



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

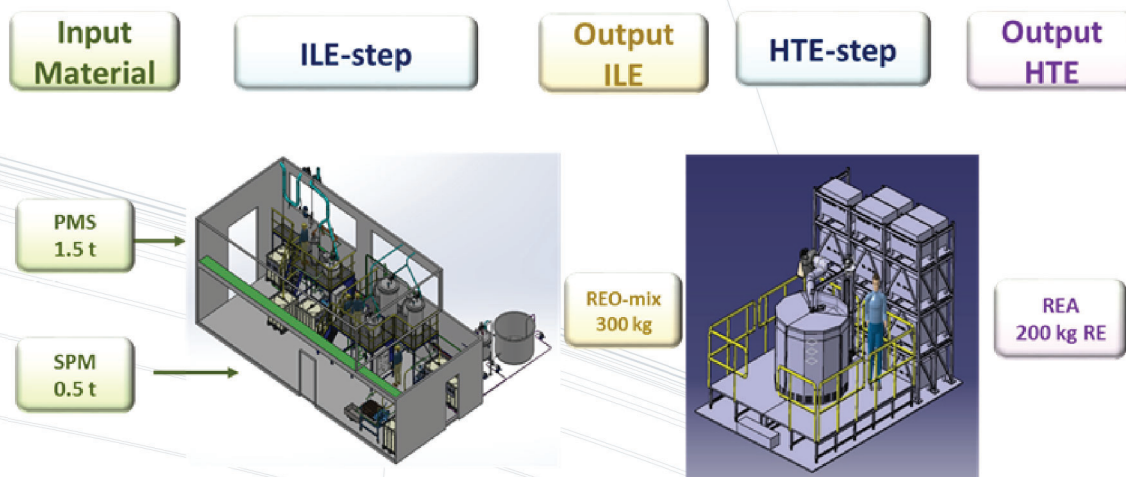
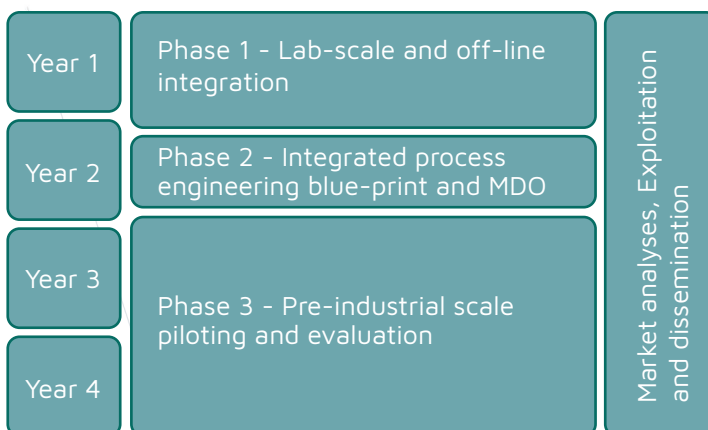


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REE4EU project's progress

During the third year of the project, the work has been focused on constructing and running the REE4EU's pilot units, i.e. high temperature electrolysis (HTE) and ionic liquid extraction (ILE) units, installed at Elkem's premises.

The REE4EU's technology has now been demonstrated at pre-industrial scale using permanent magnet (PM) wastes.



