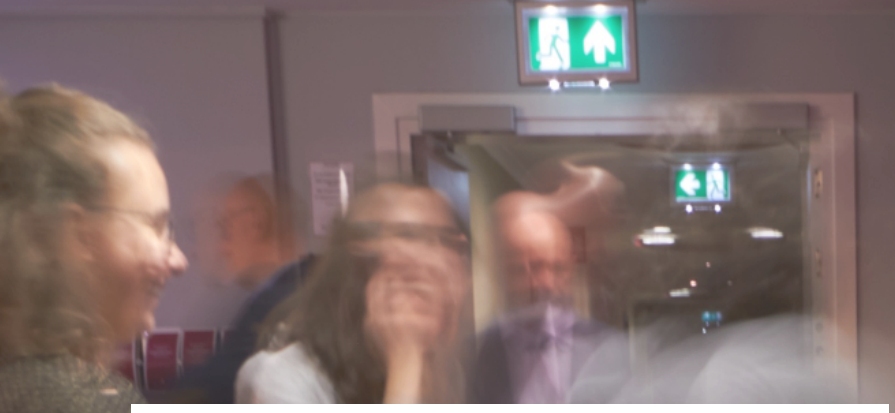

Brussels, 15 November 2022

SecREEts
Final Conference

SecREEts

Secure European Critical Rare Earth Elements

This project has received funding from the European Union's horizon 2020 Research and Innovation Programme under Grant Agreement No 776559

Brussels, 15 November 2022

Prospex Institute
Francesca Ferrara, Miro Prek

About SecREEts

Started in 2018, the SecREEts project, funded by the European Commission research and innovation programme Horizon 2020 (GA 776559), aims at establishing a secure and stable supply of Rare Earth Elements (REEs) in Europe, using sustainable extraction methods from European apatite sources used in the production of NPK fertiliser.

With the main objective of creating a new integrated European value chain for extraction, refining and production of REEs, for the past four years SecREEts partners have worked towards the development of pilot processes for a sustainable extraction, separation and manufacturing of REEs to create permanent magnets for application to areas such as electric vehicles, industrial motors, wind turbines, with replication potential in consumer products or medical equipment.

SecREEts partners are:
SINTEF AS – Norway – Coordinator
Yara International ASA – Norway – Industrial pilot
REEtec AS – Norway – Industrial Pilot
Less Common Metals Ltd – UK – Industrial Pilot
Vacuumschmelze GMBH & Co KG- Germany
Quantis – Switzerland
Institut National de l'Environnement et des Risques INERIS – France
Prospex Institute vzw – Belgium

Please find all relevant information and latest updates on the project website:
www.secreets.eu

Abbreviations

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A: Answer
CRM: Critical Raw Material
EU: European Union
EoL: End of Life
ESG: Environmental, social, and governance
LCA: Life Cycle Assessment
JRC: Joint Research Centre
PM: Permanent Magnet
Q: Question
R&I: Research and innovation
REE: Rare Earth Element
RM: Raw Material
SINTEF: research and Innovation organisation

Executive Summary

SecREEts final conference was organised on 15th November in the morning as a satellite event of the European Raw Materials week. The event was organised in a hybrid format and took place at the NH Collection Brussels Centre with possibility of joining online via ZOOM.

During the first part of the conference representatives from project partners presented achievement of objectives of the project and shared lessons learnt. In the second part, SecREEts invited other European projects focusing on REEs to discuss the place of a European rare earth value chain and associated challenges. While the first part was organised in a form of successive presentations of work of the project partners in their respective work packages, the second part was organised in the form of a panel discussion where the panellists engaged in brief presentations of their current work and engaged in the discussion with the audience in the room as well as on-line.

The presentations of the project development and results by work packages showed the attainment of the project objective. The European value chain in REE is demonstrated, as underlined by the project leader, Dr. Arne Petter Ratvik. This value chain and its output cannot provide for the needs of the industry, however the technological knowledge and know-how are now developed and can be used. The presentations of individual work packages showed the challenges in the life cycle of the project and how these were successfully overcome: every workpackage without exception found itself facing a problem that needed an innovative solution to deal with the problem identified.

The presentations and the ensuing discussion in the Q&A session showed vivid interest and active involvement of participants, who contributed their vision of certain specific aspects of the REE value chain or are related to it (mostly in the area of magnets). Amongst the challenges mentioned in the discussion was the existence of technical barriers, mainly related to the difficulties in identifying and sorting EoL products containing REE, impeding correct processing and recycling operations. A further interesting point was the consensus among the speakers regarding the need of a unified approach and standardization and the importance of diversification as well as for design for recycling.

The conference ended on a very positive note as the project objectives of SecREEts are achieved, acknowledging at the same time the importance of events such as the SecREEts final conference, which bring experts together allowing discussion on needs and actions to be taken.

Session I – SecREEts updates and lessons learnt

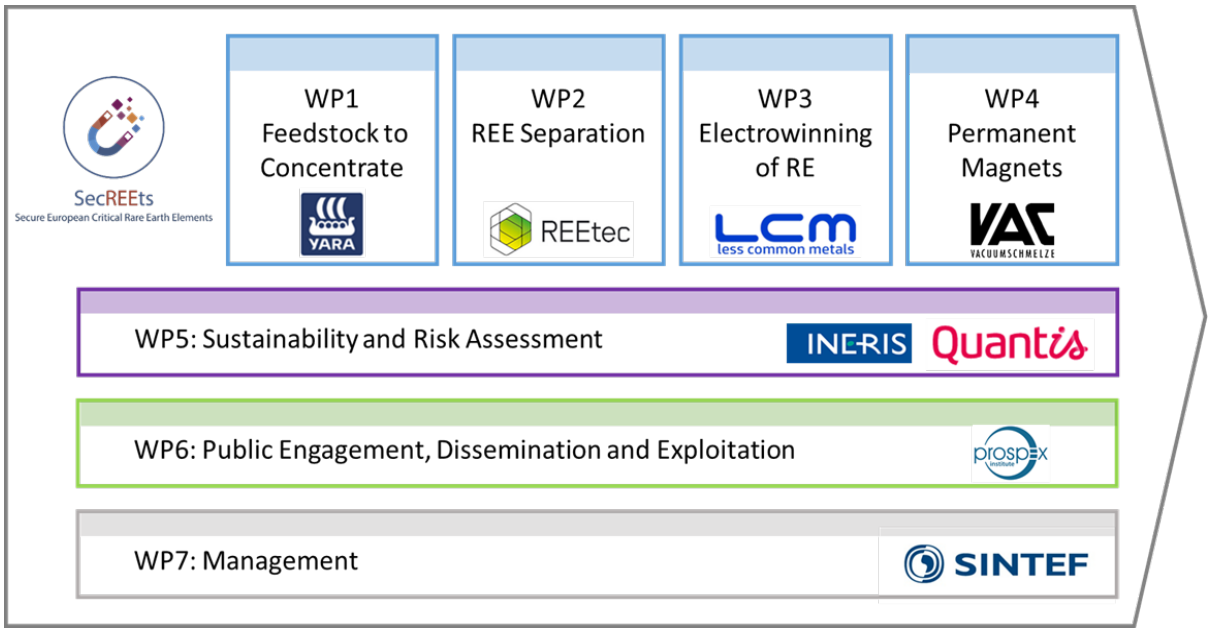
1.1 Outcomes of SecREEts - Arne Petter Ratvik

The first session of SecREEts final conference focused on the overview of the SecREEts project. The session was opened by a keynote speech by SecREEts Project Leader Dr. Arne Petter Ratvik, Senior Scientist at SINTEF, who gave an overview of what happened over the past 4 years and the contribution of the different partners. HIs presentation highlighted the contribution of the SecREEts project in the field of REE to the development of a European REE value chain.

Dr. Arne Petter Ratvik, Senior Scientist at SINTEF and SecREEts Project Leader

The session then continued with presentations by the different project partners on their achievements and lessons learnt during the past 4 years.

The presentations by the different SecREEts partners can be found in Annex. Below an overview of the SecREEts value chain and roles of consortium partners:



Session II – EU projects in discussion

The second session of the conference saw a roundtable discussion with other EU funded projects and initiatives on the place of a European REE value chain as well as associated projects.

Following projects were represented:

- H2020 SUSMAGPRO,
- H2020 PASSENGER,
- Horizon Europe REEPRODUCE,
- Horizon Europe REEsilience
- EIT-funded project INSPIRES

What follows are some questions for the panellists that illustrate the nature of the discussion.

2.1 Nader Akil – Business Operations Manager PNO - REEproduce project

Q. We know there was a previous project to recover REE from RE-containing waste streams, Ree4eu. Could you tell us what this new project has to offer more?

A: REEproduce is based on a previous project, REE4EU, which demonstrated the production of significant quantities of REE. In that project we used permanent magnets dismantled by hand from wind turbine generators and processed about 1 ton and produced around 200 kg of REE metal alloys. We had calculated the environmental impact, but also economic assessment, which looked very positive compared to prices of China.

With REEproduce we wanted to go then one step further, as many companies were approaching us telling they had big amount of waste but did not know what to do with it. Based on this demand we realised that there was a need to expand the value chain and focus more on dismantling the REE elements from different kinds of waste.

The innovation in REEproduce will be to make automated sorting of the waste and automated dismantling in the waste processing line.

Q; How do you see SecREEts feeding into your project?

We are all having same issues - cost is really the key issue, it is nice to have environmental friendly processes, but the first question is what are the costs of the material that you are producing, and this is the real barrier for moving forward for the value chain in EU: maybe something could be done for the technical and innovation side to lower the costs, but we should have thorough discussions with the legislatiors, with coordinating the funds. Investors ready to invest in this market need to be able understand the risks they are taking and what are the mechanism that can support him.

2.2 Spomenka Kobe - Scientific Advisor at Jožef Stefan Institute - EIT project INSPIRES

Q: How ambitious are you with your project? How successful are you so far? What is missing?

INSPIRES is financed by EIT Raw Materials. We are now 2 years in and as everybody else influenced by COVID-19. The project is very ambitious: it starts with collecting the EoL magnets from waste which was not tackled so far: domestic appliances – everything we use on a daily basis. The main point of the project is that it is regional innovations in Slovenia. We grouped 5 factories, it starts with the producers of domestic appliances – and then 2 more Slovenian companies focused on waste collection, but who did not work with magnets until now. At the end we have producer of final motors, so it is a closed circle.

What is challenging is that so far, we were not used to so many different sources of EoL magnets. Even for the same applications there are different qualities of magnets. We have to deal with the composition, the different coatings. We have obstacles, but we are successfully dealing with them.

2.3 Carlo Burkhard - Coordinator of Horizon 2020 SUSMAGPRO and Horizon Europe REEsilience

Q: How do you see the role of SecREEts and how is it fitting into your project, especially if there is a potential of ramping up sufficient qualities of the materials that will be needed at later stages?

A: In Susmagpro, we are looking into the whole manufacturing chain of recycling, extracting magnets from different components, optimization of recycling process itself. Here the links to SecREEts are limited, this are two different supplies of material to make sustainable magnets in EU. Here the projects go in parallel.

