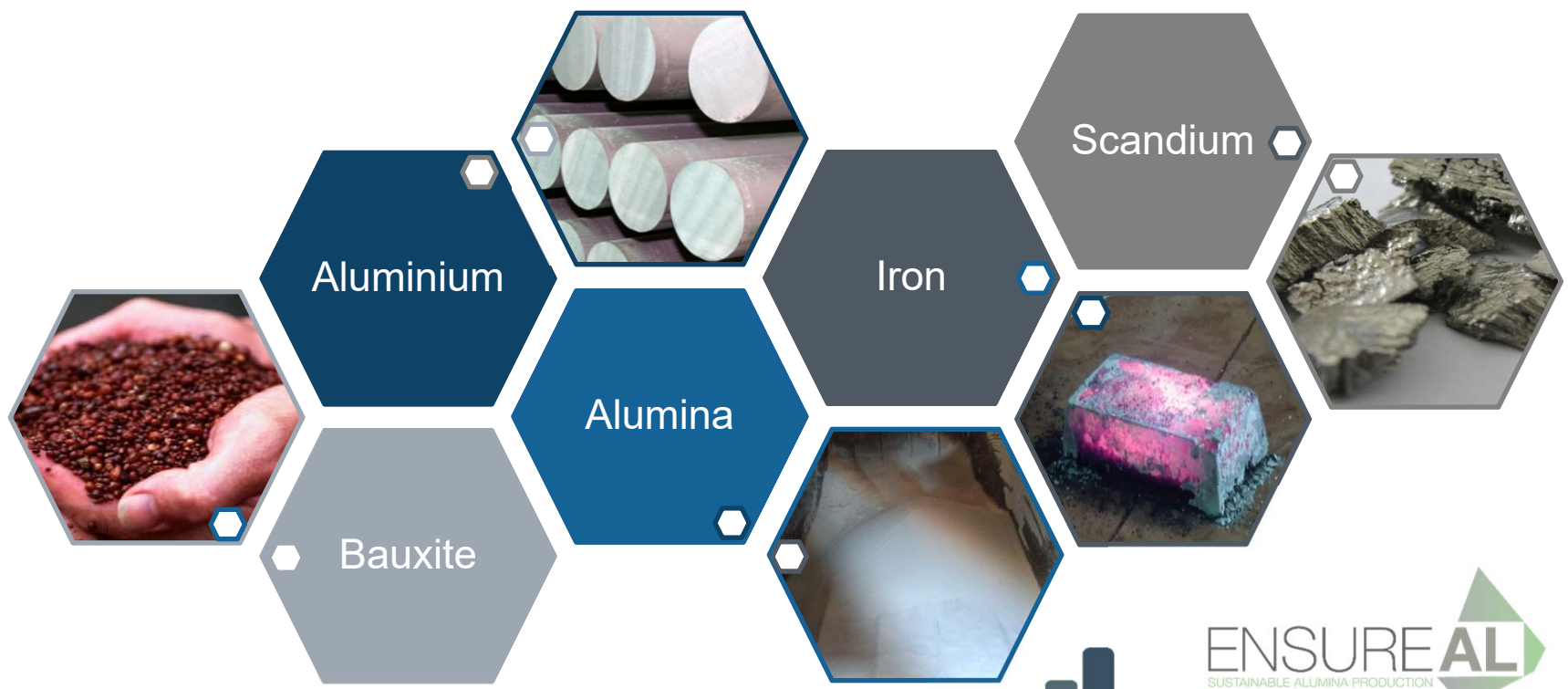


# RESEARCH ACTIVITIES IN RESIDUE VALORIZATION



# The ENEXAL BR Treatment Process

- 2012: Electric Arc Furnace and Melt Fiberizing unit installed in AoG Pilot Plant
- During a two-year long experimental campaigns treated more than **30 t of BR**
- **More than 5 t of Pig Iron** produced and tested in secondary steel production
- **High Quality mineral wool product** produced from the slag (zero waste process)