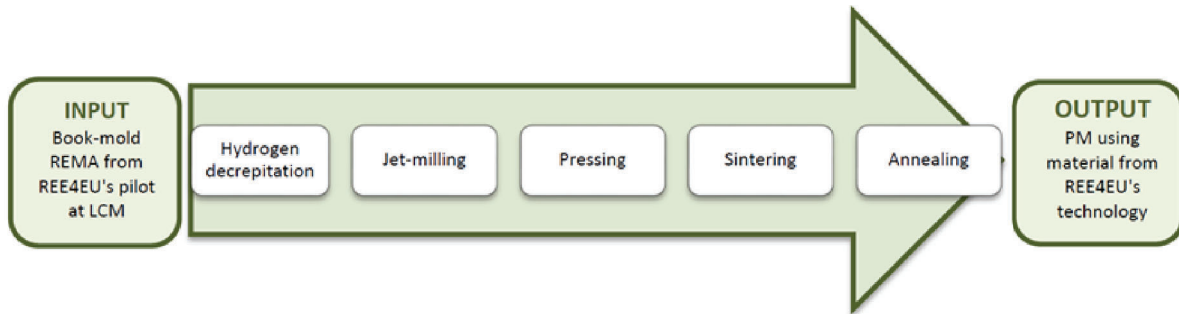
Material flow of the REE4EU main pilot

As per today, enough waste material (in-process waste and end-of-life magnets) has been treated to almost get the amount of rare earth alloy (REA) needed to run a 600 kg batch of strip cast rare earth master alloy (REMA) at the premises of the partner LCM.

In addition to technical aspects, the REE4EU project is carrying out a great number of dissemination, communication and exploitation activities.

First Batch of permanent magnets derived from the REE4EU's technology

The output material from the HTE pilot cell installed at Less Common Metal's premises, was used by Vacuumschmelze to manufacture PM in its laboratory line.



Schematics of the different steps followed in the manufacture of sintered NdFeB PM in the REE4EU project

VAC determined both the quality of both the REMA input obtained by LCM and the PM output obtained in terms of magnetic properties and chemical composition.

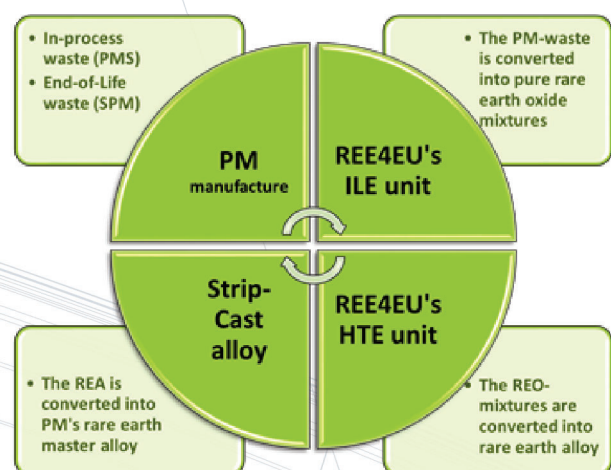
The results obtained showed that the PM prepared from the book-mould REMA processed in the HTE pilot at LCM have the same properties as magnets from mass production at VAC using virgin materials.

That means that the REE4EU technology is suited for obtaining REA for PM production using PM-waste materials.

REE4EU's Pilot for REA production using permanent magnet waste

The new pilot plant for the demonstration of the REE4EU technology was built at the premises of Elkem in Norway. It has enabled the optimisation of the two-step HTE and ILE technologies for the direct REA production, suitable for REMA to be used in PM manufacturing.

In this way, a complete closed-loop PM recycling has been demonstrated at a pre-industrial scale using less steps than conventional methods currently carried out in China.



The REE4EU's technology suitable for closed-loop permanent magnet recycling

The ILE unit was engineered by Inovertis in close collaboration with Elkem. The technology behind the extraction process was provided by TecNALIA. The excellent team-work between TecNALIA, Inovertis and Elkem made it possible to realise at pilot scale the effective conversion of PM wastes into pure RE oxalate mixtures in several steps. In the ILE unit, the end-of-life magnets can be treated as big ingots in specially designed reactors, thus avoiding the use of metallic powder material, minimising HSE risks.



Details of different steps during the operation of the REE4EU's ILE pilot unit

In the calcination unit, the pure RE oxalates obtained in the ILE step, are converted into pure RE oxide (REO) mixtures.



(A) The rotary kiln calciner, which uses (B) RE-oxalate mixtures from the ILE unit as input material, and gives (C) RE oxide mixtures as output material.

The REO mixtures obtained after the ILE unit and subsequent calcination are treated in the high temperature electrolysis (HTE) pilot unit.

The HTE pilot unit was engineered by Idener in close collaboration with Elkem and SINTEF. The technology behind the electrolysis process was provided by SINTEF. The experience in RE electrolysis shared by UPS was of great help. The outstanding team-work between SINTEF, UPS, Elkem and Idener's teams made it possible to realise and operate the HTE unit at a pre-industrial scale.