The REEsilience project is working on building a sustainable and resilient supply chain for REE magnet production in EU. The recycled material is in no way enough to meet the growing demand. If we really want to gain some independence from China, we have to look at other supply chains. The idea of REEsilience is to look into virgin and secondary material and into a mix of these. Here SecREEts' material could play a vital role, we have to clarify what are the planned streams of these materials. What we are doing is to validate all the available "non-Chinese" sources, on the ESG criteria to see what is the best available sustainable material at a given time. The hope is to come up with something that is comparable and also accepted by industries. In REEsilience, we are also aiming at building a fully traceable supply chain.

2.4 Irina Sokolova - ICAMCy - PASSENGER project

Q: How ambitious are you with your project? How successful are you so far? What is missing?

A: The background of project is based on the fact that there is currently a serious supply risk, and this especially concerns the permanent magnet production, as it is integral part of these. In our belief, there are there are two ways to compensate this criticality: 1) diversification 2) substitution.

Passenger aims for substitution in order to demonstrate an innovative and new improved quality of magnets with usage of raw materials that are widely available in EU. Presently we have very good results.

About the risks that we tackle in PASSENGER, we need to be careful when speaking about RM that are not in the CRM list. Manganese is in our belief high risk to be in CRM list due to the Russian invasion of Ukraine, as Ukraine has very large RM resources, including manganese. In this regard we need to consider diversification and put in the arena additional exploration efforts and identification of RE new deposits in the EU, but not only.

In the framework of PASSENGER, we are creating a link with sister projects, including SecREEts, and this cooperation will be based on the principle of clustering.

2.5 Ester Palmero – IMDEA Nanoscience - PASSENGER project

Q: What can we expect from innovation in the existing or in new materials to contribute to solve the critical dependency on strategic raw materials?

The criticality of these elements can be solved by diversification of the use of the different materials and also by considering substitution.

About RE-free permanent magnets – there are two ways: we can consider to improve the PM properties of the materials that we already know (e.g. ferrites) and also to work on different RE-free alternatives that are neo-alloys, as manganese-aluminium alloys. It is also possible not only the diversification in materials we can use, but also to work in the design of the different devices to be able to use these RE-free PM materials.

Considering PASSENGER, we are working on using RE-free PMs. It is a challenging project but based on very strong pillars. The preparation and processing of these materials has been already demonstrated at the lab scale. Now we are in the process of scaling-up to be able to fill the value chain going from the preparation of the different materials, the processing and the fabrication of different magnets and implementation and integration in different devices such as in the electromobility sector and water pumps.

Session III – Q&A

Q: Do we have a mapping of Europe to show the different areas where RE are, so it is easy to know the real amount of RE that is available, in terms of deposits, in different locations – establish potential there actually is?

Carlo Burkhard: In REEsilience we have a WP on mapping of resources – but there are so many activities happening that the map has to be re-drawn constantly, but REIA has a good overview of the different activities that are happening.

Q: I understand that when the magnets reach EoL there are difficulties in recycling. If Europe needs to start making new magnets, are there any activities aiming at standardizing in order to make the processing easier when they reach EoL?

Spomenka Kobe: The producers of magnets should label them for easier recycling, which is possible and could be done. The problem is that often the producers of magnets do not disclose information about the composition of the magnets, as this is sensitive information. The composition of coatings can also become an issue as some coatings go easily away and others do not, and in this case, it is not possible to mix them.

Carlo Burkhard: One key in design for recycling is labelling of at least the components.

Mattias Katter: Marking and signing magnets according to the composition in principle is possible, but if you are the only one doing it you have all the costs. It makes only sense if the labelling can be used for separation. There has to be an international commitment and every magnet producer has to make this standardized labelling. But at the end, the best recycling for the high-end products is always going down to the elements and make new alloys.

Conclusions

Arne Petter Ratvik from SINTEF, and project coordinator of the SecREEts project, wrapped up conference by thanking all project partners, panellists and participants for attending and for their valuable contribution to the discussion.

The SecREEts final conference brought together a broad range of stakeholders and high-level key speakers, enabling an important dialogue on the future of a REE value chain in Europe.

SecREEts

Secure European Critical Rare Earth Elements

SecREEts Final Conference
15 November 2022 - Brussels

Francesca Ferrara, Amand Puerari, Miro Prek (Prospex Institute)

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 776559

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Secure European Critical Rare Earth Elements

Welcome
Some housekeeping rules

Miro Prek, Prospex Institue

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 776559

Agenda

- **8.30 - Registration & Breakfast**
- **9.00 - Welcome & Introduction**
- **Session I: Establishing a European Rare Earth value chain: lessons learnt from H2020 SecREEts**
  - Opening by **Dr. Arne Petter Ratvik**, Senior Scientist at SINTEF and SecREEts Project Leader
  - Presentations by pilot partners.
- **10.30 – Coffee Break**
- **Session II: EU projects in discussion: the place of a European RE value chain**
  - Prof. Dr, Carlo Burkhardt – H2020 SUSMAGPRO project, Horizon Europe project REEsilience
  - Prof. Kobe Spomenka - EIT project INSPIRES
  - Irina Sokolova - H2020 project PASSENGER
  - Ester Palmero – H2020 project PASSENGER
  - Nader Akil - Horizon Europe project REEPRODUCE
- **12:30 - End & Light Lunch**

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SecREEts

Secure European Critical Rare Earth Elements

SecREEts Final Conference

Establishing a European RE Supply

Dr. Arne P Ratvik, SINTEF

Contact: arne.p.ratvik@sintef.no

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 776559

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Short Overview of SecREEts project

SecREEts

- What is SecREEts
- Why consider a value chain for extraction of rare earth elements in EU
- The SecREEts integrated process line – Achievements
- Innovations

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SecREEts - Recap

SecREEts

- Establish technologies for a **European supply** of critical Rare Earth Elements (REEs)
- Innovative pilot processes in an integrated value chain
  - Main focus on rare earth elements for permanent magnets (Pr, Nd and Dy)

SecREEts pilot processes cover the hole value chain from raw materials to finished magnets

- **Extraction** of rare earth concentrate
- **Separation** into individual rare earth oxides (RE_2O_3)
- **Metal production** by electrowinning and processing to powders for magnet production
- **Verification** of magnet capabilities
- Sustainability and risk assessment
- Public engagement and dissemination

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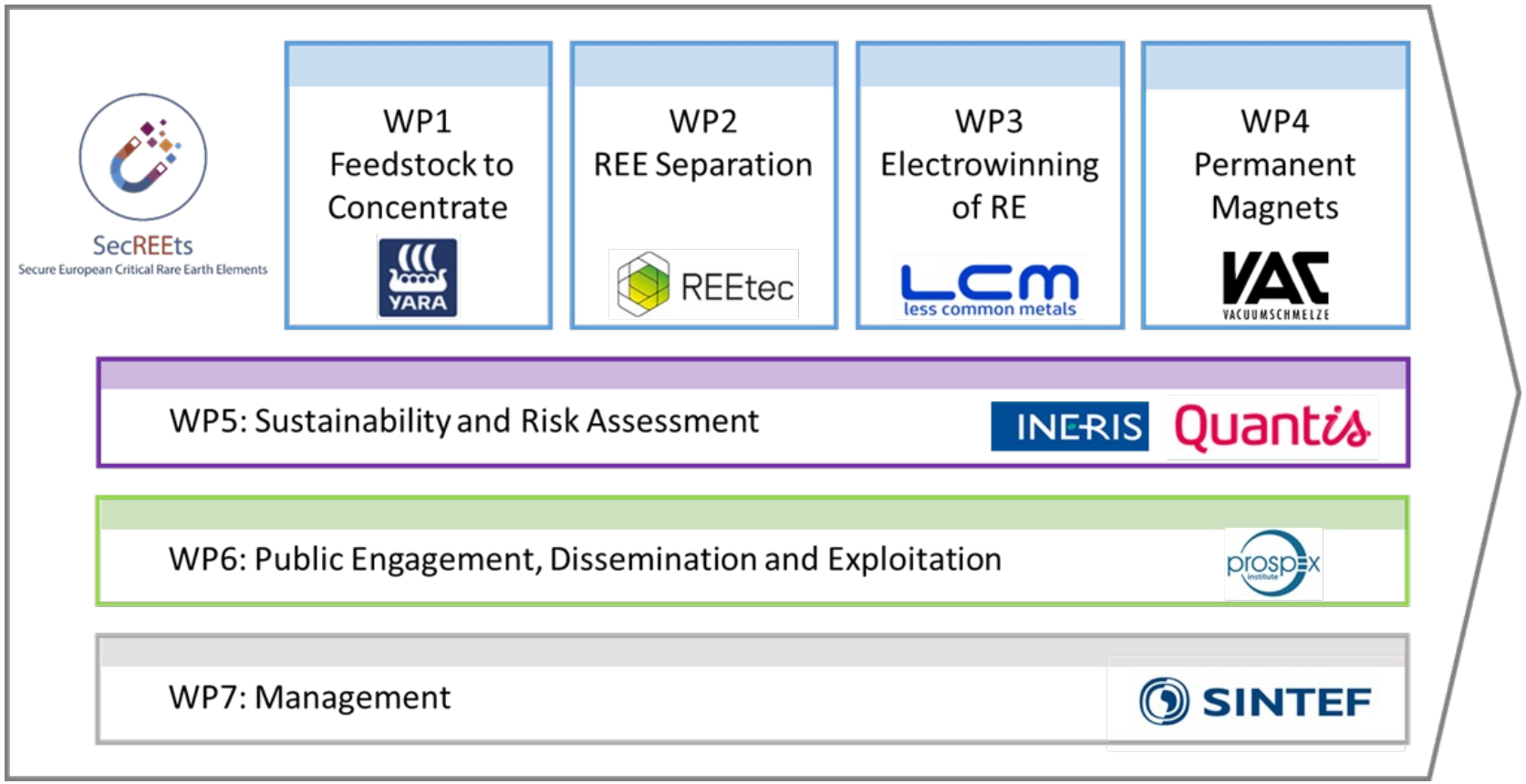
SecREEts – An Excellent Consortium

SecREEts



Eight Partners
Coordinated by SINTEF
(Dr. Arne Petter Ratvik)

Duration: 4.5 years
(started June 2018)

EU Contribution:
€ 12,880,031

www.secreets.eu

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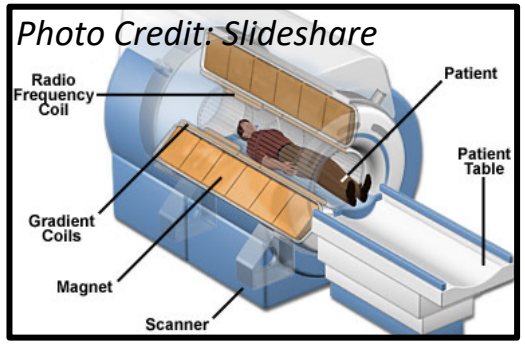
Rare Earth Magnets – Why Important?

