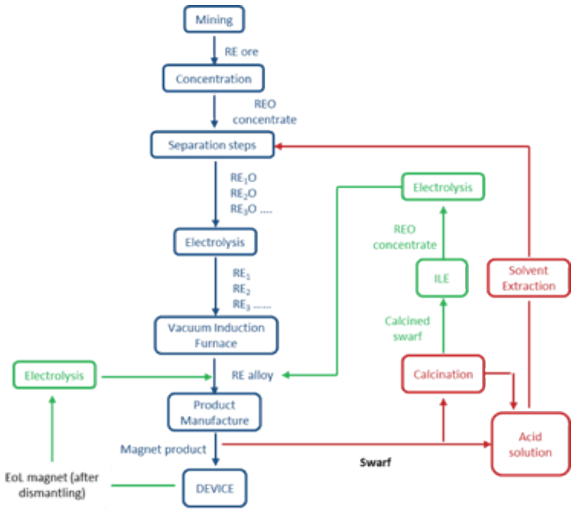
Within the first 9 months, the REE4EU partners have also implemented strategic dissemination activities, attended key EU conferences in the recycling sector, and published project updates.

The project involves in its consortium 14 partners from 7 European countries, representing the full value chain including SME and large RE metal producers, PM manufacturers, SME process engineering companies and LCA experts, large electronics and battery recycling companies (LCM, VAC, ELKEM, IDENER, A3I-INOVERTIS, SNAM, STENA), SME technology transfer, innovation specialists as well as chemical and end-user associations (PNO, CEFIC, and AVERE), together with top 4 European research institutes.

Which are the involved RTOs and Associations and what will they do?

SINTEF is the largest independent contract research organisation in Scandinavia and the 4th largest in Europe with approximately 2000 employees. It is a multidisciplinary research institute with international top-level expertise in technology, medicine and social sciences operating at the forefront of the following strategic focus areas: renewable energy, climate and environmental technology, oil and gas, ocean space technology, health and welfare, and enabling technologies.

SINTEF is the coordinator and scientific leader of the REE4EU project. Moreover, the Electrolysis and High Temperature Materials group at SINTEF Materials and Chemistry is leading the tasks dealing with extraction of Rare Earth Alloys (REA) by high temperature electrolysis (HTE) methods. The group has an extensive knowledge of electrolytic and metallurgical processes for the treatment (recycling, refining) and extraction of reactive metals (aluminum, titanium, magnesium, rare earths) and silicon. Having a wide experience in the field (more than 30 years), the group can claim an internationally leading position in the field of light metal production



REE4EU envisioned innovative value chain, including: value chain from primary raw materials, blue route. SoA recycling in-process waste via classical Hydro-metallurgical approach, red dotted route; and REE4EU Innovative process for 2 waste streams: EoL and in-process waste, green route.

methods.

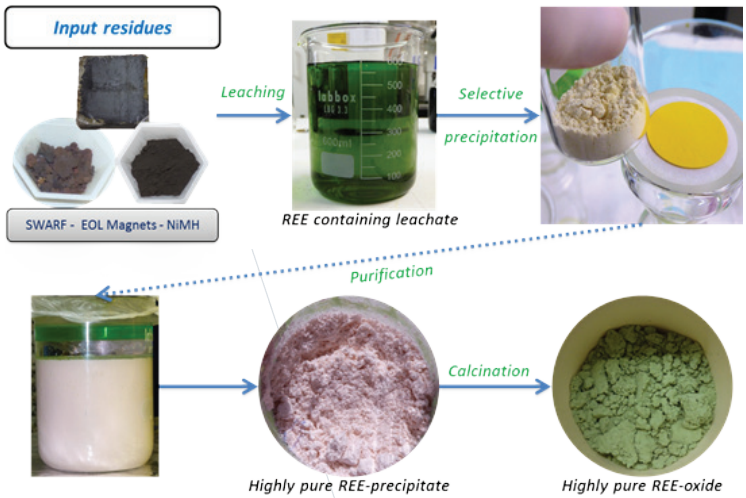
The REE4EU project takes advantage on the fact that most of the light rare earth metals (i.e., Nd, Pr, La, Ce), as well as some alloys with Fe, are currently industrially produced by HTE using rare earth oxide primary raw materials. Using different RE-containing waste streams as in-put material (including in-process and EoL wastes), the REE4EU's innovative solution will provide a way to obtain rare earth alloys with significant cost reduction and less process steps compared to SoA technologies using rare earth oxide mixtures directly in the HTE step.

In addition, SINTEF has come up with a novel approach that will allow RE alloys to be directly obtained from EoL permanent magnet waste by HTE.

Moreover, the Electrolysis and High Temperature Materials group at SINTEF has a key role in the development of the HTE industrially relevant pilots that will be up running from Q2-2017.

TECNALIA is the leading private and independent research and technology organisation in Spain and one of the largest in Europe, employing 1,400 people. The Energy and Environmental Division will be involved in the REE4EU project, with more than 250 people focusing their R&D effort on the development of technologies, products and tools for a rational and sustainable use of energy focusing on clean generation sources and future energy carriers.

TECNALIA's expertise is in the development of IL based processes for different applications, such as metal extraction from different industrial waste streams, surface treatment, coatings, and electrolytes for batteries. It has extensive capabilities of design, synthesis and characterisation of IL with tailored properties for specific applications (e.g., metal extraction, etc.). In addition, the area is growing in more IL-related research fields, such as recycling and other energy and environment related applications.