The HTE unit is one of its kind in Europe. Automatic feeding of the REO input material, as well as continuous on-line monitoring of the off-gas to avoid environmental harmful emissions, are two of its main advantages.



The HTE pilot unit in operation. SINTEF and Elkem's teams are happy about the stable and environmentally friendly HTE cell operation.

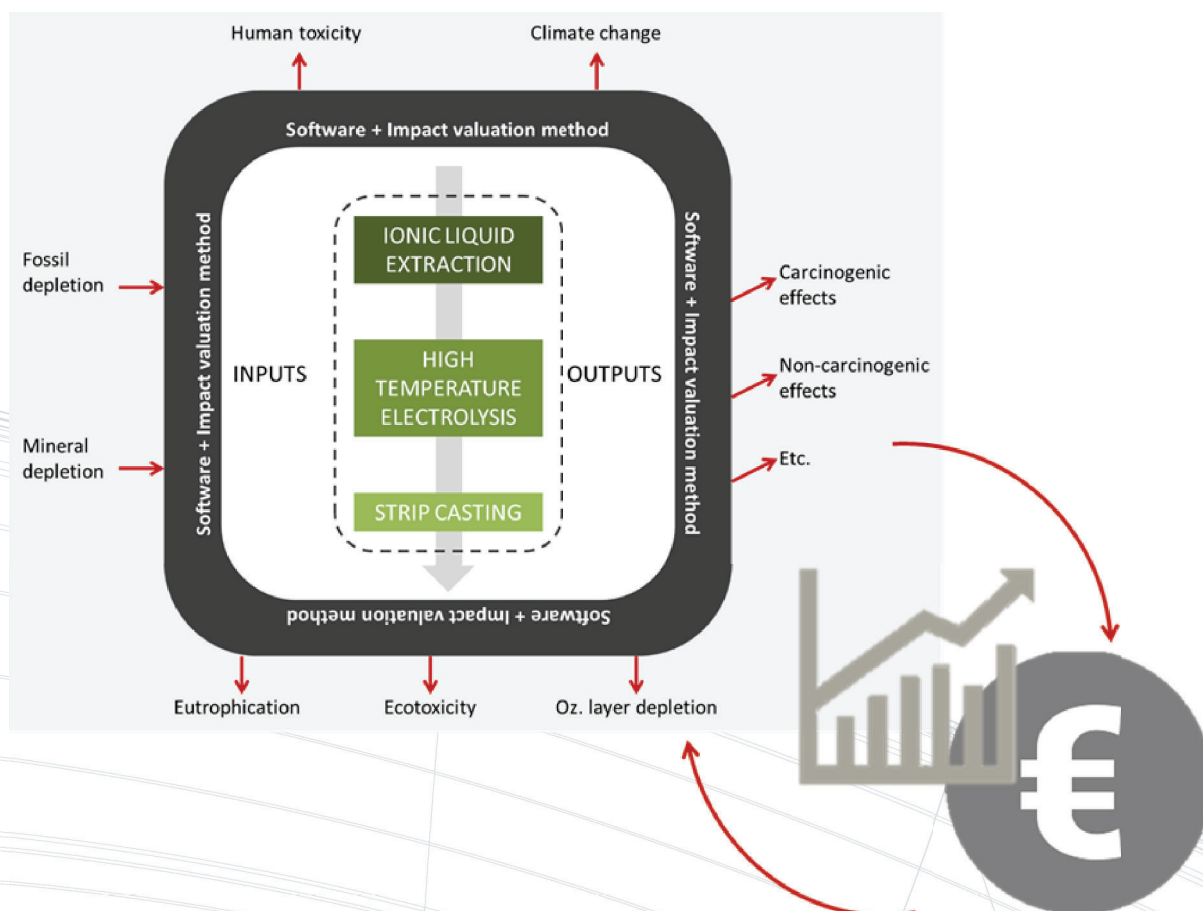
Detail of some of the ingots of REA produced

In the next months, the REA obtained in the HTE unit will be used to manufacture REMA for PM by LCM. Subsequently, VAC will use the REMA in its production line to get PM which will be benchmarked with those obtained using virgin materials.