SecREEts

- Big Motors/Generators – Wind turbines, Ship and Train, Paper machines, Elevators
- Automotive - Hybrid/E-drive motors, Solenoids/Valves, Sensors (ESP), Power steering, Electrical auxiliary motors (water pump, van, fuel pump, etc)
- Industrial Motors/Generators – Servo drives/Torque motors, Linear drives, Micro motors
- Medical and Science – Magnetic resonance imaging (MRI), Special motors (dental, surgery, …), Nuclear magnetic resonance (NMR), Mass spectrometers, Precision balances


Pfleiderer Wind Energy


Photo: Volkswagen



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Rare Earth Elements

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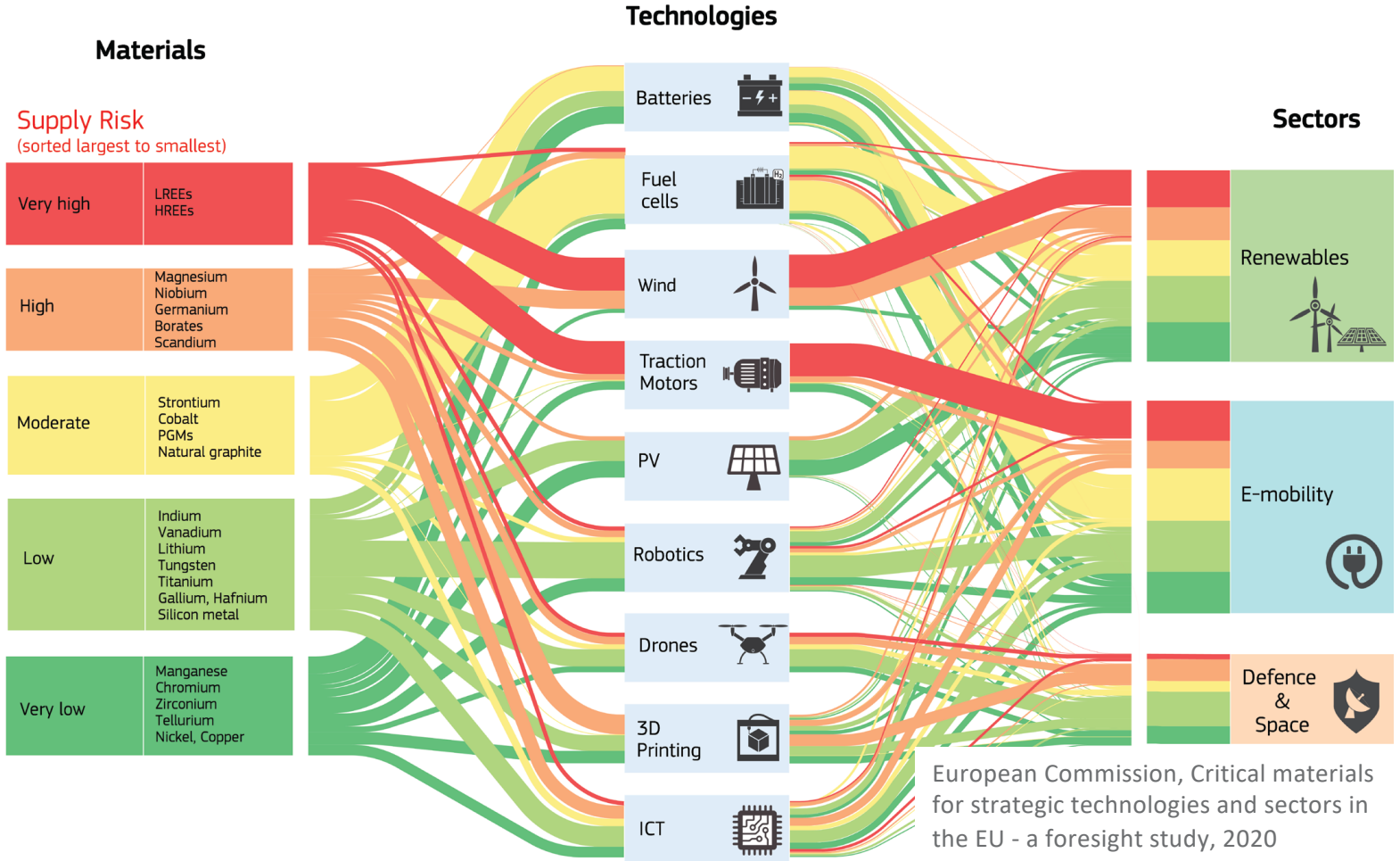
- Very important due to its strong magnetic properties and, hence, smaller magnet size
- Crucial for European hi-tech industries
- Very high supply risk as EU is 100 % dependent on import
- China dominates the global production and the whole magnet value chain



European Commission, Critical materials for strategic technologies and sectors in the EU - a foresight study, 2020

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Global Rare Earth Situation

SecREEts

- China is the largest producer of refined rare earth elements
  - China dominates the global supply of rare-earth products (about 85 % in 2020)
  - China accounts for close to 60 % of the global mining
- Extraction is increasing outside China
  - Many global activities to reduce the dependence on China
  - US Department of Defense has awarded Lynas US$ 120 million funding for a heavy rare earth facility and US$ 30 million funding for a light rare earth facility in US
- Europe is still 100 % dependent on import, mostly from China

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SecREEts Pilots – Developed for Industrial Scaleup

SecREEts

- Yara pilot – Extraction of Concentrate
  - Pilot installed in fertiliser plant
  - Optimised processes and delivered 24 IBCs to REEtec
- REEtec pilot – Separation of REE
  - Developed state of the art separation technology
  - Focus on NdPr, Dy and Tb oxides for high quality magnet production
- LCM pilot – RE Electrowinning and Magnet Alloys
  - State of the art electrolysis technology
  - Strip casting alloys and hydrogen decrepitation to produce magnet powders

Yara Extraction Pilot

LCM Electrowinning Pilot

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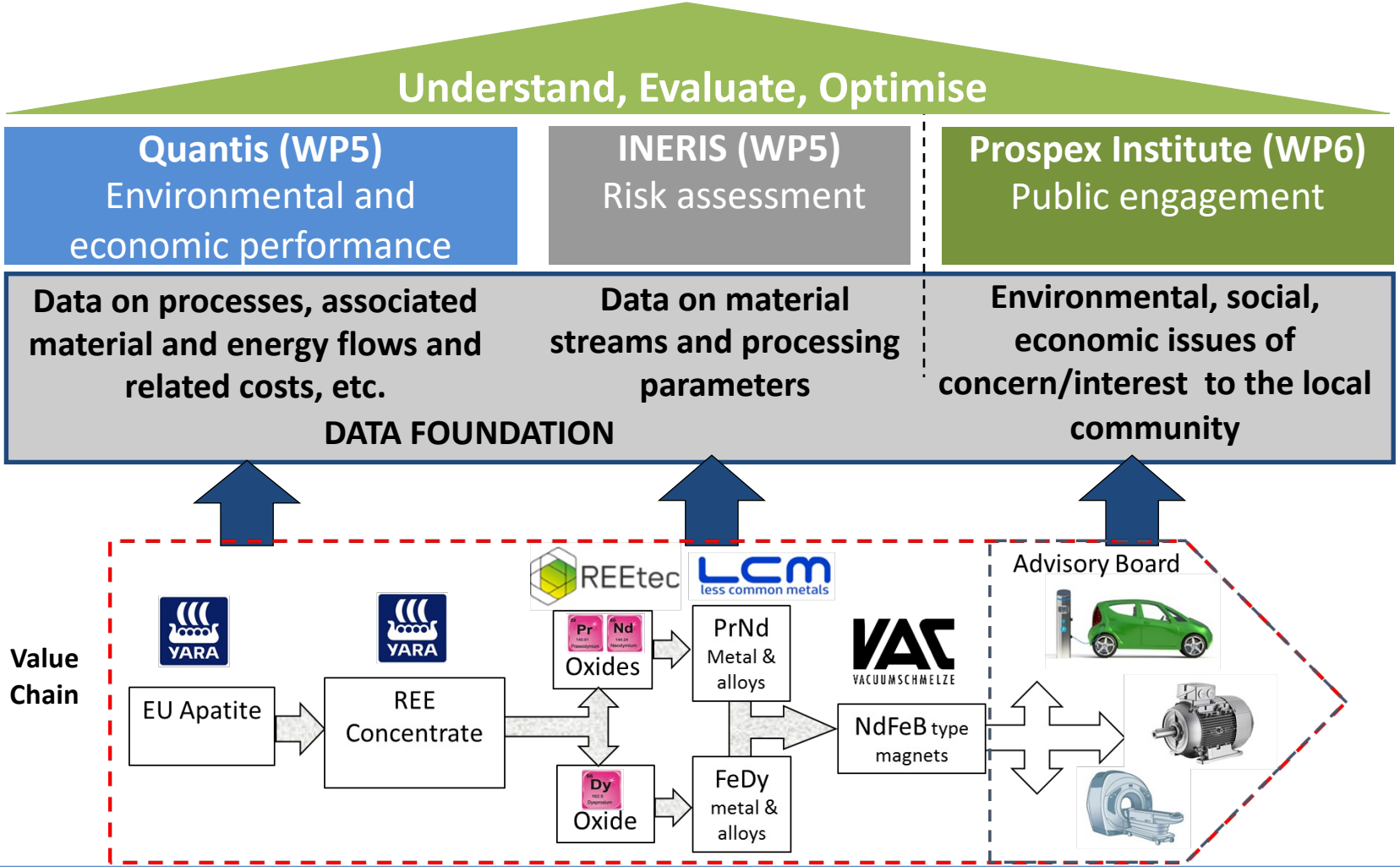
Sustainability, Risk, and Public Engagement

SecREEts



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Life Cycle Analysis results

- Boundaries: cradle-to-gate, from extraction to permanent magnet production
- Baseline system

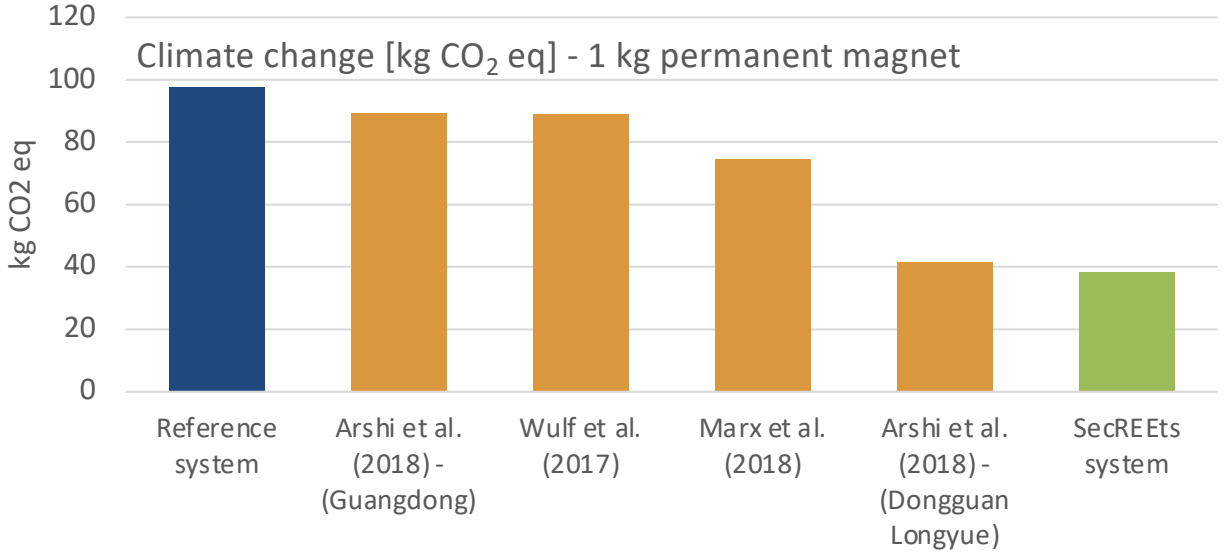
Medium data quality

  - Current practices in China
  - Tailings and wastewater excluded
  - Data available from literature only

