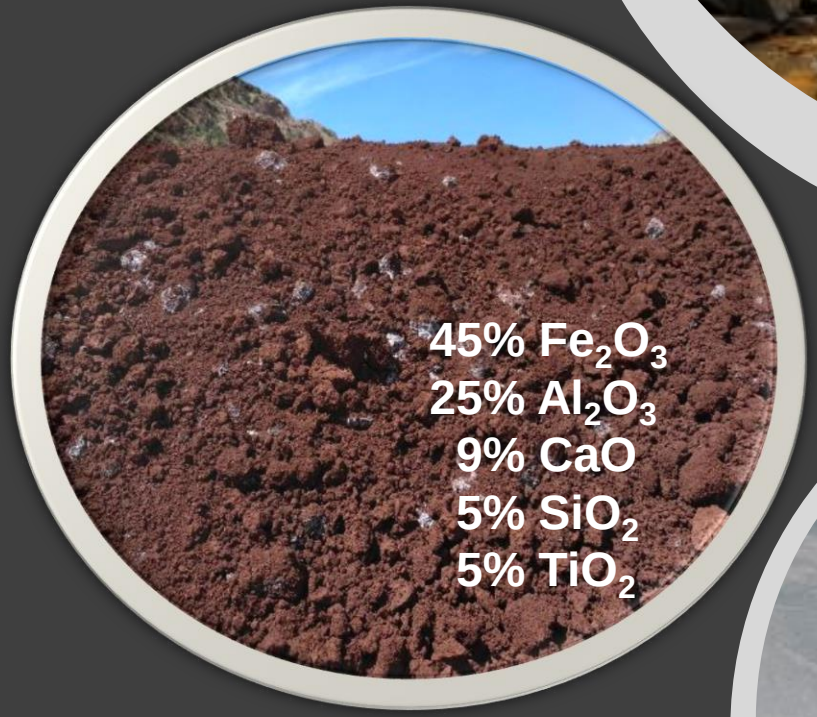
The RemovAL case study: Boosting the re-use of Bauxite Resiude

EFTYMIOS BALOMENOS,

MYTILINEOS, METALLURGY BU

Bauxite Residue [BR]

- Bauxite Residue is produced during the production of alumina from Bauxite in the Bayer process
- The bauxite ore is digested under high temperature and pressure in alkaline solution to selectively leach alumina content.
- The undissolved part of the ore forms the Bauxite Residue by-product.
- Depending on the initial bauxite ore, for each t of alumina 0.8-1.5 t of BR are produced.



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Bauxite Residue Handling Practices in EU

Strong trend to produce BR with:

- **lower moisture**
- **lower pH value,**

termed "BAT-treated Bauxite Residues"

These "BAT-treated Bauxite Residues" are easier to rehabilitate and allows greater opportunities for re-use.

- **Disposal as slurry/ pulp [red mud] in tailings damns**
- Older practice. Today most plants use deep thickeners and/or dry stacking techniques to reduce moistute content
- 40 – 55% Moisture.

- **Mud Farming**
- The pulp is dewatered and compacted in the storage site
- Final moisture achieved on site 25-28%.

- **Filterpressing**
- The pulp is dewatered in high pressure filters and is transported to storage area as a filter cake.
- Moisture 24 – 28 %
- Can reach 18-20% with weathering

BAT PRACTICES IN EU

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In the EWC 'red mud' is listed under two codes only:

- EWC 01 03 09 (MNH – Mirrored Non-Hazardous): "red mud from alumina production other than the wastes mentioned in 01 03 10";
- EWC 01 03 10* (MH – Mirrored Hazardous) code: "red mud from alumina production containing hazardous substances other than the wastes mentioned in 01 03 07

Bauxite Residue Handling Practices in EU

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These "BAT-treated Bauxite Residues" are easier to rehabilitate and allows greater opportunities for re-use.

- *BAT BR refers **to a solid** filter cake/paste obtained after pressure filtration/farming of the red mud slurry;*
- *BAT BR normally has a significantly **lower soda content** than the corresponding unprocessed red mud slurry;*
- *BAT BR is **stored in a completely different way** to the red mud slurry (and with significant less risk);*
- *BAT BR transport **is feasible by land or sea.***

Hence, the existing EWC assigned to the bauxite residue slurry (i.e. red mud) that was historically produced by wet disposal methods, does not apply to the BAT BR presented in these slides.

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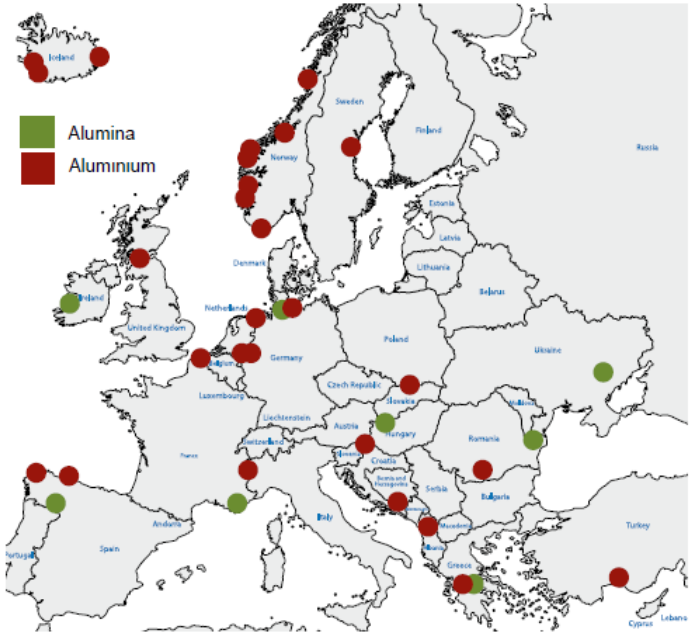
European BR as a Resource

