

Recycled magnet manufacturing

High performance  
Sustainably sourced  
Low carbon footprint

*ETHICAL | INNOVATIVE | GREEN*





# WHO WE ARE

HyProMag (UK) was founded in 2018 by leading experts in magnetic materials, recycling and hydrogen technologies – Prof Allan Walton, Mr David Kennedy, Dr John Speight and the late Prof Rex Harris. The Company is 100% held by Maginito Ltd, a subsidiary of AIM/TSXV listed Mkango Resources

- 1 A company capable of manufacturing rare earth magnets with a significantly reduced carbon footprint
- 2 Our directors have over 100 years combined experience of Rare Earth Elements and Magnets
- 3 We have access to the highly energy efficient, patented Hydrogen Processing of Magnet Scrap (HPMS) technology developed over many years at The University of Birmingham
- 4 A strong network of partners has been built both within industry and research, and we can draw on expertise from The University of Birmingham and Pforzheim University



**Will Dawes**  
Director  
HyProMag Ltd



**Prof Allan Walton**  
Director  
HyProMag Ltd



**Dr John Speight**  
Director  
HyProMag Ltd



**David Kennedy**  
Director  
HyProMag Ltd



**Prof Carlo Burkhardt**  
Director  
HyProMag GmbH



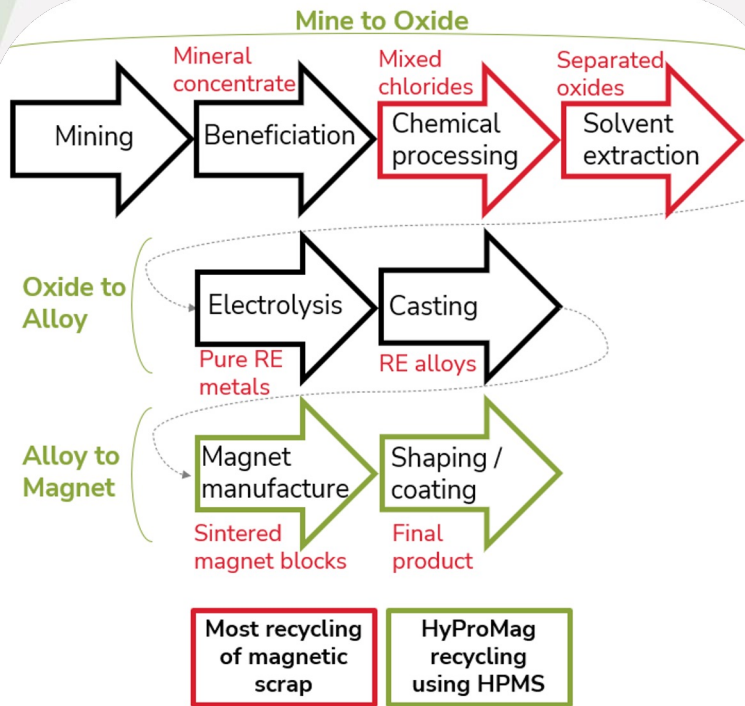
**Nick Mann**  
Operations Manager  
HyProMag Ltd



