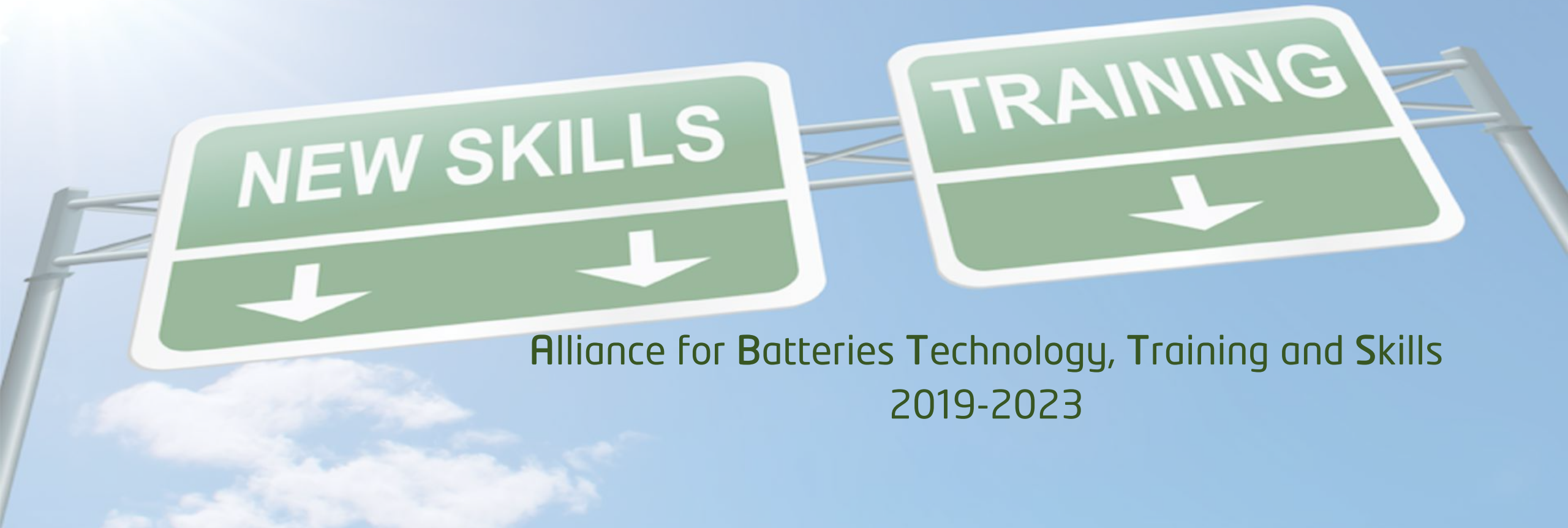
albatts
Alliance for Batteries Technology, Training and Skills



Alliance for Batteries Technology, Training and Skills 2019-2023

Co-funded by the Erasmus+ Programme of the European Union

What is **ALBATTS**?

- 4-year (2019-2023) Erasmus+ funded project
- Blueprint for Sectoral Cooperation on Skills in Battery sector
- Contributes to the electrification of transport, green energy and environmental goals in Europe
- Gathers demand and supply sides of competences in the battery value chain

Co-funded by the Erasmus+ Programme of the European Union

What is **ALBATTS**?

- Identification of needed skills and job roles
- Enabling education sector to provide education and training for the future employees and specialists needed by the battery sector
- Covers the battery life cycle - batteries developed for and used in both stationary and mobile applications

Co-funded by the Erasmus+ Programme of the European Union

What is **ALBATTS**?

- The battery value chain:
  - Raw materials and processing
  - Component and cell manufacturing
  - Module and pack manufacturing
  - Battery integration
  - Operation, repair and maintenance
  - Second life
  - Recycling

Co-funded by the Erasmus+ Programme of the European Union

20 Partners from 11 EU countries

Skellefteå municipality
AIA Automotive Industry Association
atec
eupportunity
MERINOVA Technology Centre
vamia
VSB Technical University of Ostrava
ACEA European Automobile Manufacturers Association
APIA
Corvus Energy
efacec
U.PORTO Universidade do Porto
HE3DA
ISCN
northvolt
Realize it
Spin360
Univerza v Mariboru
Vaasan yliopisto University of Vaasa
Vestland fylkeskommune

Co-funded by the Erasmus+ Programme of the European Union

ALBATTS will…

- Analyse new job roles/skills
- Suggest learning objectives
- Develop course plans
- Develop learning material
- Try out adaptive learning
- Pilot-test innovative courses
- Train-the-trainer guidelines
- Network!
- Use European instruments
- Implement results

Co-funded by the Erasmus+ Programme of the European Union

ALBATTS Results

- **WP4: Intelligence in Stationary Applications**
  - D4.4 - Desk Research and Data Analysis for sub-sector ISIBA – Release 2
- **WP5: Intelligence in Mobile applications:**
  - D5.4 Desk research and data analysis for sub-sector IMBA - Release 2
- **All deliverables:**
  - https://www.project-albatts.eu/en/results
- **Events:**
  - https://www.project-albatts.eu/en/listnewsevents

Co-funded by the Erasmus+ Programme of the European Union

albatts
Alliance for Batteries Technology, Training and Skills

To get involved with the **ALBATTS** stakeholders group:

Stakeholder registration **here**

Follow us on:

Web: https://www.project-albatts.eu

LinkedIn: LinkedIn

Facebook: Facebook

Twitter: Twitter (@ALBATTS1)

Mail: info@project-albatts.eu

THANK YOU

Contact: kari.valkama@merinova.fi

Co-funded by the Erasmus+ Programme of the European Union

The European Commission support for the production of this publication under the Grant Agreement Nº 2019-612675 does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Lithium resources in Europe:
EU perspective on self-sufficiency and current forecast on Gigafactories' implementation

27 April 2022

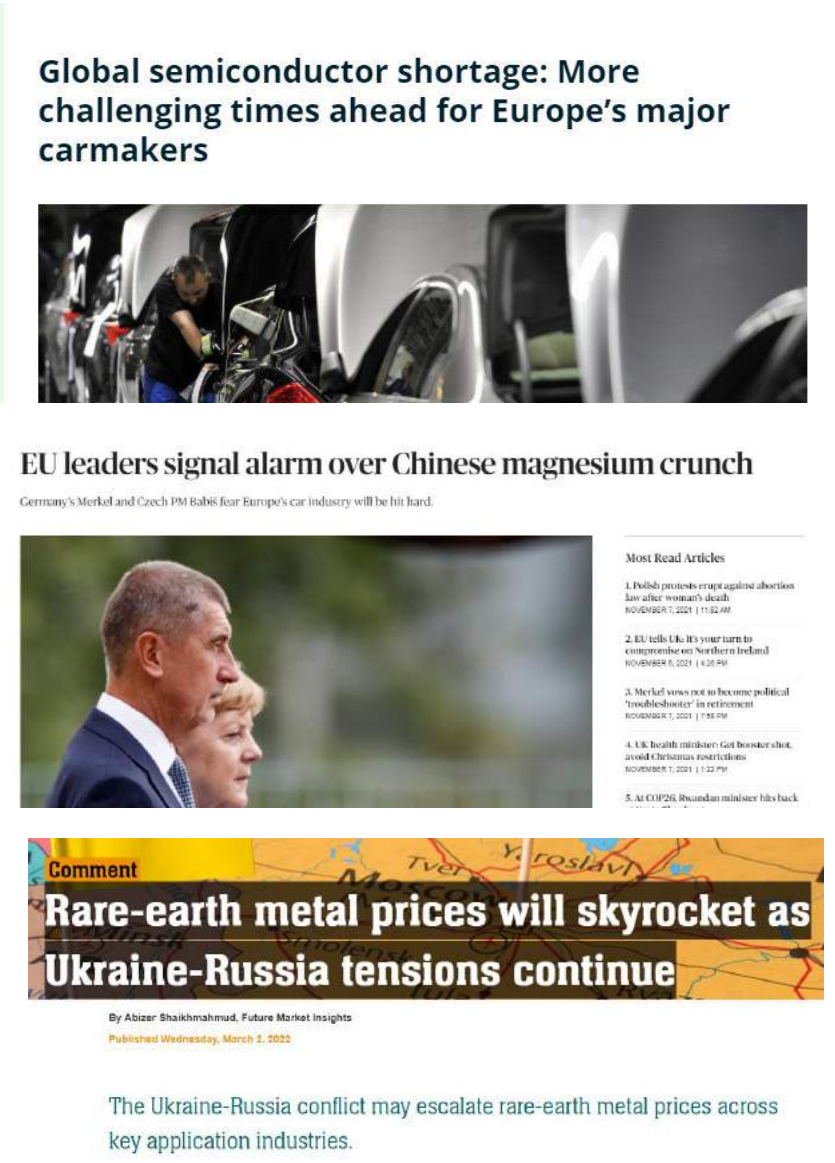
Allbatts

Gerardo HERRERA & Daniel CIOS

GROW i1 – Energy Intensive Industries and Raw Materials

Supply chain disruption

- The invasion of Ukraine by Russia affects the critical raw materials supply chain
- There is a political momentum at highest political level to secure our CRM supplies
- Key actions are needed to strengthen EU production and diversify supply sources



Global semiconductor shortage: More challenging times ahead for Europe's major carmakers

EU leaders signal alarm over Chinese magnesium crunch

Germany's Merkel and Czech PM Babiš fear Europe's car industry will be hit hard.

Most Read Articles

1. Polish protests erupt against abortion law after woman's death

2. EU tells UK: It's your turn to compromise on Northern Ireland

3. Merkel vows not to become political 'troubleshooter' in retirement

4. UK health minister: Get booster shot, avoid Christmas restrictions

5. At COP26, Rwandan minister hits back

Comment

Rare-earth metal prices will skyrocket as Ukraine-Russia tensions continue

By Abizer Shaikhmahmud, Future Market Insights

Published Wednesday, March 2, 2022

The Ukraine-Russia conflict may escalate rare-earth metal prices across key application industries.

Political climate ripe for action on CRM strategic autonomy and resilience

President Von Der Leyen (23/02/2021)

‘Green and digital technologies currently depend on a number of scarce raw materials. […] 98% of the rare earth elements we need come from China. This is not sustainable'.

- We must **invest** in **circular technologies** that re-use resources instead of constantly extracting them.
- We must **diversify** our supply chains.’

EP support - Bentele report: EU strategy for CRMs

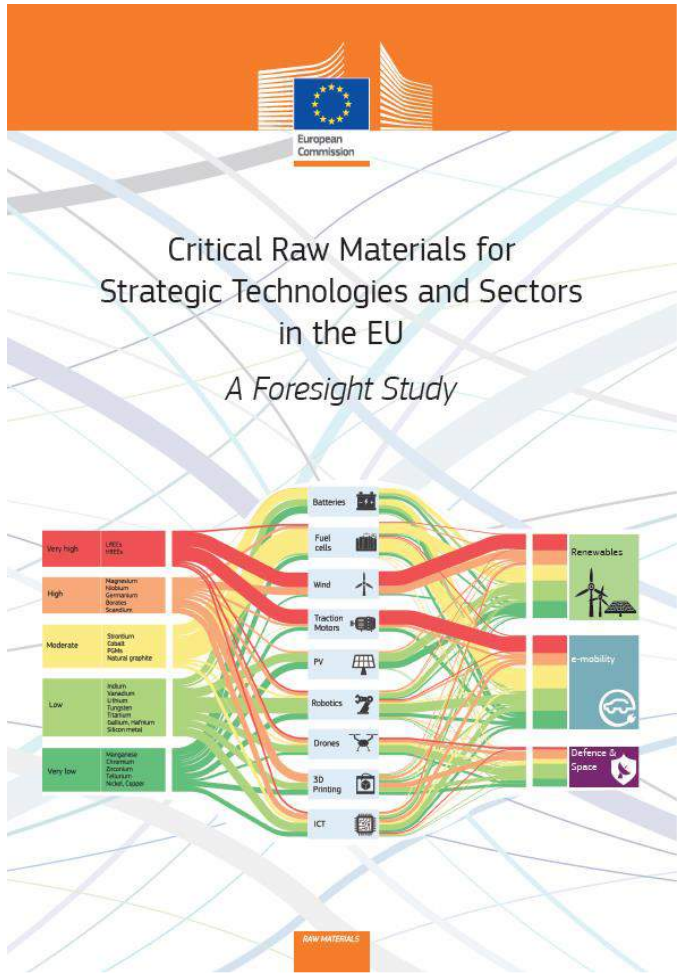
- **Investment** throughout the CRM value chain
- CRM **Task force ; Stockpiling** of critical raw materials
- Diversification, more **recycling** and **domestic sourcing**
- **Future FTAs & PAs** should include CRM provisions

Varin report and French strategy to secure CRMs

- Stimulate & blend private and public **investment**, pool EU demand
- **Observatory** for CRMs
- **Sustainable** mining standard
- Support **industrial projects in third countries**

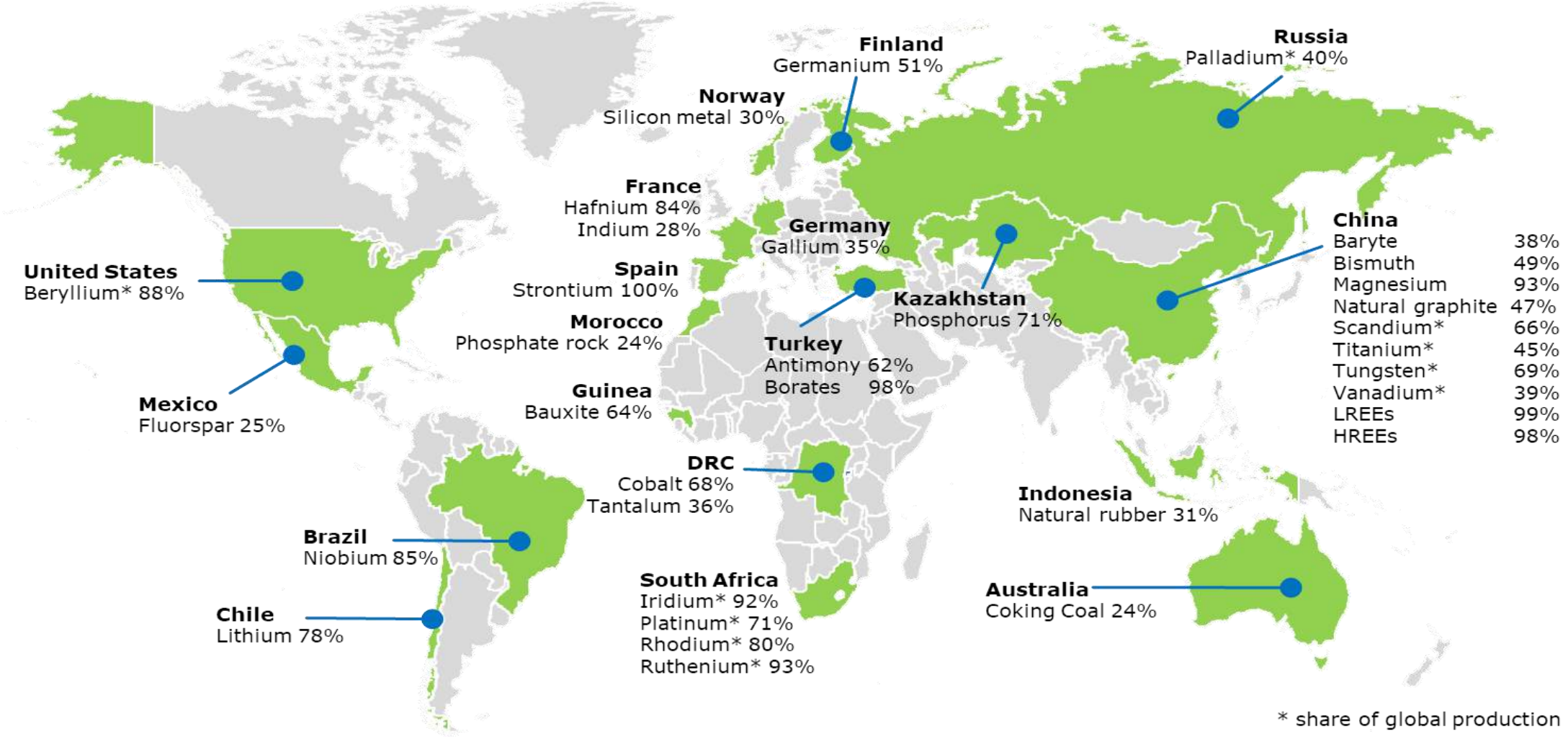
EU CRM assessment 2020

2020 Critical Raw Materials (new as compared to 2017 in bold)		
Antimony	Hafnium	Phosphorus
Baryte	Heavy Rare Earth Elements	Scandium
Beryllium	Light Rare Earth Elements	Silicon metal
Bismuth	Indium	Tantalum
Borate	Magnesium	Tungsten
Cobalt	Natural Graphite	Vanadium
Coking Coal	Natural Rubber	**Bauxite**
Fluorspar	Niobium	**Lithium**
Gallium	Platinum Group Metals	**Titanium**
Germanium	Phosphate rock	**Strontium**



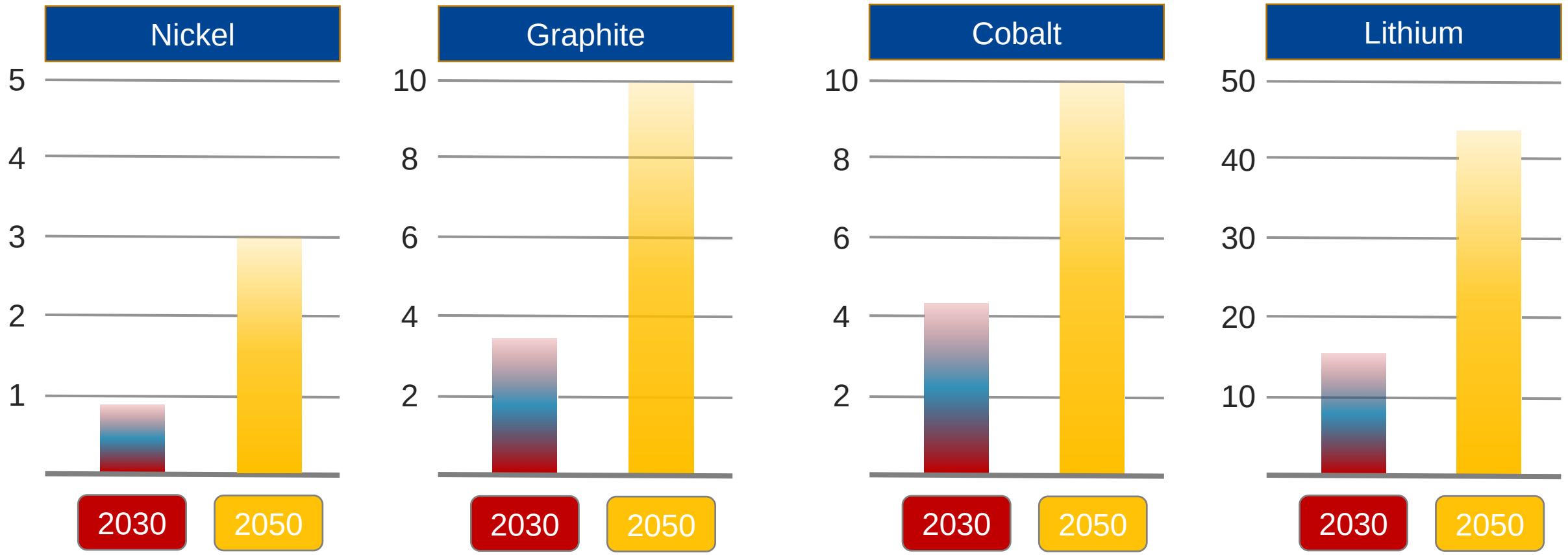
2023 Critical Raw Materials assessment is on its way

Main CRM suppliers of the EU



Source: "European Commission, Study on the EU's list of Critical Raw Materials – Final Report (2020)"

The demand for battery raw materials will increase



Source:
Critical Raw Materials for Strategic Technologies and Sectors in the EU; A Foresight Study.
Joint Research Centre, European Commission, 2020

10 actions to ensure Europe's access to raw materials

1. **European Industrial Alliances**
2. **Develop sustainable financing criteria for mining**
3. Research and innovation on waste processing, advanced materials and substitution
4. Map the potential supply of secondary CRM from EU stocks and wastes
5. **Identify priority mining and processing projects for critical raw materials in the EU**
6. **Develop expertise and skills**
7. Deploy Earth observation programmes for exploration, operation and post-closure environmental management
8. Develop research and innovation projects on exploitation and processing of CRMs
9. Develop strategic international partnerships to secure CRMs supply
10. Promote responsible mining practices for CRMs

EU industrial alliances

Kick-starting the EU hydrogen Industry to Achieve the EU Climate Goals

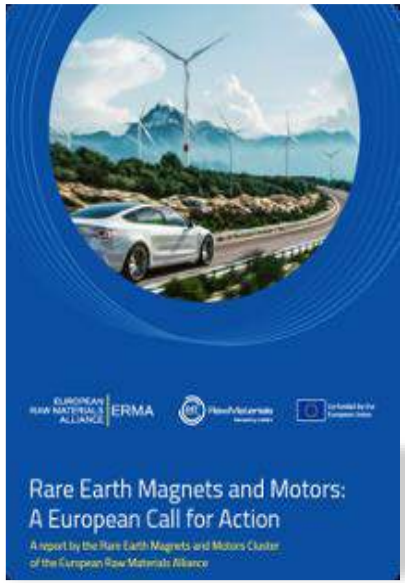
- 2 IPCEIs of 20 Bn EUR to build EU battery value chain
- 28 ready to go CRM projects for 11 Bn EUR to strengthen EU CRM value chain
- On-going discussion on 2 IPCEIs including to develop green hydrogen value chain in EU
- Clean Technology Materials Task Force to foster investments in the critical raw materials value chain.