- SecREEts system

Good data quality

  - European innovative supply chain
  - One main production pathway
  - Primary data available from SecREEt's partners



The SecREEts value chain has **low environmental impact**

Main contributor in **SecREEts system** is the permanent magnet step

Main contributor for **reference system** is REO extraction & separation

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Technological Risk Assessment (INERIS)

SecREEts

- RE extraction from the SecREEts value chain gives several advantages in terms of safety and environmental impacts
  - process integration with fertiliser plant removes dedicated steps for mineral processing in the REE production
  - benefits derived from grafting the process in a fertiliser plant with existing solid safety safeguards and environmental protection while offering other technical services
  - well known substances/processes employed in the SecREEts project
  - no barriers in terms of safety and environmental regulations as they are well defined

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Public Engagement, Dissemination and Exploitation (Prospex Institute)

SecREEts

- Engaged local communities at the main industrial sites (Citizen Labs)
- Mapping stakeholder groups including local authorities, businesses, media, politicians, consumer groups, associations, youth groups…
- Engaged with relevant organisations and projects in yearly Policy Councils
- Introduced SecREEts and discussed RE-related challenges – e.g. RE market, competition, social sustainability…

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SecREEts - Overall Achievements

SecREEts

- Pilot to extract rare earth concentrate verified
- Separation processes for production of high purity Nd/Pr (and other rare earth) oxides successfully developed
  - First industrial plant in progress
- State of the art electrowinning of NdPr and DyFe alloys successfully developed meeting European standards for safety and environmental regulations
  - Modular design
- Quality of products verified by magnet producer
- Proven sustainability and risk assessments
- Successful outreach at all pilot sites

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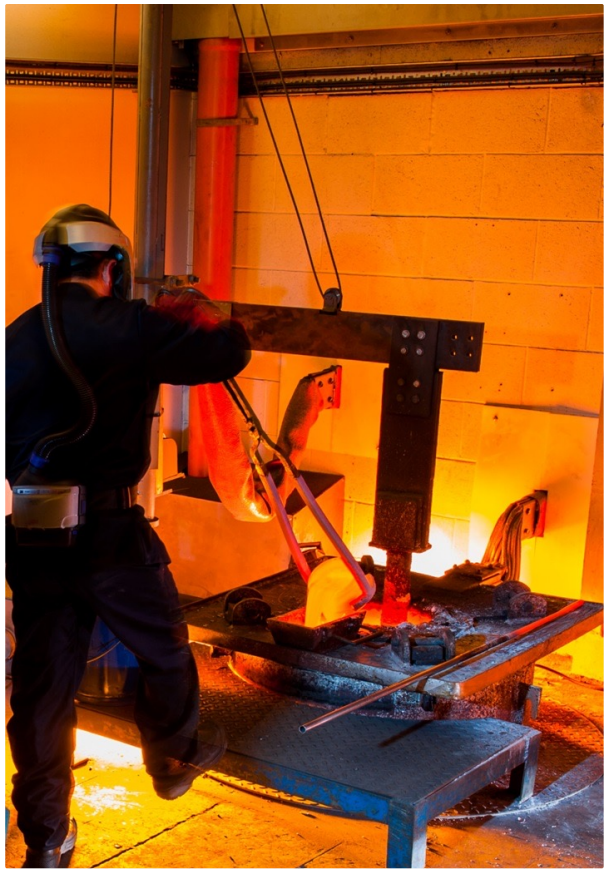
Innovation Capacity

SecREEts

- Concentrate extraction
  - Separation of concentrate can be deployed to other nitrophosphate fertiliser plants
  - Several large European producers using the nitrophosphate route (Odda Process)
- Separation of RE elements from concentrate
  - Modular design, high throughput
  - High flexibility to RE concentrates
- Electrowinning of NdPr and DyFe alloys from rare earth oxides
  - Modular, industrial scale, state-of-the-art electrolysis cell
  - High energy efficiency – Low emissions
  - Hydrogen decrepitated strip cast alloys for magnet production



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Advisory Board

SecREEts

Members:

- Reinhold Schindler, SIEMENS
- Jun Shi, BROSE
- Roland Gauß, EIT Raw Materials
- Badri Veluri, Grundfos
- Erlend Schou Faevelen, GE Healthcare

Retired Member:

Odd Einar Ingvoldstad, GE Healthcare

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Secure European Critical Rare Earth Elements

Yara: achievements and lessons learnt

Fredrik Rodahl

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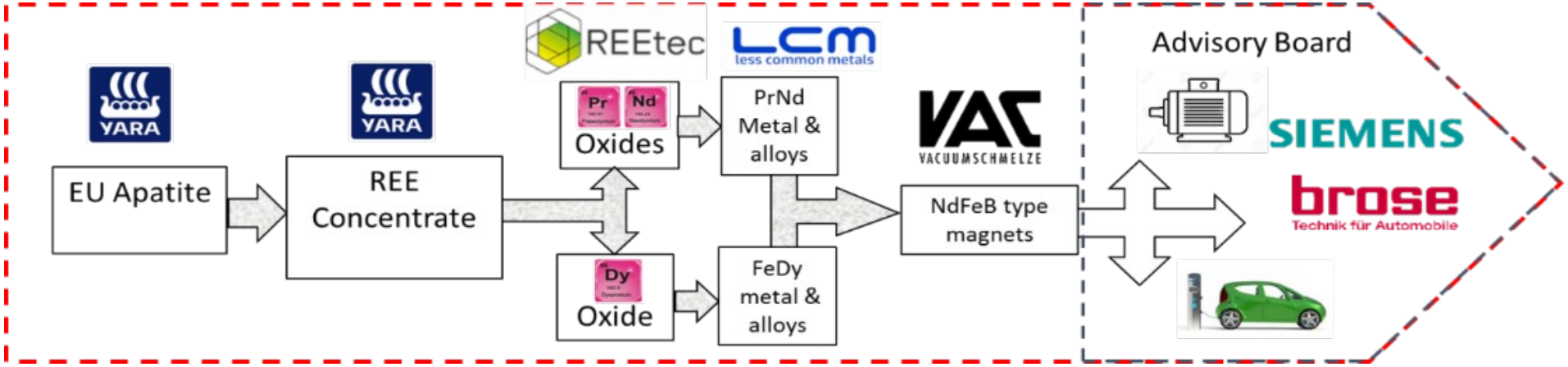
SecREEts: Overview

SecREEts

- **Project goal**: Produce magnets based on REE to be used in wind mills
- **WP1 goal**: Extraction of REE from fertilizer process
  - Build a pilot plant at Yara Porsgrunn in the NPK3 plant
  - Produce Ce-depleted REE-concentrate for Reetec
  - Optimize process



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SecREEts

Who is Yara?

- Norway based – International fertilizer company
- Manufacturer of many types of fertilizer
- Global leader within nitrophosphate fertilizer production

Role in project

- Extraction of Rare Earth Elements originating from phosphate rock used in the nitrophosphate fertilizer process.
- Production of a mixed REE-concentrate in **pilot scale.**

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SecREEts

Summary of achievements and progress

Pilot plant

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Pilot Plant overview

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- Design basis
  - 2 stages – 1 tested, 1 new research design
  - Real process feed
- Tie-in to nitrophosphate plant
  - Upstream and downstream restrictions
  - Raw material requirements
- Time criticality

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Pilot plant

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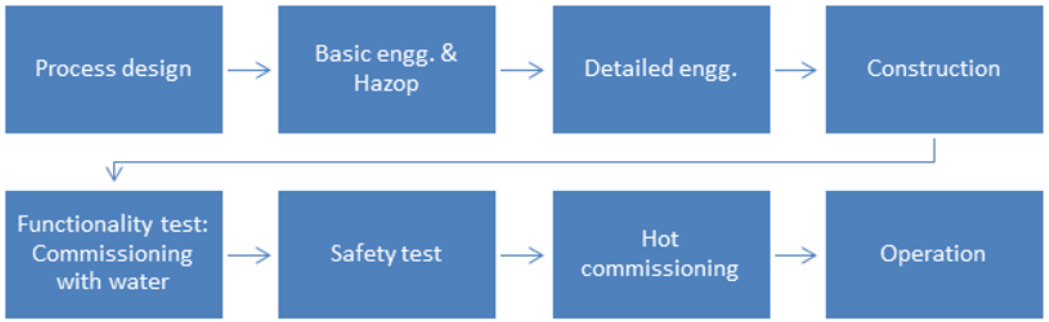
Pilot plant - construction

- Design verification
  - Equipment selection
  - Raw material test
- Covid-19 during commissioning
  - Follow safe procedures in NPK plant
  - No option for shift-work
  - Progress production of REE-concentrate for Reetec

Pilot plant milestones



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Pilot plant timeline

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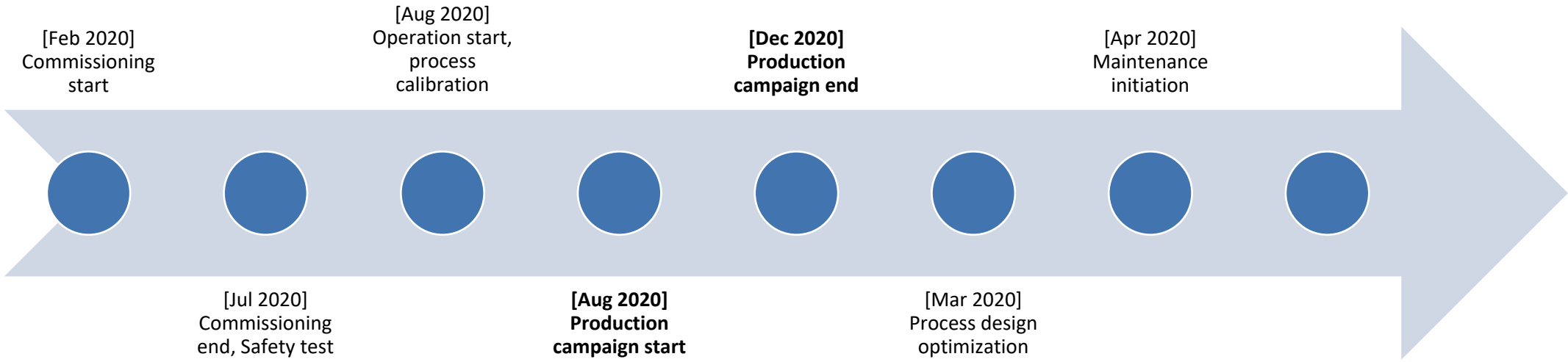