**Nelson Brito**  
Managing Director  
HyProMag GmbH

# WHAT WE DO

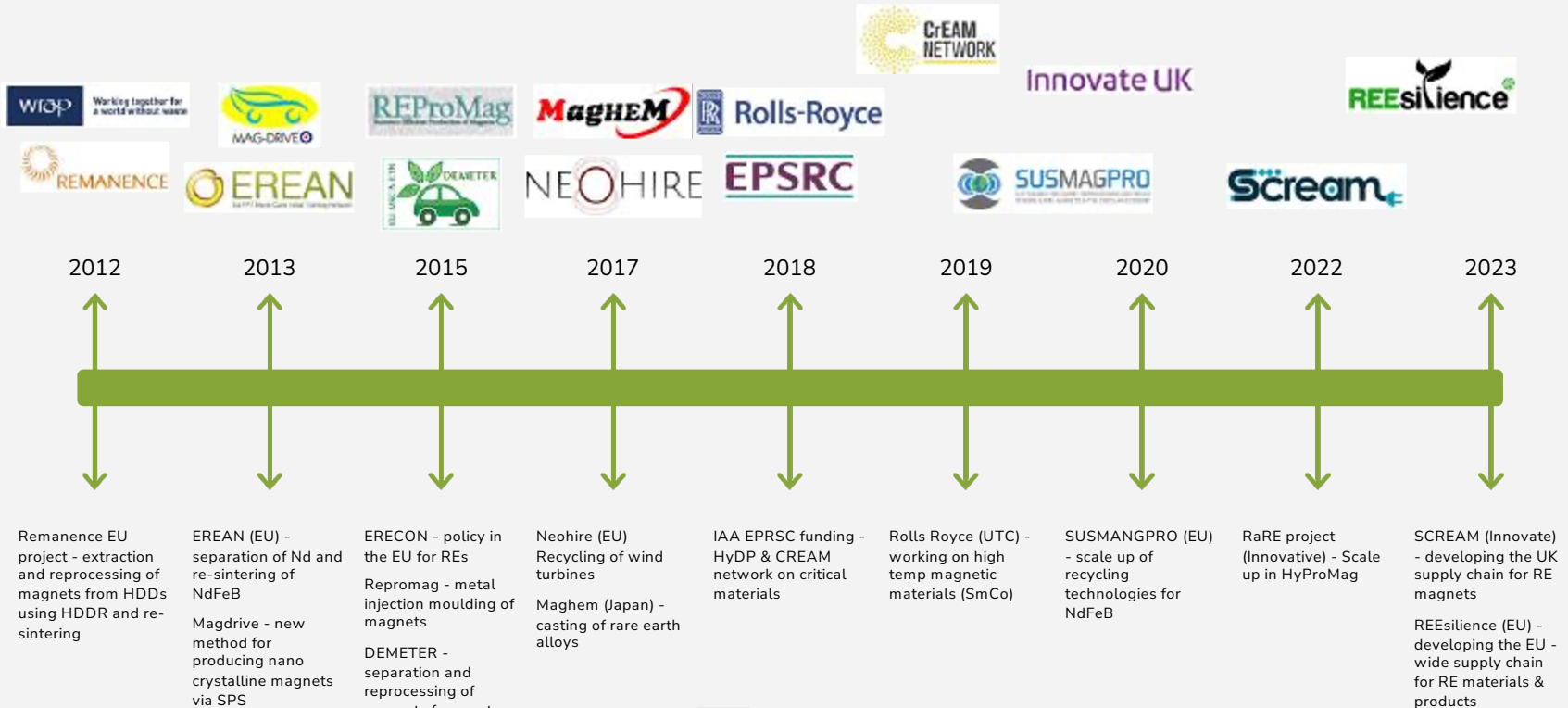
- The HPMS process being commercialised by HyProMag uses **hydrogen to break down and demagnetise the NdFeB magnet embedded in a component**. In the short loop process a magnet or alloy is produced from the resulting NdFeB powder
- HPMS technology addresses two key issues for recycling magnets embedded in an assembly: **economically viable extraction and low energy demagnetisation**
- **HPMS is much more energy efficient** than competitors focused on recycling via chemical process
- **NdFeB Magnet Recycling is currently very limited** and almost exclusively involves scrap being put back in at the Chemical Processing or Solvent Extraction stages. **Short Loop Recycling allows us to avoid not only these stages but also Electrolysis and Casting**
- HPMS technology **underpinned by US\$100m collaborative research between the University of Birmingham and associated partners**





# SIGNIFICANT R&D FUNDING TO DATE

Significant development and de-risking of HPMS during past and ongoing projects



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# GOVERNMENT GRANT FUNDED SUPPORT

Grant Funded Projects – HyProMag, University of Birmingham and Mkango Rare Earths UK

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**SusmagPro Project** – sustainable recovery, reprocessing and reuse of rare earth magnets in a European circular economy

€14m project with 19 partners across the supply chain

**RaRE Project** - establishing an end-to-end supply chain to incorporate recycled rare earth magnets into Evs

£2.6m project with Bentley Motors, Unipart, AEMR, ILS

**REAP Project** - recycling rare earth magnets from speakers used in automotive and electronics applications

£0.3m project with European Metal Recycling (EMR) – completed Sept 2021

**SCREAM Project** – scrap processing pilot plants, HPMS, remelting, strip casting, chem processing, magnet production

£3.4m project with Mkango Rare Earths UK, B&W, EMR, GKN, Jaguar Land Rover

**REsilience Project** – creating a more robust supply chain integrating primary & secondary sources, magnet pilot plants

€14m project with 22 partners across the supply chain

**Innovation Centre for Science & Economy Northern Black Forest IZWW** – development of production facility in Baden-Württemberg State

€6.1m project led by HyProMag GmbH



# THE NEED FOR RECYCLING

EU is estimated to import ~14,000t/a of NdFeB in products, almost all of which is from China – less than 5% recycled

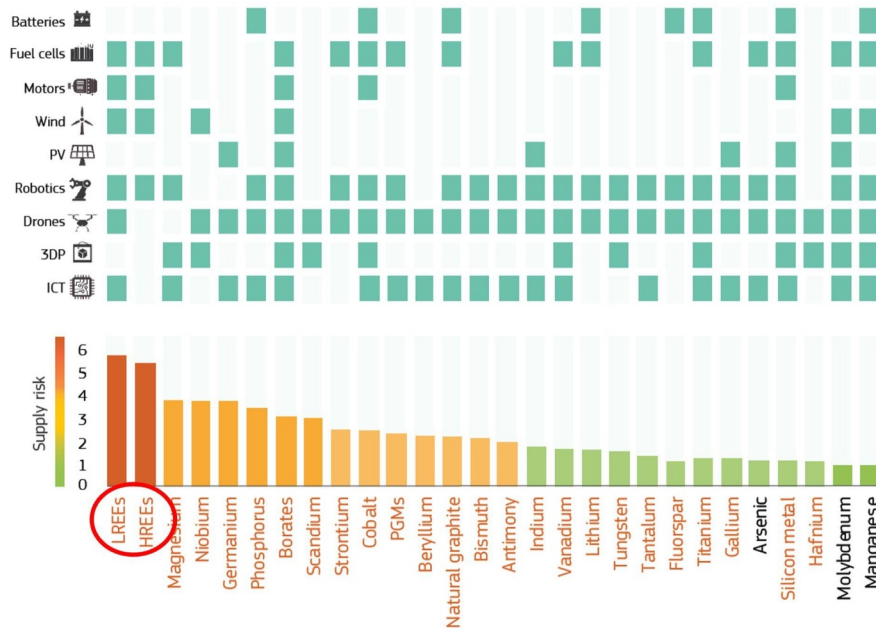
China dominates rare earth magnet manufacturing leading to geopolitical and supply chain concerns