Country	Location	Total Alumina Annual Capacity (kt) (source EA)	Estimated BR (kt)
Greece (AoG)	**Viotia**	**850**	**750**
Ireland (AAL-RUSAL)	**Aughinish**	**1,990**	**1,800**
Romania (ALUM)	**Tulcea**	**500**	**450**
France (ALTEO)	Gardanne	635	570
Germany (AOS)	Stade	1,050	950
Spain (ALCOA)	San Ciprian	1,500	1,350
Turkey	Seydisehir Alumina	490	440
Bosnia Herzegovina	Birac	600	540
	TOTAL	**7,615**	**6,850**



- **Fe_2O_3**: With an average iron oxide content of 40 wt%, it can be considered to be the equivalent of 3.4 Mt of iron ore available in Europe.
- **Al_2O_3:** With an average alumina content of 20 wt% and an inherent clay-like behaviour, BR is a valuable raw material for various building applications.
- **REE/Sc**: Extracting the REE from Mytilineos - Aluminium of Greece's annual BR production can meet approximately 10% of the European REE demand.
- **Ga**: Extracting gallium from both the BR and Bayer liquor from a single European alumina refinery Could amount to global levels of gallium production (annual world production 284 t in 2012).

AoG Vision for Red Mud

To remove the water content from the slurry so:

- ➢ It can be **safely deposited in-land** in full accordance with EC waste directives.
- ➢ It can be **easily transported** in other industrial facilities **for re-use.**

- 2006: Installation of 1st Filterpress .
- 2007: Pilot tests- Automation and improvements.
- 2008: Installation of 2nd Filterpress, storage site.
- 2009: Installation of 3rd and 4th Filterpress - gradual increase of operations.
- **2012 - today: 100% dry disposal of all bauxite residue produced from the alumina refinery.**

MYTILINEOS

ALUMINIUM OF GREECE

METALLURGY BUSINESS UNIT

Since 1991, AoG BR was been tested for use in

- **Cement Industry** (iron/alumina source in clinker)
- Iron production
- Brick/Tile Industry (substitution of clay)
- Geopolymer bricks
- Soil Remediation/ Vegetation cover
- Road Base Construction
- Landfill barrier / cover
- Backfilling of closed Mines

Examples of BR reuse tested in Greece:

1. Cement Industry (iron/alumina source in clinker)
2. Iron production (iron oxide source)
3. Brick/tile industry (subsitution of clay) cover
4. Geopolymer bricks
5. Soil remediation / vegetation
6. Landfill barrier/cover
7. Backlifilling of abandoned bauxite mines
8. Road base construction
9. REE/Sc extraction

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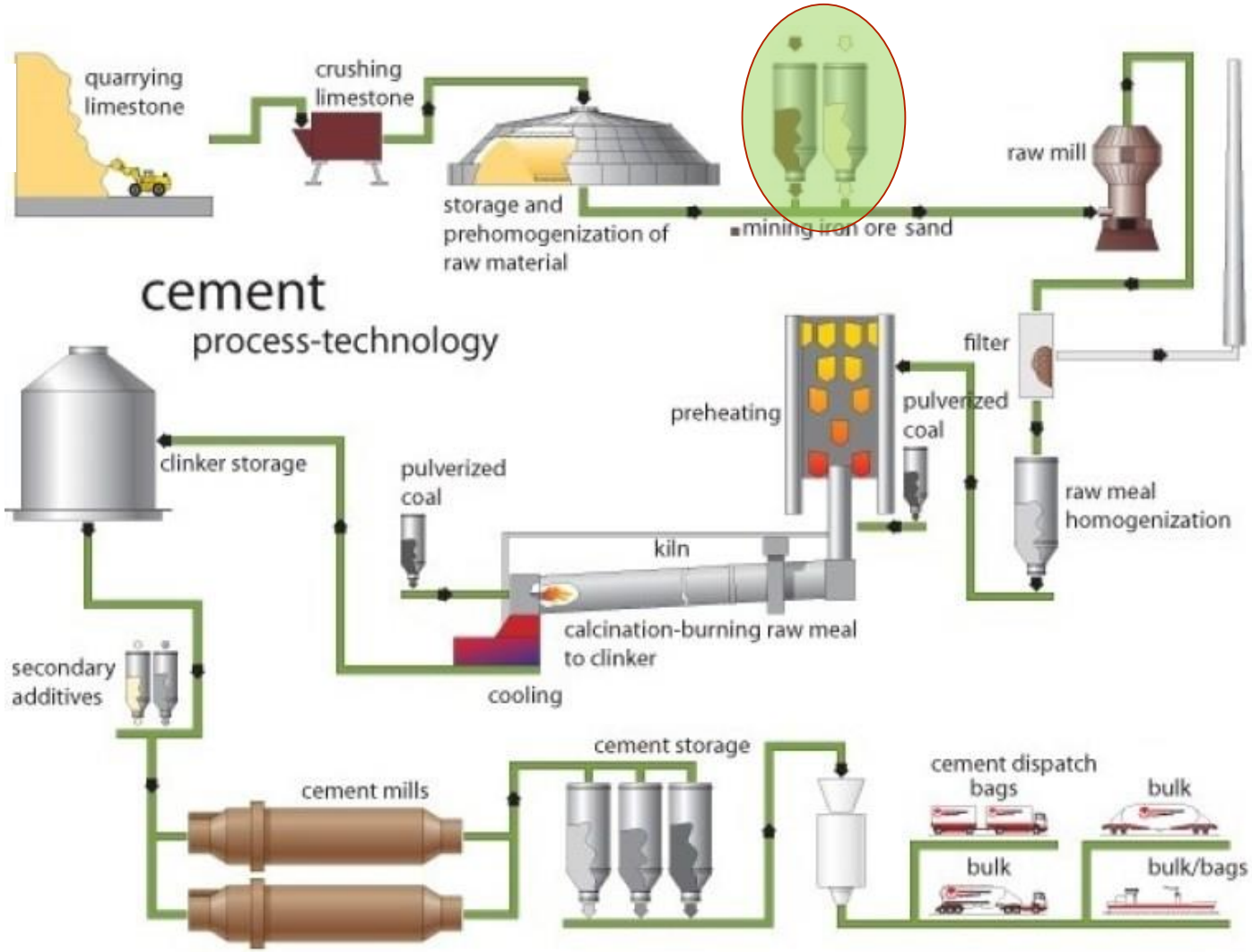
BR Utilization In OPC Production