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Secure European Critical Rare Earth Elements

SecREEts Final Conference

On behalf of REEtec

Dr. Arne P Ratvik, SINTEF

Contact: arne.p.ratvik@sintef.no

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Pilot – Designed for Industrial Scaleup

SecREEts

- Yara pilot – Extraction of Concentrate (NO)
  - Pilot installed in fertiliser plant
  - No waste
- REEtec pilot – Separation of REE (NO)
  - State of the art separation technology
  - Main focus on NdPr, Dy and Tb oxides for high quality magnet production
  - Modular expansion
- LCM pilot – RE Electrowinning and Magnet Alloys (UK)
  - State of the art electrolysis technology
  - Strip cast alloys and hydrogen decrepitation to magnet powders

Energy efficient vaporization in the REEtec plant

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Production of Cost Competitive Magnet Metal Oxides

SecREEts

- Developed completely new and game changing process for manufacturing of high purity rare earth elements
- Technology has been proven through successful operation of an industrial scale demo pilot
- Significant innovations over traditional technology
- Sufficiently mature for full scale operations

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 776559

SINTEF

Proprietary Technology

SecREEts

Benefits of the REEtec technology

1. Few process steps
2. Separates all REE elements as needed
3. Closed loop and no organics, low exposure and fire risk
4. All process chemicals recycled, no need for waste disposal
5. Automated process
6. Flexible feedstock and product purity
7. Verified green technology. Carbon footprint <10 % of others

✓ ***Few process steps with flexibility on feedstock and product purity***

✓ ***Modular and scalable solution cost competitive at low volumes***

✓ ***Compliant with Western HSE requirements***

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REEtec Outcome

SecREEts

- First industrial plant near Porsgrunn, Norway, planned with a capacity of 750 tonnes of NdPr oxide
- Based on mixed carbonates produced by Vital Metals in Canada
- Substantial part of sales from first plant secured
  - Contract with Schaeffler
    - leading automotive drive train producer
  - Other significant users of magnets
    - developing own magnet value chains

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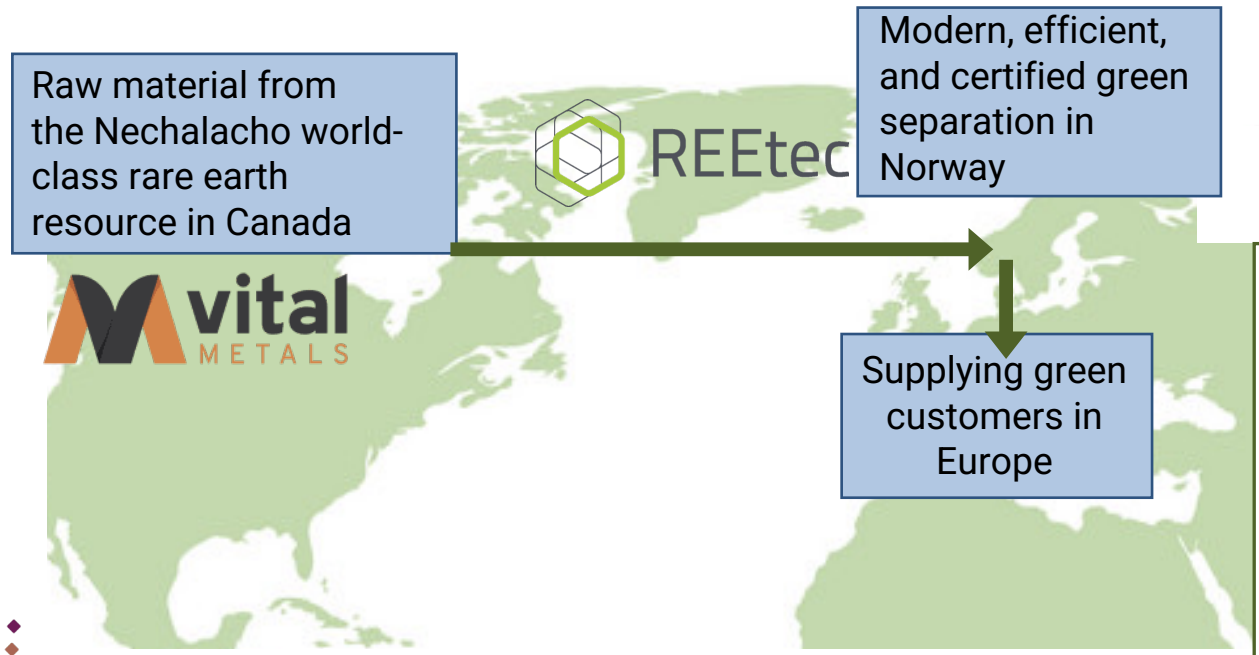
REEtec and Vital Metals

- Vital Metals supply mixed carbonate concentrate for the first industrial plant with a capacity of 750 tonnes of NdPr oxide



REEtec positioned in critical steps in the value chain

vital METALS		REEtec		
Reserves	**Mining & processing**	**Separation**	**Refining & forming**	**Manufacturing**
Rare Earth reserves	Rare Earth concentrates	Blended mix of REEs → REO 1, REO 2, REO n → Single Rare Earth oxides	Metals, alloys & compounds	Rare Earth magnets

REEtec procures feedstock, separates and sells NdPr oxide for further processing
REEtec technology is also suitable in recycling REE from EOL and magnet production waste

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REEtec: Last Week's News

SecREEts

- LKAB becomes largest owner in REEtec
- Financing secured for the first full scale factory to at Herøya in Norway
- Start-up planned for autumn 2024 based on concentrate from Vital Metals
- LKAB will supply rare earth concentrate for REEtec's next expansion, estimated to 2027
- Builds a strong Nordic industry for rare earth elements

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REEtec products, NdPr, Tb and Dy

SecREEts

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 776559

SINTEF

SecREEts

Secure European Critical Rare Earth Elements

Less Common Metals: achievements and lessons learnt

Ian Higgins

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 776559

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LCM's role in SecREEts

Conversion of separated rare earth oxides into metals then alloys suitable for permanent magnet production

Key technologies utilised and developed:

- Electrolytic production of rare earth metals and master alloys
- Production of rare earth fluorides as needed for metal making
- Strip casting neodymium iron boron alloys
- Production of coarse neodymium iron boron powders via hydrogen decrepitation

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 776559

Key challenges

Much of the key core processing technology has been developed in China

- Accessing technology and knowhow
- Developing commercial processes that fully comply with western world environmental, health and safety standards
- Ensuring all processes are as cost-competitive as possible
- Establishing a framework whereby environmental impacts can be quantified and areas for improvement identified
- Enabling ongoing development work focused on achieving the highest possible standards of both ESG and economic viability

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Electrolytic Production of RE Metals challenges

Simultaneous dissolution and reduction of rare earth oxides in a molten rare earth fluoride salt bath using direct electrical current

- LCM has developed commercial production of Nd and NdPr master alloy by electrolysis
  - Only non-Chinese commercial production of such metals globally
- Focus areas:
  - Technology transfer from established experts
  - Health and safety of operators and the wider community
  - Emissions control
  - Quality of product
  - Rate of production
  - Yield

Electrolytic NdPr produced at LCM in 2021

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 776559

Key metal making achievements

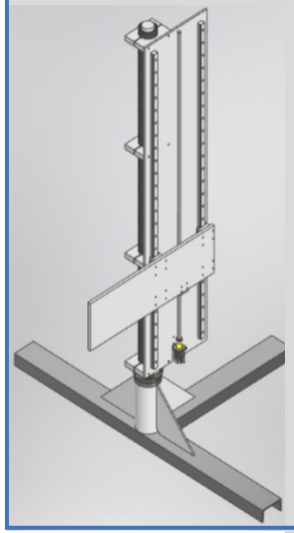
Range of products

Emissions control

Realtime process monitoring

Improved design to cathode arm

Primary Design Considerations



- Exposure to high temperatures
- Exposure to corrosive gas
- High turning moment forces on cathode cross member
- 180kg lifting requirement with LOLER safety margin
- Fast extraction and re-insertion
- Space constraints
- Accurate positioning
- 90-degree rotation for anode replacement etc.

XRD to monitor bath chemistry

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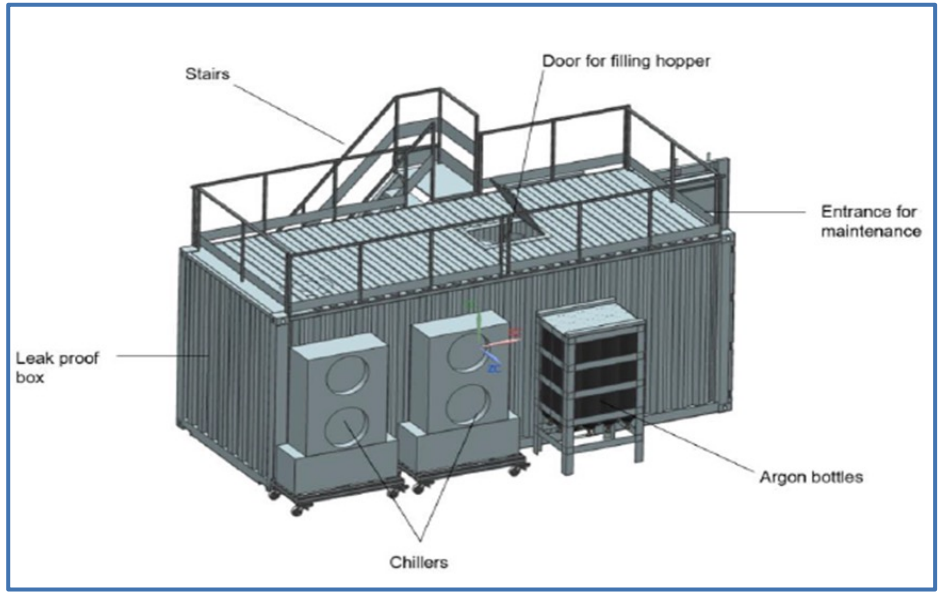
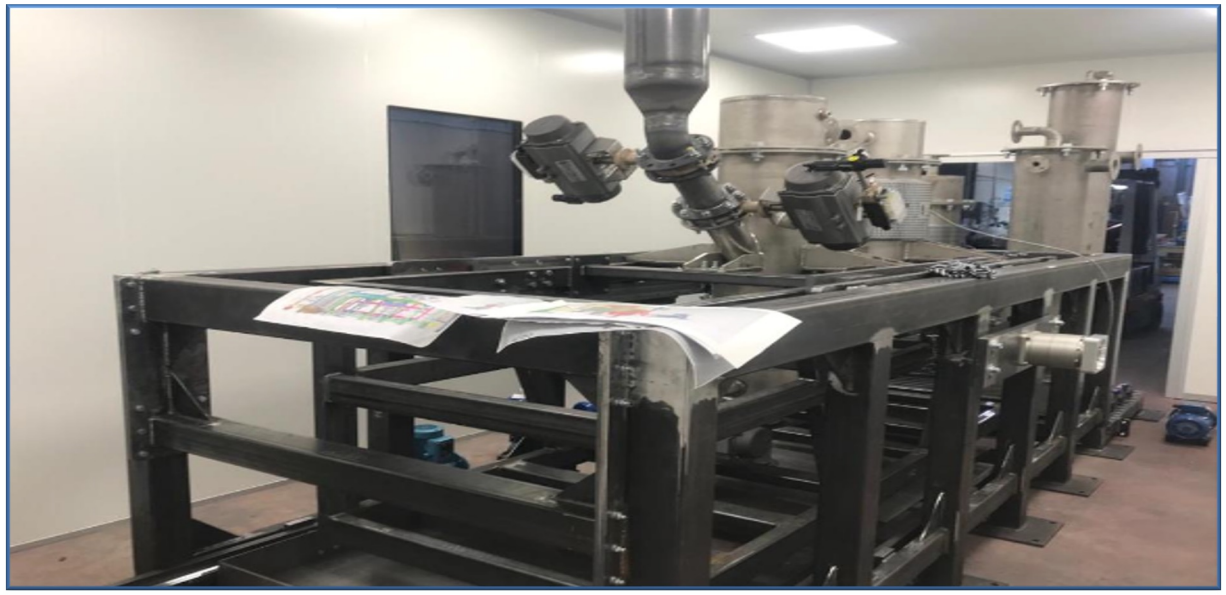
Production of RE fluorides