Raw Materials

European Raw Materials Alliance

Resilience through improved security and sustainability of the supply to critical raw materials

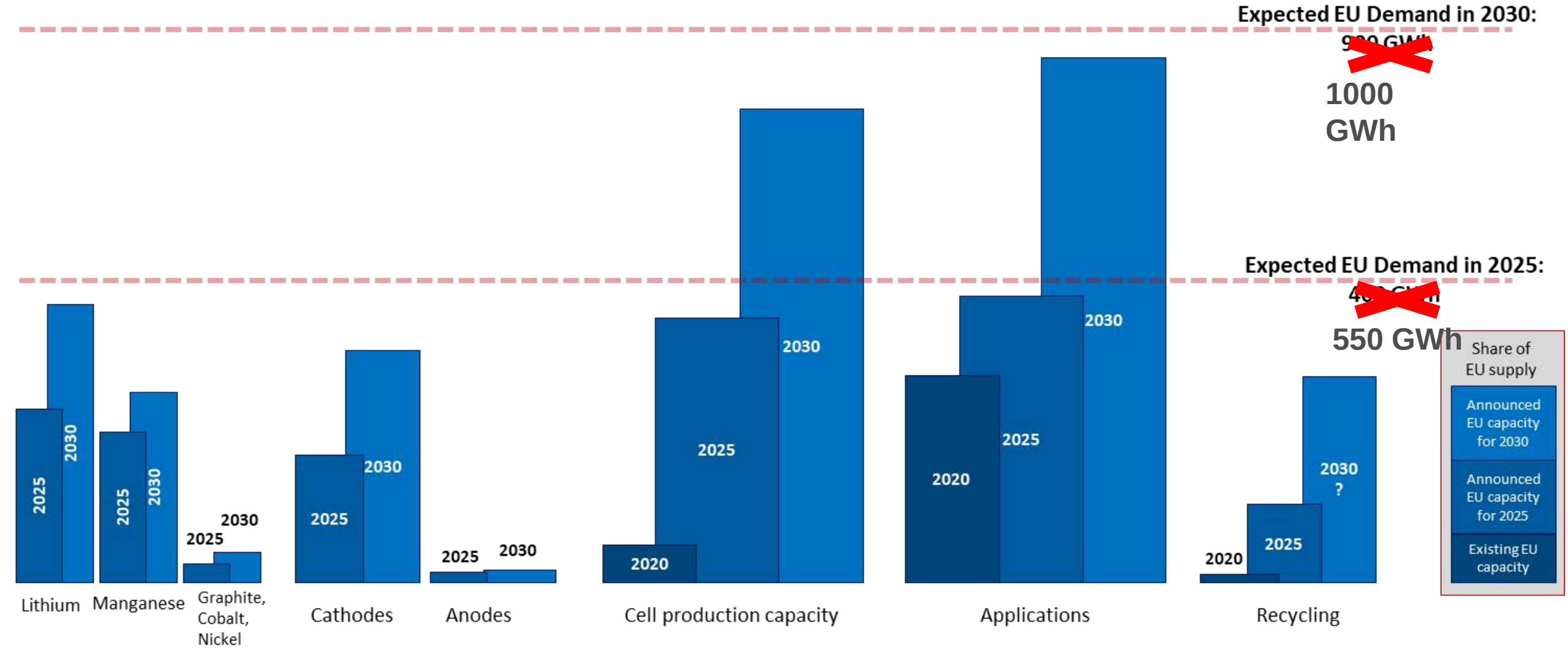
- *600 separate entities and 1000 individuals*
- *Cluster 1 on Rare earths and Magnets; Cluster 2 on Energy conversion and storage; Cluster 3 tbd. in 2022*



- ***Investment pipeline 114 proposals (€ 10.6 billion) → 28 promising cases***
- ***Action Plan on rare earths magnets and motors in 9/2021***
- *Support to the strategic* ***raw materials Partnerships with third countries***

Continued efforts needed to fill gaps in value chain

Raw materials | Active Materials | Battery Manufacturing | Application & Integration | Recycling & 2nd life



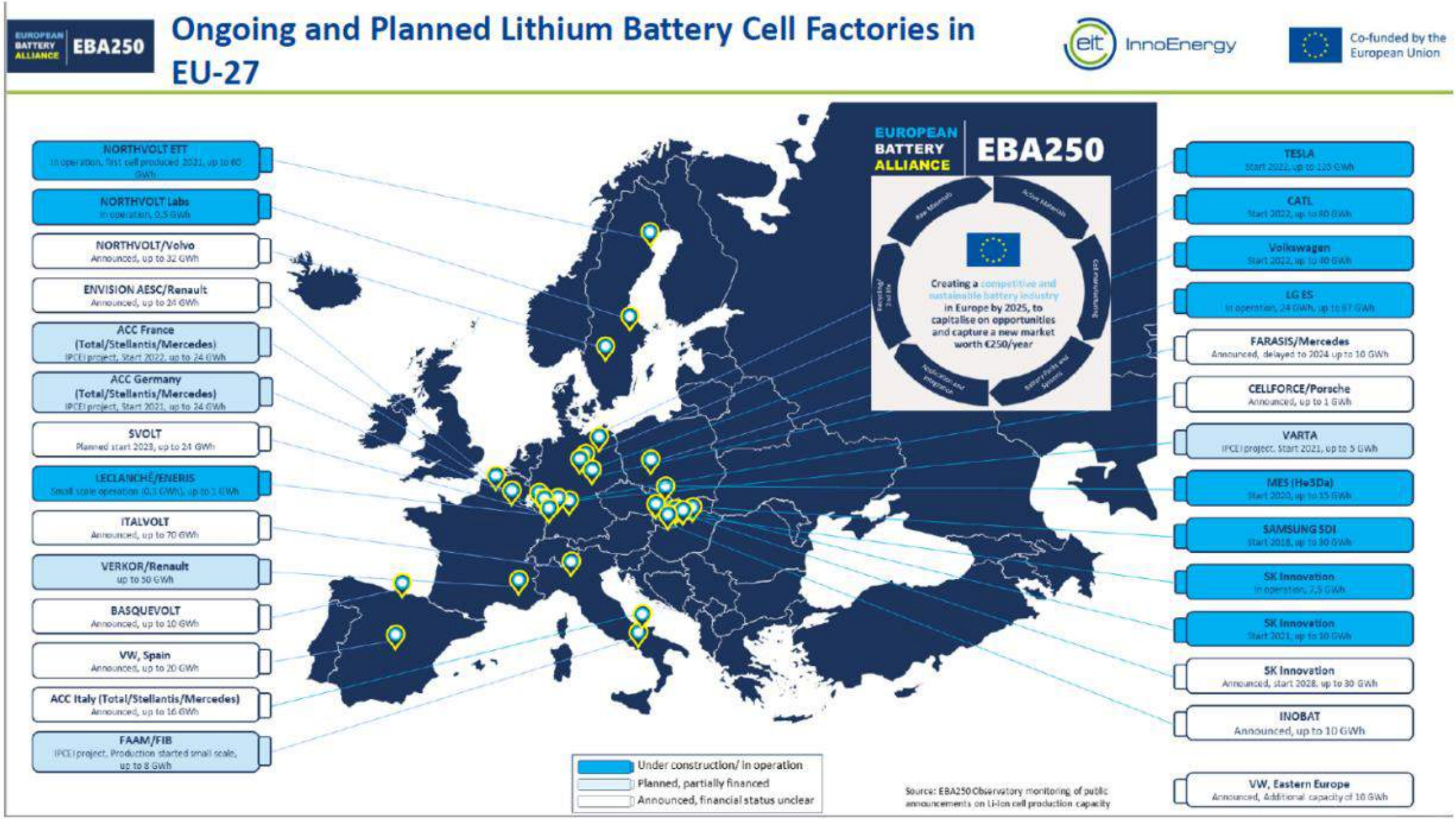
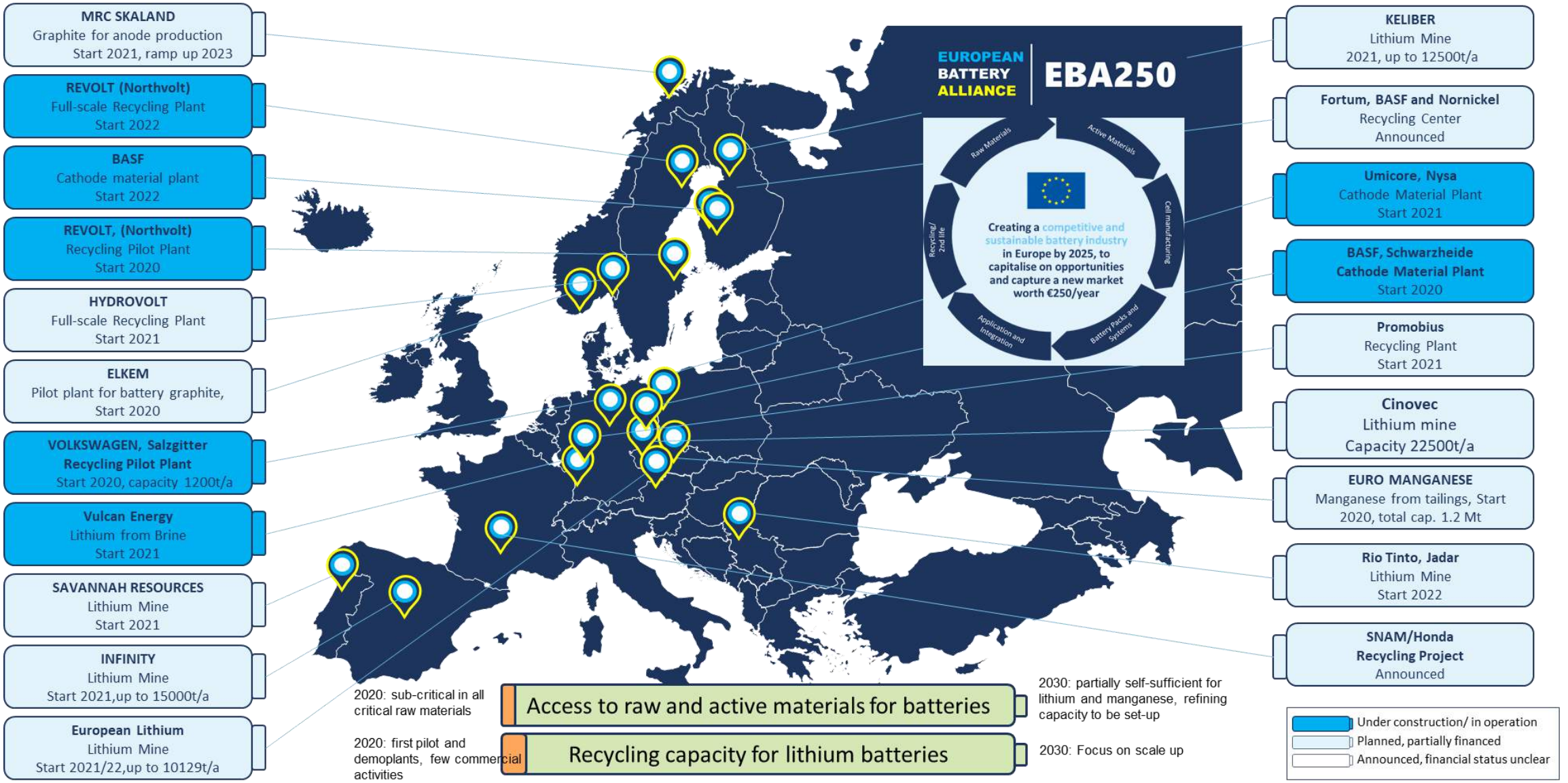


Figure 8 – Examples of the lithium battery cells giga-factories

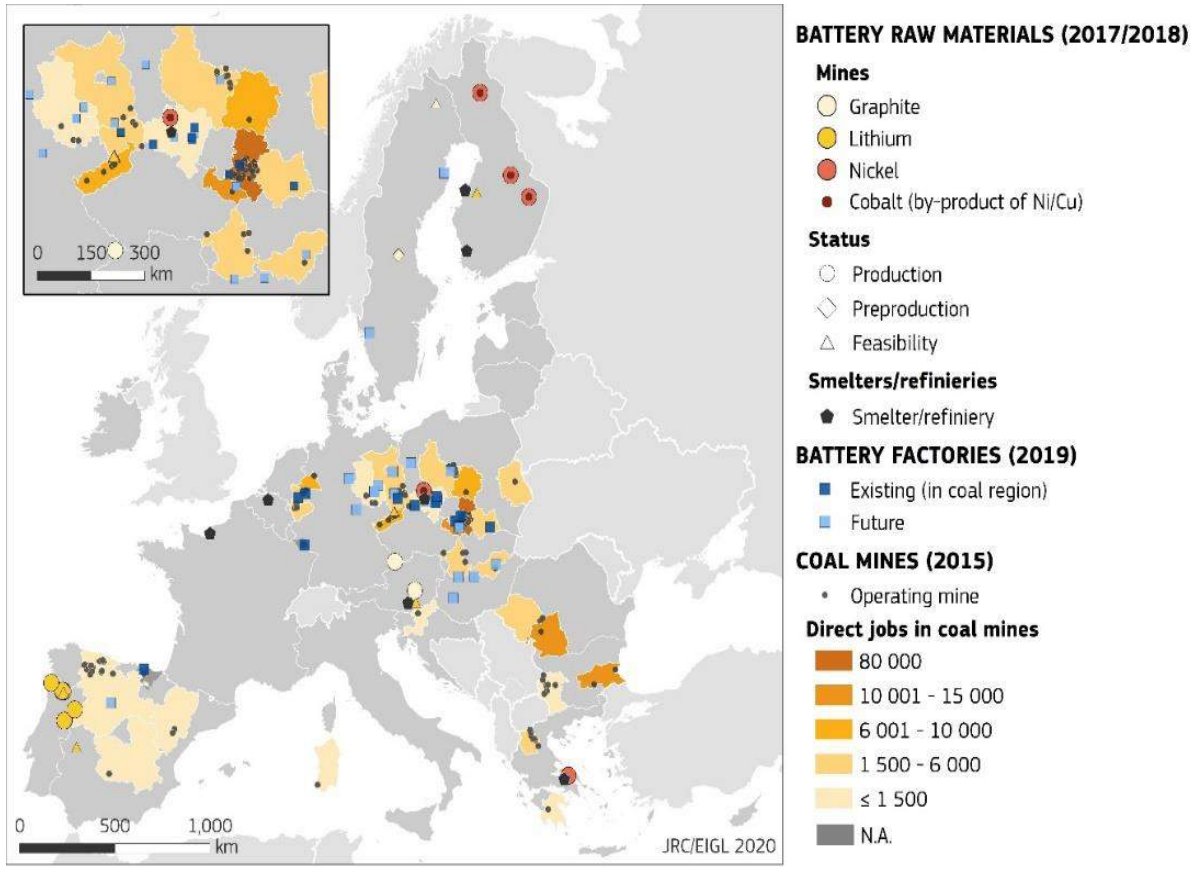
Selection of BRM projects in Europe



Expertise and skills

EIT Battery Academy:

- skills for 800.000 people by 2025 to manufacture and recycle batteries
- Pack for skills: €10 million under the Recovery Assistance for Cohesion and the Territories of Europe (REACT-EU).
- Spain, France and Hungary – have already engaged with the Academy by signing a MoU to train up to 340,000 workers.
- The Academy complements existing long-term initiatives, such as the Alliance for Batteries Technology, Training and Skills (ALBATTS)
- It also complements, the industry-led Automotive Skills Alliance



EC priorities for 2022:

- Providing a new legal framework for the battery industry
- Diversifying supply sources and routes for battery raw materials
- Streamlining and accelerating permitting procedures for battery raw material projects at national and regional level
- Improving and facilitating access to funding for primary and secondary battery raw materials projects
- Launching of national re-skilling and up-skilling programmes.

Thank you

European Commission

albatts
Alliance for Batteries Technology, Training and Skills
Co-funded by the Erasmus+ Programme of the European Union

eit RawMaterials
Connecting matters

Co-funded by the European Union

European deposits, active mines and exploration projects

3
Li

27 April 2022

Dr. Patrice Christmann – krysmine@gmail.com

Warning

- While this presentation has been prepared with great care, no implicit or explicit guarantee is provided as to its exactness or completeness, and no claim regarding direct or indirect damages that its users may incur from the use of this presentation will be accepted.
- This document is not an invitation to engage whatever investment decision. Such a decision requires professional advice and due diligence.
- The opinions reflected in this presentation are strictly personal, and do not commit any third party whatsoever.
- This warning forms an unseparable part of this presentation.

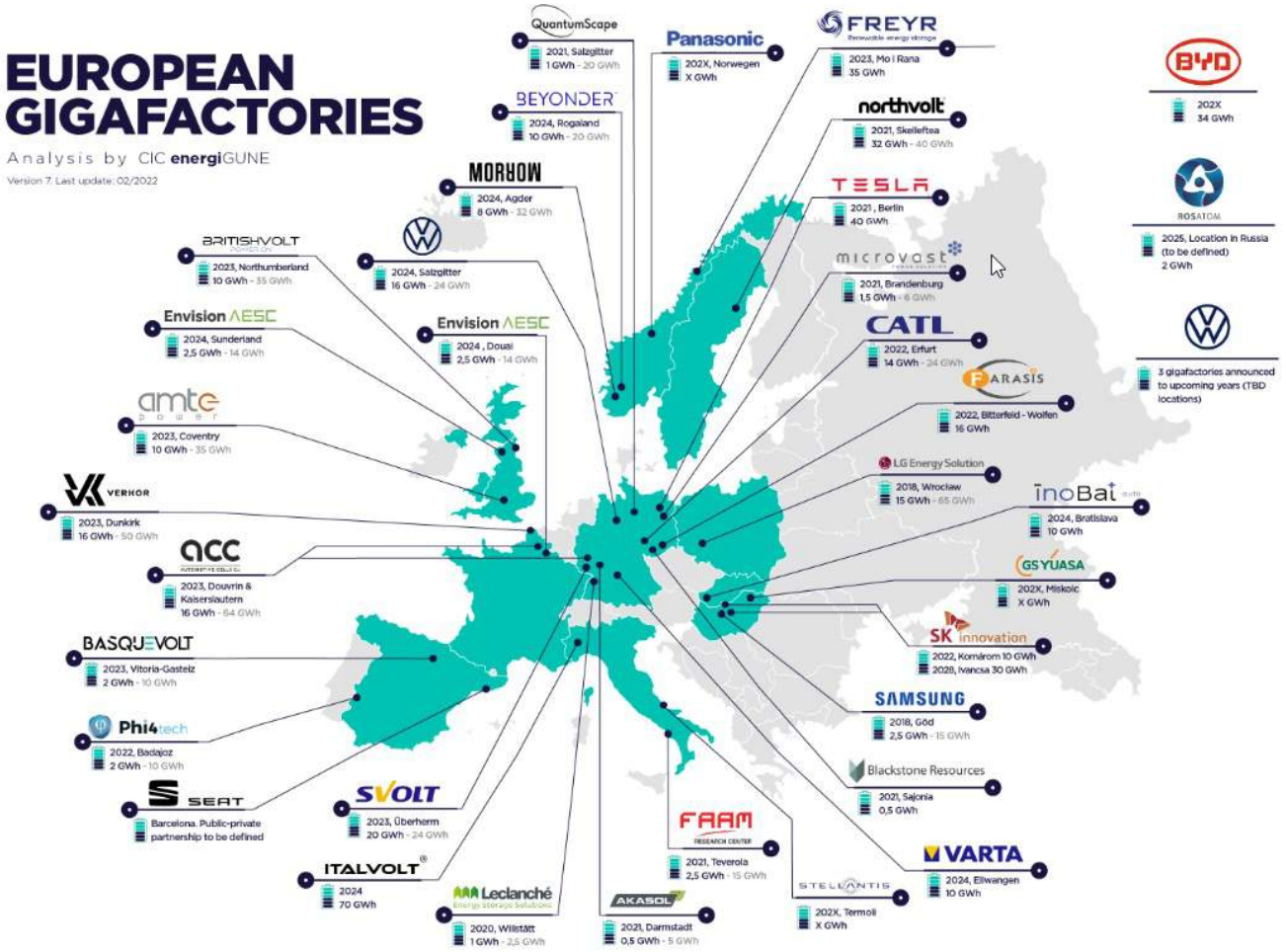
Current European lithium production

The 2020 European primary lithium production (from geological resources) is insignificant, being limited to 0.2% of the world production, all from the the Alvarrões mine, in Gonçalo, Guarda, Portugal. It is used for the ceramics industry.(130 t Li eq. compared to about 86 000 t global Li eq. Production – Data Source: World Mining Data, 2022 ed.). Over the 2010-2020 period this share has fluctuated between 0.2 and 0.5%. In 2022 Europe will have produced 0% from its own resources of the Li-materials used in its current Li battery industry!

The European production of the two key Li battery chemicals is limited too:

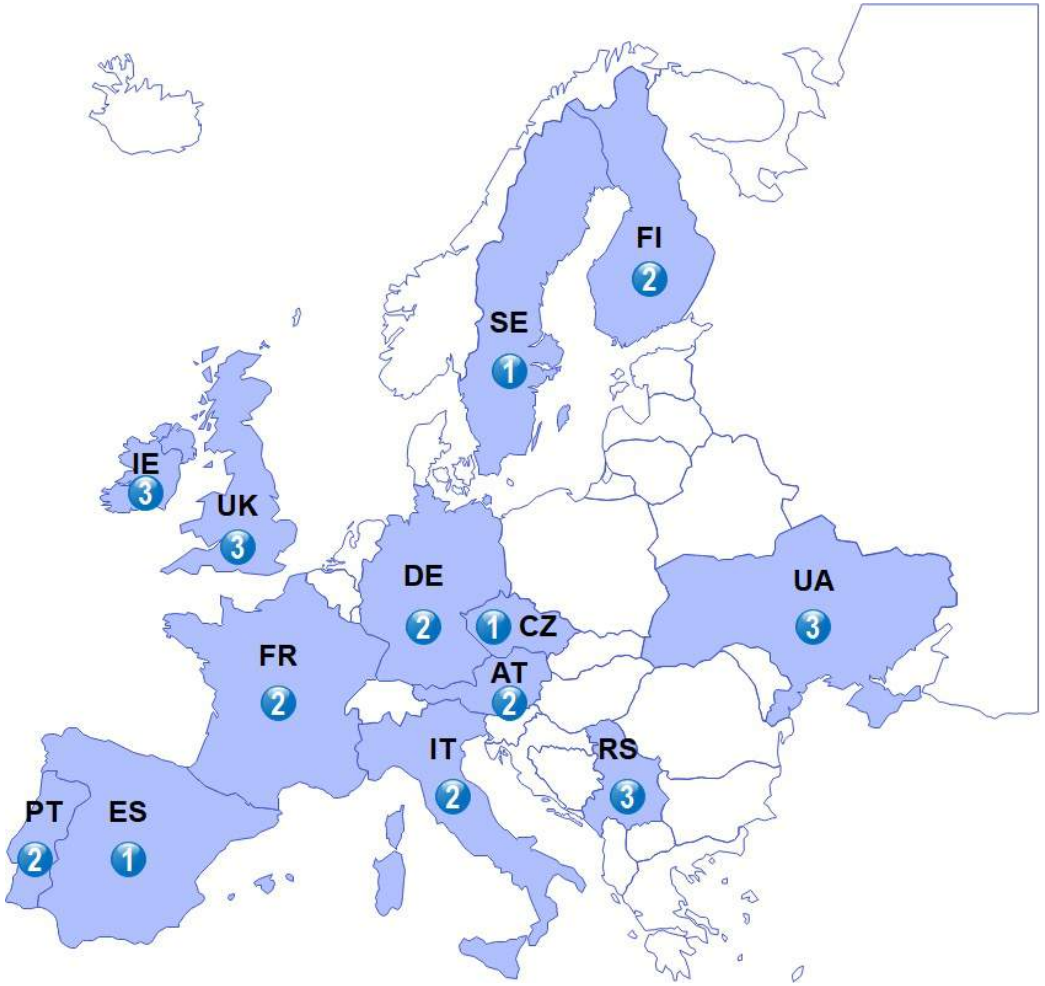
- Li carbonate: 0.3% of the world production (UK and Germany, from imported Li raw material)
- Li hydroxyde: 11% of the world production (Romania, Germany and UK, from imported Li raw material)

Near future (2024) European lithium demand for Li-batteries gigafactories



Map of existing and foreseen Li batteries gigafactories (Status: 02/2022, more projects likely). By 2024 they would represent a production capacity of 377.5 GWh, demanding in the range of 38 000 t Li per year, that is about 44% of the 2020 world production (Map source: CIC energiGUNE, https://cicenergigune.com/en/blog/gigafactories-europe-commitment-economic-recovery-battery-factories)

European lithium exploration activities: 26 projects – Status: 04/2022, highlighting the large European lithium potential and the likeliness of additional future exploration projects. Alltogether these 26 projects represent a more or less well documented inferred resource of 3.9 Mt Li eq. (about 100 years of the estimated 2024 European Li-batteries demand).