- BR can substitute up to 5-10% of the cement raw material feed as iron and alumina sources.
- The installed production capacity of the Greek cement industry could utilize all 750,000 t of BR produced in AoG with a 5% substitution in the raw meal

BR use in OPC worldwide

The Mykolayiv alumina refinery in the **Ukraine** has supplied **250,000 t/y BR** to 10 cement plants in the Ukraine, Russia, Georgia, Moldova and Belarus **up to a distance of 1200 km.**

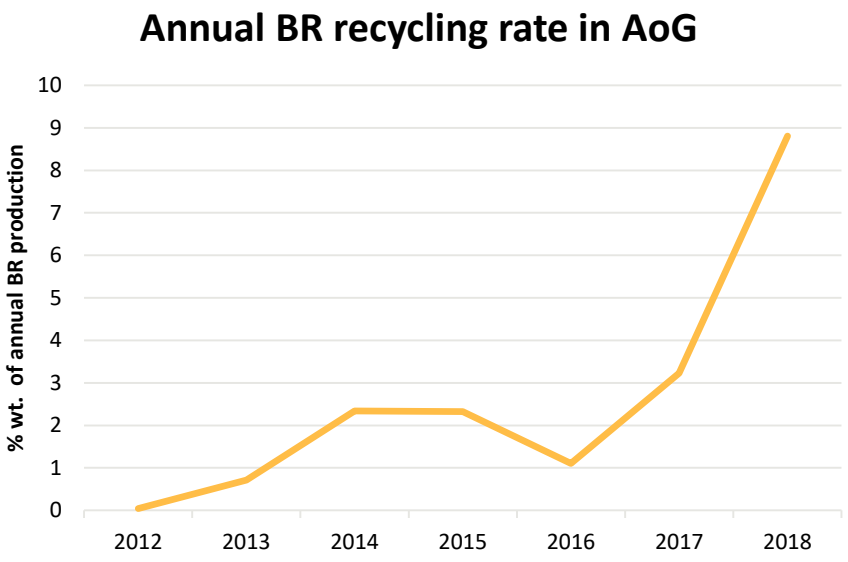
Experience from the Mykolayiv refinery confirms that

- BR does not cause complications in clinker manufacturing process,
- it does not require additional equipment,
- the cake is free flowing and no caking or bridging occurs when it is fed
- The increased content, up to 12-20 %, of aluminium oxide in the residue cake provides an increase in alite content in clinker by 1 – 2 %.

In **India** over 200,000 t/y of bauxite residue from the Belgaum (state of Karnataka) and Lanjigarh (state of Orissa) alumina plants are used in clinker production .

In **China** a cement plant was constructed adjacent to the Shandong alumina plant in 1965 and was expanded in 1985 to a production capacity of 1.1 million t/y.

Greek BR Use In OPC



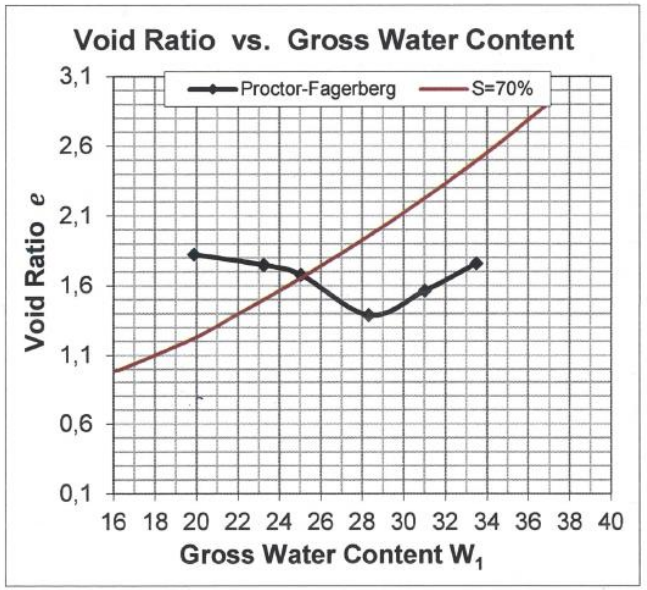
- Since the adoption of the filterpessing in AoG, BR recycling rates are increasing.
- 'Weathered' BR (~20% moisture) is transferred by ship to nearby cement plants
- **In 2018 BR was shipped for the first time outside of the Greece, to Cyprus**
- **Up till now AoG's BR bas been used at rates of 1.5 - 3% substitution in the clinker.**

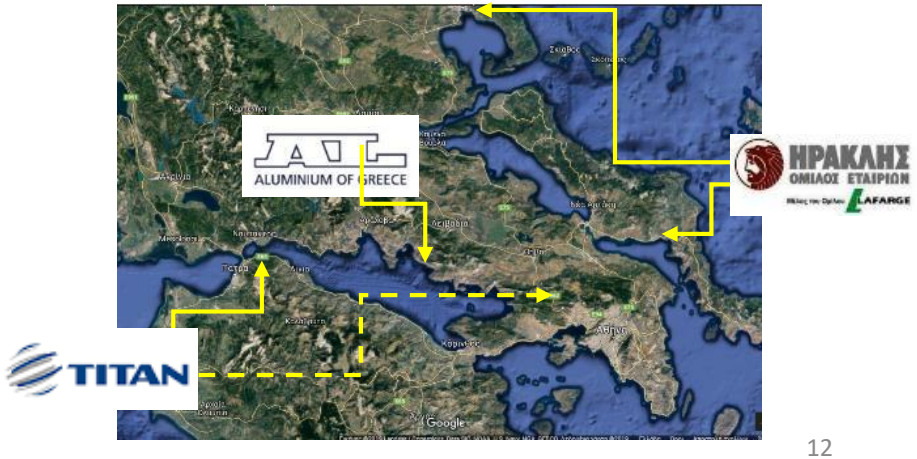
In 2018 Mytilineos recycled in total **85,000 t of BR** in 3 different cement plants in Greece and Cyprus

*In 2019 we will ship to -**at least** - 4 cement plants and exceed 100,000 t*

Transport of BR to cement plants

- Cement plants prefer BR as cheaper and iron (and sometimes) alumina raw material for OPC clinker. **There is no other incentive for cement plants to use BR.**
- **Bulk transport of weathered BR is feasible** (TML 25%)
- The BR is delivered/sold to the cement plant by '*raw material traders' t*hat have the appropriate licensing to perform waste transport operations in EU.
- So far we have loaded small vessels of up to **11,000 t** (usual is 3,000 t) and shipped to distances up to **1000 km.**
- BR unloading in commercial harbors is a problem.
- BR transport by road (trucks) is not economically viable.