Recycling can provide a secure NdFeB supply for sustainable energy and electrification, and diversify the supply chain

Short loop magnet recycling can significantly reduce the carbon footprint of NdFeB magnets

The costs for building a recycling plant would be a fraction of that required for primary production on a much shorter timescale

## SUPPLY RISK OF RAW MATERIALS FOR KEY TECHNOLOGIES

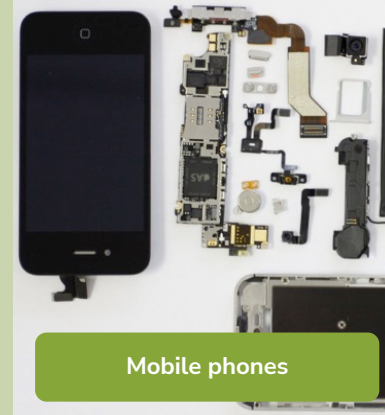


# HPMS OVERCOMES RECYCLING CHALLENGES

- Products are **not designed** with recycling in mind
- Current recycling processes **are not suitable** for NdFeB magnets
- **HPMS solves the issue by extracting and demagnetising** embedded NdFeB magnets



Rotor from an automotive drive motor



Mobile phones



Shredded automotive motor – courtesy of Axion



Shredded HDDs



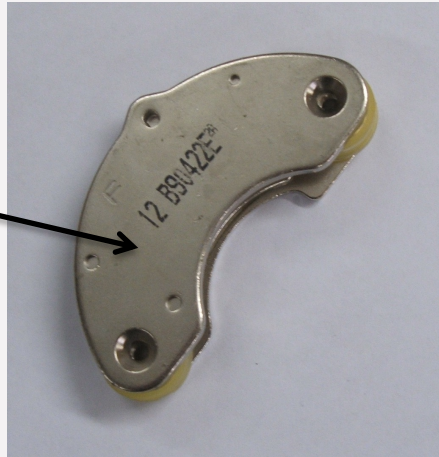
Hard disk drives





# HPMS **ENABLES** NdFeB EXTRACTION

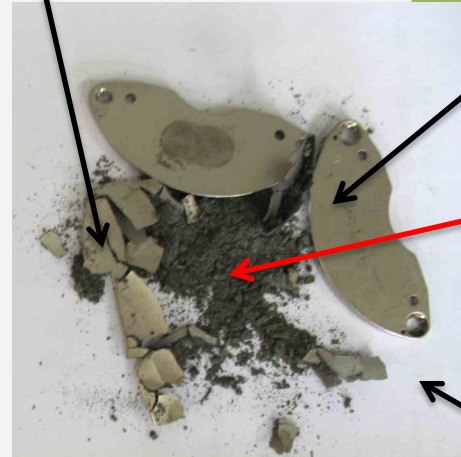
Voice coil assembly  
extracted from hard  
drive