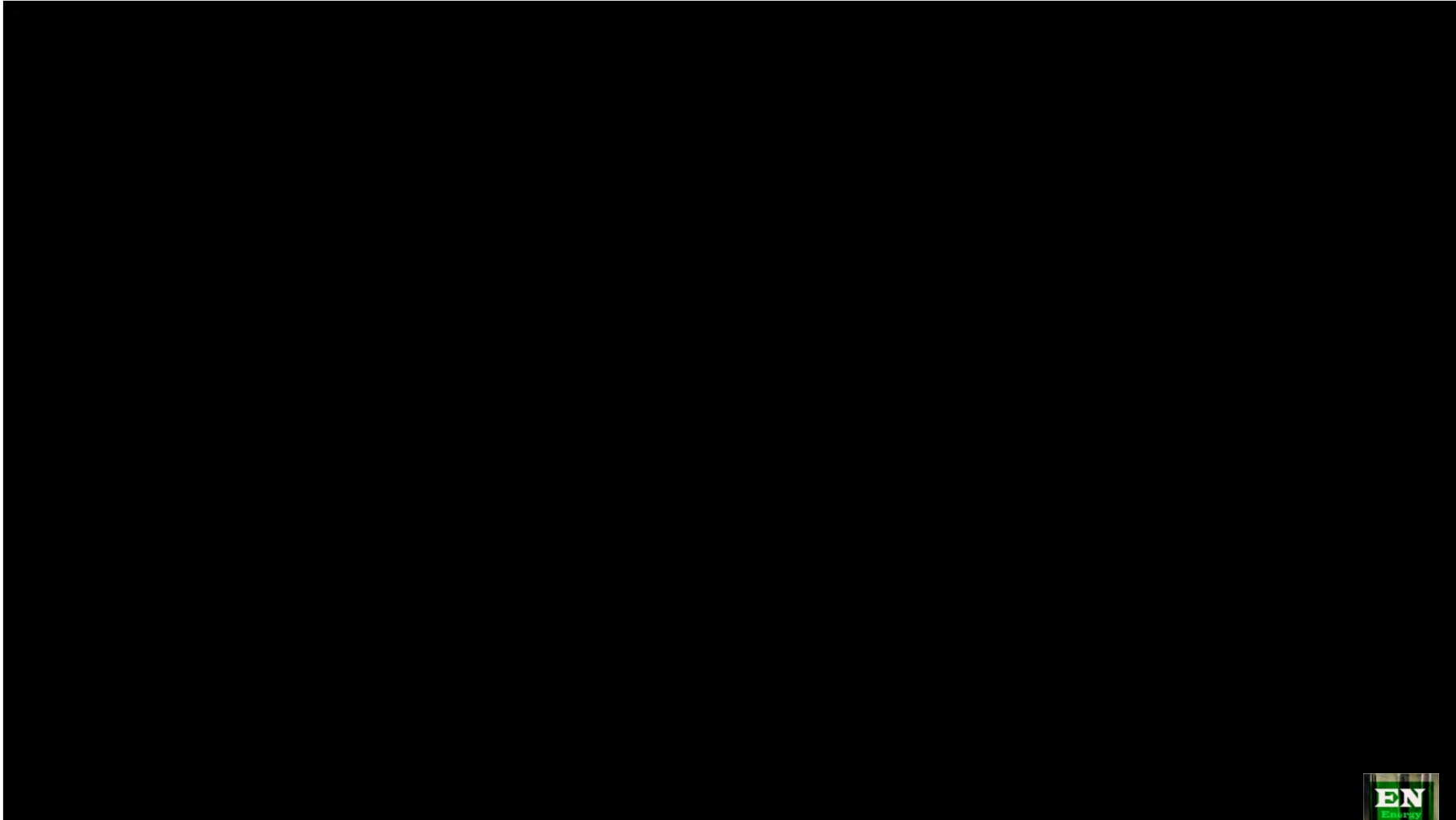




# Activities for Residue Valorization



METALLURGY BUSINESS UNIT



ENEXAL AoG Pilot Plant



# Conclusions from ENEXAL

- ✓ The revenues of pig iron and mineral wool could match and exceed the operational cost of the unit
- ✗ Pig iron revenues alone would only cover up to 35% of operational costs
- ✗ The mineral wool market is limited in size (60,000 -100,000 t) and could not absorb the mineral wool that would be produced from a full BR processing (>300,000 t of slag)