Why not more ? – Key Barriers

Technical Barriers

Soda content, Cr content, moisture are the most common technical barriers, yet none of them is crucial.

Legislative Barriers

EWC code 01 03 09 = waste/non-hazardous

EC waste transport legislation is a complicated process requiring specific permits from all parties involved. Cross boarder transport even more complicated.
There is no classification for dry BR only for red mud.

Financial Barriers

Logistics is a key issue. Cement plants are willing to utilize BR only as long at is a cheaper alternative to other iron and alumina sources.

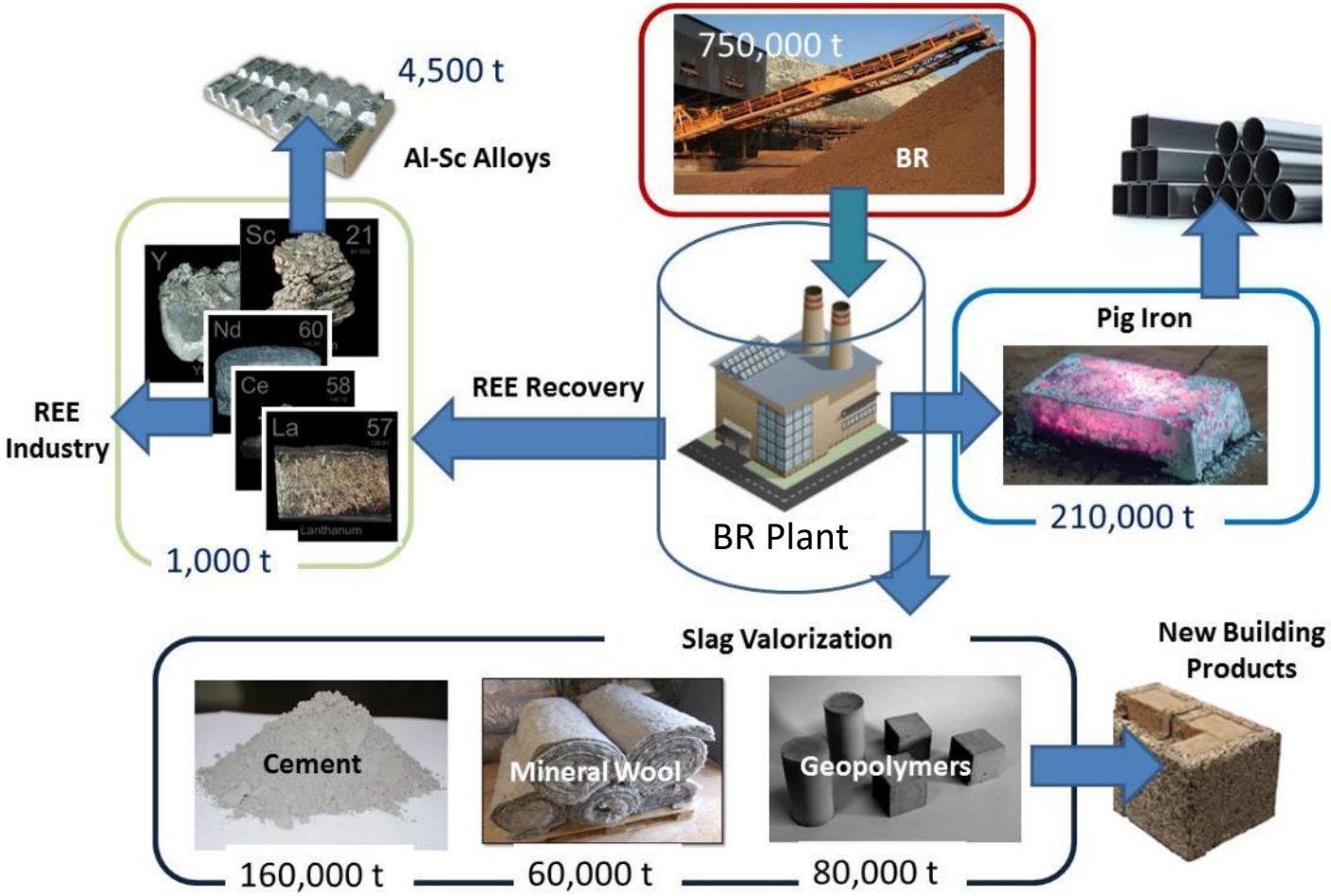
Social Barriers

Local Societies are always eager to protest against cement plants treating wastes 'in their backyard'.
BR handling during unloading and mill feeding is the biggest issue as any potential dusting of the BR would create significant protests by local societies.