… but only a few projects are documented with detailed publicly available data and information produced by using one of the internationally recognised national reporting codes (NI 43-101, JORC, SAMREC …)

Only few of these projects are advanced, with documented reserves that could turn into production within this decade. Publicly documented resources are 3.9 Mt Li eq., publicly documented reserves are only 0.15 Mt. Only reserves are demonstrably exploitable.

Summary data about Europe's 5 largest publicly reported lithium production projects

Country	Location	Company	Resources (Meas. + Ind., Mt Li eq.)	Type	Status
Germany	Insheim, Upper Rhine Graben	Vulcan Energy Resources	2.98	Geothermal brine	Feasibility study in progress. Awaiting permitting. Target: 40 kt Li hydroxyde/yr.
Czech Republic	Cinovec	European Metals	0.87	Pegmatite	Feasibility study in progress. Awaiting permitting. Target: 29 kt Li hydroxyde/yr.
Serbia	Jadar	Rio Tinto	0.44	Jadarite	Project suspended due to exploration licence revoking/ local opposition. Feasibility was in progress. Target: 58 kt Li carbonate/yr.
Spain	San Jose	Infinity Lithium	0.13	Pegmatite	Feasibility study in progress. Awaiting permitting. Target: 19.5 kt Li hydroxyde/yr.
Germany	Zinnwald	Zinnwald Lithium	0.13	Li-mica greisen/ aplite	Feasibility study completed in 2019. Awaiting funding. Target: 7.5 kt Li carbonate eq./yr.

Summarizing statements

- These 5 projects represent 96% of all documented European indicated + measured resources.
- Their cumulated planned annual production capacity is equivalent to about 29 kt Li eq./ year, 9 kt below (24%) what would be needed by 2024 to supply the planned European batteries gigafactories. The shortfall could well be 100% as it is unclear if any of the stated projects will start full production in 2024.
- None of the stated projects is fully permitted yet, and permitting procedures may face strong local oppositions to any project. The NIMBY syndrome hits hard in Europe!
- These 5 projects will require a cumulated initial capital investment so far estimated at +/- 4 bn $US.

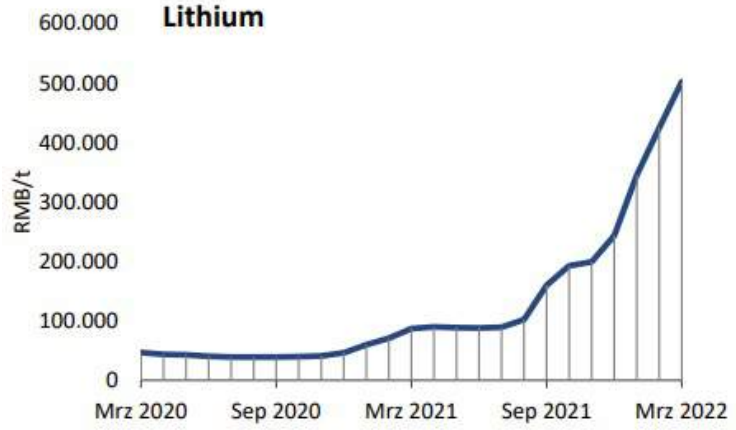
My personal conclusion is that the development of the planned EU gigafactories will face a major raw materials supplies (Li, but also graphite, Ni and Co) issue, unless some projects have already secured supply agreements with existing or near-production non-EU Li producers. Battery producers must invest in exploration and mining, or as a minimum secure long-term supply agreements with miners (but there is a long queue in front of their offices) or face supply bottlenecks!

The global competition for access to battery-grade raw materials is very stiff, and will further rise in the coming years, with Chinese companies being very active internationally, a potential security issue for the EU.

Summarizing statements

- The global competition for access to battery-grade raw materials is very stiff, and will further rise in the coming years, with Chinese companies being very active internationally, a potential security issue for the EU, while the EU has no legal basis to develop a full raw material strategy that would be legally binding for the member states.

- The anticipated global demand/ supply imbalances is likely to put further strong upward pressure on Li-battery raw materials prices (e.g. SPOT Li carbonate prices rose by 450% in the last few months!)



SPOT lithium carbonate price curve, ex-works China, 03/2020 to 03/2022
Source: DERA Rohstoff Preismonitor 03/2022

- Raw materials prices have already translated in higher prices for some battery-operated vehicles. Further significant price rises may negatively impact the whole EV industry and the transition to electromobility.

Employed at Keliber Oy

albatts
27.4.2022

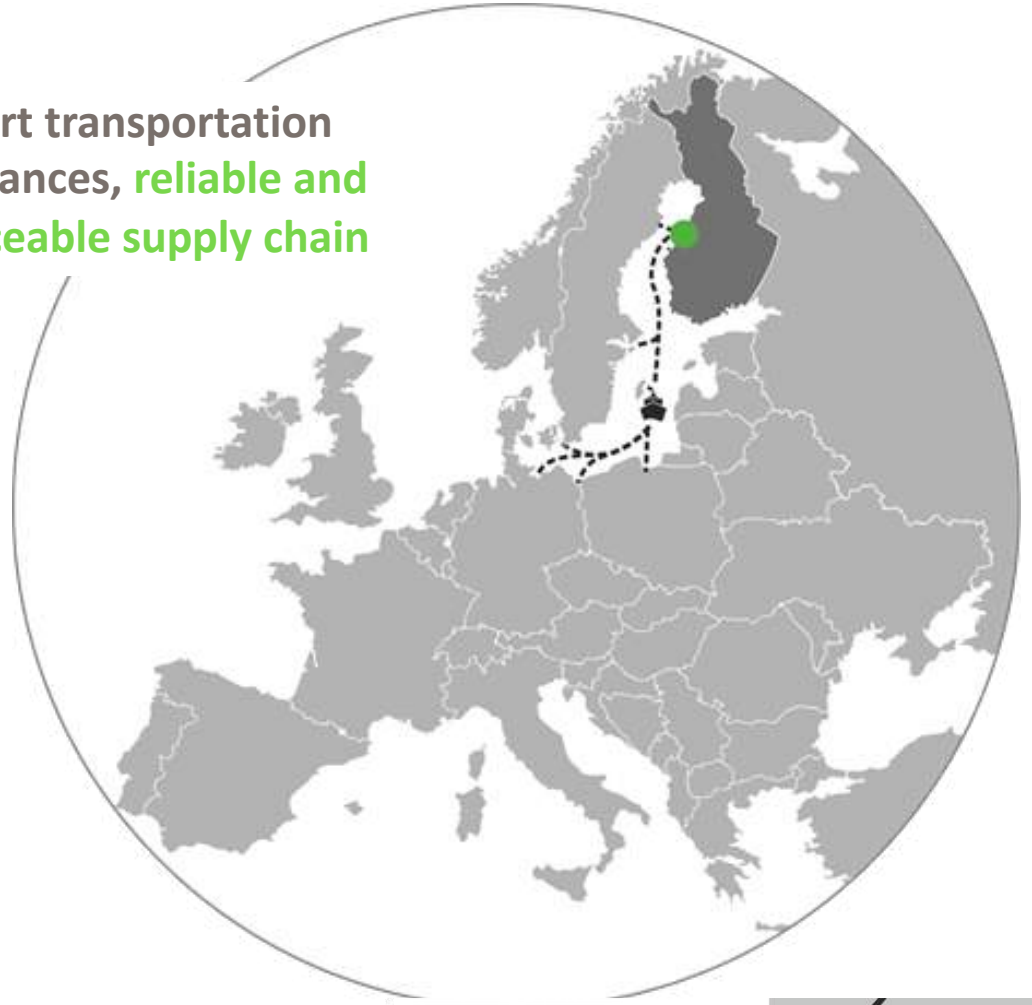
Asko Saastamoinen, Chief HR Officer

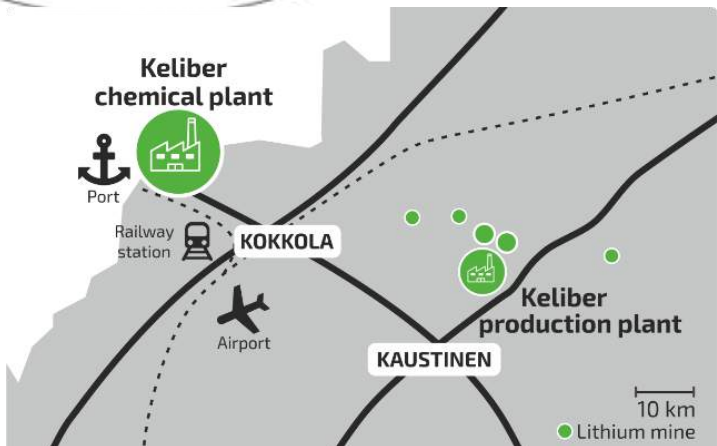
KELIBER

Keliber in Brief

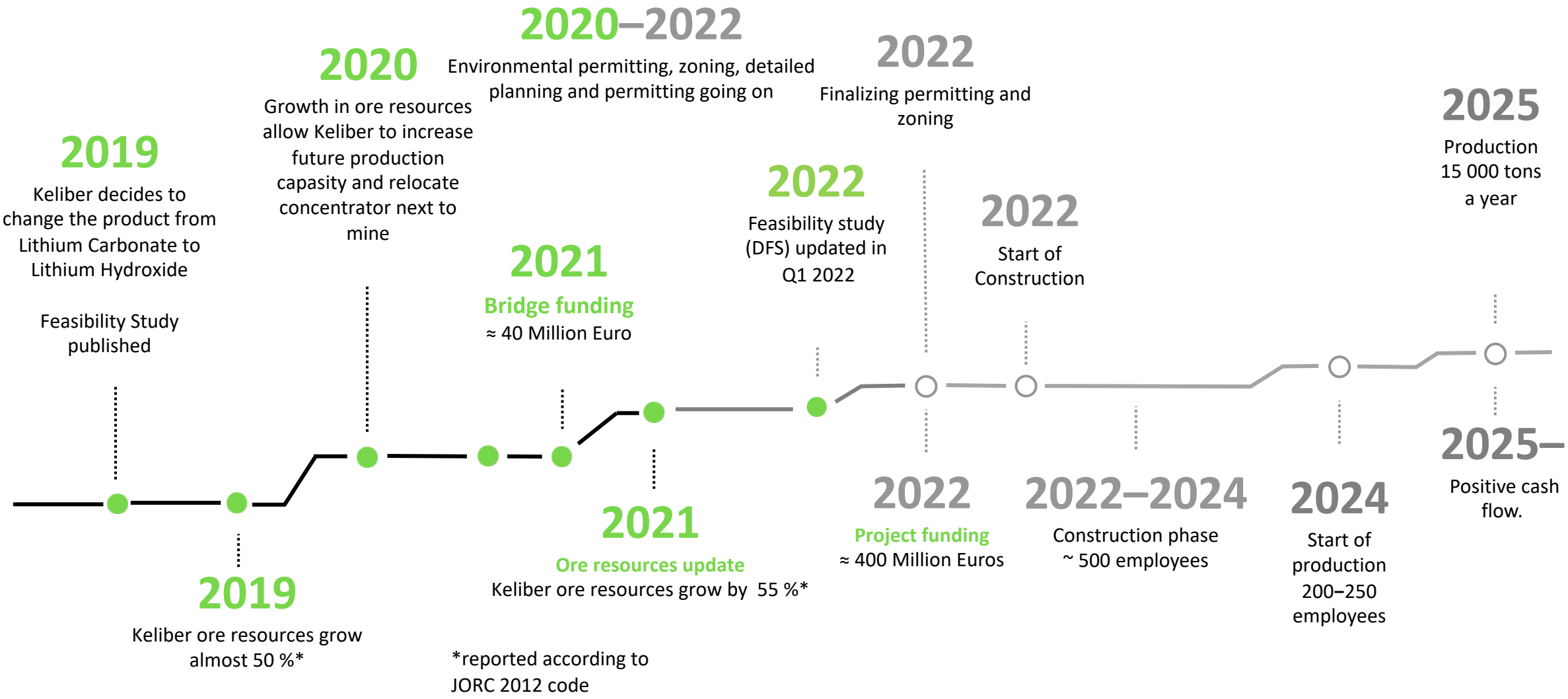
- Keliber is a Finnish mining and battery chemical company that aims to start the sustainable production of **battery-grade lithium hydroxide, utilizing its own ore, in 2024,** for the growing needs of the battery markets.
- The company operates in Central Ostrobothnia, in a region where some of **the most significant lithium deposits in Europe** are found.
- The construction phase of Keliber's project is scheduled to start in **2022.** The future mining activities are located in the municipalities of Kaustinen, Kokkola and Kruunupyy, where a **concentrator plant** will be built as well. The **lithium chemical plant** will be located in the Kokkola Industrial Park, which offers **excellent transportation connections.**
- The company is committed to implementing the **best available technologies,** aiming at **the smallest possible CO_2 footprint.**

Short transportation distances, reliable and traceable supply chain





Keliber entering market at the right time



*reported according to JORC 2012 code

Keliber mining – conventional ? mining

EXPLORATION -> ORE RESERVES

- Satellites, flights, geological maps
- Sample collecting
- Drilling, analyzing

MINING -> FROM RESERVES TO ORE

- Drilling
- Blasting
- Loading and transportation

PROCESSING -> FROM ORE TO PRODUCT

- Crushing
- Grinding
- Floating
- Leaching
- Chrystallization

Keliber mining

EXPLORATION -> ORE RESERVES

- **Satellites, flights, geological maps**
  - **Sample collecting**
  - **Drilling, analyzing**

- Collecting geological data 3 – 15 years
- Collecting samples on surface 3 – 10 years
- Drilling samples 3 – 15 years
- Focused drilling on selected areas
  - Defining ore resources; grade, minerals, amount
  - Usability to plan processing
  - Economical value
  - Life of mine

Keliber mining

MINING -> FROM RESERVES TO ORE

- **Drilling**
- **Blasting**
- **Loading and transportation**

- Drilling a tight net for blasting; laser and GPS location
- Blasting with matrix –explosives
- Directed to certain grade ore to feed the production
- Loading with excavators
- Transportation with mine trucks (100 – 200 tn)
- Yearly moving < 1 Mtn ore + 4 – 7 Mtn side rock

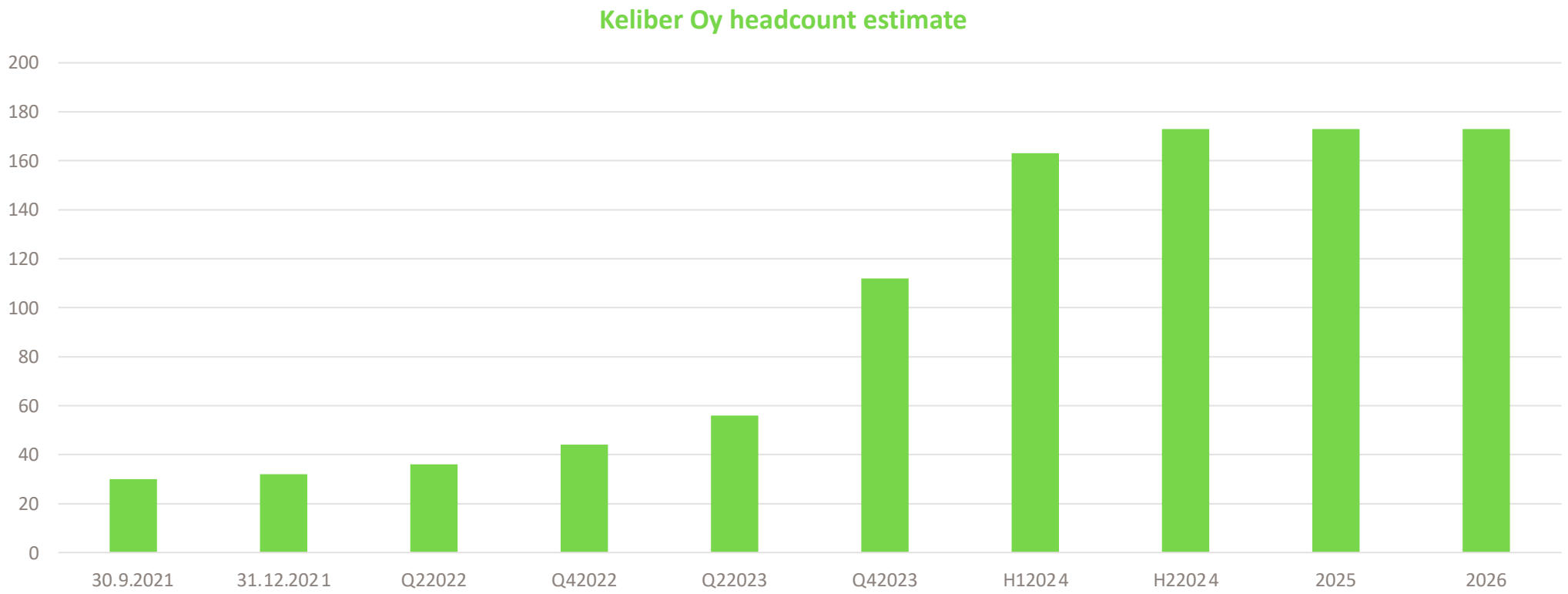
Keliber mining

PROCESSING -> FROM ORE TO PRODUCT

- **Crushing**
- **Grinding**
- **Floating**
- **Leaching**
- **Chrystallization**

- Crushing in separate crushers to size of max a football
- Grinding in mills to powder
- Floating, Leaching and Pressure leaching in order to separate wanted minerals from others
- Finally chrystallizing the end product for transportation to customers

Keliber headcount v. 2021-2026



Work at Keliber

- Mines
- Concentrator Plant
- Chemical Plant
- Maintenance
- Laboratories
- Logistics
- Supportive and administrative functions

- **Process Operators**

  Qualified chemical process operators, multiskilled for electricity or maintenance technicians
- **Maintenance Technicians**
  - *Electricity, automation, mechanical*
- **Laboratory technicians, Chemists**
- **Supervisors, Engineers**

  With technical education and industrial experience
- **Mining**
  - *Geologists, drillers, loaders, drivers*

SKILLED LABOUR

Respecting people and environment

- We build a **good and safe** company culture, where people are treated **fair and with respect**
- **We operate openly** and communicate regularly
- We **cooperate** actively with stakeholders
- **We are proactively working for the Environment** aiming to minimize harmful impact
- Focusing in: **water management, nature diversity, recycling and chemical safety.**

Näätinkiojan kunnostustalkoot syyskuussa 2021.

Keliber – skills required




- Basic education needed, experience recommended:
  - Process, chemical, mechanical, electricity, automation engineering
  - Geology, chemistry
- Mining and process industry need people with vocational or special education.
- Right mindset essential: match between people and employer.
- Workplace skills:
  - Working with teams, flexibility, resilience, development attitude
  - Safety, Environment, IT skills
- Fit for the team; different skills to fill the gaps.