Ni electroplate

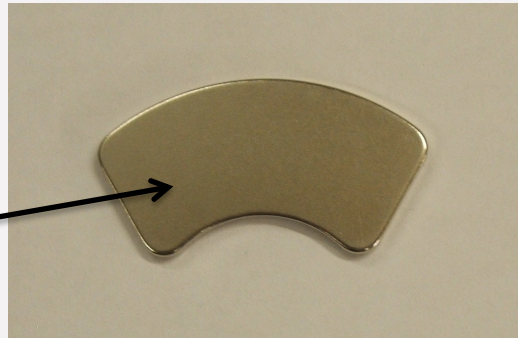
Soft magnetic Fe  
casing

Hydrided NdFeB  
powder



Voice coil assembly after HD  
process

Ni electroless plated voice  
coil magnet

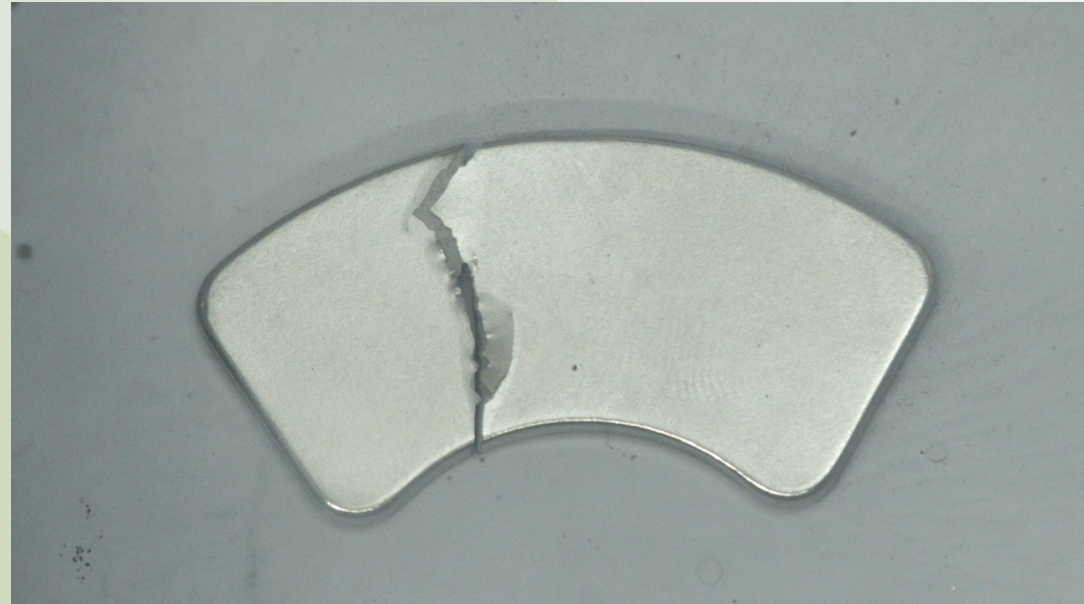
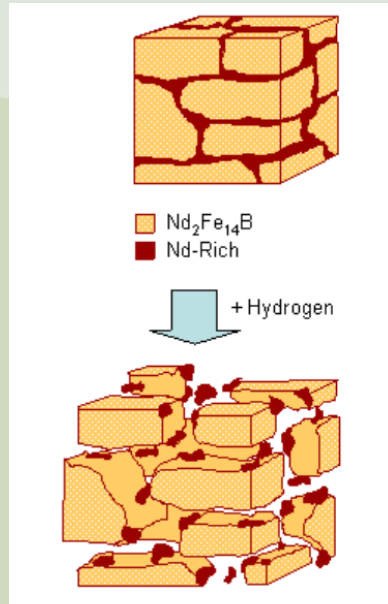


US patent – No.13/169839



# HYDROGEN DECREPITATION **IN ACTION**

HPMS – HDD Voice Coil Magnet Assembly

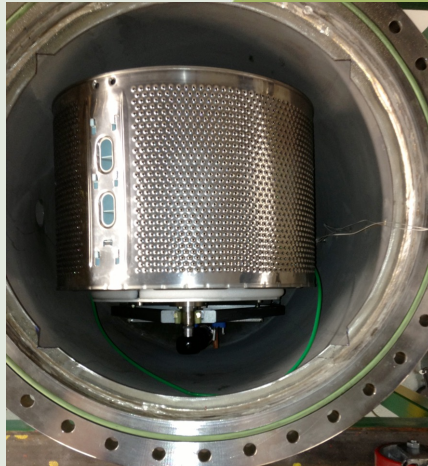


# INITIAL HPMS REACTOR

HDDs loaded into porous drum



Porous rotating stage inside vessel







# SCALE UP OF HPMS PROCESS UNDERWAY

- University of Birmingham pilot HPMS Reactor – **50 to 100kg per batch**

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- Tyseley Energy Park demo plant – **400kg per batch** equivalent to minimum capacity of around **100tpy NdFeB**

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- HyProMag GmbH scaling up in Germany based on Tyseley and UoB developments



# PILOT PLANT DEVELOPMENT

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Jet mill (7kg / hour)



Hydrogen reactor (50-100 kg batch sizes)



# HPMS PROCESSING OF **100KG OF DRIVE MOTORS** (EXTRACTION OF 25KGS OF NdFeB POWDER)

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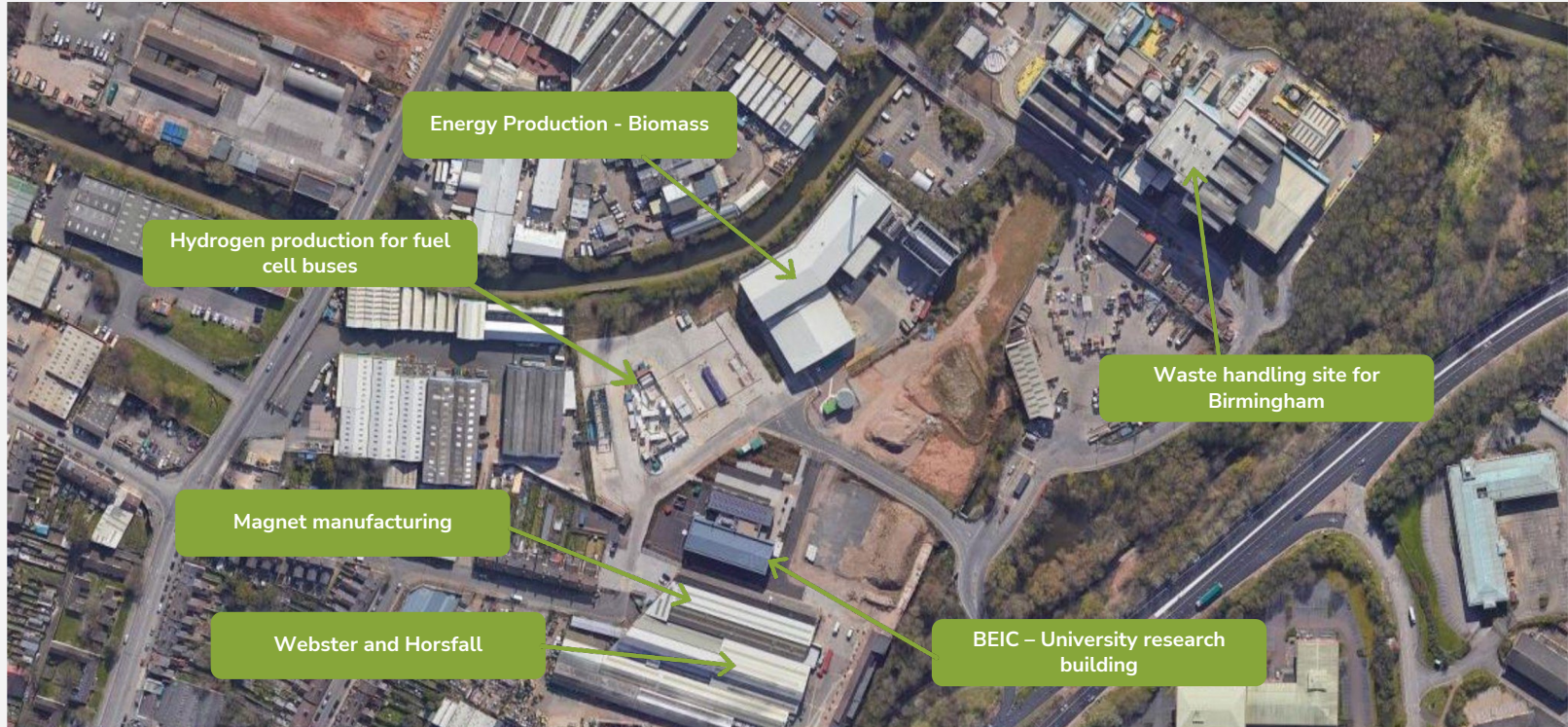
These types of assemblies typically process with **over 98% material recovery rate**