Going beyond OPC raw meal

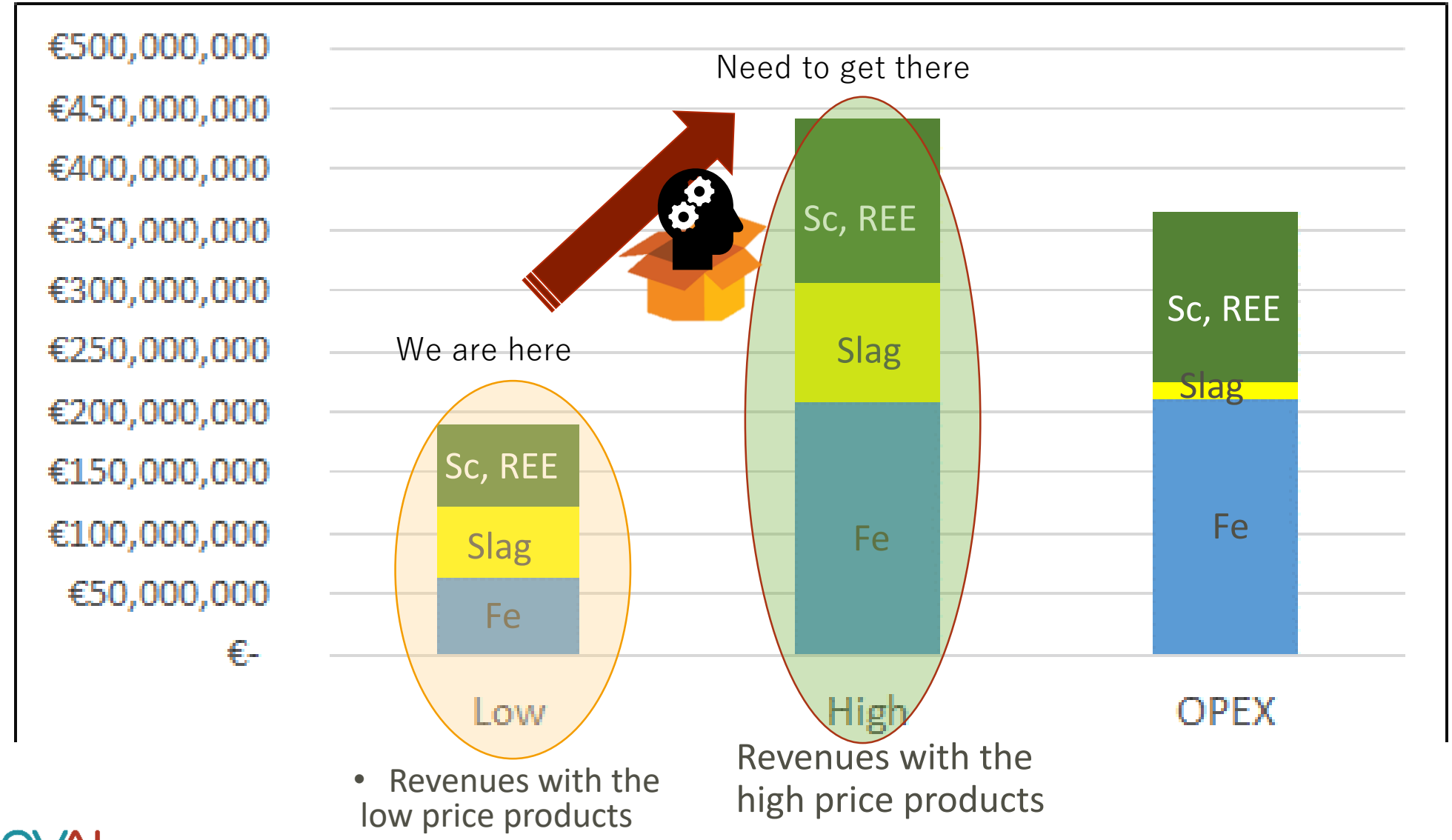
Mud2Metal: Holistic Valorization of BR

- The biggest challenge is to transform BR from **waste to product**
- **BR–Centric Processing**
- Targeting both Niche and bulk markets



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

Crude Economics



- Revenues with the low price products

Revenues with the high price products

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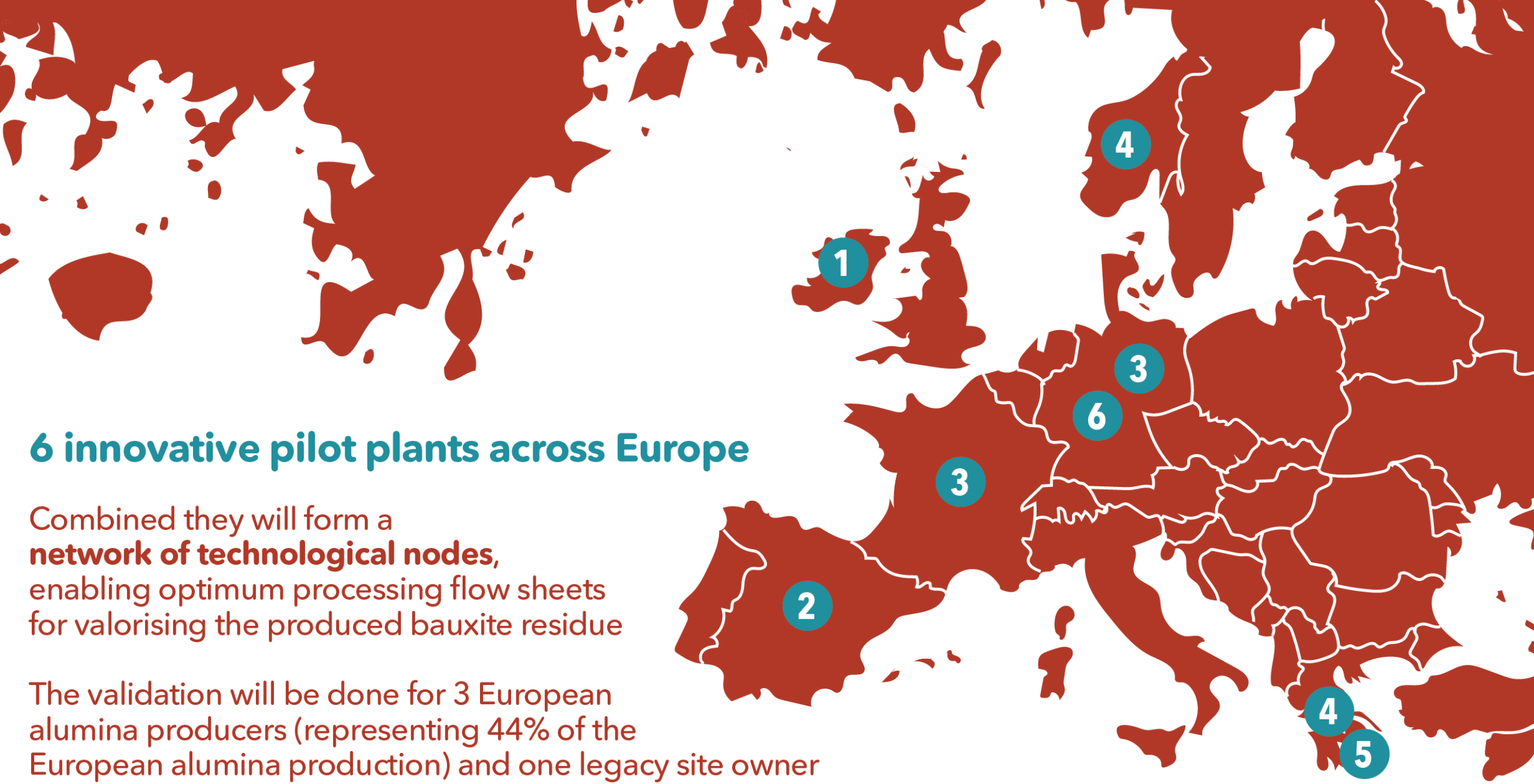
removing waste from alumina production