KELIBER

Challenges for Employer and Schools

Employer

- Keeping promises
- Comparable working conditions - updating the company image
- Existing safety and environmental culture **Change is here to stay**
- Fast adaption to changes

- **New generations & new employment**
  - Flexibility
  - Competition on work force
  - Work place culture
  - Values

Schools and Universities

- **Core skills – general skills**
  - The basis for employment
  - Key to change management
- **Special skills**
  - How to be employed
- **Introduction to work**
  - Work and companies
- **Continuous development**
  - Cooperation with companies to respond to the needs and to update latest technologies

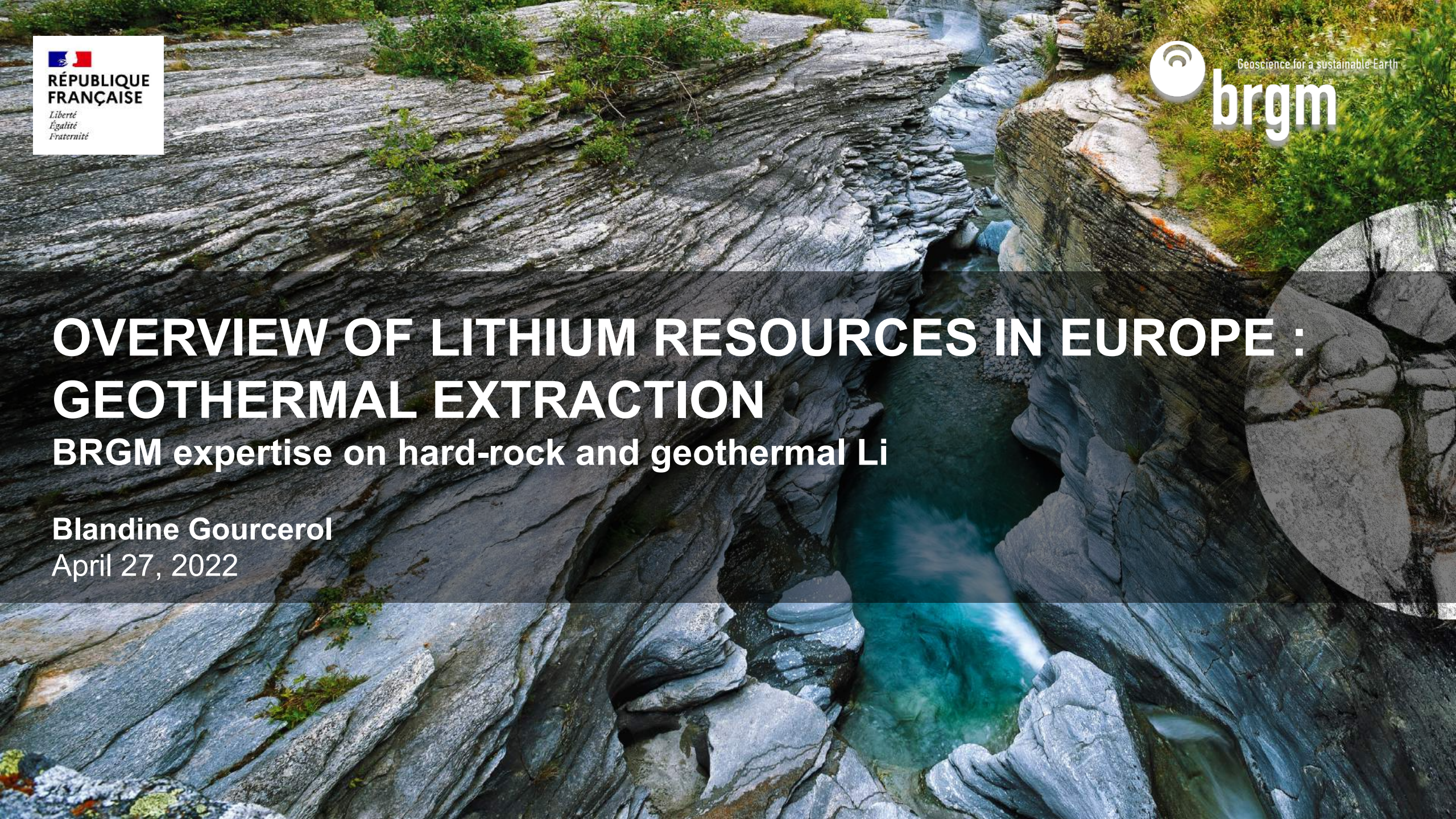
Sustainable Lithium From Europe

You can follow us at

LinkedIn and Facebook!

www.keliber.fi

KELIBER



RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

Geoscience for a sustainable Earth
brgm

OVERVIEW OF LITHIUM RESOURCES IN EUROPE : GEOTHERMAL EXTRACTION

BRGM expertise on hard-rock and geothermal Li

Blandine Gourcerol
April 27, 2022

Geoscience for a sustainable Earth

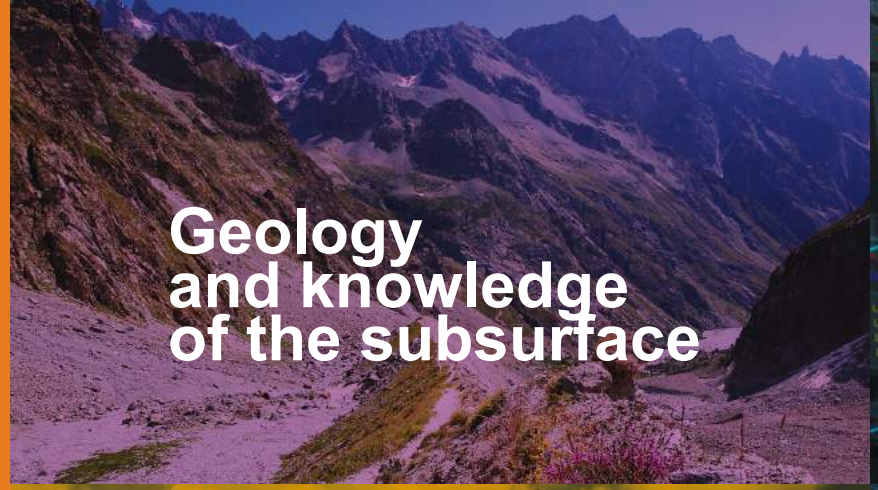
brgm

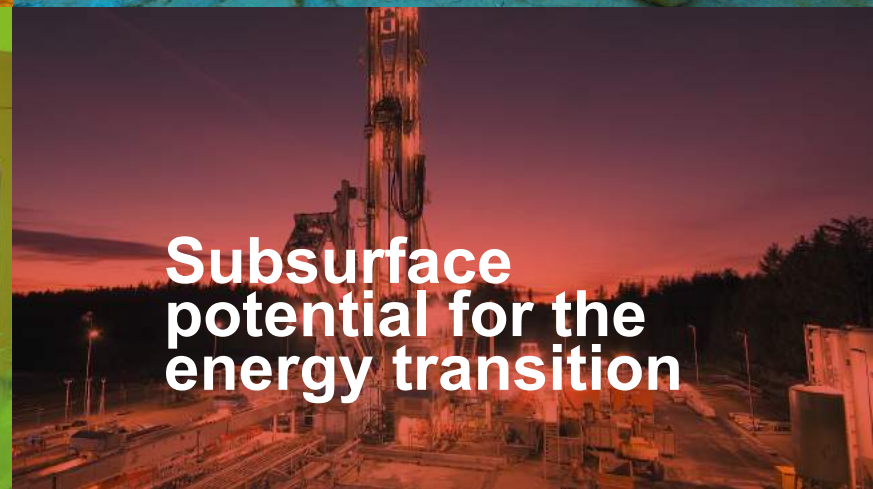
BRGM

THE FRENCH GEOLOGICAL SURVEY

The BRGM is France's public reference institution for Earth Science applications for the management of surface and subsurface resources and risks.

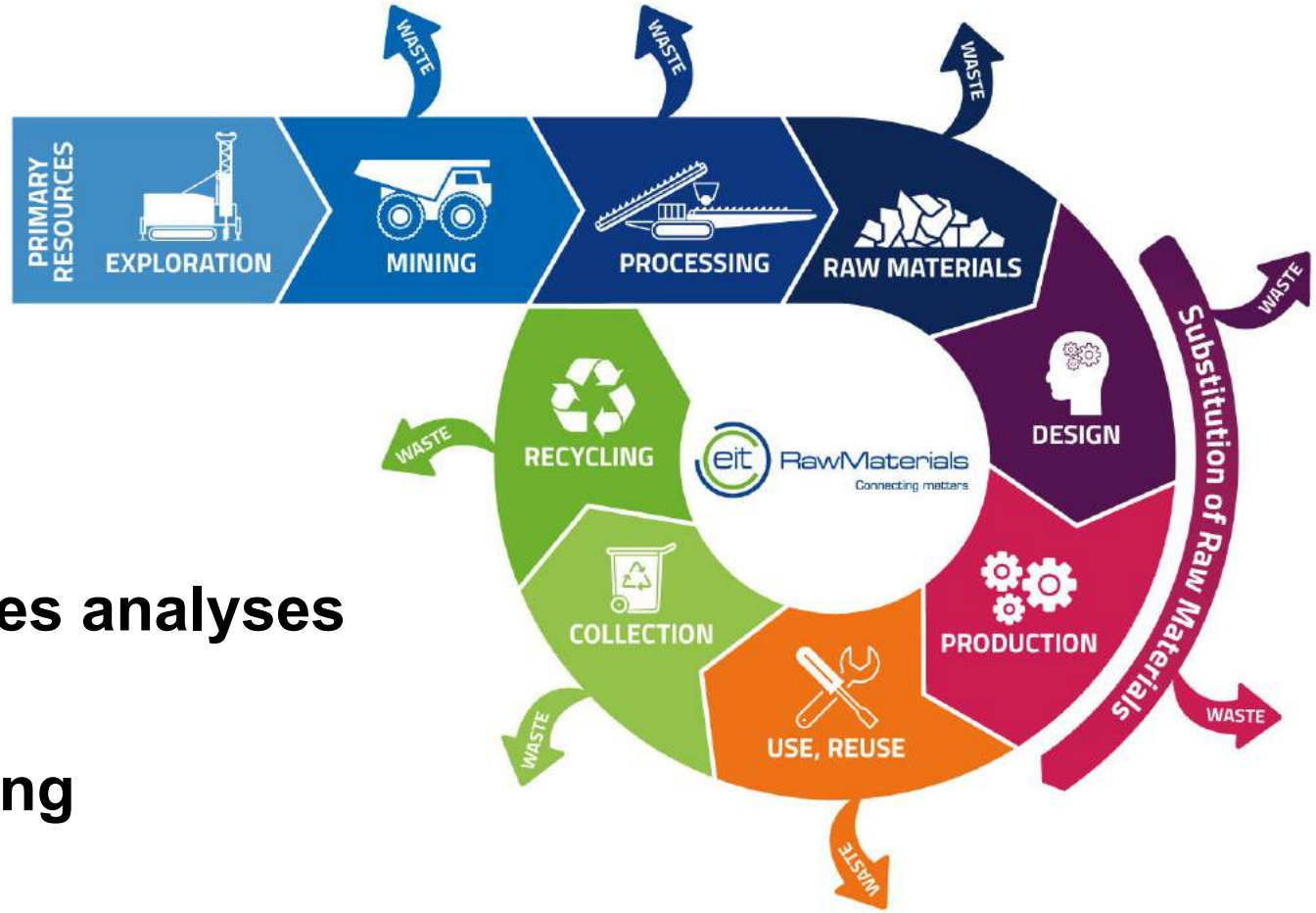
Its activities are geared to scientific research, support to public policy development and international cooperation.





BRGM expertise

focus along the value-chain



- **Exploration**
- **Mineral characterization**
  - **Geochemistry & lithium isotopes analyses**
- **Market and use**
- **Sustainable Processing & Recycling**

GeoERA RAW MATERIALS

FRAME
FORECASTING AND ASSESSING EUROPE'S STRATEGIC RAW MATERIALS NEEDS

european Lithium Institute

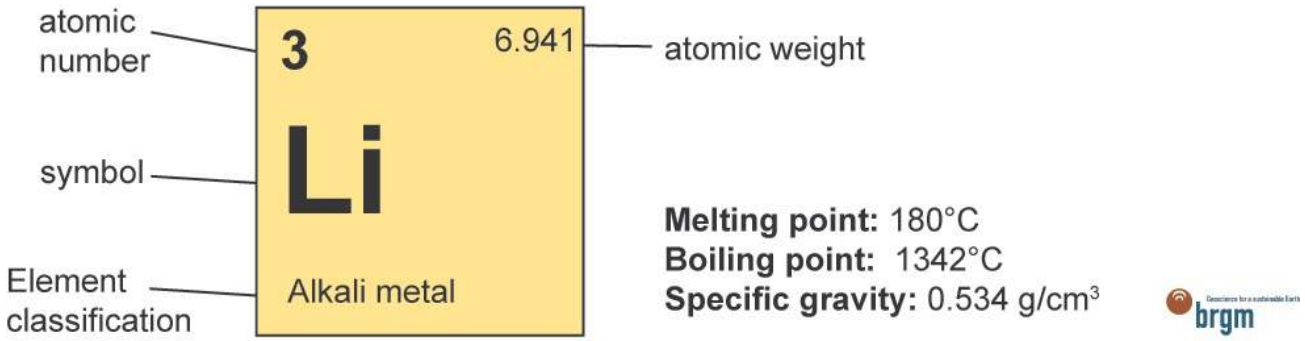
EuGeLi

LABEX VOLTAIRE

Geoscience for a sustainable Earth
brgm

What is Lithium?

- Silvery-white alkali metal
- Highly reactive
- Excellent electrical conductivity
- The most electronegative metal



An excellent candidate for electromobility and green technologies such as in:

- Energy storage device
- Batteries (Li-ion batteries)

Lithium sources

BRINES

- Li-rich **lacustrine evaporates**
- Relatively **recent**, enclosed, **tectonically active** basins
- In **arid** to **hyper-arid** climates

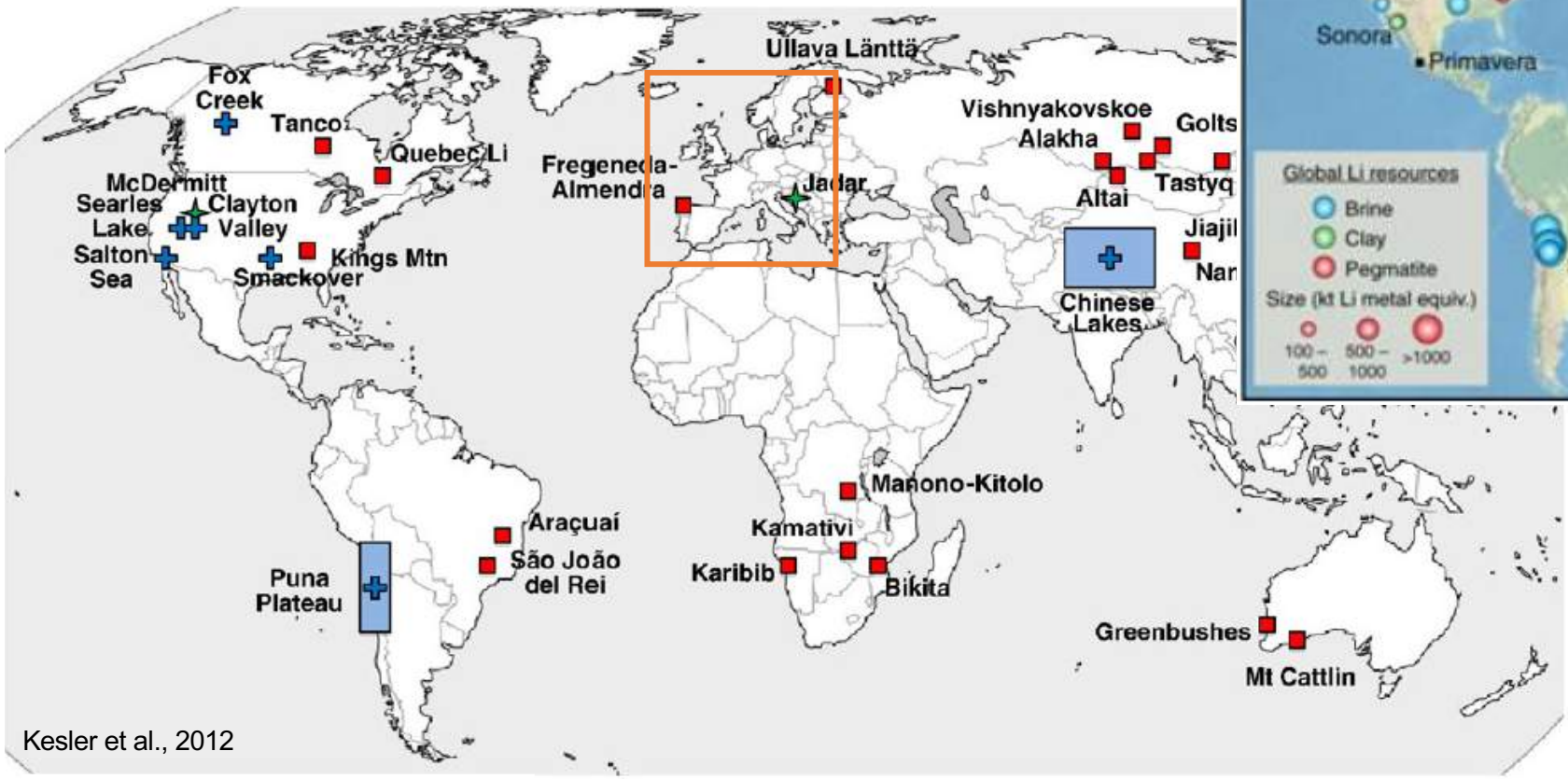
HARD-ROCKS

- Li-rich mineralization in **magmatic** and/or **sedimentary** rocks
- Related to **endogeneous** or **exogeneous** processes
- Widespread varieties of **Li-bearing minerals**

UNCONVENTIONNAL

- Seawater
- Hectorite
- **Geothermal brines**
- Etc.

Global Lithium resources and reserves: EU Inventory



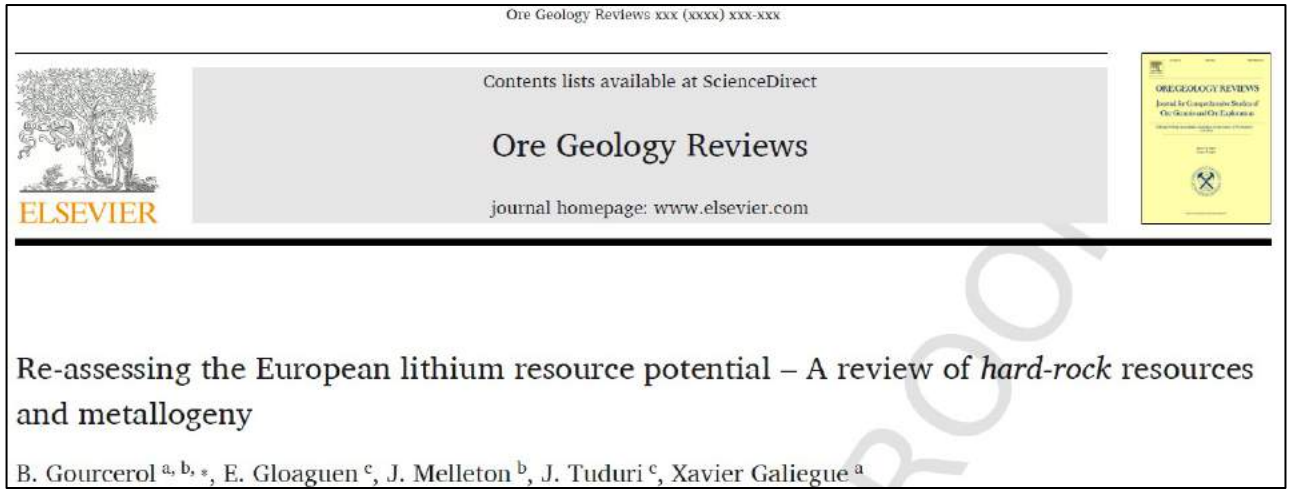
Kesler et al., 2012

Benson et al., 2015

- Brine deposits
- Hard-rock deposits
- Non conventional deposits

Lithium resources from hard-rock deposits

Compilation of European *hard-rock* lithium occurrences & deposits


Ore Geology Reviews xxx (xxxx) xxx-xxx

Contents lists available at ScienceDirect

Ore Geology Reviews

journal homepage: www.elsevier.com

Re-assessing the European lithium resource potential – A review of *hard-rock* resources and metallogeny

B. Gourcerol [a, b, *], E. Gloaguen [c], J. Melleton [b], J. Tuduri [c], Xavier Galiegue [a]

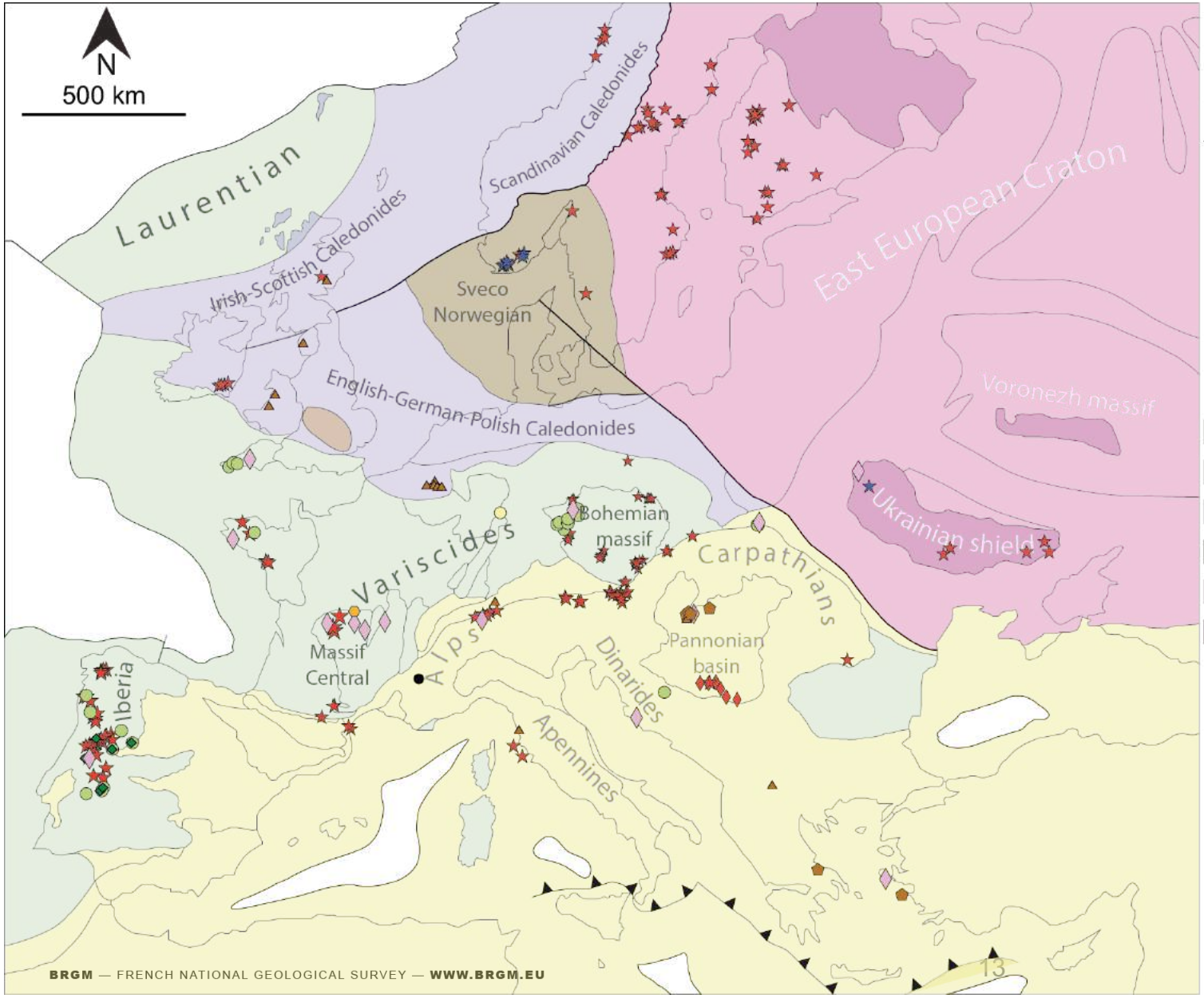
527 lithium occurrences and deposits

This is almost **five times more** than the previous **Mineral4EU-ProMine** (http://minerals4eu.brgm-rec.fr/) inventory (Cassard et al., 2015).