LCA activities

Data collection and modelling activities of the PM wastes' recycling routes are being carried out by Inovertis. TecNALIA helps in the inventory of data.

First results are planned to be released during the AvniR Conference which will be held in November in Lille. These results will be used to eco-design the recycling chain and to compare it to the conventional supply route of REA currently used for PM production.



Business planning strategy

PNO has undertaken the task of setting up three business cases ("REE4EU scenarios") and create a three-fold value chain business plan. A thorough economic analysis model is in progress for the purpose of assessing the feasibility of the above-mentioned business cases. The (on-going) study will:

- integrate insights from other project activities, such as the Life Cycle Impact Assessment (ongoing) and the REE4EU Market and Stakeholder analyses (available via the link: <http://www.ree4eu.eu/public-documents/>);
- consider necessary activities upstream of the REE recovery plant, for example, the expenses associated with the pre-treatment of End of Life products (i.e. collection, dismantling and recovery of REE-rich product components);
- yield capital and operating cost estimates as well as other financial indicators that will reflect near-future required investment for industrial-scale operations;
- finally, conclude on the most critical techno-economic bottlenecks and cost risk factors, based on a rationally designed sensitivity analysis.

Dissemination activities

REE4EU is joining the most important event for the Critical Raw Material sector in Europe.

The coordinator (Ana Maria Martinez, SINTEF) presented the project and the results obtained so far at the Nature Conference "Minerals and Materials for a Sustainable Future" held September 11-13, 2018 in Trondheim (Norway) (<https://www.nature.com/natureconferences/mmsf2018/index.html>).

Moreover, the coordinator (Ana Maria Martinez, SINTEF) pitched the project to relevant industrial stakeholders in several Norwegian conferences and workshops, like: Process Industry (PROSIN) Conference, which is a process industrial arena for research-based innovation in Norway, held 13-14 August 2018 in Arendal (Norway) (<https://prosin.no/calendar/prosin-konferansen-2018/>); and the workshop arranged by the Norwegian governmental organisation "Vekst i Grenlad IKS", which aims at the industrial development of the Grenland municipality in the county of Telemark in Norway, held 13th September 2018 in Skien (Norway) (<https://www.vig.no/english>).

In the last months, the project has also been presented at NAMEC Workshop in Brussels (Belgium), at the SCREEN Clustering event in Rome (Italy) and at the 31st International Electric Vehicle Symposium in Kobe (Japan) among other conferences and international events.

NAMEC (www.namec-cluster.org) is an overarching cluster set up by the European Commission in order to bring together EU funded R&I projects focused on advanced materials and nanotechnologies for renewable energy, energy storage and energy efficiency technologies. The EMIRI Tech Talk & NAMEC workshop on advanced materials and nanotechnologies for wind energy, organised by EMIRI and NAMEC, with the support of the European Commission, was held on June 29, 2018 in Brussels. The workshop was an opportunity to meet other coordinators of EU projects and other organisations interested in materials for the wind energy sector. PNO presented the REE4EU project and discussed a potential collaboration with some organisations on the valorisation of their in-process waste containing REE in the REE4EU pilot. The agenda of the workshop can be found here.

On 11 July 2018, 8 project coordinators (CRM Recovery, SCALE, PC-REC, REE4EU, CHROMIC, NOI EXTREME, SusCritMat, COLLECTORS) and EIT Raw Materials presented their activities on CRM in the context of Circular Economy. The event organised under the umbrella of SCREEN's clustering work-package allowed project coordinators to exchange project activities, objectives and challenges.

On the last 3rd October, the REE4EU project has also been presented in the 31st International Electric Vehicle Symposium in Kobe (Japan) with a poster by the partner AVERE and the next 7th November 2018, Inovertis is going to present the first results of the Life Cycle Assessment and of the Socio-Economic Analysis during the Avnir congress in Lille (France). Let attend the presentation in the session B "RECYCLING: a driving element to limit environmental impacts in Life Cycle Assessment?"



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



REE4EU is a project funded by the European Commission

This project has received funding from the European Union's Horizon 2020 Research and Innovation program under Grant Agreement n° 680507