Removing the waste streams from the primary Aluminum production in Europe

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 ecostystem of each alumina plant

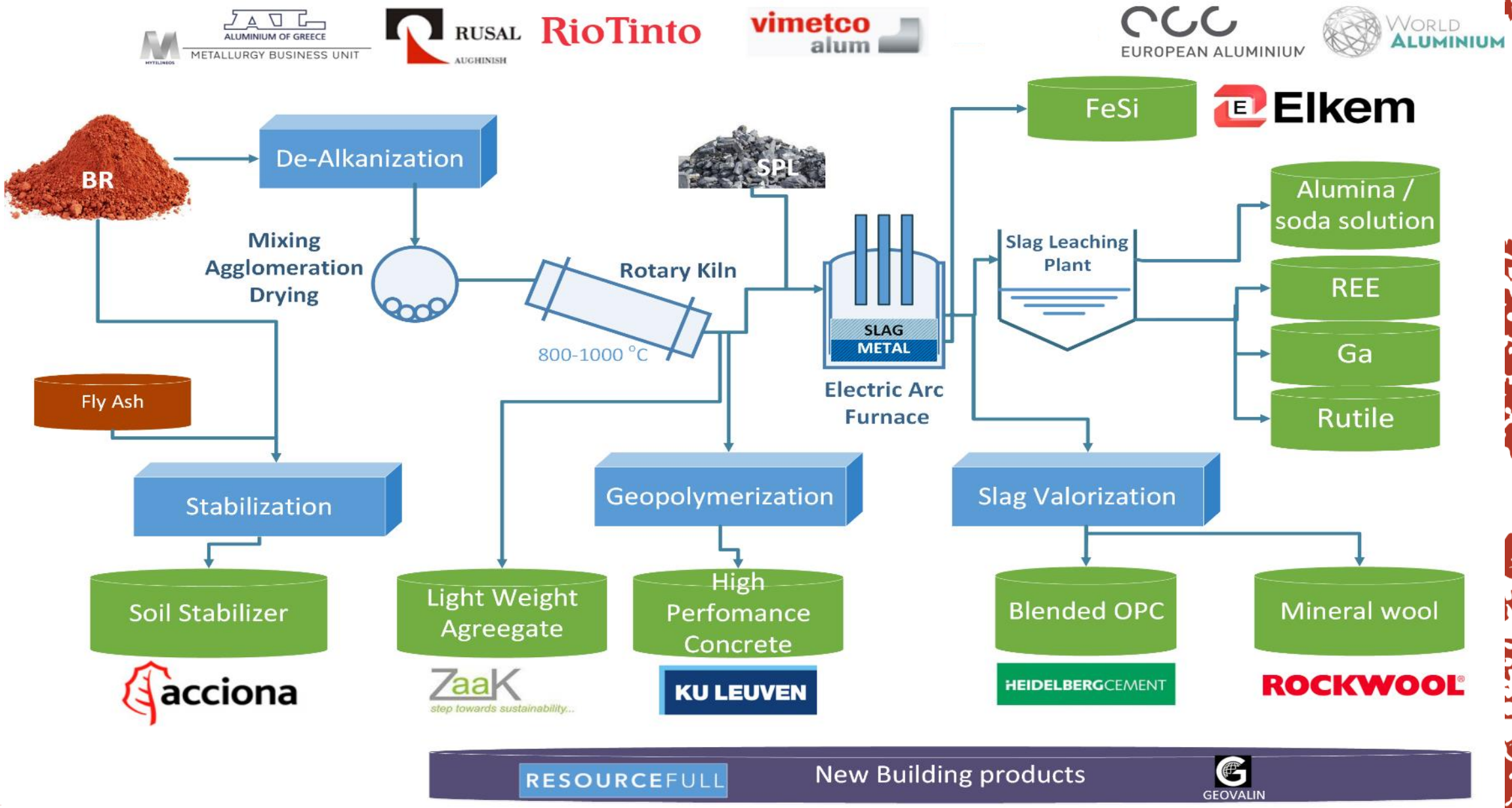
near zero-waste processing, near break-even flowsheets



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


ALUMINIUM OF GREECE
METALLURGY BUSINESS UNIT
RUSAL
AUGHINISH
RioTinto
vimetco alum
EUROPEAN ALUMINIUM
WORLD ALUMINIUM
FeSi
Elkem
BR
De-Alkanization
SPL
Mixing
Agglomeration
Drying
Rotary Kiln
800-1000 °C
SLAG
METAL
Electric Arc Furnace
Slag Leaching Plant
Alumina / soda solution
REE
Ga
Rutile
Fly Ash
Stabilization
Geopolymerization
Slag Valorization
Soil Stabilizer
Light Weight Agreegate
High Perfomance Concrete
Blended OPC
Mineral wool
acciona
ZaaK
step towards sustainability...
KU LEUVEN
HEIDELBERGCEMENT
ROCKWOOL
RESOURCEFULL
New Building products
GEOVALIN