According to this compilation (and previous ones, e.g., Christmann et al., 2015), **two distinct categories** of lithium deposits and occurrences are found in Europe:

1) Magmatic-related
2) Sedimentary/hydrothermal-related deposits

Lithium resources from hard-rock deposits



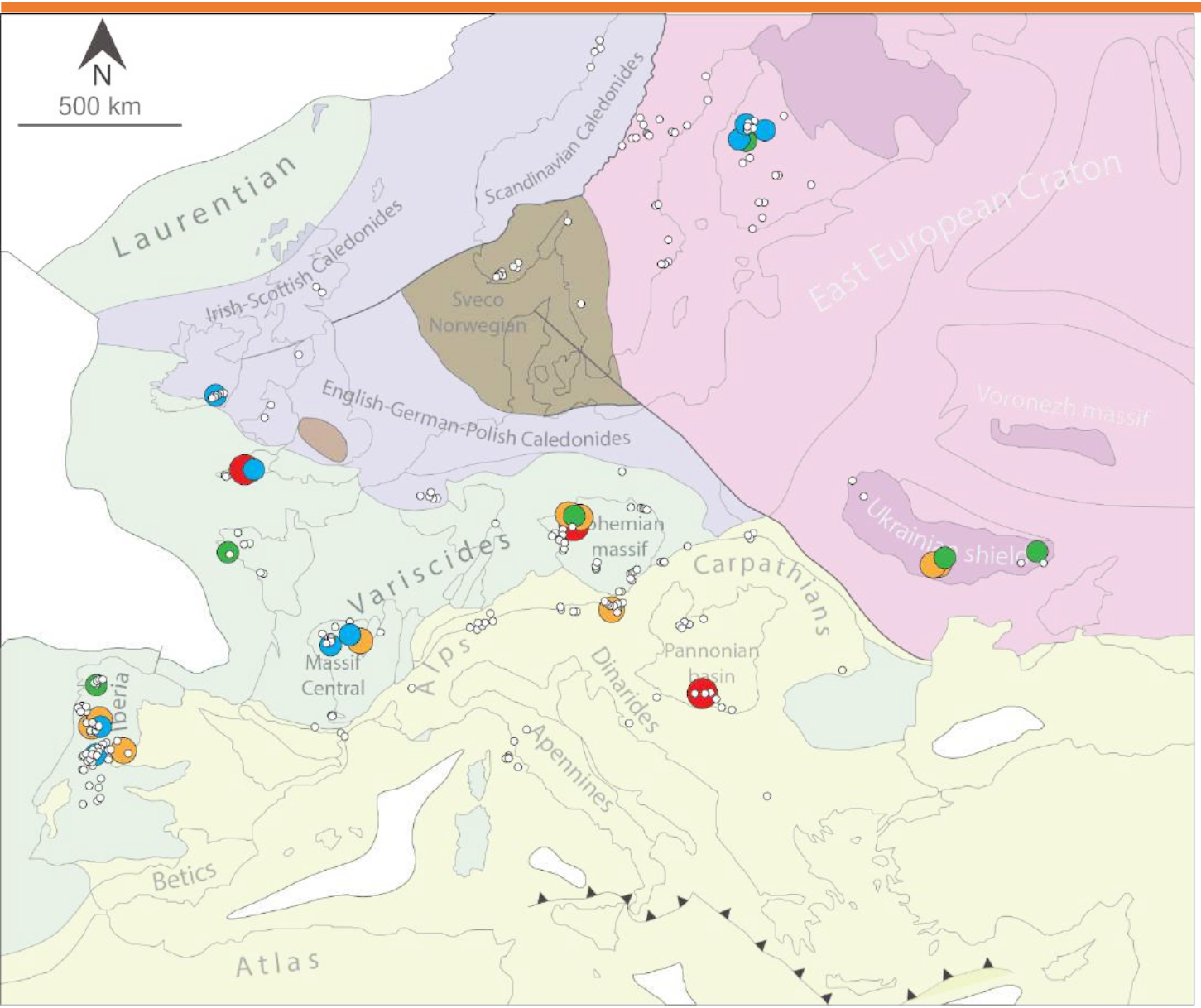
Legend

- Evolved rare metals granites
- LCT pegmatites
- Mixed NYF-LCT pegmatites
- Greisen
- Li-bearing MVT deposits
- Li-bearing Bauxite deposits
- Li-bearing Mn-(Fe) deposit
- Quartz-montebrasite veins
- Li-bearing tosudite
- Cookeite occurrence

- Meso-Cenozoïc
- Middle to Late Paleozoïc
- Early Paleozoïc
- Late Proterozoïc
- Early Proterozoïc
- Archean

Geoscience for a sustainable Earth
brgm

Lithium resources from hard-rock deposits



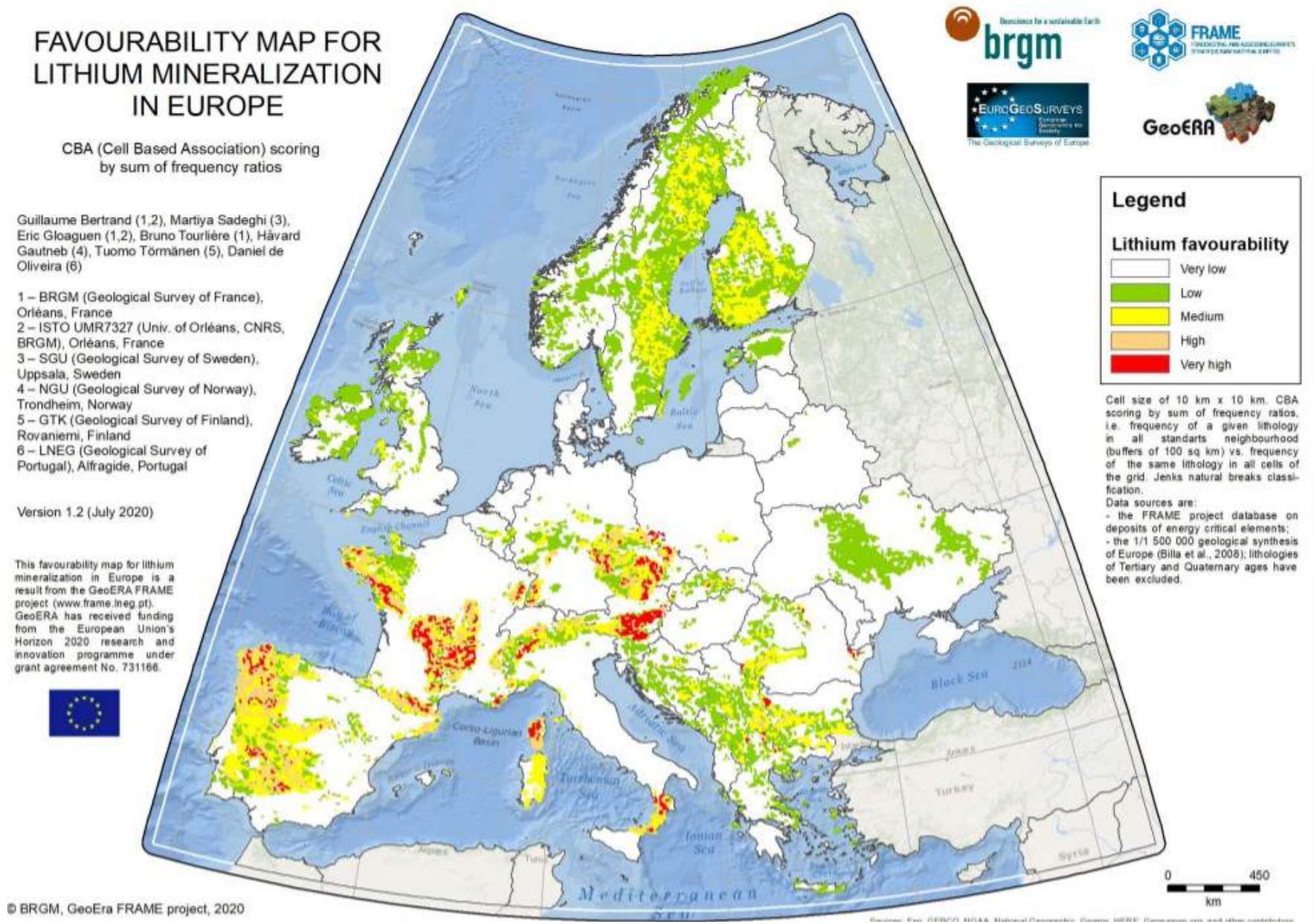
Among the **527** lithium occurrences and deposits

27 identified deposits

8 Mt Li2O corresponding of **21 Mt LCE**

Geoscience for a sustainable Earth
brgm

Lithium resources from hard-rock deposits



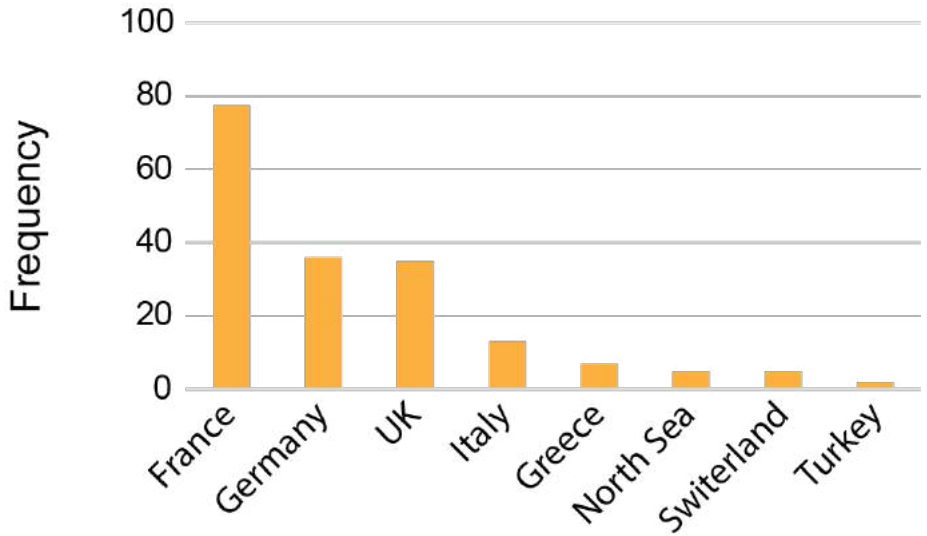
Mainly related to the

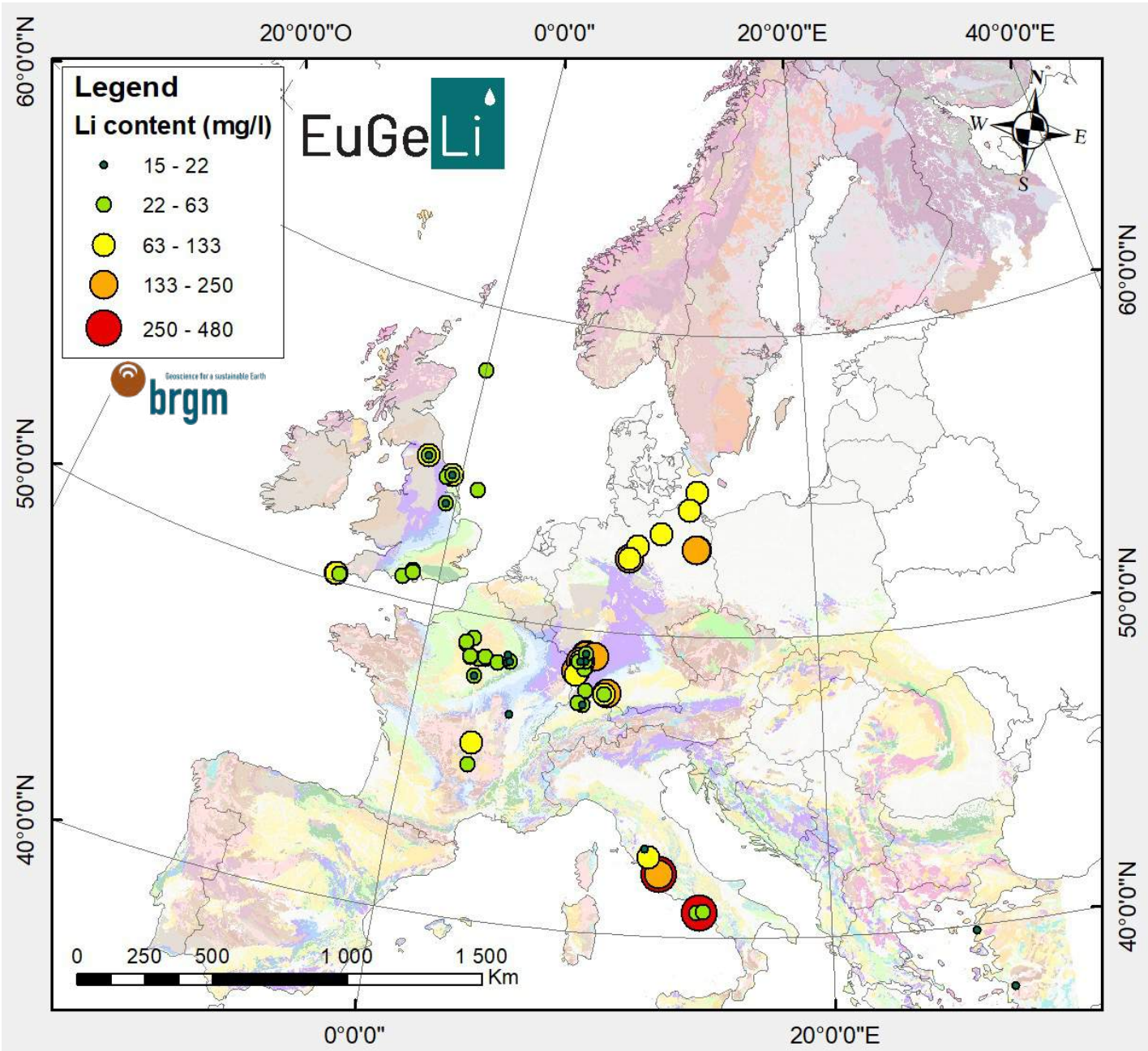
Variscan orogen

Geoscience for a sustainable Earth
brgm

Lithium resources from geothermal brines: Inventory

182 occurrences identified



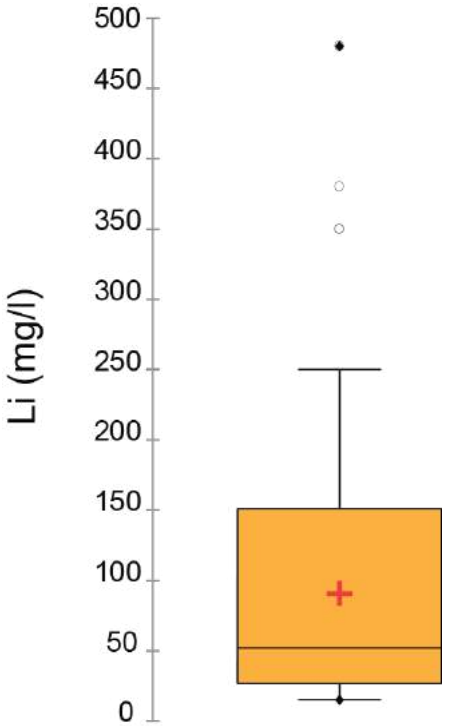


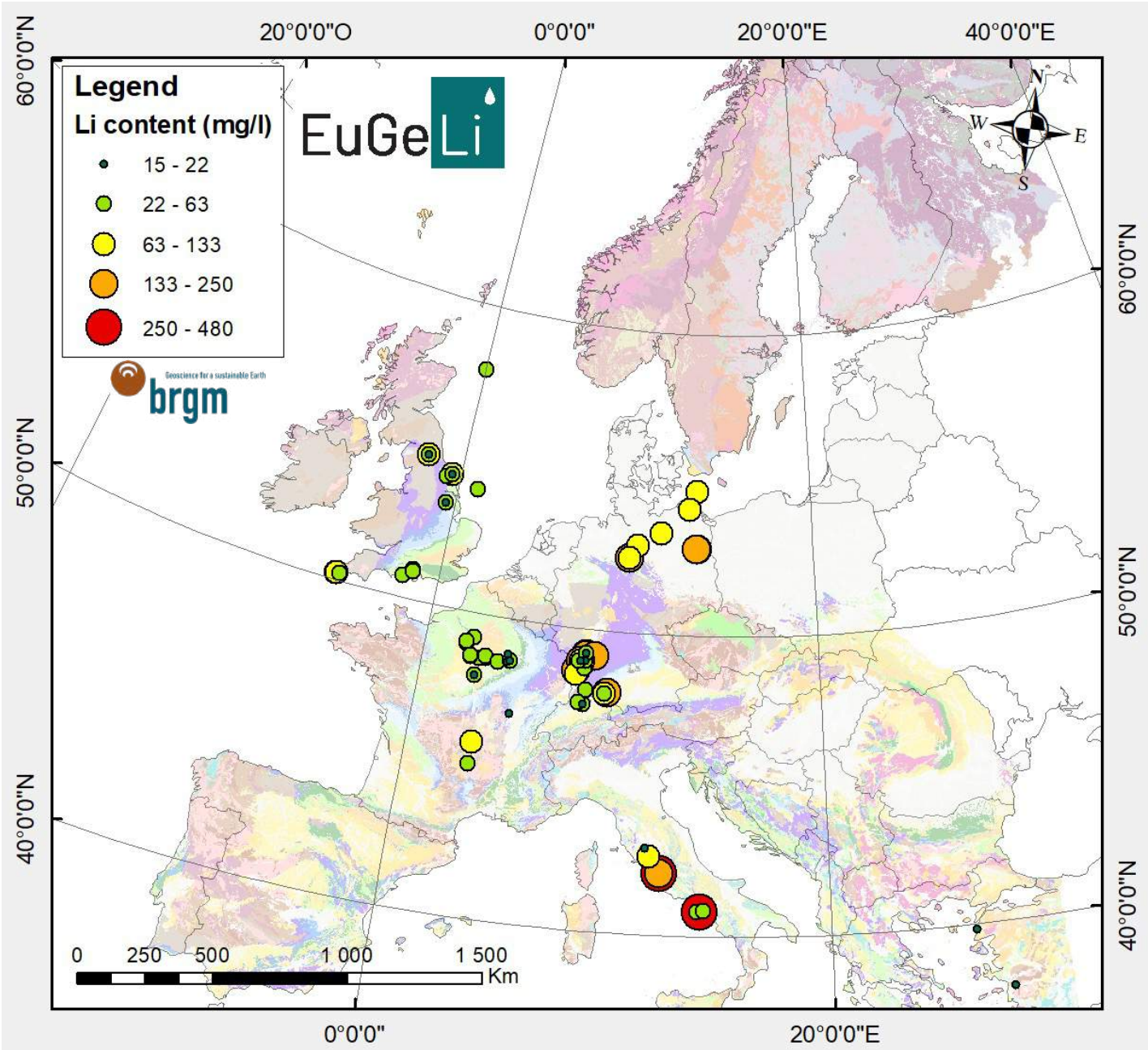
EuGeLi

eit RawMaterials Connecting matters | European Institute of Innovation & Technology

Lithium resources from geothermal brines

182 occurrences identified



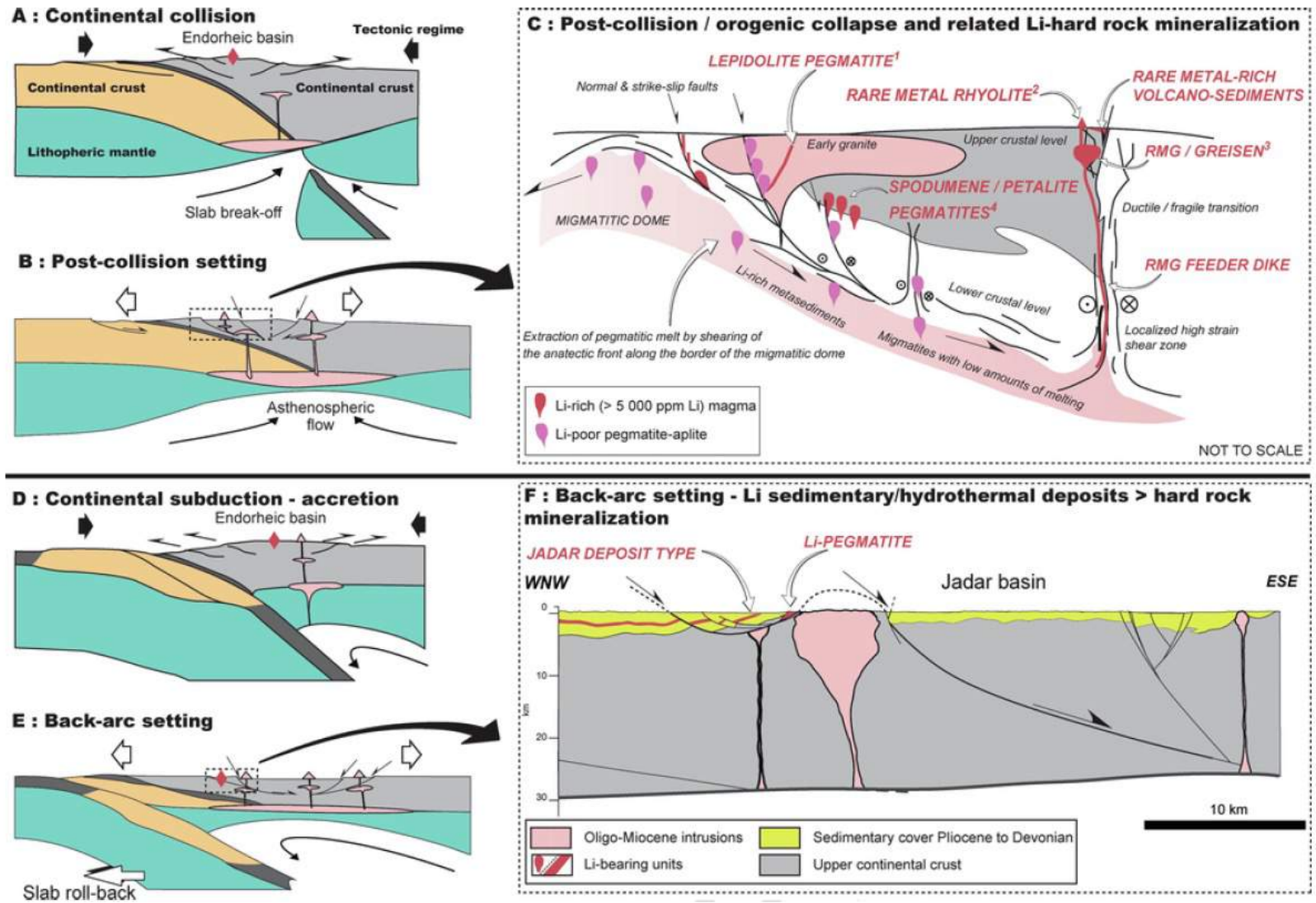


EuGeLi

eit RawMaterials Connecting matters

European Institute of Innovation & Technology

Hard-rock verus geothermal brines



A **pre-existing Li-rich source** related either to paleoenvironmental sedimentation conditions or a crustal anomaly;