Essential for rare earth metal production

- Large scale pilot plant designed and commissioned in Italy
  - Production of rare earth fluorides demonstrated
- Alternative western world producers of fluoride identified
  - Currently developing industrial processes with support from LCM





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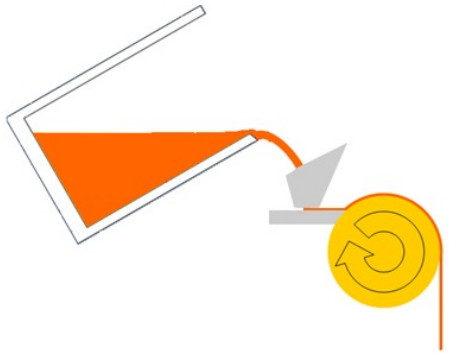
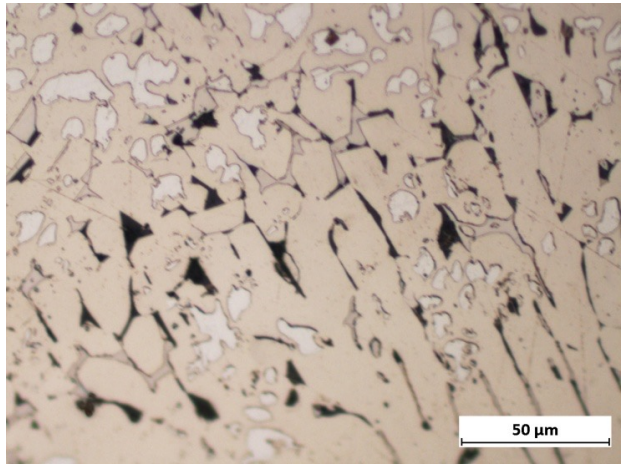
Strip casting of NdFeB alloys

Industry standard for high performance rare earth permanent magnet production

- LCM operates two 600kg strip cast furnaces
  - Only commercial operation in the western world

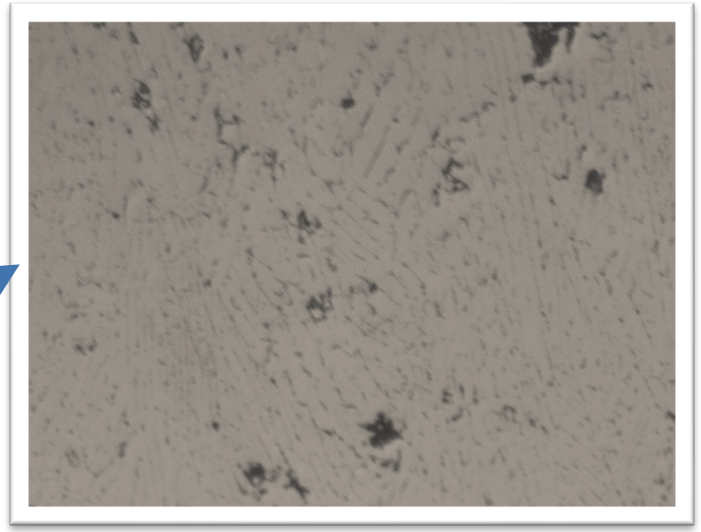


Molten alloy cast onto rotating water-cooled copper wheel



Conventionally-cast alloy

- Irregular grains
- Undesirable free α-iron



Strip cast alloy

- Regular grain structure
- No undesirable phases

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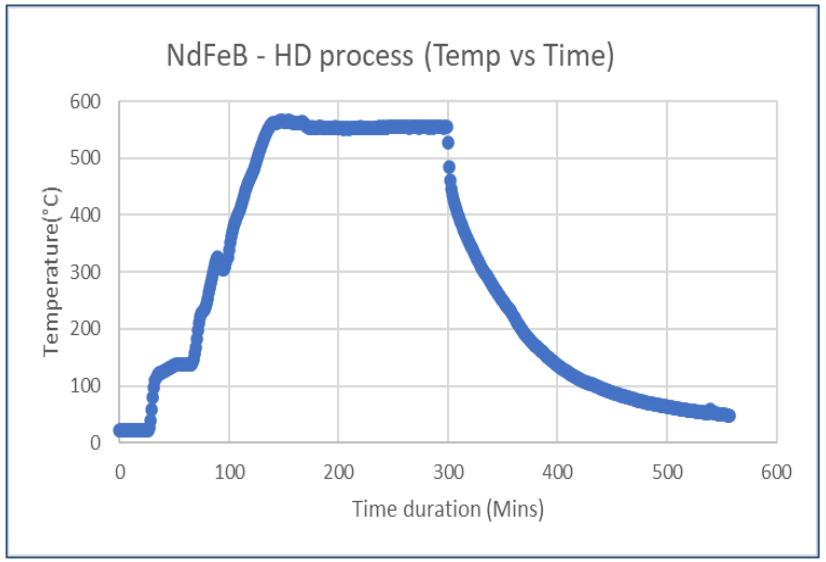
Production of NdFeB powders

Based on hydrogen decrepitation of strip cast alloy

- Commercial HD and powder packing processes established at LCM as part of SecREEts project
- Plant installed, commissioned and product approved by key customers

HD furnace



HD process in operation

Powder packing

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Key deliverables

Two electrolytic cells, each capable of producing **65 tonnes per annum** of **rare earth metal**, installed	**XRD** facility established to **characterise salt bath** chemistry	**210kg NdPr metal produced** from oxide supplied by REEtec
HD furnace and associated **powder packing equipment** installed	Metal converted to **strip cast alloy,** powdered via **hydrogen decrepitation** and submitted to Vac for processing into **magnets**	Pilot **rare earth fluoride plant** designed, built and now under commissioning

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Who is LCM?

- Small-Medium enterprise located in Northwest England
- Manufacturer of rare earth metals and alloys
- Key supplier of NdFeB & SmCo alloys to global magnet manufacturers

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SecREEts

Secure European Critical Rare Earth Elements

Vacuumschmelze: achievements and lessons learnt

Dr. Matthias Katter

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SINTEF

Your partner for advanced magnetic solutions

VACUUMSCHMELZE

The world of magnetism is our home

Together with our customers we develop application solutions that meet constantly increasing requirements. We push technical boundaries with groundbreaking solutions and make our customers' systems smaller, lighter, more efficient and, last but not least, safer. Thereby we contribute significantly to the saving of resources and the protection of our environment.

500+
Customized solutions

170+
alloys

4.000
employees

2.000+
active customers

500+
patents

SecREEts

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SINTEF

	Crystalline	Rapid Solidification	Permanent Magnets
Innovative Products	Cobalt-iron laminated packages  Current sensors 	BENVAC sensors  Common Mode Chokes based on VP550 HF and 712 	Advanced magnet assemblies  Magnets for position sensors 
Applications	Hyper Car / F1 / FE Aviation eMotors  PV-Inverters and industrial drives 	ICCPD – applications  PV-Inverter and industrial drives 	Large Energy Gen. Automotive  Double-clutch gear box 
End Markets	• Automotive • Aerospace • Renewable energy • Industrial	• Consumer electronics • e-mobility • Renewable energies • Industrial drives	• Automation & Drives • Automotive • Aerospace • Automotive

VAC solutions developed from VAC material technology

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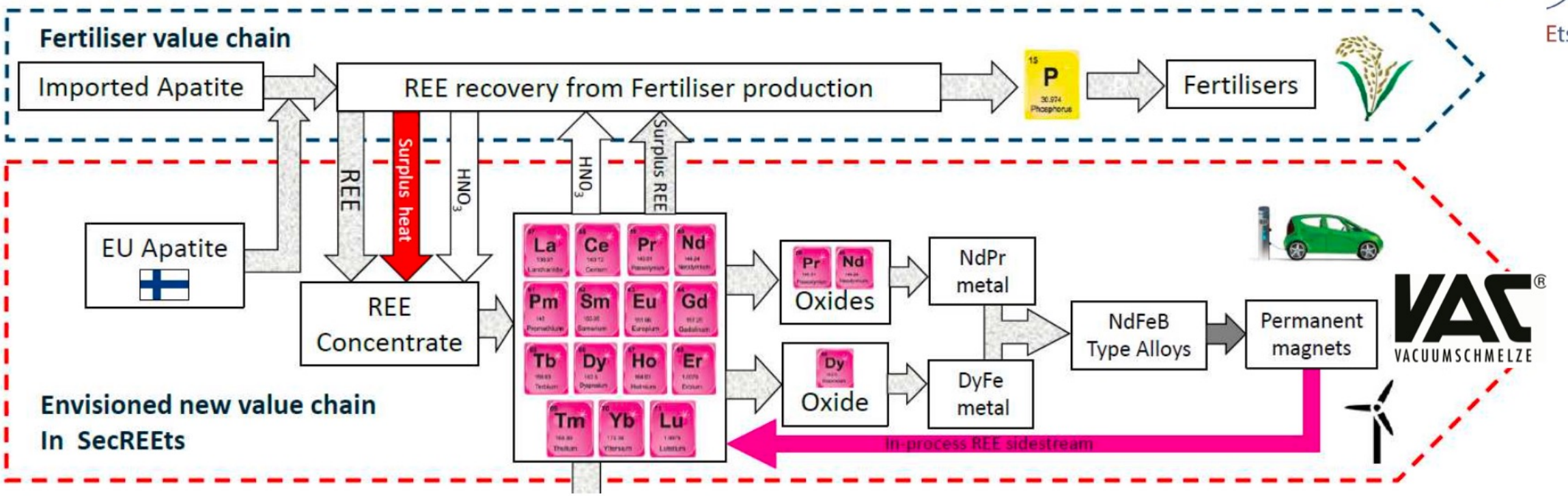
Roll of VAC in SecREEts