## NEXT STEPS

- Produce more products to achieve a viable process



RESOURCES IN EUROPE

Deposit	Occurrence	Project
●	★	▲
○	☆	△
□	✦	▽

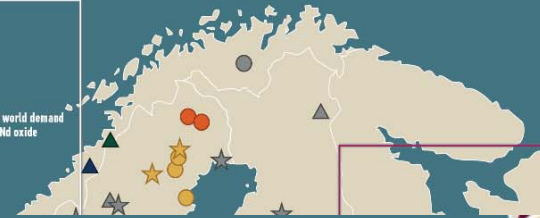


NORRA KÄRR DEPOSIT, SWEDEN



TASMAN METALS LTD

Unique HREE/LREE % ratio: 49/51  
 23.1% of TREO (0.44% TREO grade)  
 40 Year Mine Life  
 No radioactivity  
 Simple magnetic concentration  
**Potential to supply 14% of the projected world demand in Dy oxide, 7% in Tb oxide and 2.2% of Nd oxide**  
 Exploitable Zr content  
 Geological Setting: Peralkaline nepheline  
 Major REE mineral: Euxialite  
 Status: Mining Licence



# BAUXITE RESIDUE, GREECE

## ALUMINIUM OF GREECE



**Industrial by-product of primary aluminium industry**  
 More than 700,000 t produced annually in Greece and stored near the plant  
 0.14% TREO including Sc (Potential global Sc resource)

The amount of REE present in the Bauxite Residue produced annually in Greece, amounts to nearly the 10% of the annual European demand



deposits (Greenland,  
 in analysis performed  
 produced for 5 samples  
 mal, 1 placer deposit)