Presence of **lithospheric thickening;**

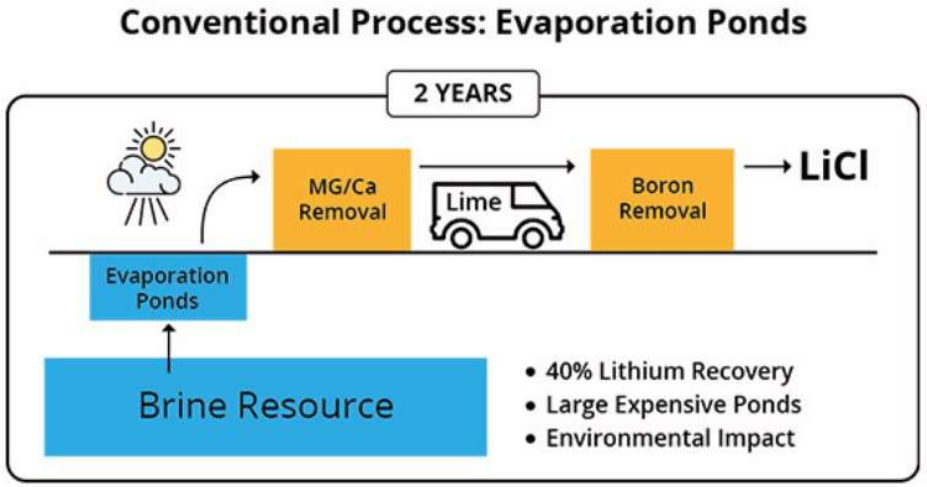
A regional or local **extensional** regime;

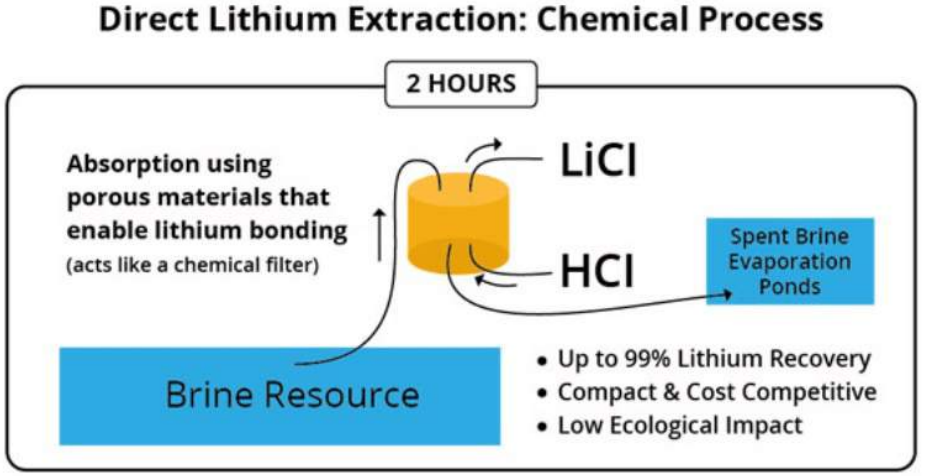
Existence of **fracture sets** acting as channel ways.

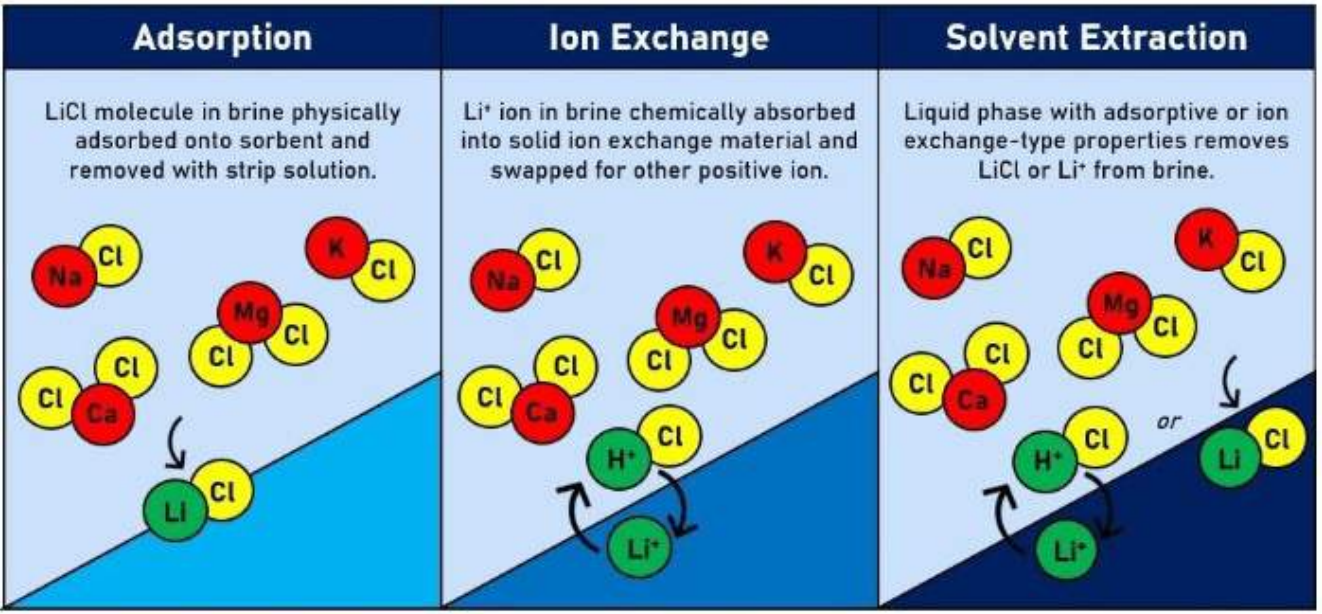
Gourcerol et al., 2019

Lithium resources from geothermal brines : Processes

- Direct Lithium Extraction (DLE) Process applied on geothermal brine and petroleum brine projects



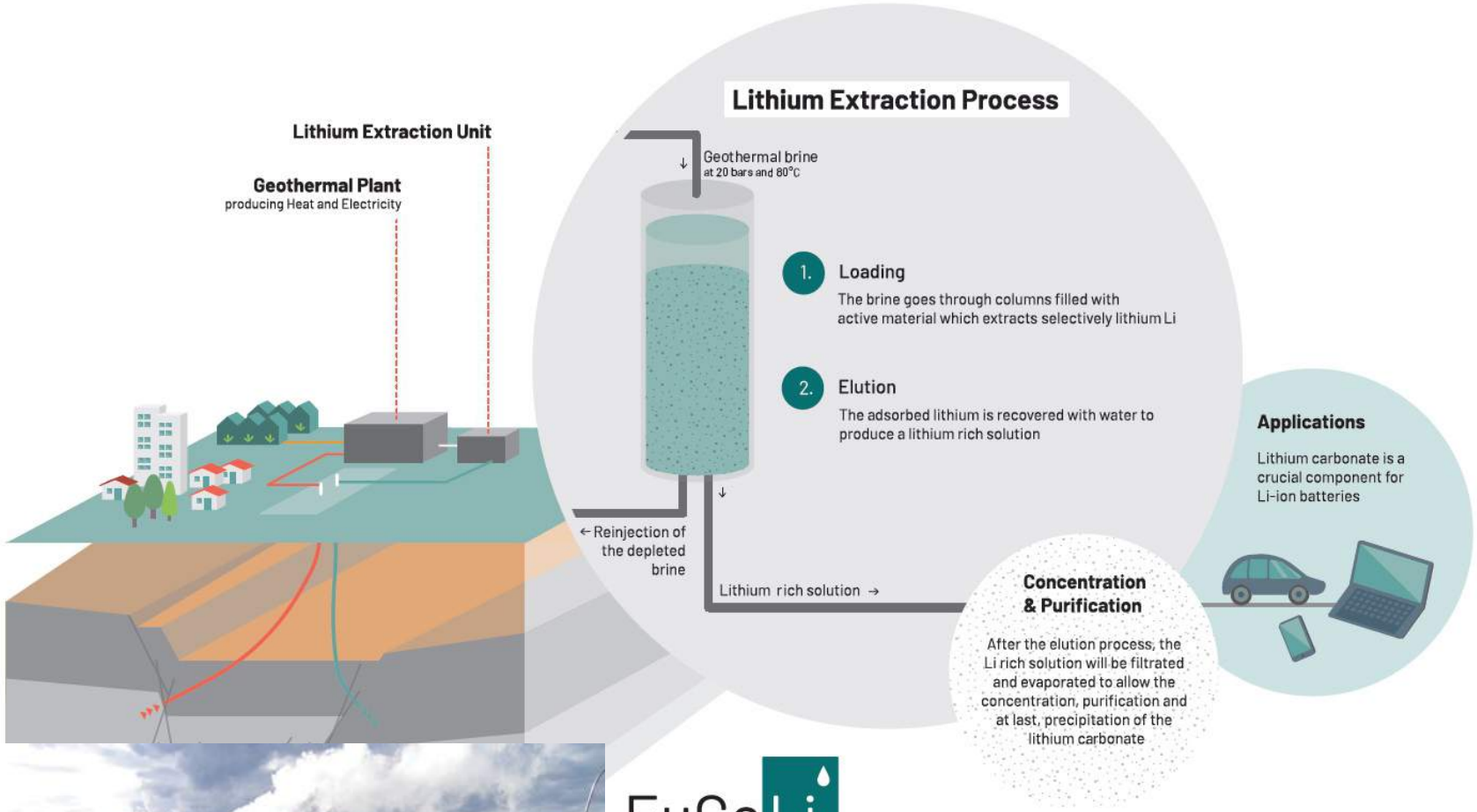




- 3 main types of DLE

Geoscience for a sustainable Earth
brgm

Lithium resources from geothermal brines : Processes

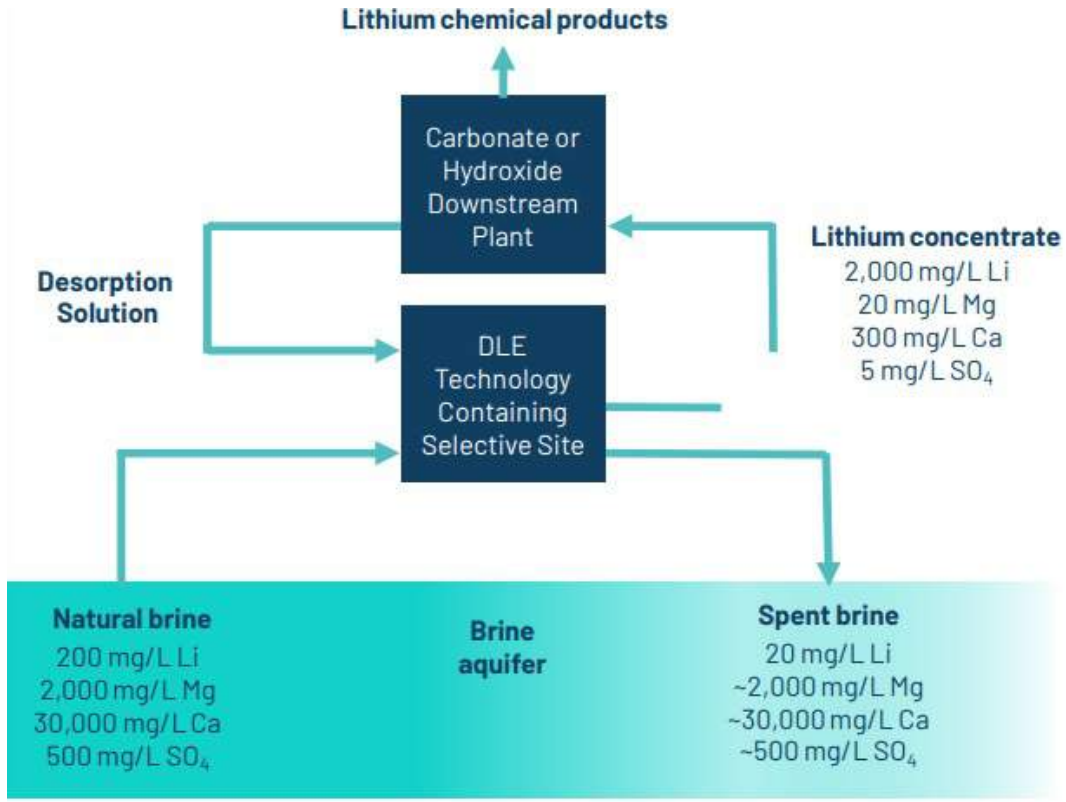


- Direct Lithium Extraction (DLE) by adsportion process co-developed by Eramet in partnership with Electricité de Strasbourg
- Pilot Stage
- Rittershoffen geothermal power plant (northern Alsace, France)
- Production of Lithium carbonate

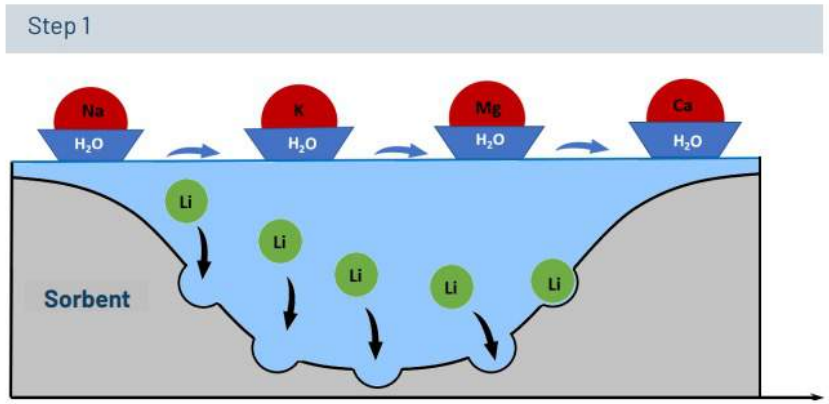
EuGeLi

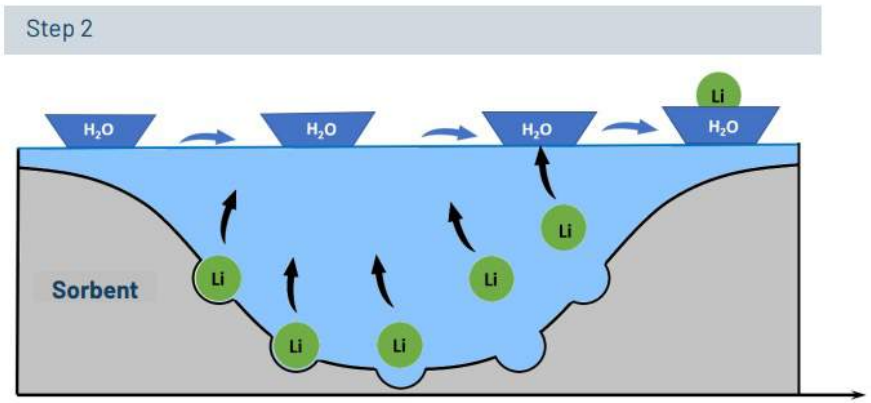
eit RawMaterials
Connecting matters
European Institute of Innovation & Technology

Lithium resources from geothermal brines : Processes



- Direct Lithium Extraction (DLE) by adsportion process developped by Vulcan Energy
- Pilot Stage
- At the Insheimand Landau deposit (Taro and Orteneau licenses, Germany)
- Production of Lithium hydroxide





Lithium resources from geothermal brines : Processes

Per tonne of lithium hydroxide produced

Hard rock mining
60% of world lithium production

Evaporation ponds
40% of world lithium production

VULCAN ENERGIE
ZERO CARBON LITHIUM™

Skills and competences – job roles

focus along the value-chain

- **Exploration**
- **Mineral characterization**
  - **Geochemistry & lithium isotopes analyses**
- **Market and use analyses**
- **Sustainable Processing & Recycling**

JOB ROLES:

Geologists
Geochemist
Metalurgist
Engineer

THANK YOU FOR YOUR ATTENTION

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

www.brgm.eu

Geoscience for a sustainable Earth
brgm

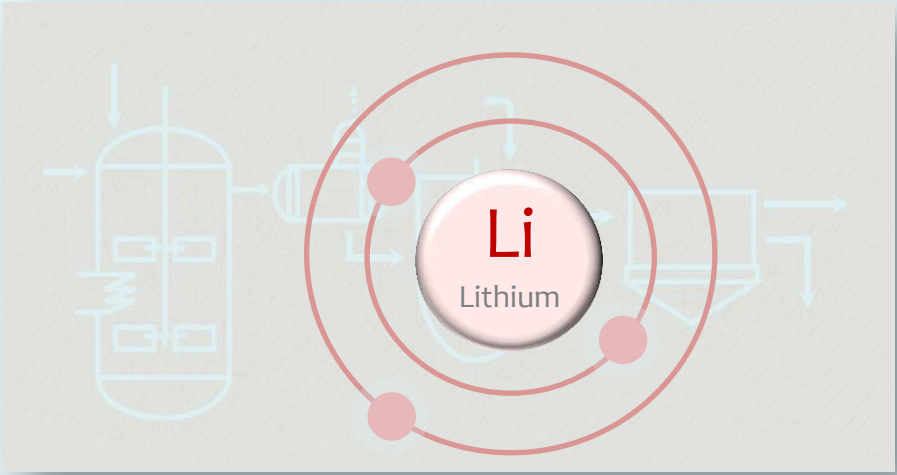
Lithium metallurgical processing from primary resources

from Li mineral concentrates to Li commodities

Carlos Nogueira

April 27, 2022

LNEG



albatts
Alliance for Batteries Technology, Training and Skills

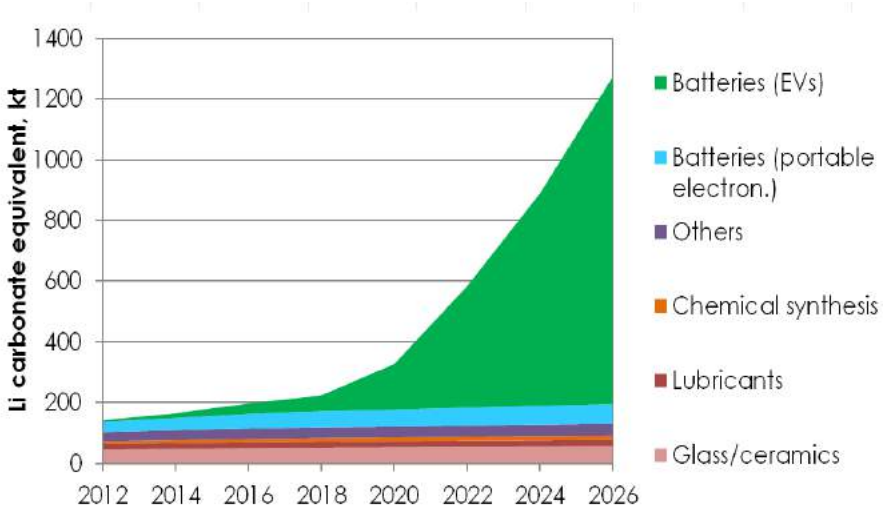
Lithium Mining and Extraction:
European Sourcing and Skills

Session: EXPERTS PRESENTATIONS:
LITHIUM PROCESSING

Outline

1. Introduction – Li applications and value chain
2. Li primary resources
3. Metallurgical treatment
4. Detailed description of process
5. Needs and Solutions
6. Skills and Training in Metallurgical Processing

Li applications

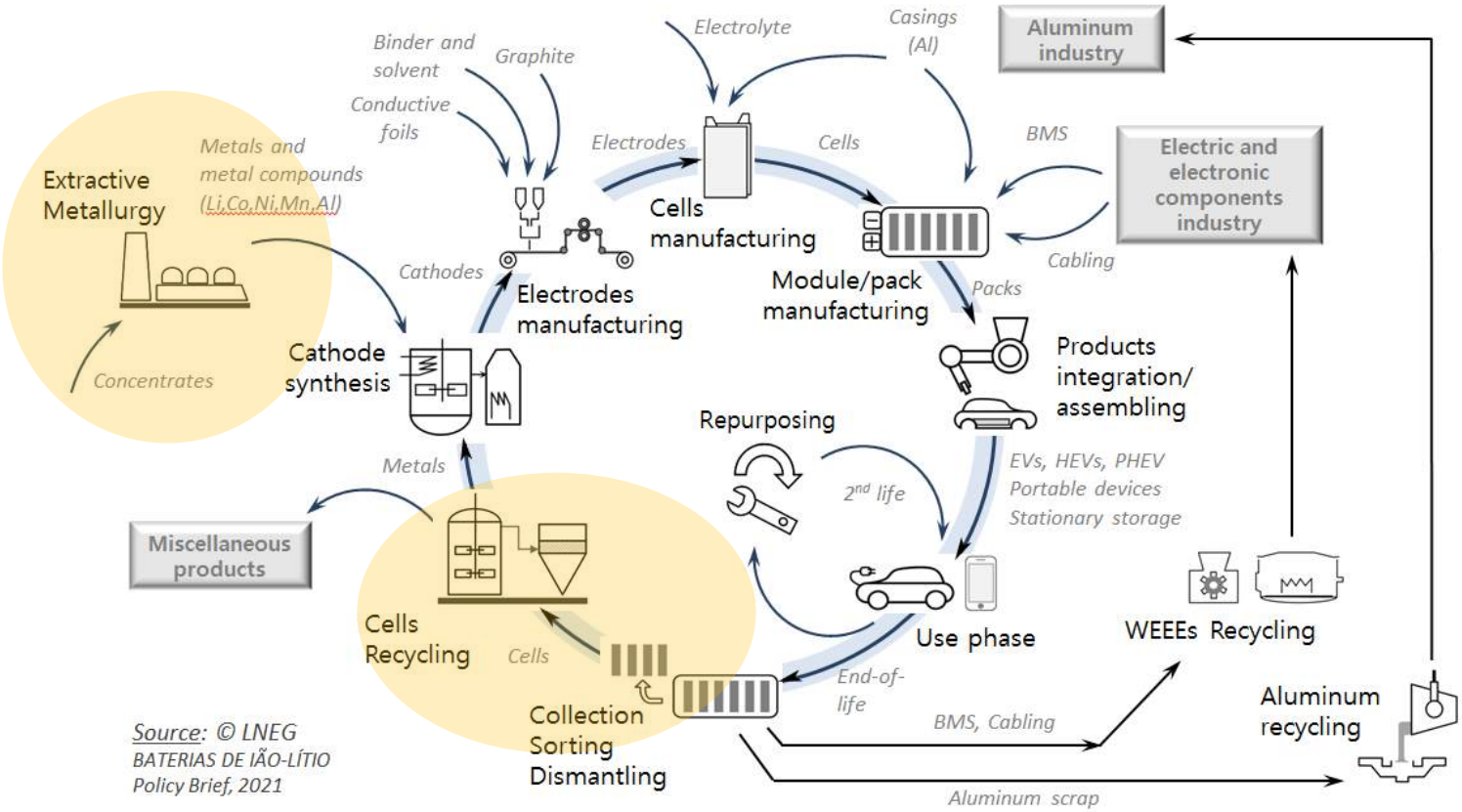


Lithium – a strategic and critical metal for EU

Li-ion batteries: the current state-of-the-art battery technology, supporting:

- Energy Transition
  - Electric mobility
  - Electrochemical energy storage (residential storage, energy communities, grid balance)
- Electronic portable devices

1.1 Li-ion Batteries (LIBs) value chain



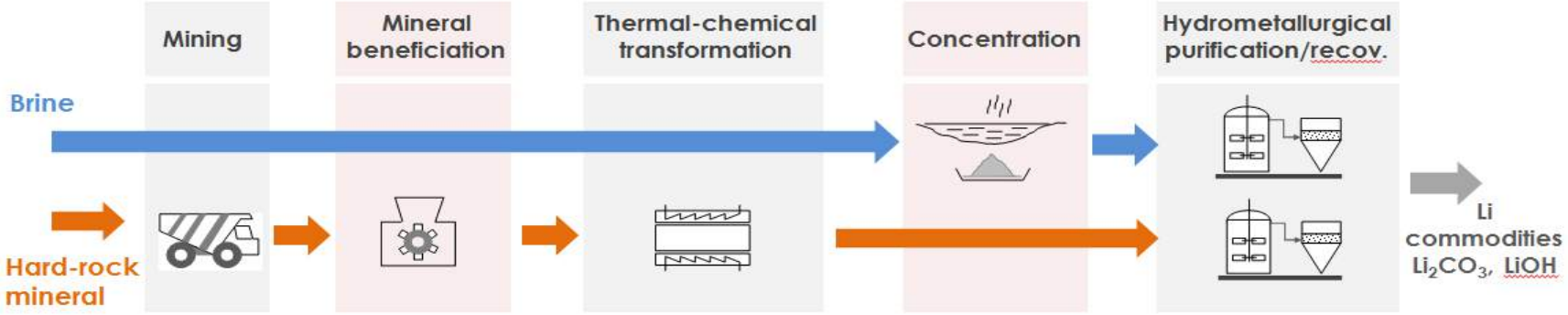
Source: © LNEG
BATERIAS DE IÃO-LÍTIO
Policy Brief, 2021

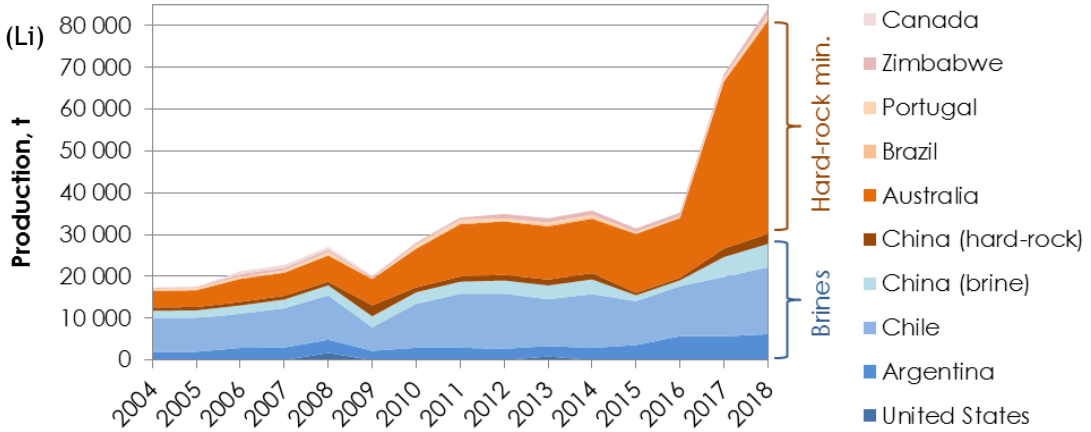
Highlights

- An extend and complex value chain
- A circular economy approach
- Two different Li sources: primary (ores) and secondary (recycled batteries)

2. Li primary resources

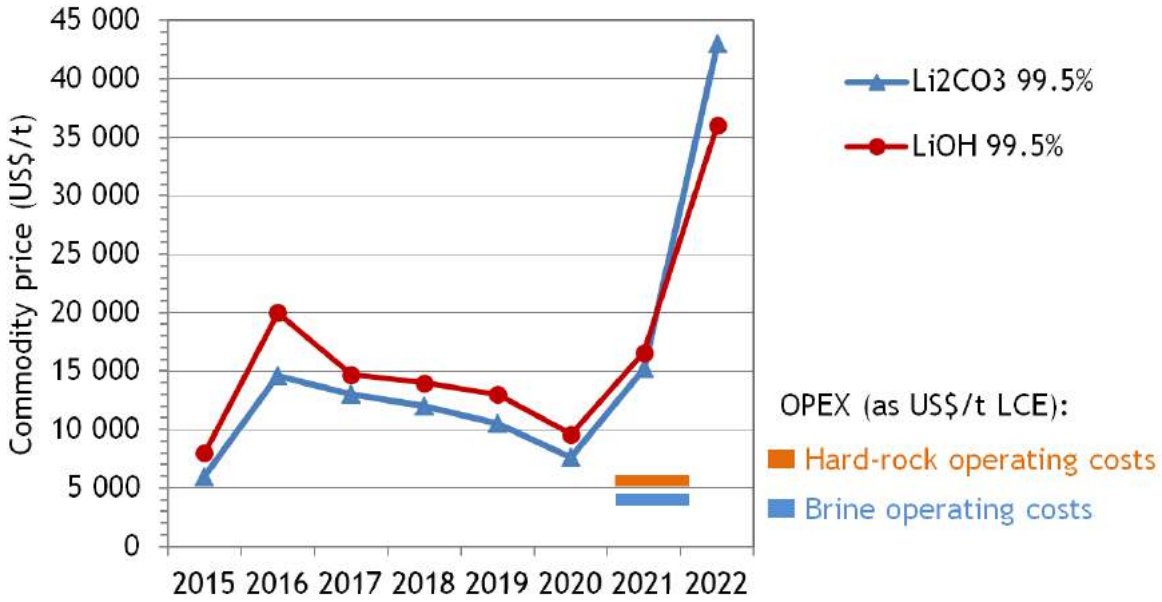
2.1 Brines vs. Hard-rock minerals





- Hard-rock minerals are making their way and becoming more and more relevant due to:
  - cost reduction
  - increase in the value of Li commodities in the markets

2.2 Prices and Processing costs

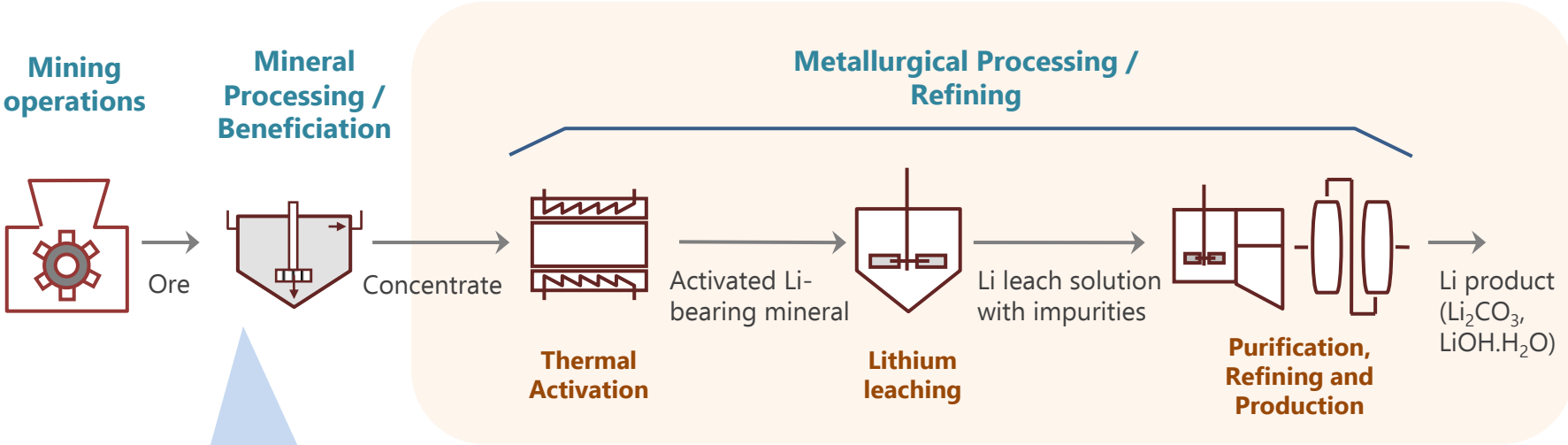


- Li commodity prices rapidly grow 400% in just one year;
- Massive demand for electric vehicles and labour shortage in Australian mining operations are reasons justifying the huge grow in a short time.
- The added value of commodities are substantially higher than operation costs, but ...
- These figures do not yet take into account the effects of the current energy crisis.

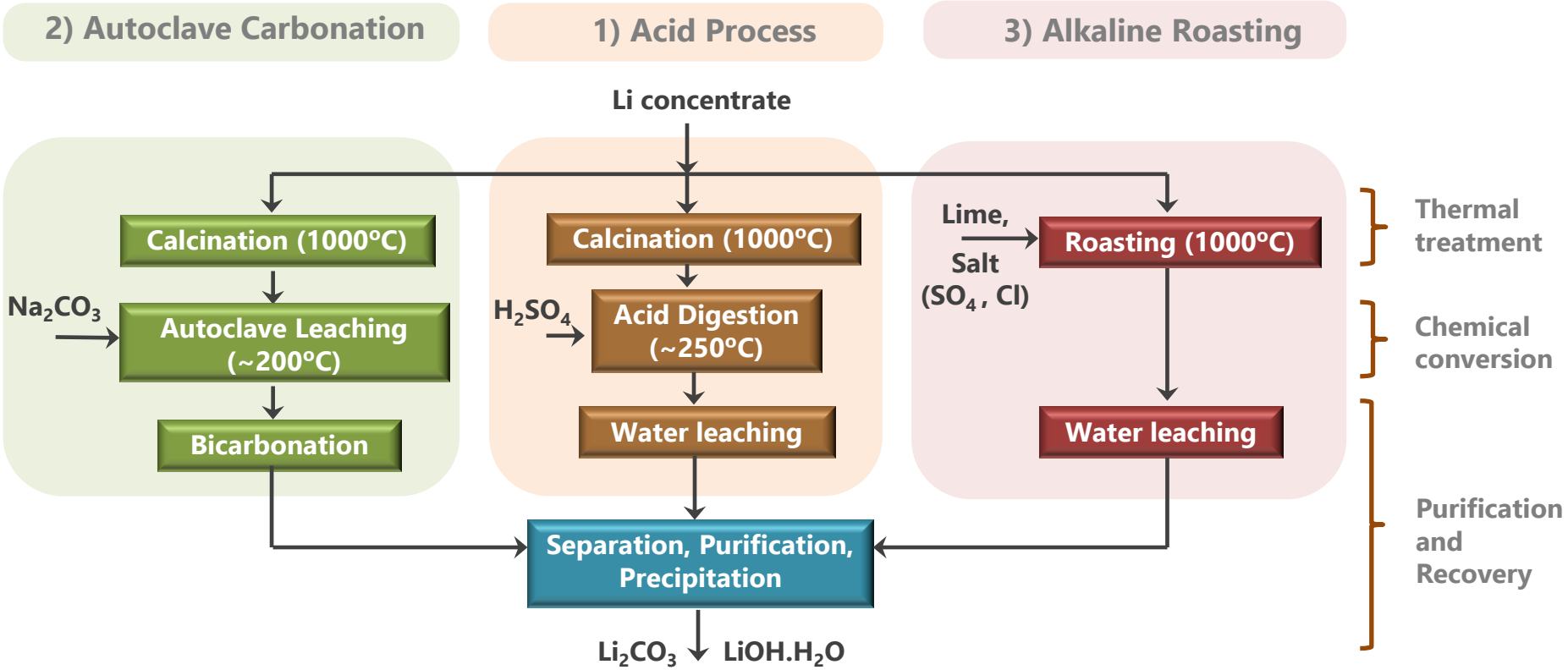
Typical grades

Mineral	Formula	Grade, Li (%)		
		Theoretical	Ocurrence Range	Concentrate grade
Spodumene	$Li_2O.Al_2O_3.4SiO_2$	3.7	0.2 – 1.5	3.3
Lepidolite	$K(Li,Al)_3(AlSi_3O_{10})(OH,F)_2$ (*) $KLi_2Al(Si_4O_{10})(OH,F)_2$ (**)	2.6 3.6	0.2 – 2.0	1.5-2.5
Petalite	$Li_2O.Al_2O_3.8SiO_2$	2.3	0.4 – 1.1	1.4
Eucriptite	$Li_2O.Al_2O_3.2SiO_2$	5.5	-	-
Zinnwaldite	$KLiFeAl(AlSi_3O_{10})(F,OH)_2$	1.6	0.3	1.0-1.3
Ambligonite Montebrasite	$LiAl(PO_4)(F,OH)$	4.7	0.1 – 1.0	2.6-3.4

(*) *Trilithionite* (**) *Polilithionite*

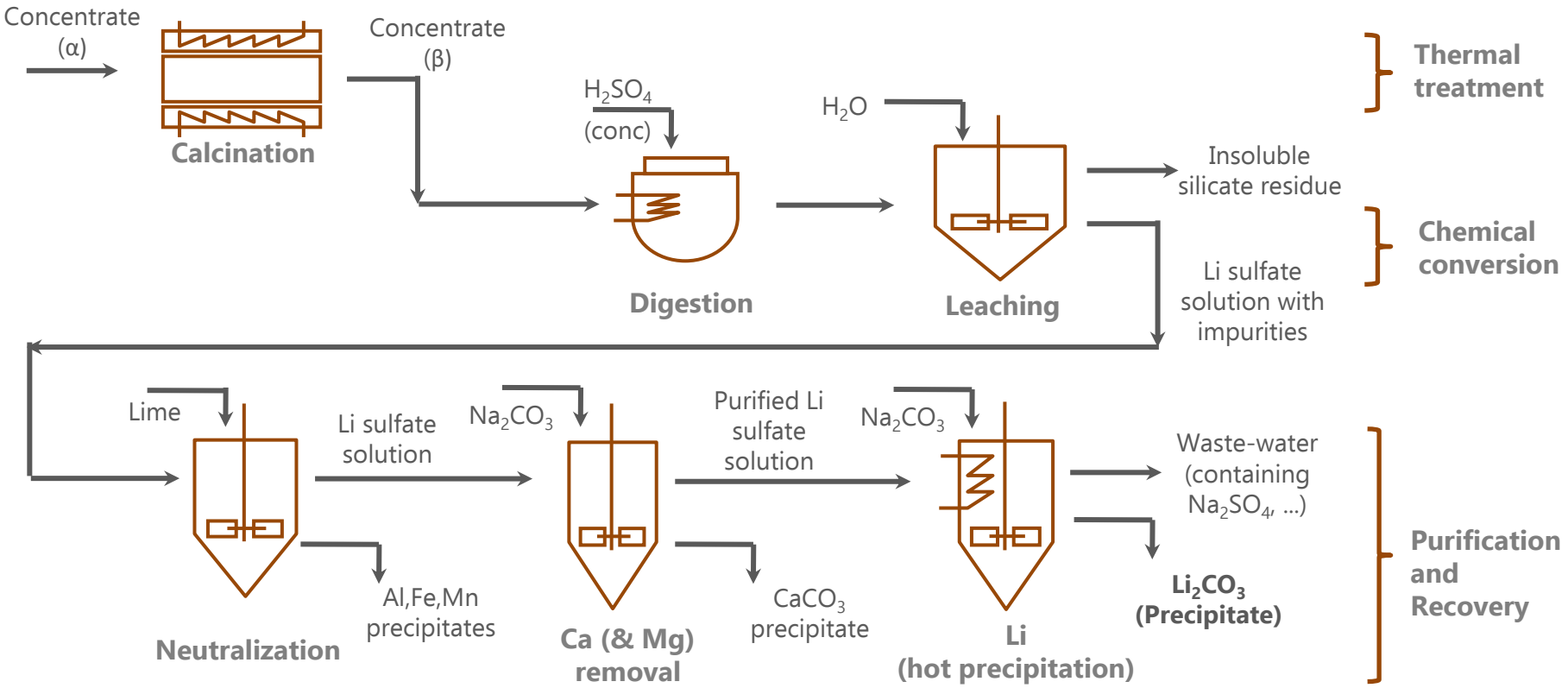

Mining operations
Mineral Processing / Beneficiation
Metallurgical Processing / Refining
Ore
Concentrate
Activated Li-bearing mineral
Li leach solution with impurities
Li product (Li_2CO_3, $LiOH.H_2O$)
Thermal Activation
Lithium leaching
Purification, Refining and Production
Li ores are extracted from the mine and separated from the other mineral species (tailings), obtaining a Li concentrate
Li silicates are very refractory to chemical attack. Require a previous structure activation to improve reactivity.
Li oxides are transformed to water-soluble Li species (e.g Li sulfate).
Impurities (Fe, Mn, Ca, Mg, …) are removed from solution prior to precipitation/crystallization of Li product.

3.2 Hydrometallurgical processing options



4. Detailed description of process

4.1 Acid Process

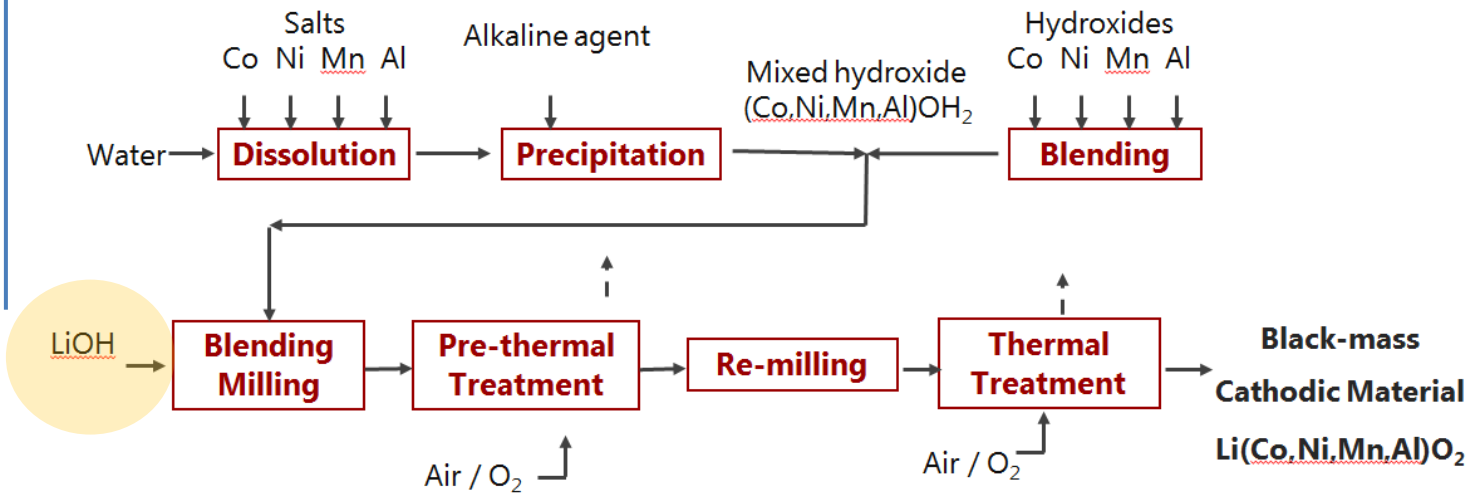


- **Energy Consumption and Energy Efficiency**
  High temperature calcination / roasting required to improve minerals reactivity
- **Chemicals consumption**
  Acid digestion (H_2SO_4); neutralization ad purification (lime, soda, soda ash)
- **Need for high purity Li commodity for battery applications**
  High purity $LiOH.H_2O$ instead of Li_2CO_3
  Increase purity grade: 98% → 99% → 99.5% → …
  More demanding and efficient purification / refining operations
- **Application to other mineral resources (other than spodumene / petalite)**
  Lepidolite, Zinnwaldite, Ambligonite, Li-clays ! …
- **Environmental concerns (Green mining / green metallurgy)**
  Green process design, waste-water management in hydrometallurgical operations, gas emissions in thermal treatment.