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# SCALE UP – TYSELEY ENERGY PARK (2023)



DER (UK) have provided £4.4 million of predominantly capital funding to scale up the HPMS process and magnet manufacture. HPMS at 400kg batch sizes (semi continuous)

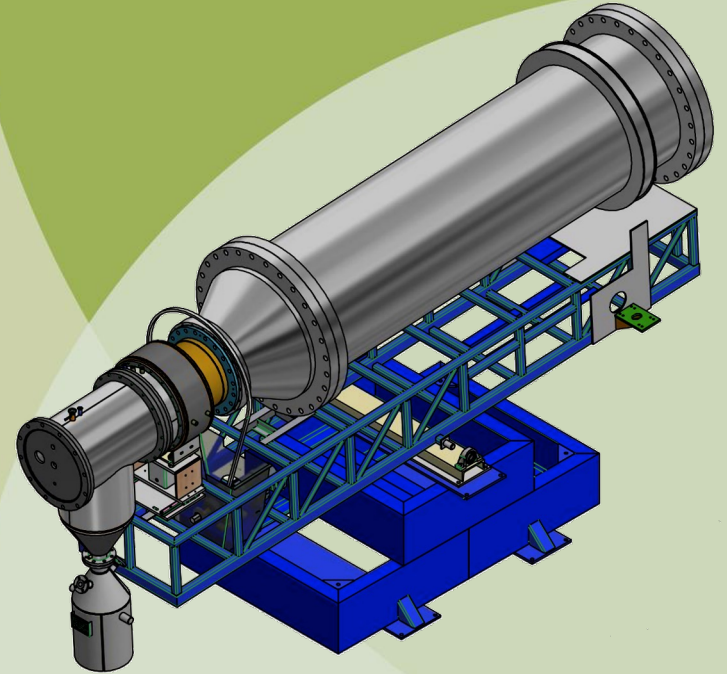


# SCALE UP OF THE HPMS PROCESS

**Larger HPMS Vessel – 300-400kg output per batch** from a total processing load of up to **6 tonnes**

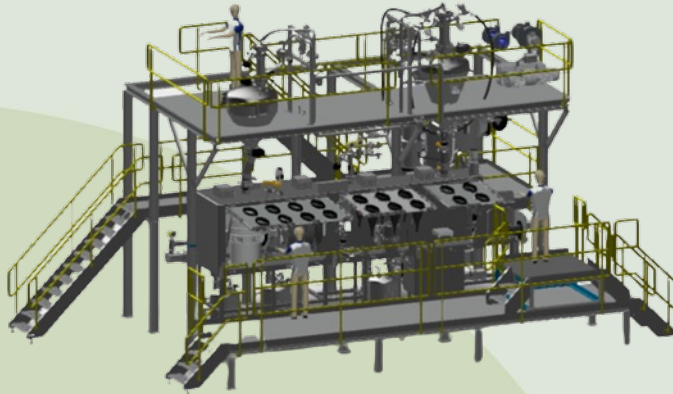
DER industrialisation centre equipment -

- HPMS reactor
- Powder processing (sieving, milling, blending)
- Pellet press
- Axial aligning press
- Inert sintering system
- Transverse aligning press
- EDM
- Grinding



# POWDER PROCESSING LINE

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Mobile PTS system for moving powder between processes