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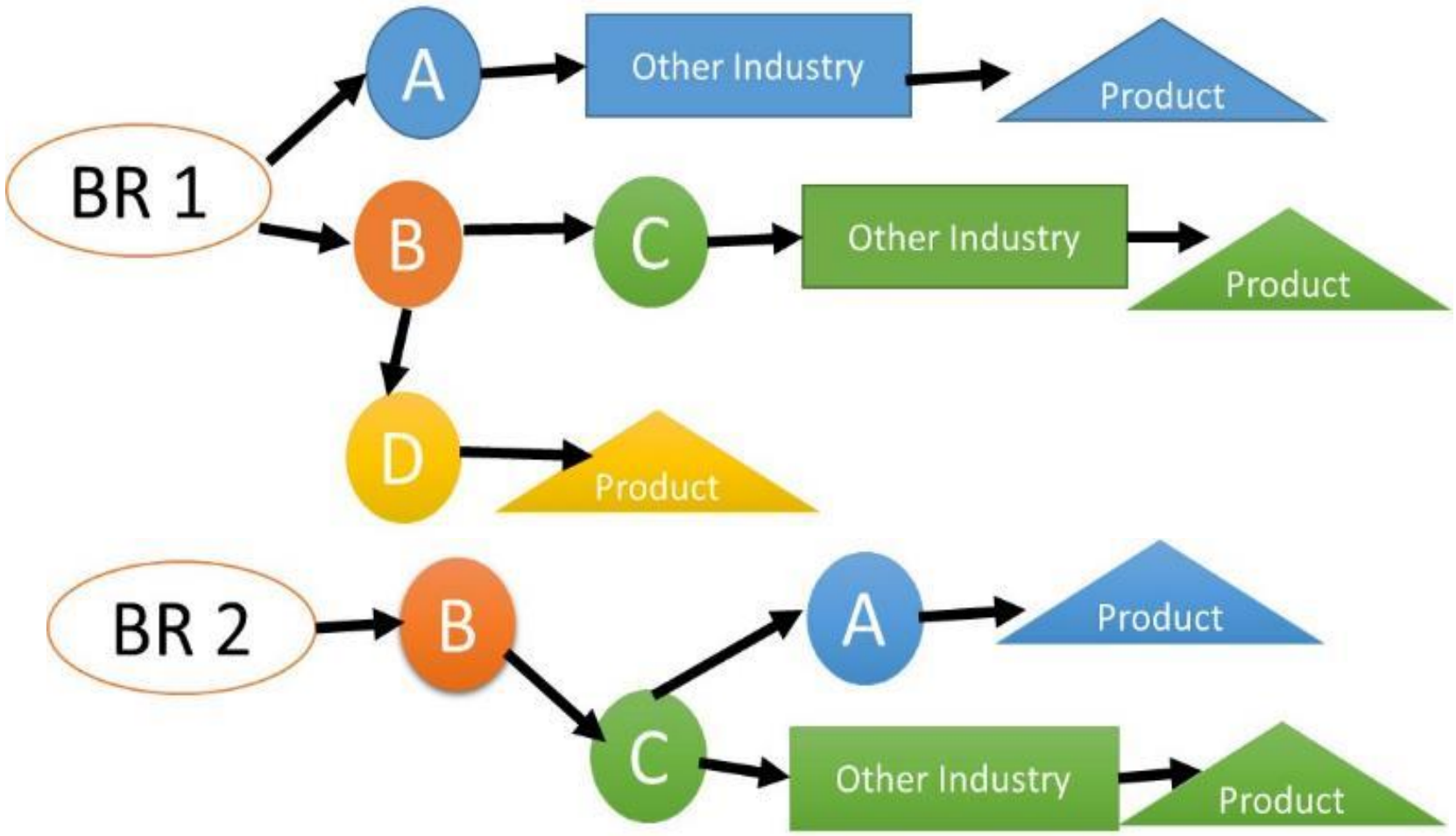
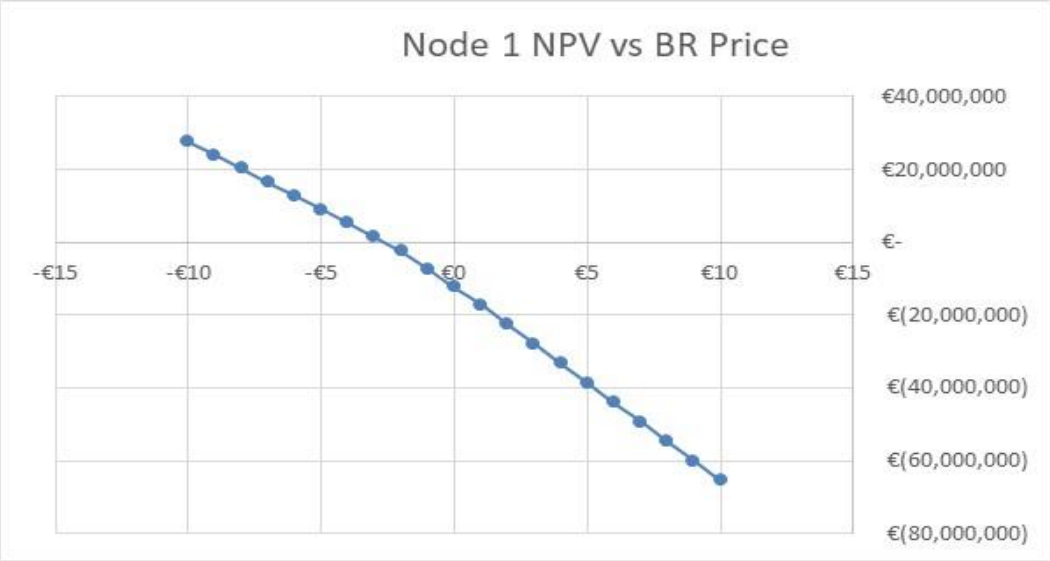
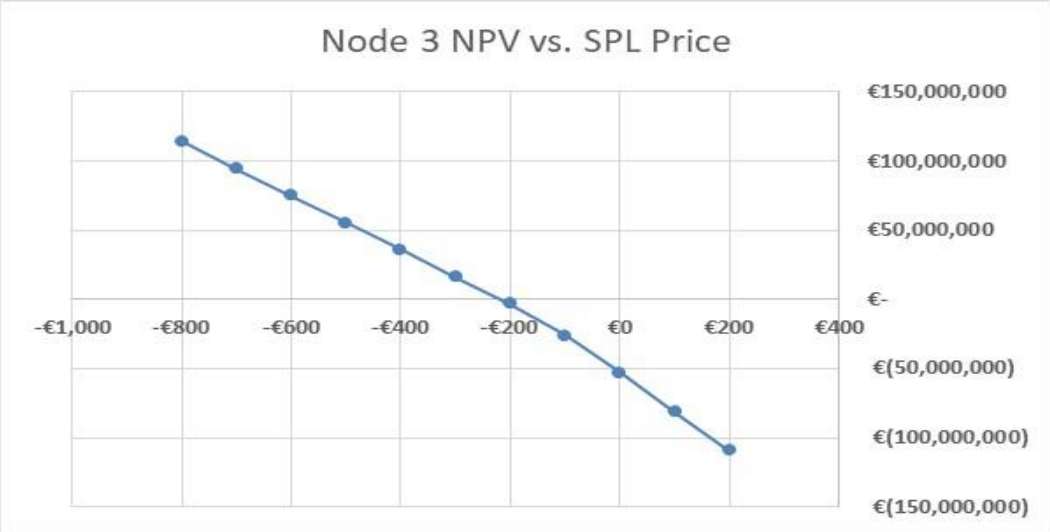
near zero-waste processing, near break-even flowsheets