- production of NdFeB magnets on laboratory and production scale
- assistance for the establishment of a hydrogen decrepetation process at LCM
- validation of the NdFeB alloys produced with RE metals out of the new European value chain

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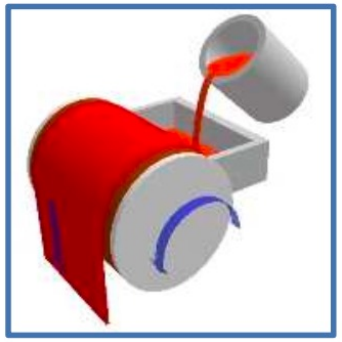
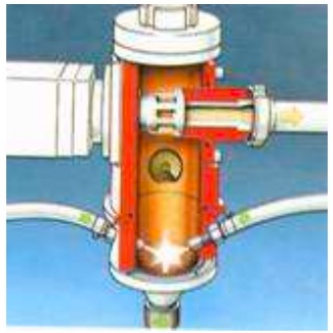
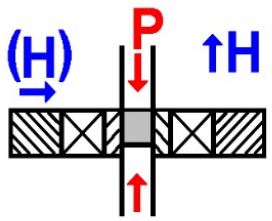
Powder metallurgical production of RE magnets

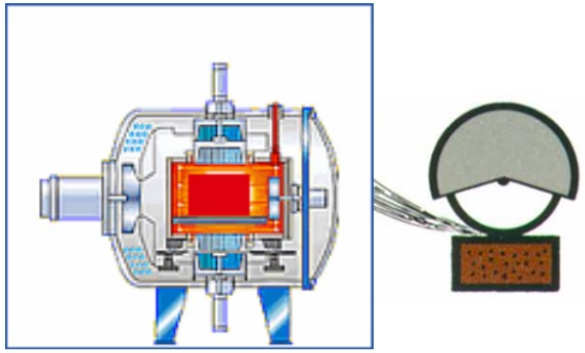


Showa Denko www.sdk.co.jp

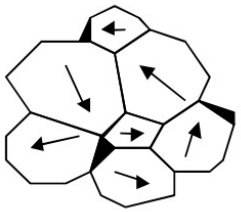


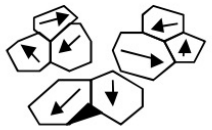


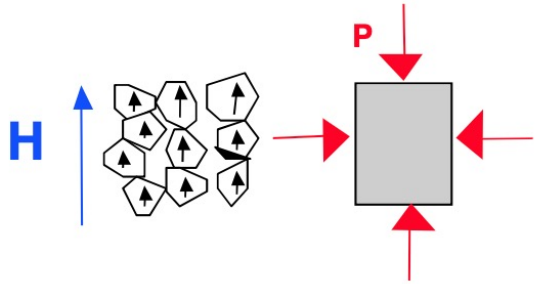
die pressing



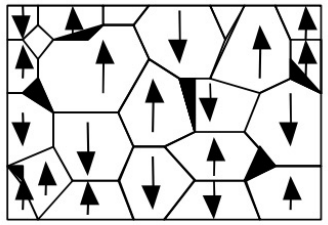
melting under vacuum → coarse milling (HD) → fine milling → aligning & compaction: **CIP - AP - TP** → sintering & annealing → cutting, grinding & coating → magnetizing

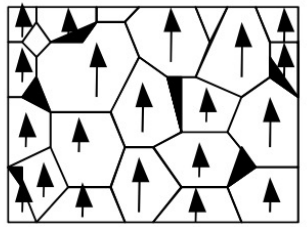






isostatic pressing





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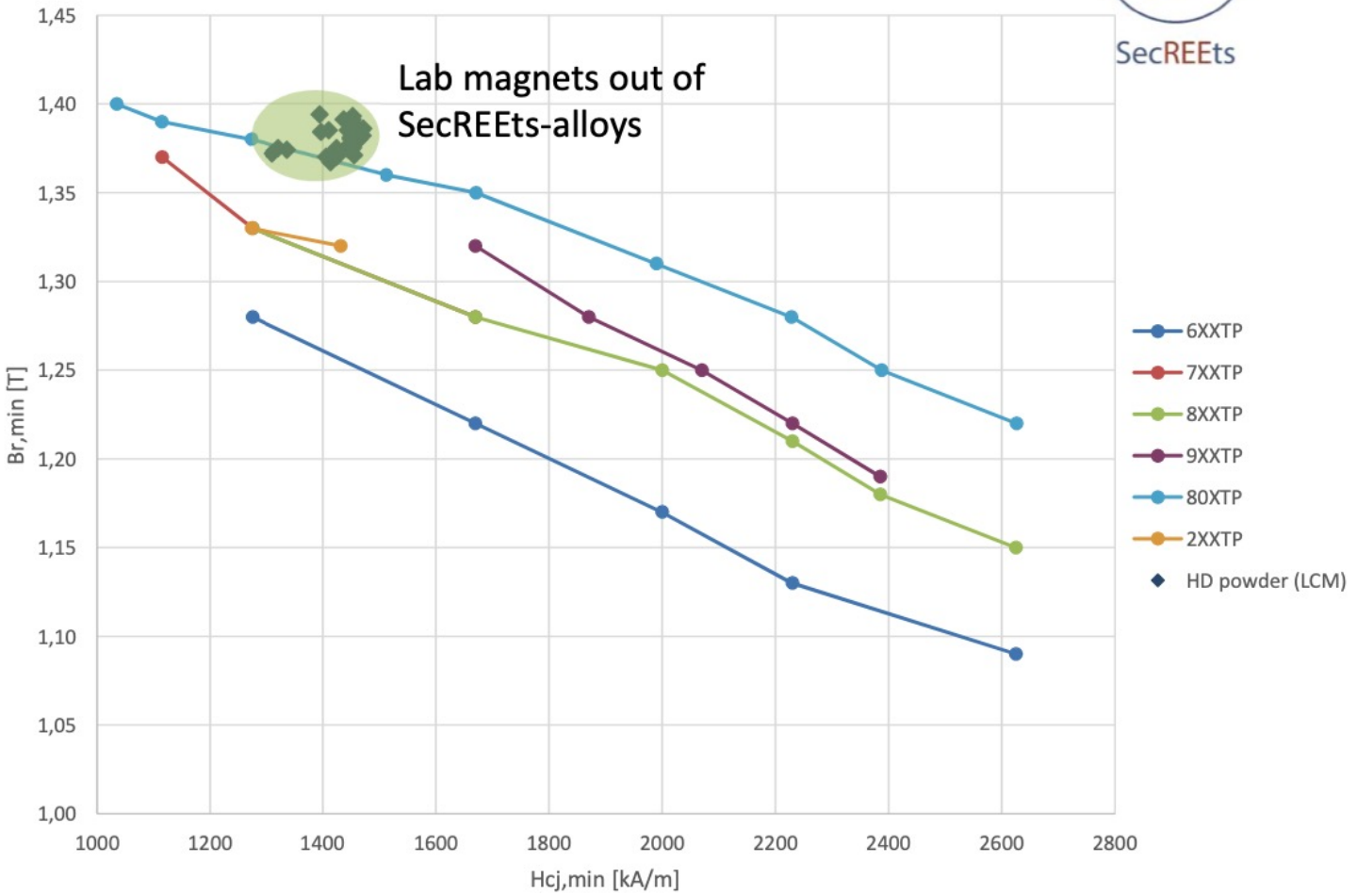
Lab magnets out of SecREEts-alloys

alloys from LCM



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Validation of the HD process at LCM

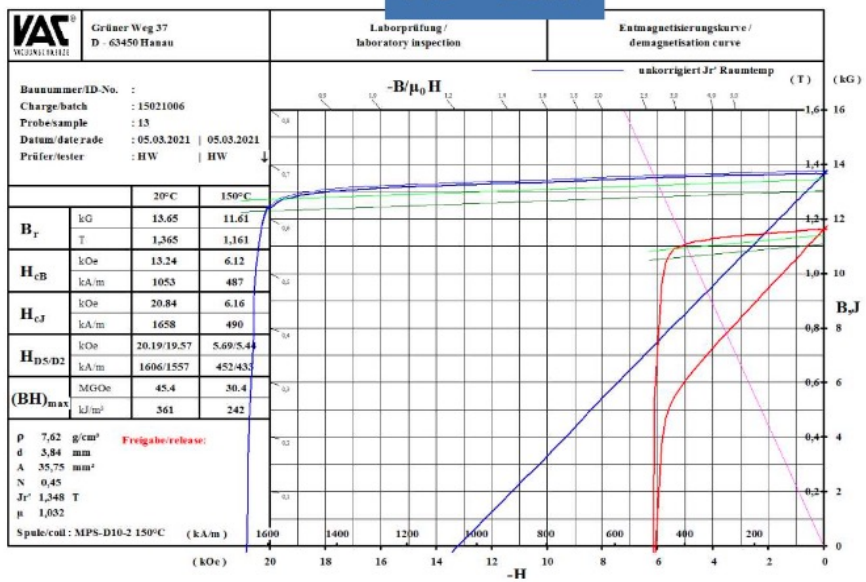
SecREEts

Laboratory scale

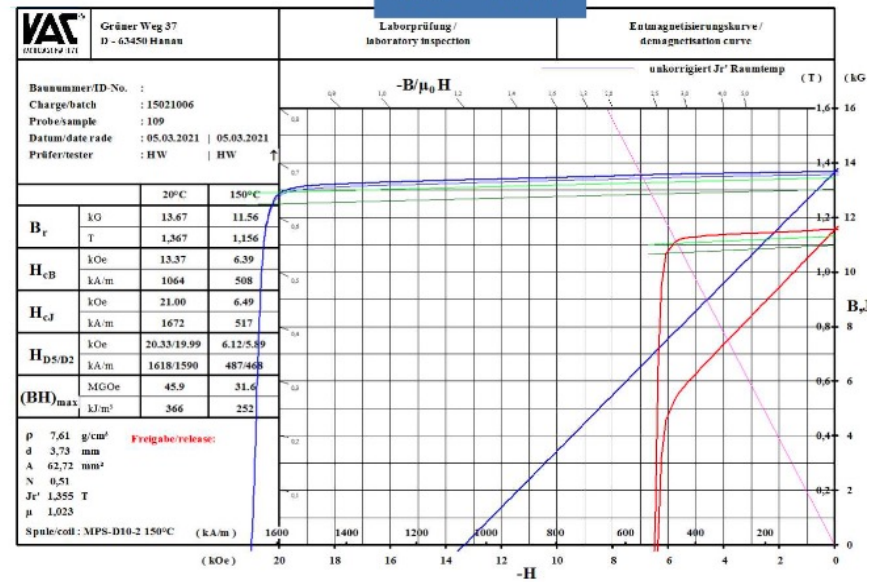
- 2 powder batches
  - SC – material
  - HD – material