# PRESSING AND SINTERING

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Aligning Press



Sintering Furnace

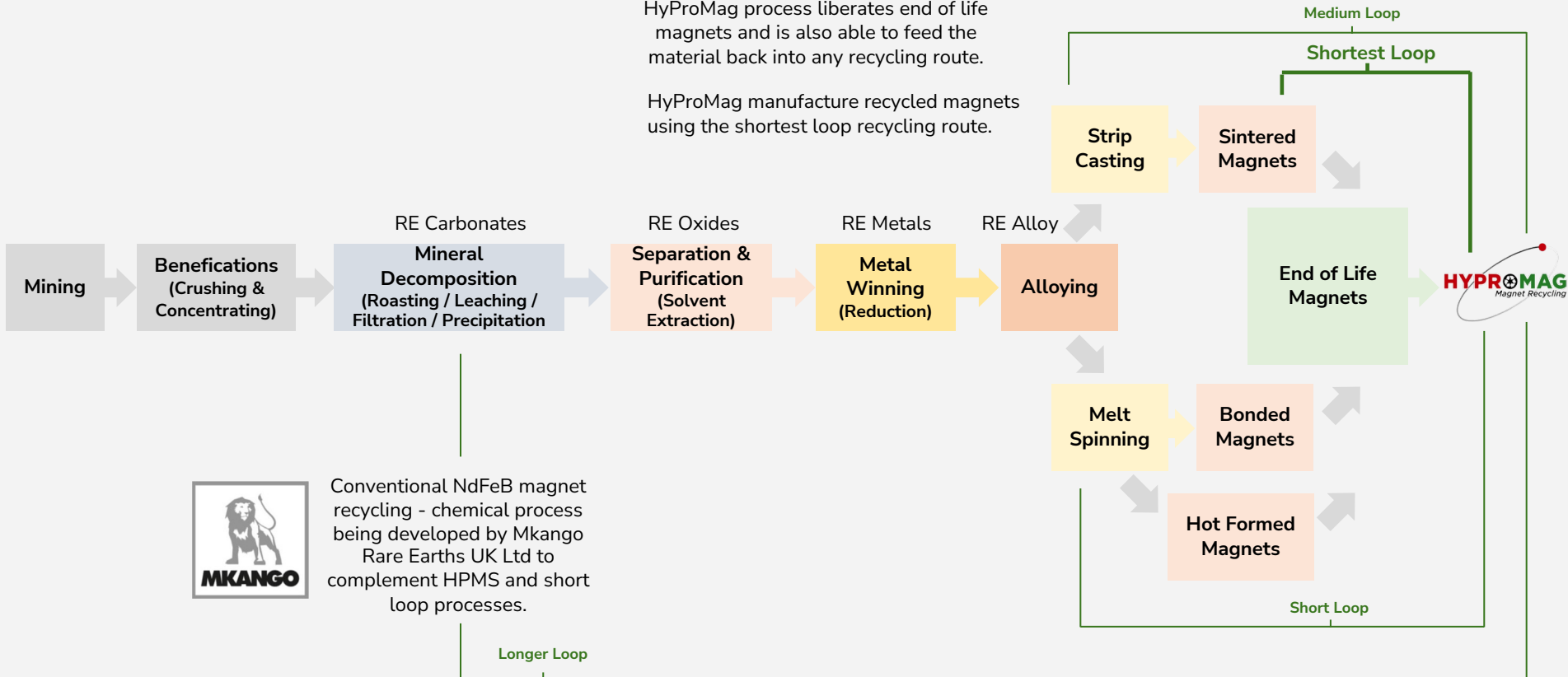




# MKANGO DEVELOPING CHEMICAL PROCESS

HyProMag process liberates end of life magnets and is also able to feed the material back into any recycling route.

HyProMag manufacture recycled magnets using the shortest loop recycling route.