customise the solution to the industrial ecostystem of each alumina plant

near zero-waste processing, near break-even flowsheets





treat waste with waste

RemovAL business plans become more and more sustainable as the cost for landfilling of by-products becomes higher (or not an option at all) and industrial symbiosis becomes more and more necessary

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Demonstrate the production of new, marketable building products from the building materials produced in the pilot demonstrations

A demo house 25 m² will be built exclusively with bauxite residue building products in the housing settlement next to the AoG alumina plant

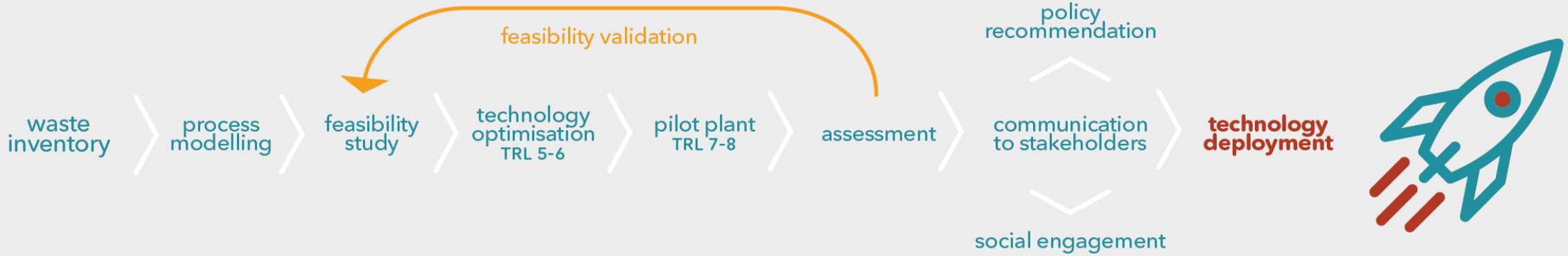
develop marketable products

feasibility studies

for each of the 3 alumina producers and the 1 legacy site owner, detailing the optimum processing flow sheet for valorising the produced bauxite residue along with other industrial by-products, taking into consideration:

- waste characteristics
- logistics and
- symbiosis with other plants in the geographical vicinity

the method


feasibility validation
policy recommendation
waste inventory
process modelling
feasibility study
technology optimisation
TRL 5-6
pilot plant
TRL 7-8
assessment
communication to stakeholders
technology deployment
social engagement

Key conclusions

- A win-win strategy is not only the recovery of valuable metals, **but also the intrinsic reduction of the environmental risk associated with the residues.**
- A clearly identified bottleneck is the currently weak knowledge base.
- The experience gathered suggests that **the metal recovery of low-grade (secondary) resources is only viable if a (commercial) solution is provided for the large bulk (residual matrix) of the material**

Conclusions – RemovAL of Barriers

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6 innovative pilot plants across Europe

Technical Barriers

✓ The technology(-ies!) for reusing BR are available

Legislative Barriers

EWC code 01 03 09 = waste/non-hazardous

- Simplify the framework for waste transfer/reuse.
- **Waste Declassification /End-of-Waste is a central policy decision.**

Financial Barriers

- **Incentives** should be provided for utilizing BR and similar **wastes over fresh materials**.
- **Gate fees and landfill taxes** will only drive away the industry (or result in CO2-leakage type countermeasures).

Social Barriers

- More effort should be placed on increasing social awareness – reducing NIMBYSM.
- '**Popularizing science' through RTD projects** could be a key.

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New barriers always appear

- A new classification of TiO2 powders as carcinogenic will most likely make BR a hazardous waste…

Index No	Chemical Name	EC No	CAS No	Classification		Labelling			Specific Conc. Limits, M-factors and ATEs	Notes
				Hazard Class and Category Code(s)	Hazard statement Code(s)	Pictogram, Signal Word Code(s)	Hazard statement Code(s)	Suppl. Hazard statement Code(s)		
'022-006-002	titanium dioxide; [in a powder form containing 1% or more of particles with diameter ≤ 10 µm]	236-675-5	13463-67-7	Carc. 2	H351 (inhalation)	GHS08 Wng	H351 (inhalation)			V, 10

www.removal-project.com

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BR 2020

3RD INTERNATIONAL
Bauxite Residue Valorisation
and Best Practices Conference
11-15 MAY 2020 CONSTANȚA ROMANIA