TECNALIA's role in REE4EU will include the extraction and separation of "REE" by Ionic Liquid Extraction. TECNALIA will be involved in selective precipitation of REE for added value REO mixtures which will be sent to SINTEF. TECNALIA will develop these activities at lab scale and will support pilot activities. Moreover, replication of IL extraction into NiMH batteries wastes and support of pilot activities will be carried out.

CEA is the French Alternative Energies and Atomic Energy Commission (Commissariat à l'Energie Atomique et aux Energies alternatives). As a leader in research, development and innovation, CEA is active in four main areas: low-carbon energies, defense and security, information technologies, and health technologies.

Based on the knowledge developed in metal separation by HydroMetallurgy, CEA is getting involved in projects on the extraction/separation and valorisation of critical metals. For 6 years CEA teams, located in Grenoble, have worked on recycling of the devices developed internally, such as batteries (Li-ion, NiMH,...), fuel cells, solar panels and more recently permanent magnets by setting up recovery techniques for valuable metals or materials.

In the REE4EU project, CEA will mainly work on replication of NiMH batteries. The work carried out on HM at lab scale will be up-scaled in an industrial leaching cell (5Liters). CEA will pre-treat raw materials and will work together with

IDENER (engineering) and SINTEF (HTE process). The HM process developed for PM will be adapted and tuned for spent NiMH batteries. The data will be used for the subsequent pilot design and HM pilot test on various sources of spent NiMH batteries. The work on scaling up will be done together with SNAM for piloting their HydroMetallurgical process. This includes effort on the improvement and reliability of the HM processes.

The **UPS' Laboratoire de Génie Chimique** (LGC – UMR5503) (Toulouse, France) is managed by CNRS together with Université Toulouse III Paul Sabatier (UPS), and the Institut National Polytechnique de Toulouse (INPT). The team Molten Salts and Electrochemical Processes is an expert in the field of physico-chemical properties, kinetics, thermodynamics, chemical engineering, and electrochemistry.

The group studies new electrochemical processes in molten salts (separation, oxide conversion into metal, recycling…) or ways to optimise existing processes.

In the REE4EU project, UPS will complement SINTEF expertise in the field of HTE as well as facilitate the interaction with some of the consortium partners, including CEA and SNAM. In particular, UPS will focus on HTE solutions for Spent Permanent Magnets and for other End-of-Life wastes, such as Spent NiMH Batteries, both at laboratory (mainly) and pilot scale.

CEFIC, as the voice of the European chemical industry, is a committed partner of the EU policymakers, facilitating dialogue with industry and sharing its broad-based expertise.

CEFIC represents 29,000 large, medium and small chemical companies in Europe, which directly provide 1.2 million jobs and account for 17% of world chemical production. Based in Brussels since its foundation in 1972, CEFIC interacts every day on behalf of its members with international and EU institutions, non-governmental organisations, the international media, and other stakeholders. CEFIC has been one of the main drivers and is the key facilitator of the SPIRE roadmap and association, collaborating with 7 other process industries to deliver impact on innovation for energy and resource efficiency towards a more competitive European process industry sector.

The REE4EU project will be based on recent highly promising research results to develop and validate a completely new 2-step REE recovery technology and process for both in-process and End-of-Life wastes, which is highly flexible, potentially applicable to various REE and cost effective, as such opening the route towards large volume REE recovery for various European value chains. CEFIC will support dissemination activities through Europe and beyond within the relevant Process and Chemical industries with particular attention to the EIP RM and SPIRE frameworks.

Founded in 1978, **AVERE** brings together vehicle and equipment manufacturers, electricity utilities, associations, interest groups, public bodies, research and development entities and users. AVERE is an umbrella association that groups 13 national associations and two European networks, CITELEC and Eurelectric, as well as direct members. In total, AVERE has over 1,000 direct and indirect members.

Together with EVAAP (covering Asia Pacific) and EDTA (covering the Americas), AVERE forms the World Electric Vehicle Association (WEVA). These associations organise the annual EVS, which in 2017 will be back in Europe (Stuttgart, Germany). AVERE also participates in regional events in different countries and in many specialised conferences and workshops.

AVERE's main objective is to promote the use of battery, hybrid and fuel cell electric vehicles - individually and in fleets and for priority uses – in order to achieve greener mobility for cities and countries. AVERE is also active in the field of Light Electric Vehicles (LEVs) and has a **Task Force specifically dedicated to LEVs**.

The main activities to achieve AVERE's objectives are related to dissemination, networking, monitoring, participation in European and multilateral projects, advocacy, research and development, etc. AVERE is a founding member of the **Platform for Electro-Mobility**.

AVERE has joined the REE4EU project consortium to support dissemination activities for the project throughout Europe and beyond within the relevant REE demanding electric vehicle sector. The ERECON Network, established by the European Commission, has identified 9 product groups for which recycling REE may present a significant opportunity, one of these being electric bicycles. AVERE is currently carrying out a market analysis for the REE4EU project to determine the type of REE in electric bicycles, their amount as well as the potential for collecting and recycling.

www.avere.org – averelev.wordpress.com

REE4EU Consortium

SINTEF
www.sintef.no

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For more info about project visit the REE4EU website at: www.ree4eu.eu

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