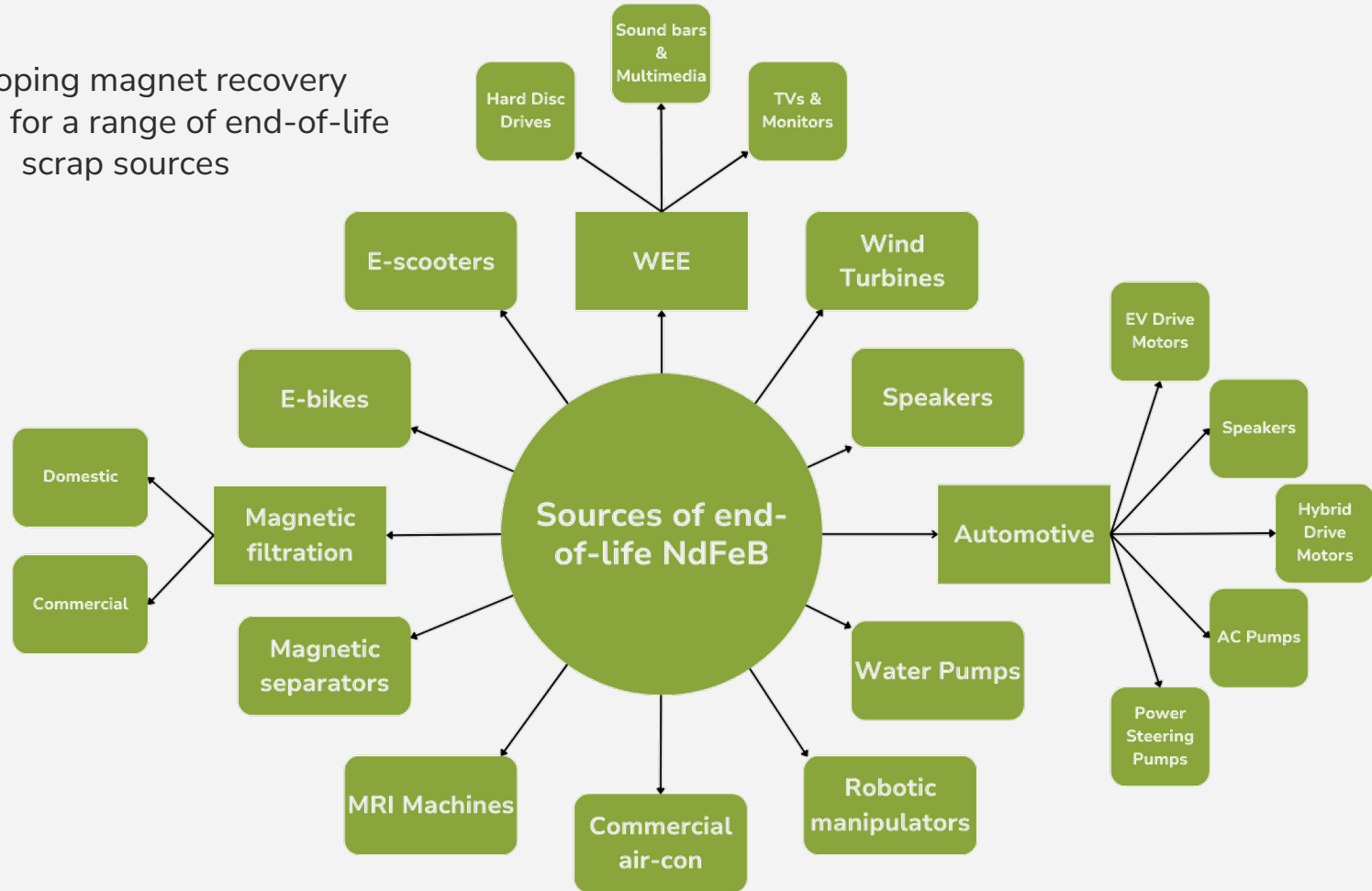


Conventional NdFeB magnet recycling - chemical process being developed by Mkango Rare Earths UK Ltd to complement HPMS and short loop processes.

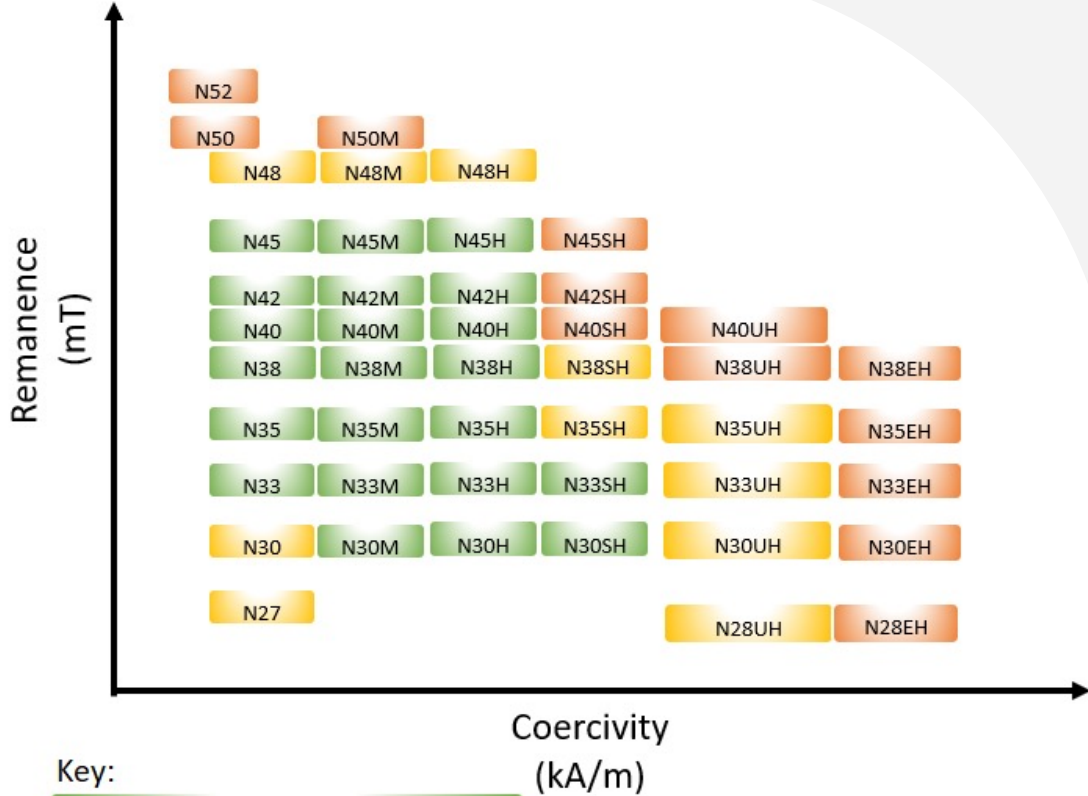


# INPUTS

Developing magnet recovery solutions for a range of end-of-life scrap sources



# OUTPUTS



Key:

Current manufacturing capability

Expected manufacturing capability soon

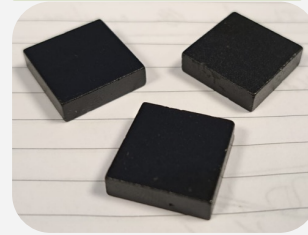
Further research being undertaken

Sintered NdFeB magnet and alloy products with low carbon footprint

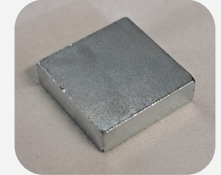
Epoxy coated motor magnets



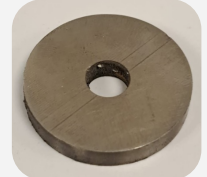
Epoxy coated magnets



Zinc coated magnet



Uncoated loudspeaker magnet







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## RaRE – RARE EARTH RECYCLING FOR E- MACHINES

- RaRE will establish an end to end supply chain for recycled rare-earth ancillary motors. Building on work completed at the University of Birmingham to devise a method to extract magnets from waste electronics the process will be scaled and the material re-processed back into new magnetic materials at pilot scale by HyProMag to demonstrate the quality of material which can be produced in terms of its magnetic behaviour, mechanical performance and corrosion resistance which are key to the end user application.
- The recycled magnets will be built into an ancillary electric motor designed by Advanced Electric Machines Research to a Bentley Motors specification and focused on reducing the overall complexity of electrical systems in electric vehicles and designed with recycling in mind. This will be the first time that such a recycled motor will have been demonstrated. Unipart will take this motor design and use it as the core focus for the design of a flexible volume motor assembly line suitable for production volumes of 100,000 units p.a.





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## REAP - RARE EARTH EXTRACTION FROM AUDIO PRODUCTS

- REAP will assess the recycling potential for NdFeB magnets contained in loudspeaker scrap from the automotive and flat screen TV market. The project will build upon previous work using the HPMS (Hydrogen Processing of Magnet Scrap) route which has been used to liberate and to reprocess magnets from computer hard disk drives. Current lab scale recycling technology at the University of Birmingham has proven that the patented HPMS process has the ability to liberate NdFeB alloy powder from hard disk drive scrap that has been through a simple pre processing step.
- For this technology to become commercially viable multiple scrap sources from varied sectors must be utilised, therefore alternative material feeds must be evaluated. This project is focussed on scrap found in audio applications using feeds that EMR already have access to such as automotive speakers and flat panel TV speakers.





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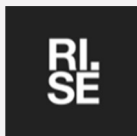
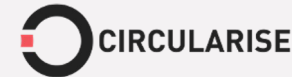


# SCREAM

SECURING CRITICAL RARE EARTH  
MAGNETS FOR THE UK

- The aim of SCREAM is to provide a UK based supply of critical rare earth materials by recycling magnets from end of life scrap. The SCREAM consortium will demonstrate two innovative paths to introduce scrap material back into the rare earth supply chain. The first is to scale up a process developed at the University of Birmingham, "Hydrogen Processing of Magnetic Scrap" from automotive, robotic, separator, loudspeaker scrap streams. The second is to produce a mixed rare earth carbonate for the rare earth supply chain. HyProMag will scale this process to develop magnets that are different grades for a range of applications.
- Bowers and Wilkins, GKN and JLR will assess the suitability of the magnets for a range of products, and calculate the environmental footprint for production of these materials. The output of the project will be motors, loudspeakers and holding magnet applications containing recycled magnets.





- REEsilience project aims to build a more resilient and sustainable supply chain for rare earth magnetic materials and products in Europe and will create new market opportunities for critical raw materials more sustainably produced in the continent.
- The REEsilience project partners will categorise Rare Earth Elements by geographic locations, quantities, chemical composition, ethical and sustainable indicators, ramp-up scenarios, and pricing, considering all value streams from virgin to secondary material to achieve the goal. The project will also build a production system that ensures a more resilient and sustainable supply chain for Rare Earth materials and magnets for the e-mobility, renewable energy and other strategic sectors in Europe with fewer dependencies on non- European economies.





# NEAR TERM PRODUCTION PIPELINE



## HyProMag Ltd / University of Birmingham (UoB)

- Developing demonstration scale plant at Tyseley Energy Park based on pilot plant at UoB
- Minimum capacity 100tpa NdFeB
- £4.3m project 100% funded by Driving the Electric Revolution
- Commissioning targeted 2023



## HyProMag GmbH

- Development of plant in Baden-Württemberg state, Germany, based on Tyseley demo plant - minimum capacity 100tpa NdFeB
- €6.1m project with 60% funded by European Regional Development Fund (ERDF) and Ministry of Economic Affairs, Labour and Tourism Baden-Württemberg
- Commissioning targeted 2024



## Mkango Rare Earths UK

- Developing pilot plant for recycling via chemical route at Tyseley Energy Park
- Mkango project budget of £1.1m with 70% funded by Driving the Electric Revolution
- Commissioning targeted 2023



## Maginito / CoTec

- Co-operation agreement to develop rare earth processing technologies in United States
- Scoping studies underway to determine optimal sites and to evaluate scope of developments
- Scope may include recycling, chemical processing & production of alloys & magnets



# THANK YOU

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To discuss magnet scrap solutions and purchasing, magnet and other product sales please contact [magnets@hypromag.com](mailto:magnets@hypromag.com)

To discuss collaboration and consultation please contact [technical@hypromag.com](mailto:technical@hypromag.com)



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