## THE KVANEFJELD DEMONSTRATION LINE:

### KVANEFJELD SAMPLE

GME, GREENLAND



### BENEFICIATION PI

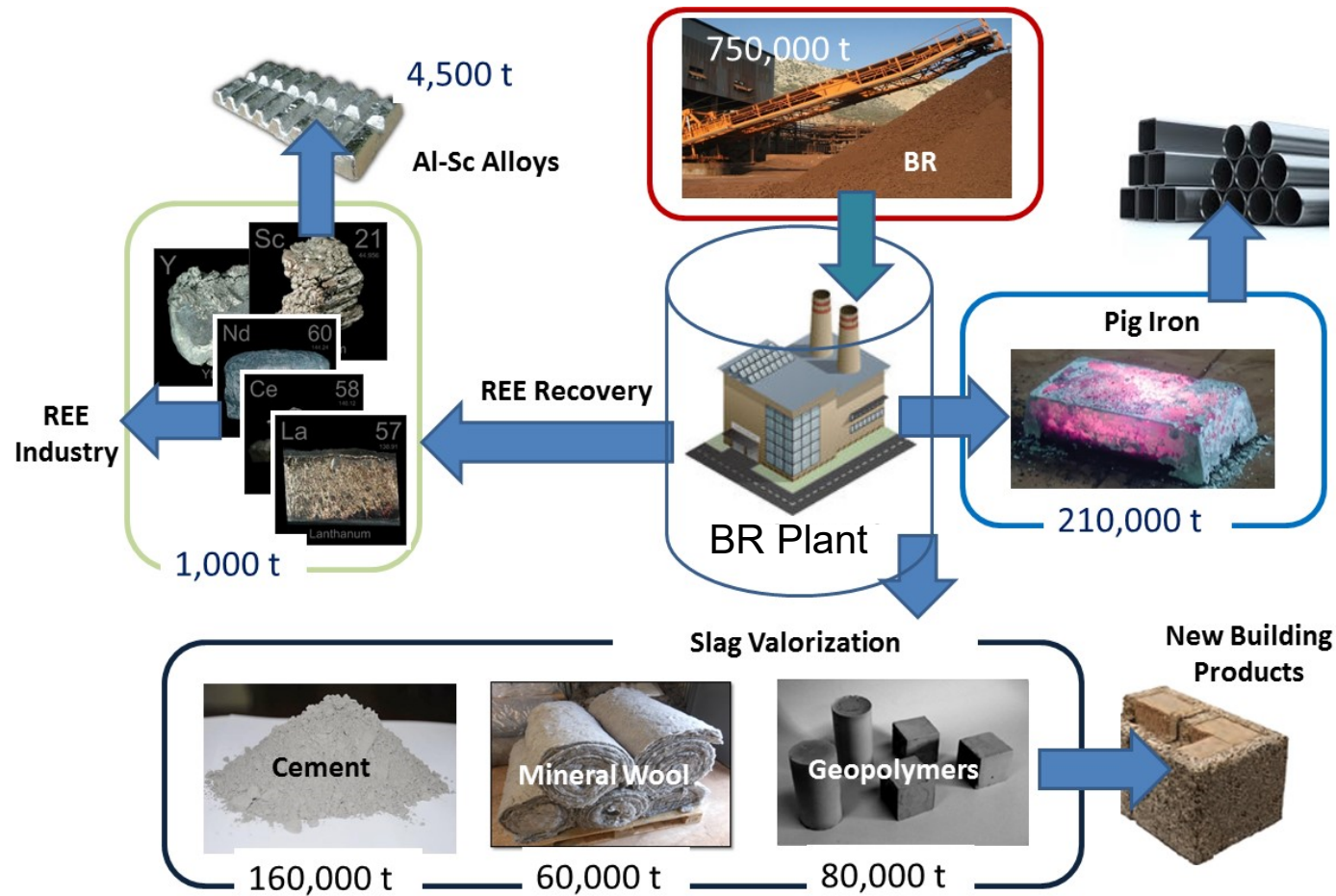
GTK, FINLAND



FUTURUS

**TREASURE FROM WASTE**

## Mud2Metal: Holistic Valorization of BR



- ✓ 100% utilization of the BR stream
- ✓ Economically Viable
- ✓ Near Zero-Waste
- ✓ Industrial Symbiosis





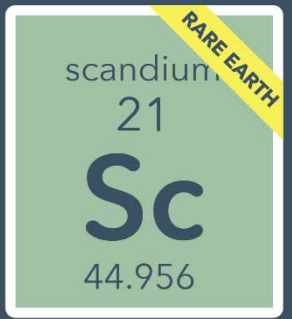
# Activities for Residue Valorization



METALLURGY BUSINESS UNIT



what is scandium?



H2020 2016-2020  
Coordinator AoG



## Activities for Residue Valorization

Sc is an “exotic” REE produced in minor quantities –not traded as a commodity

Sc can ‘substitute’ Y in many material applications achieving superior results:

- In SOFC Sc-stabilized Zirconia has lowered operational temperatures leading to commercialization of the technology
- Sc drastically improves Aluminium alloy properties increasing strength, corrosion resistance, allowing welding and others

The Al-Sc-Mg alloy powder is used in additive layer manufacturing (3D printing) by AIRBUS



APWorks, 2 December 2015

“We did produce 122 out of the 162 parts on our M400 out of SCALMALLOY®.

The partition weighs a massive 45% less than current Airbus A320 partition designs”





# Activities for Residue Valorization



Pilot plant unit to operate in AoG in mid 2019

Bauxite Residues  
TiO2 Pigment  
Acid Wastes

mg/kg

**EXTRACTING**

Sc from waste

g/kg

**REFINING**

Sc concentrates

**PRODUCING**

Sc Metal

Sc<sub>2</sub>O<sub>3</sub>

LASERS:  
YSG GARNETS

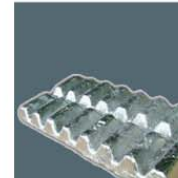


II-VI

SSZ LAYER  
SOLID OXIDE  
FUEL CELLS



AL-SC ALLOY



KBM AFFILIPS  
MASTER ALLOYS

SCALMALLOY  
3D PRINTING



AIRBUS



## SCALE:

Production of Sc compounds & Sc-Al alloys from European metallurgical by-products



*Development of new methodologies  
for InDustrial CO<sub>2</sub>-freE steel  
pRoduction by electroWINning*