- $B_{r,typ}$ = 1.37 T
- $H_{cJ,typ}$ = 21 kOe

HD - LCM



HD - VAC



✓Comparable performance

✓Task almost finished, only reports pending

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VACUUMSCHMELZE

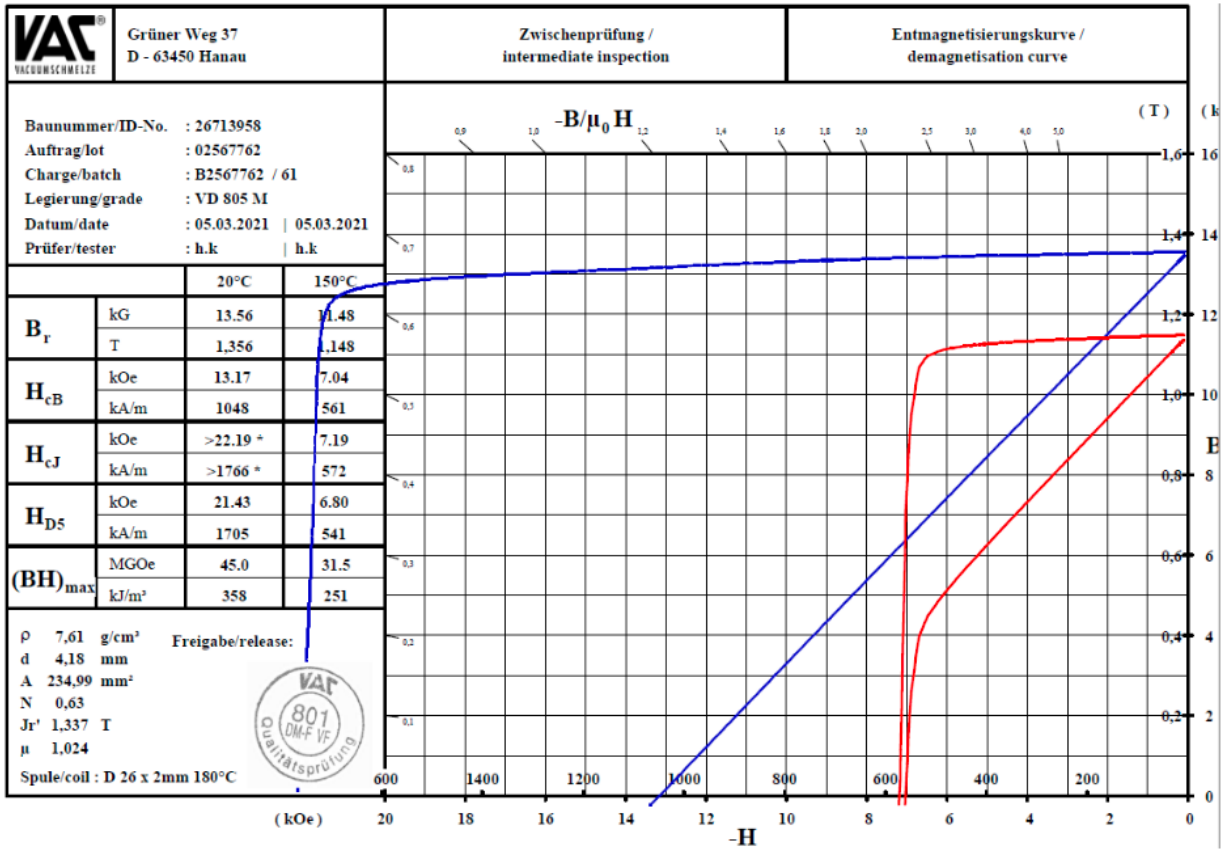
Comparison with conventional strip cast alloys from virgin metals

Production scale

- Magnetic properties:
  - ✓ $B_{r,min}$ = 1.35 T
  - ✓ $H_{cJ,min}$ = 21 kOe

➡ First evaluation successful

➡ Properties of conventional powder can be achieved



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Conclusions

- VAC produced out of SecREEts alloys lab magnets with similar or even superior properties compared to magnets out of conventional starting material
- The HD process at LCM was succesfully validated
- Also on production scale at least the same magnetic properties as for Chinese raw materials could be achieved
- In overall a complete European value chain from the RE minerals up to the final NdFeB magnets could be demonstrated

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SecREEts

Secure European Critical Rare Earth Elements

Quanits achievements and lessons learnt

Pauline Chrobot

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SINTEF

Quantis

1 kg permanent magnet

LCA results comparison

Functional unit: 1 kg permanent magnet
System boundaries: cradle-to-gate, from extraction to permanent magnet production
Database: ecoinvent 3.8

Baseline system

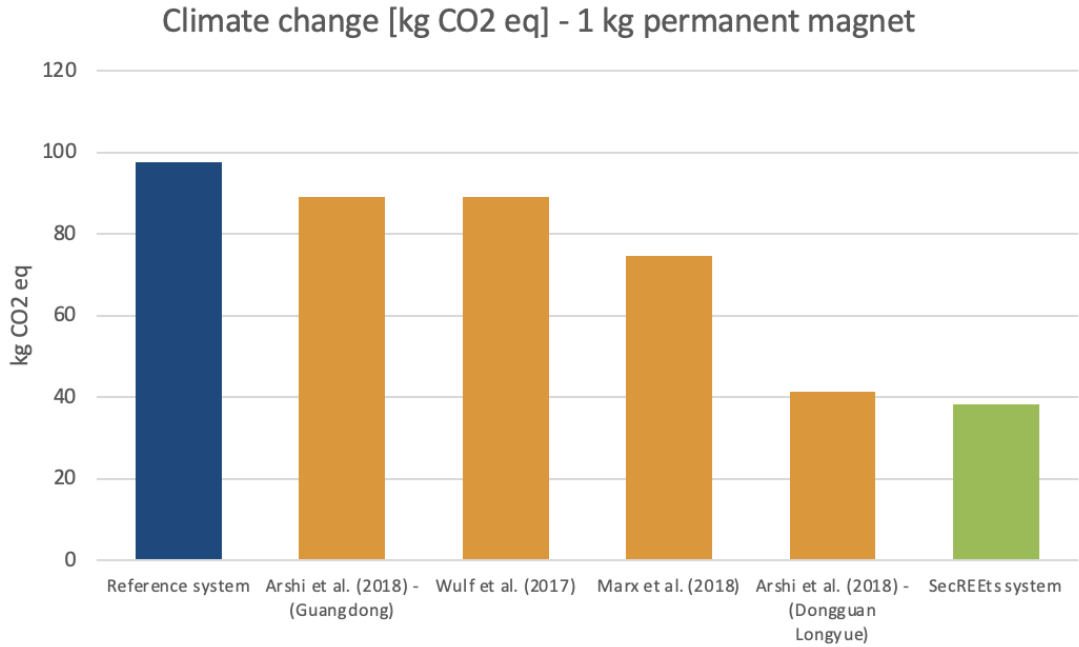
Medium
Data quality

- Current practices in China
- Two main production pathways reflecting the economically viable production sources: bastnäsite and monazite ore for Nd & Pr, ion-adsorption clay for Dy
- Excluded: tailings and wastewater treatement for mining step
- Data available from literature only

SecREEts system

Good
Data quality

- European innovative supply chain
- One main production pathway
- Primary data available from SecREEt's partners



1. The SecREEts production system has a **lower environmental impact** for the climate change indicator than the reference system and comparable references found in literature
2. The main contributor for the **SecREEts' system** climate change results is the permanent magnet production step
3. The main contributor for the **reference system** is the REO extraction & separation
4. The **main benefit of SecREEts** lies in the independency from the extraction (mining) step
5. There is a challenge regarding the **missing primary data and transparency** for the reference system, even if there is ongoing momentum and research on the topic

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SecREEts

Secure European Critical Rare Earth Elements

Prospex Institute
Public Engagement in SecREEts

Francesca Ferrara

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Role in the project:

- **WP6 -** Designing and implementing the Public Engagement, Dissemination, Exploitation strategy

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Citizen Engagement - Citizen Labs

9 Citizen Labs with the local communities in UK, GER & Norway

- **Ellesmere Port**, UK, for Less Common Metals
  - January 2019
  - February 2021
  - April 2022
- **Porsgrunn**, Norway, for REEtec and Yara
  - August 2019
  - September 2020
  - September 2022
- **Hanau**, Germany, for Vacuumschmelze
  - June 2021 (Two workshops: morning & afternoon)
  - September 2022

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From Citizen Labs to school workshops

- **Ellesmere Port, UK: Mine to magnet workshop**
  - In partnership with Less Common Metals & the Xplore! Science Discovery Center
  - Noveber 2021 – March 2022: workshops in primary schools
  - 4 workshop sessions at the yearly STEM Day of Glyndwr University in July 2022.

- **Porsgrunn, Norway: Rare Earth discovery workshop**
  - In partnership with Yara, REEtec and the Du Verden Maritime Museum & Science center
  - 4 classes, March & April 2022.
  - 110 high school students /science & chemistry tracks

- **Hanau, Germany: Student Lab**
  - In partnership with Vacuumschmelze
  - 1 class, September 2022

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Key take-outs:

- engagement goes beyond the project lifespan; it is important to include more local industries in the future;
- school workshops are the most valuable activities, making children aware of such topics is vital;
- Citizen Labs should be upscaled: they can help bridge the knowledge gap between research community and general public;
- creating an understanding around the necessity and importance of REE is key; Citizen Labs can help participants in understanding the challenges related to REE.

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DiscoveREEs

- In partnership with the Horizon 2020 SUSMAGPRO project

- Interactive online tool in English and German

- explores issues and solutions around rare earths and their societal and economic importance.

- examines the recovery process of these materials and gives ideas on how their wider recycling and reuse can be best supported.

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Policy Councils

- high-level meetings engaging experts across the European critical raw materials sector

4 Policy Councils in total:

- June 2019 - *Presenting SecREEts*
- September 2020 - *Rare Earths and the EU Green Deal: What policies for what purposes?*
- September 2021 - *Analysing Critical Incidents for Rare Earth Elements Supply & Use in Europe*
- June 2022 - *Obstacles, Impacts and Recommendations for the future of the European rare earth elements value chain*

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Secure European Critical Rare Earth Elements

Panle Discussion:
EU projects in discussion: the place of a European RE value chain

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SecREEts

Secure European Critical Rare Earth Elements

Coffee Break

Plese return by 10h50

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EU projects in discussion: the place of a European RE value chain

SecREEts

- **Prof. Dr. Carlo Burkhardt** – H2020 SUSMAGPRO project, Horizon Europe project REEsilience
- **Prof. Dr. Spomenka Kobe** - EIT project INSPIRES
- **Irina Sokolova** - H2020 project PASSENGER
- **Dr. Ester Palmero** – H2020 project PASSENGER
- **Nader Akil** - Horizon Europe project REEPRODUCE

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SecREEts

Questions and Answers, Comments and proposals

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