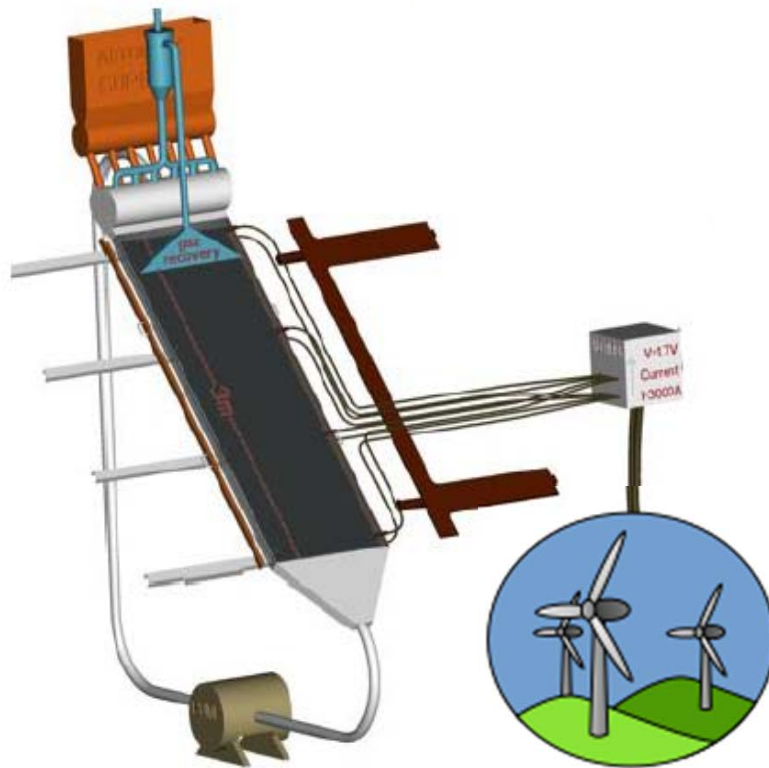
Upscaling ULCOWIN technology for CO<sub>2</sub>-Free Steel production



SPIRE, 2017-2022, Coordinator ArceloMittal



Development of new methodologies  
for InDustrial CO2-free steel  
pRoduction by electroWINning



- Iron metal electrolytically produced from iron oxide without direct involvement of carbon or fossil fuels.
- Powered by RES - cell with expert system to operate non-continuous according to RES real time availability
- Ambient temperature operation
- Soda as electrolyte
- Study for use low grade/alternative iron ores like Bauxite residue and Bauxite ore



ENSUREAL: Integrated cross-sectorial approach for environmentally sustainable and resource-efficient alumina production

Revisit the 'Pedersen' process for extracting Al and Fe from lower grade bauxites and BR

Pilot Scale tests at AoG



SPIRE 2017-2021,  
Coordinator SINTEF



# Activities for Residue Valorization



+



+



Pig iron



Leachable slag



Alumina



Residue



Soil enhancement



Rare earths



# Activities for Residue Valorization



METALLURGY BUSINESS UNIT



H2020 2018-2022, Coordinator AoG

RemovAL overcomes the barriers of economic viability by pooling together and integrating proposed stand-alone solutions, while adhering to the following principles:



treat waste with waste



recover valuable critical metals



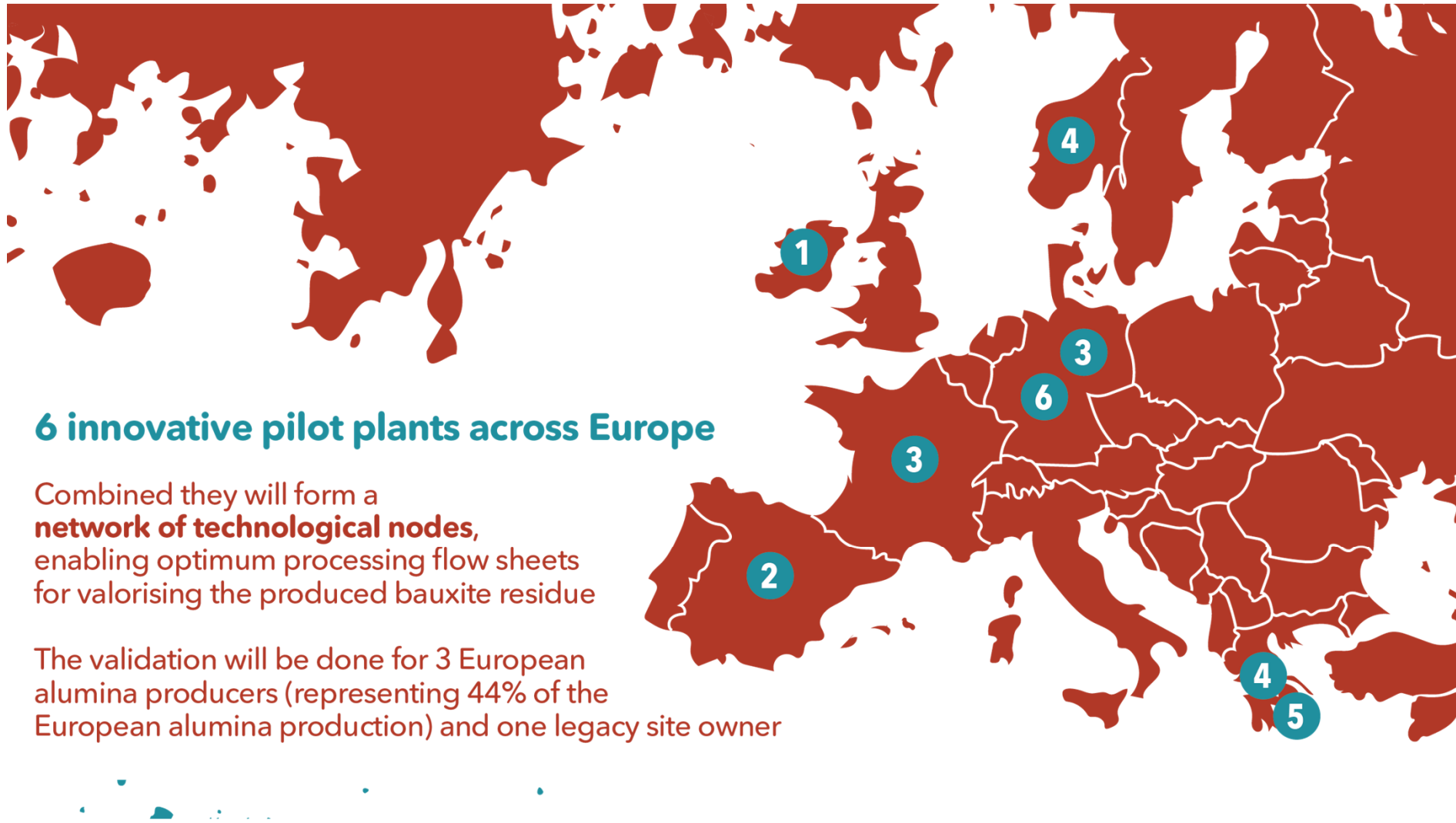
develop marketable products



customise the solution to the industrial ecosystem of each alumina plant

**near zero-waste processing, near break-even flowsheets**

RemovAL builds on the results of **9 recent research projects**



## 6 innovative pilot plants across Europe

Combined they will form a **network of technological nodes**, enabling optimum processing flow sheets for valorising the produced bauxite residue

The validation will be done for 3 European alumina producers (representing 44% of the European alumina production) and one legacy site owner

RemovAL is a consortium of 27 partners from 12 European countries





1

## de-alkalization

Demonstrate at pilot scale the de-alkalization technology to remove alkali content from bauxite residue at levels below 0.5% wt, making it suitable for various applications

At least 40 t of bauxite residue will be processed by AAL at a mobile pilot plant in IRELAND



2

Demonstrate the use of processed bauxite residue as green soil stabilizer for civil works applications, though the stabilization of bauxite residue with other industrial by products

At least 800 t of bauxite residue will be processed and used by ACCIONA as a raw material for the construction of a road in Spain

## green soil stabilizer

Demonstrate at pilot scale the production of lightweight aggregates and high performance binders, through different thermal treatments of bauxite residue

## lightweight aggregates & high performance binders

At least 10 t of bauxite residue will be processed in the RIO TINTO Pilot plant in France



3



5

## microwave furnace

Demonstrate at a prototype microwave furnace the production of metallic iron from processing bauxite residue with other industrial by-products

At least 250 kg of Bauxite Residue will be processed in CEINMAT's mobile prototype plant in both Spain and Greece

Demonstrate at pilot scale the production of ferro-silicon alloy from Electric Arc Furnace (EAF) co-processing of bauxite residue with other industrial by-products, like Spent Pot Lining (SPL) from aluminium primary production

## ferro-silicon alloy

At least 50 t of Bauxite Residue will be processed in the AoG Pilot plant in Greece and in the ELKEM pilot plant in Norway



4



6

## hydrometallurgy

Demonstrate the production of REE concentrate, Ga concentrate, alumina/soda solution and rutile concentrate from the hydrometallurgical processing of engineered slags/sinters produced in RemovAL pyrometallurgical pilot plants. Ga is co-extracted both from the slag and the Bayer liquor

At least 500 kg of slag and 100 lt of Bayer liquor will be processed at RWTH/MEAB pilot plant in Germany



# Bauxite Residue

## A future valuable mineral resource



*The research leading to these results has received funding from the European Union Seventh Framework Programme and H2020*