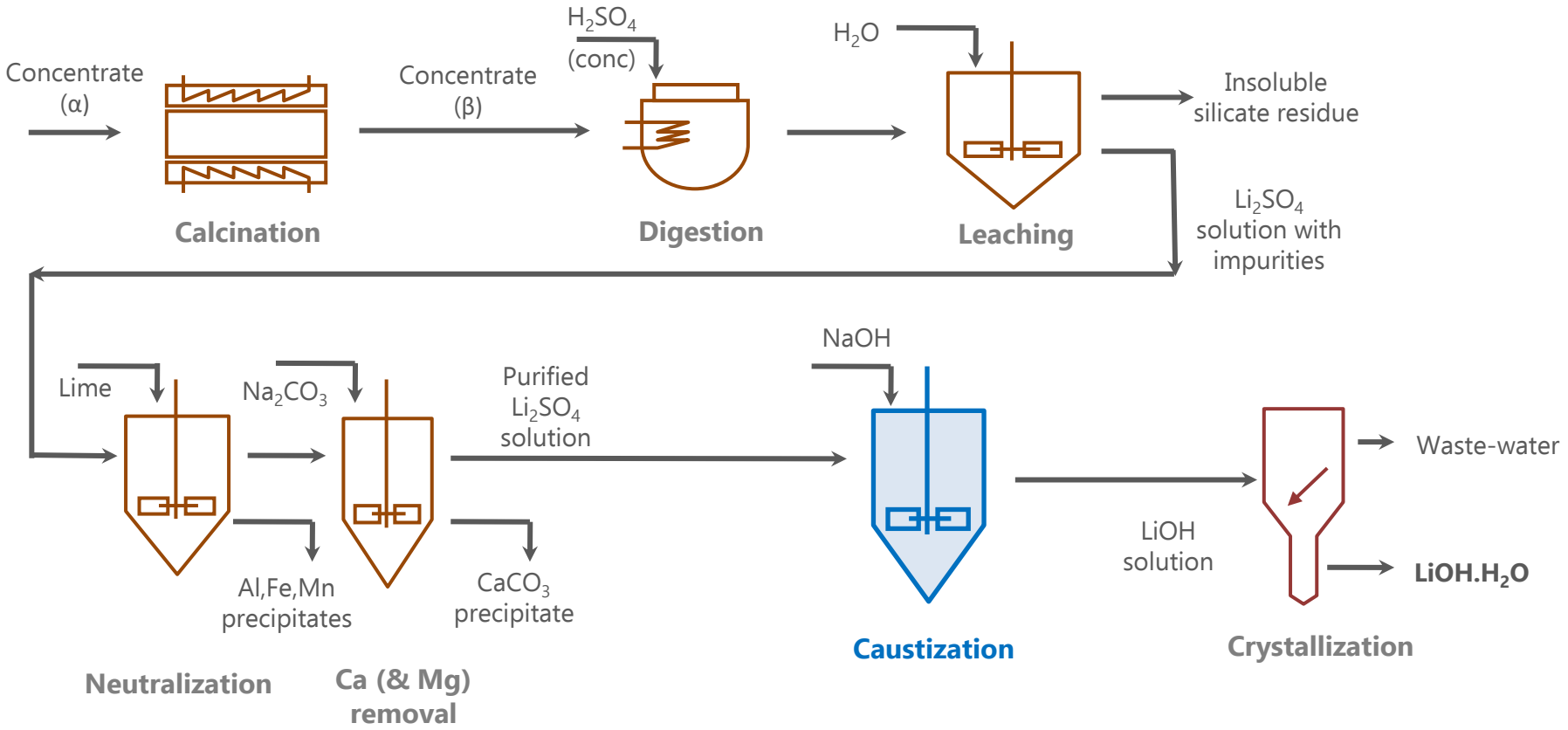
- **The advantages of producing $LiOH.H_2O$ instead of Li_2CO_3**

  Lithium hydroxide is a direct precursor for manufacturing of battery cathode materials;
  Lithium carbonate will require previous conversion to lithium hydroxide, with CO_2 release.

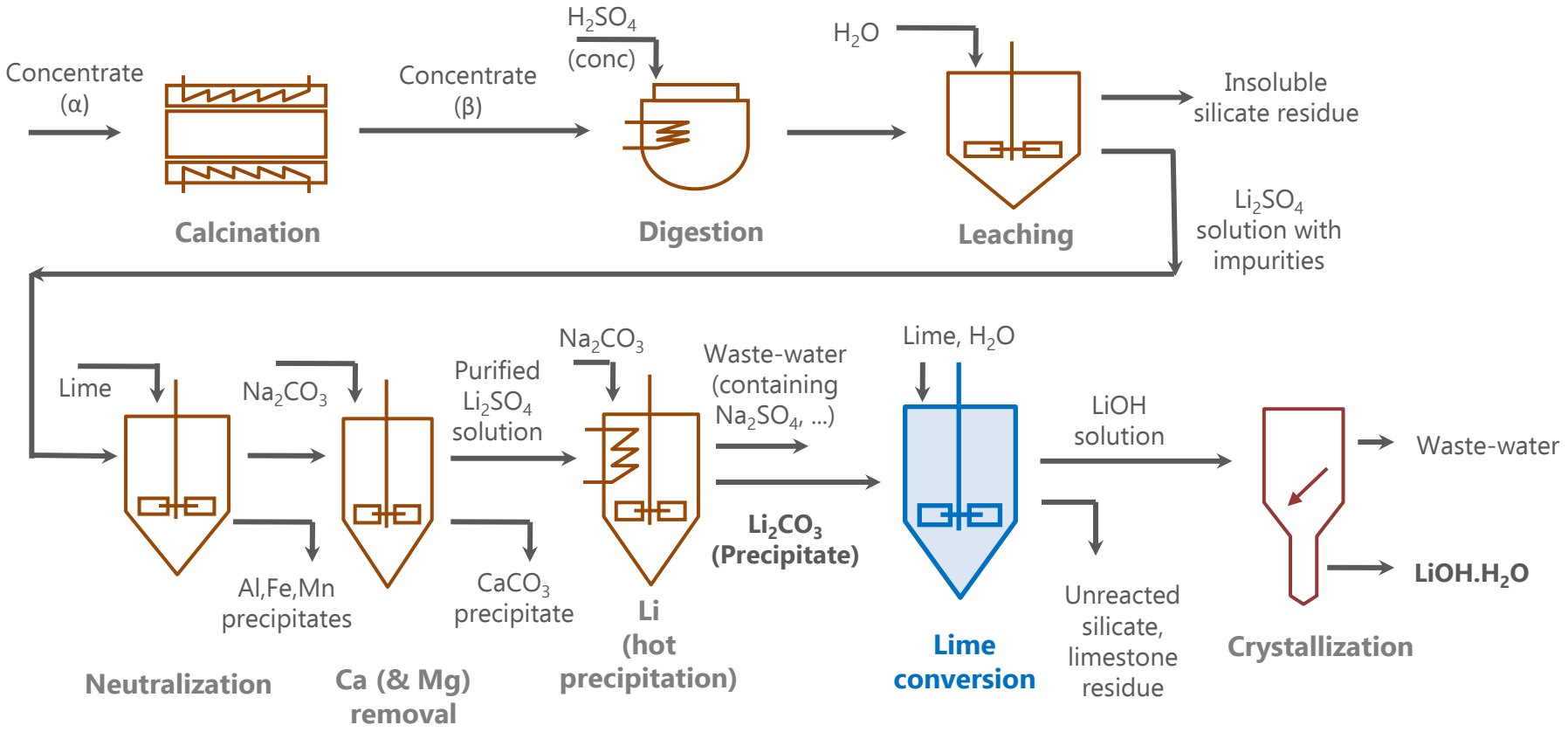
Manufacturing process of cathodic materials



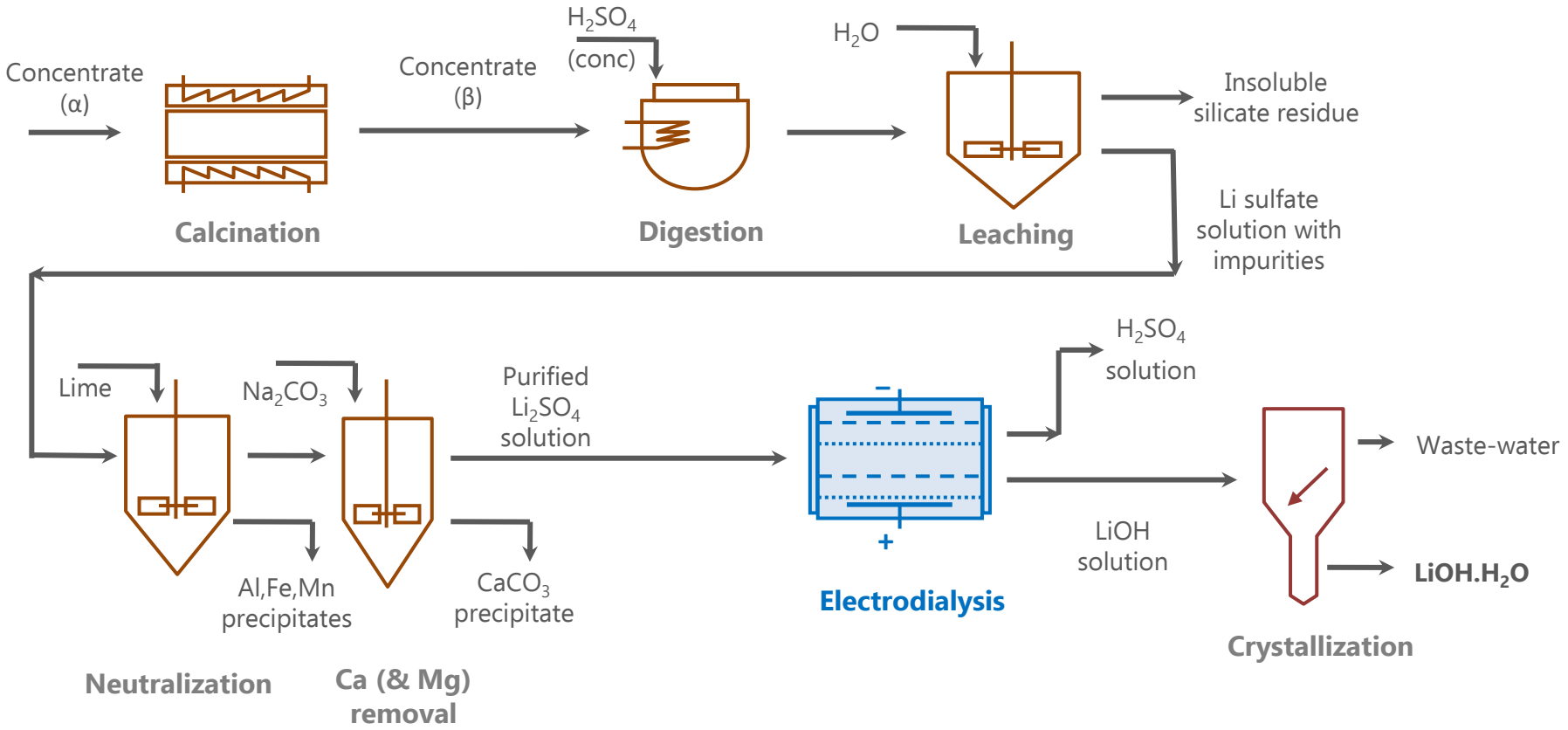
5.2 "Improved" Classical Routes – Acid Leaching



5.2 "Improved" Classical Routes – Acid Leaching



5.2 "Improved" Classical Routes – Acid Leaching



6. Skills and Training in Metallurgical Processing

Actions to be addressed:

- Resume the training effort in chemical/extractive metallurgy in universities (in Metallurgical/Materials Engineering, among others), which has been mostly forgotten in recent years in Europe;
- Promote advanced courses focusing the new purification technologies to apply in industrial projects, aiming at attaining the high purity required for battery-grade Li compounds;
- Promote training in process sustainability, a fundamental topic for the success of projects of new lithium refining facilities:
  - Water management
  - Energy needs and alternative energy sources (e.g H_2)
  - Optimization of reagents/chemicals usage

Thank you

Lithium metallurgical processing from primary resources

from Li mineral concentrates to Li commodities

Carlos Nogueira

carlos.nogueira@lneg.pt

Lithium processing from secondary resources: Recycling

Dr. Nathália Vieceli
MSc. Léa Rouquette, PhD Student

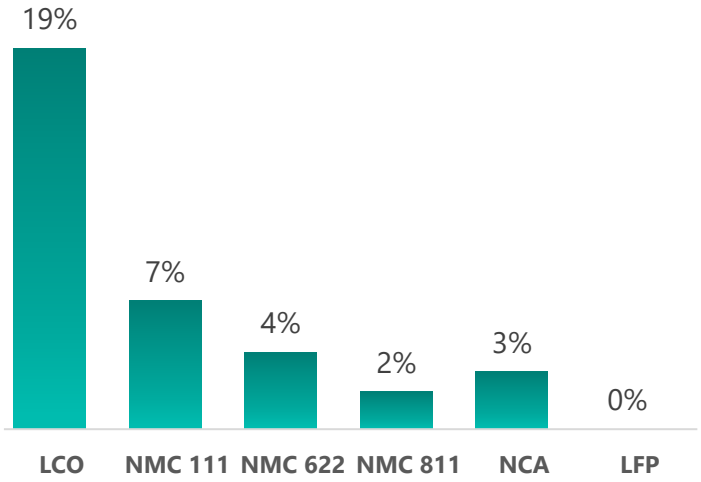
Department of Chemistry and Chemical Engineering
Industrial Materials Recycling and Nuclear Chemistry
Chalmers University of Technology

Webinar Lithium Mining and Extraction: European Sourcing and Skills | 27-04-2022

Why recycle?...

- **Critical materials**
  - Crucial for the transition to greener technologies
- **Create additional supply**
  - Reduce the need for primary resources
  - Reduce the reliance on imports
- **Environmental concerns**

Economic incentive?



Content of Co in a cylindrical cell (type 18650)

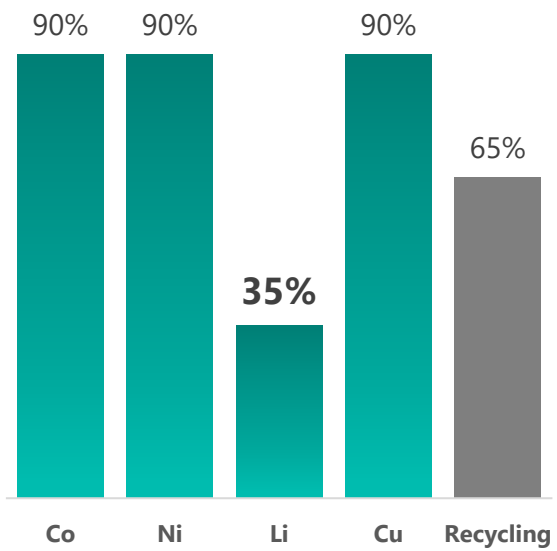
Source: Adpated from Melin, H.E., 2019. State-of-the-art in reuse and recycling of lithium-ion batteries – A research review. London. Available on: https://www.energimyndigheten.se/globalassets/forskning--innovation/overgripande/state-of-the-art-in-reuse-and-recycling-of-lithium-ion-batteries-2019.pdf

Legislation

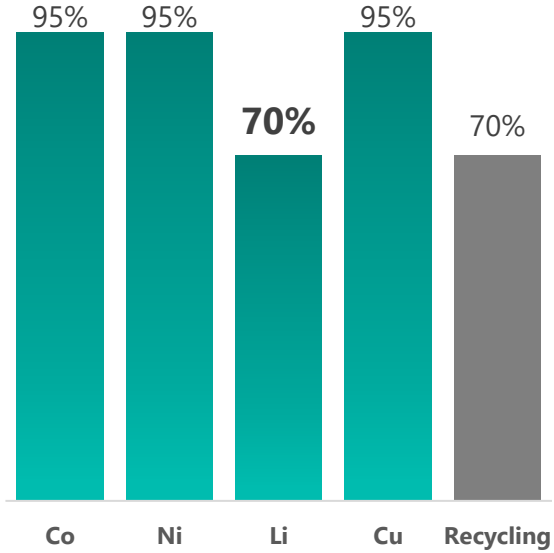
- **Battery Regulation Proposal** released in 2020 (probably implemented 2022-2023), following the Directive 2006/66/EC.
- Objective: establish clear and harmonized rules to make recycling profitable and mandatory.

Legislation

- Measure 5 about **Recycling efficiencies** for LiBs and Recovery of Co, Ni, Li, Cu:



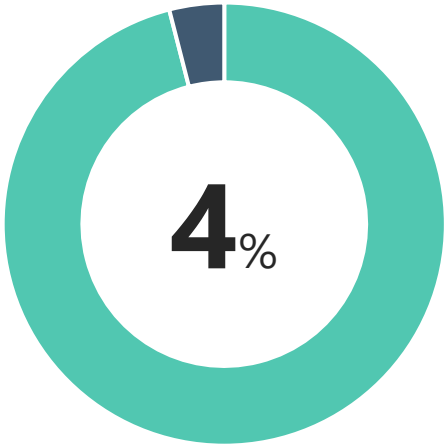
Option 2 (2025) - Medium level of ambition



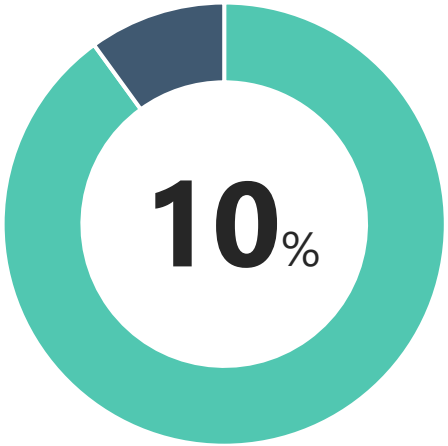
Option 3 (2030) - High level of ambition

Legislation

- Article 8 concerns the **minimum part of recycled material** in new batteries:

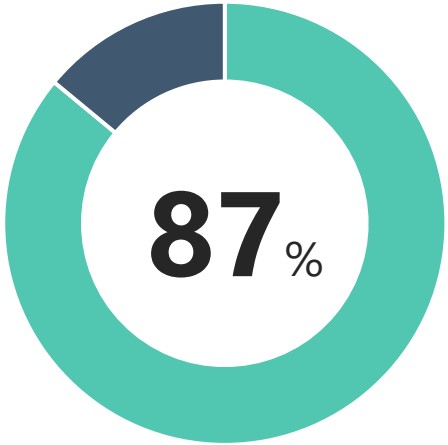


Target for recycled Li in **2030**

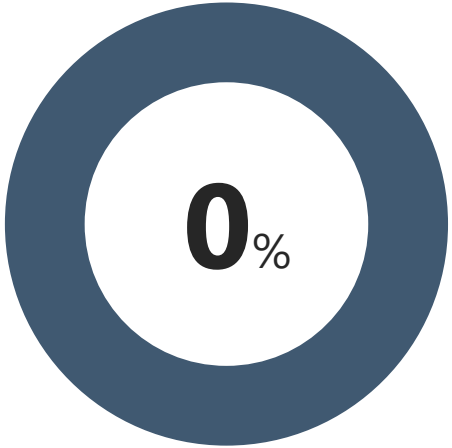


Target for recycled Li in **2035**

European panorama



EU reliance on imports of Li
for primary materials (2012-2016)



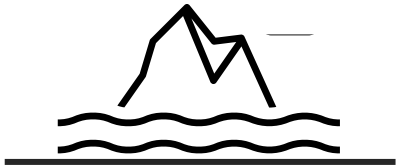
End of life recycling input rate of Li

Source: http://rmis.jrc.ec.europa.eu

How can we obtain 1 ton of lithium?

250 ton of ore

28 ton of LiBs from laptops



750 ton of brine

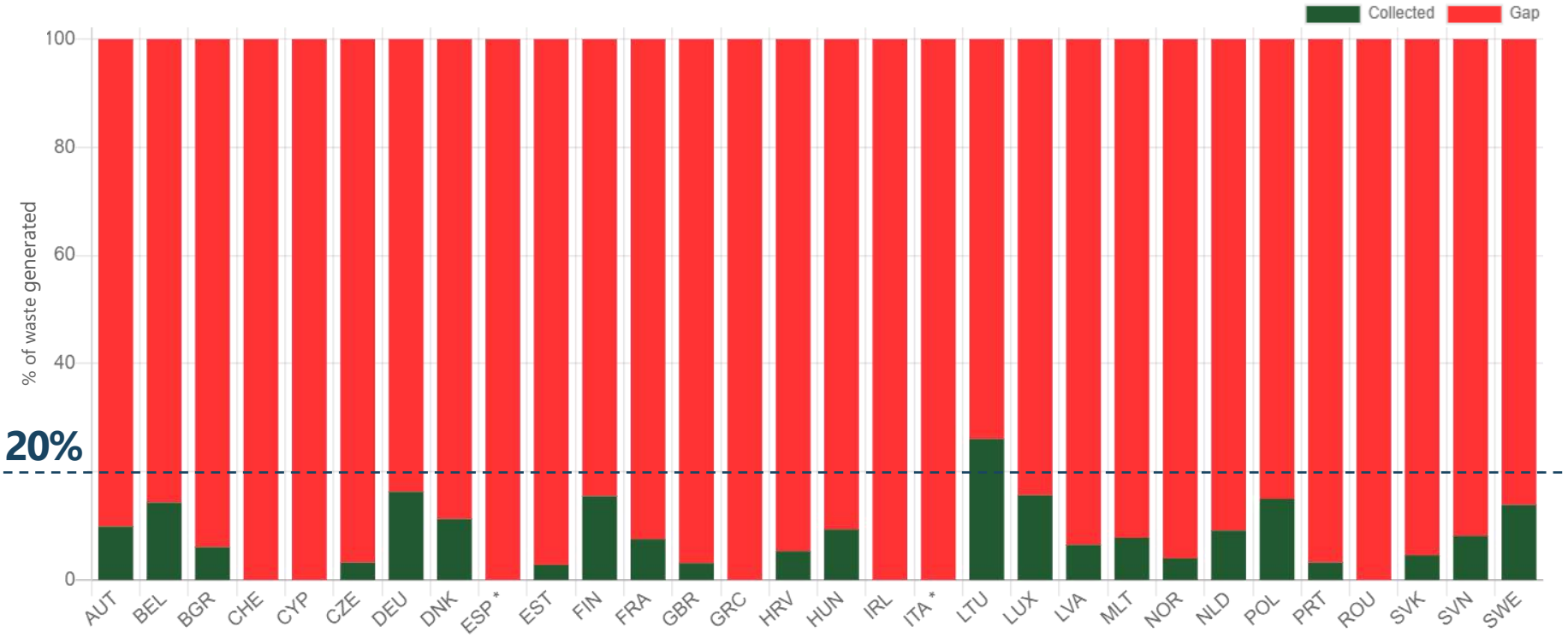
256 LiBs from electric vehicles

✓ **Primary production of metals requires more energy**

Source: F. Tedjar, Challenges for recycling advanced Li-ion batteries, Proc. International Battery Association (IBA2013), Barcelona, March 11-15, (2013). In P. Meshram et al. (2014), Hydrometallurgy, 150, p. 192-208, (2014).

Collection and sorting of spent LiBs

% of collected batteries from waste generated in 2015 for Rechargeable lithium-based batteries

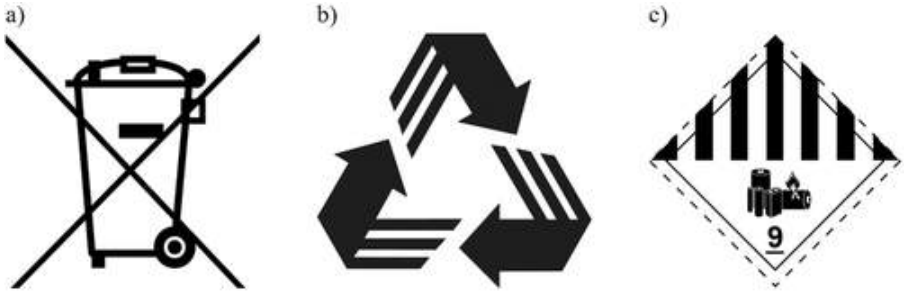


Source: *Adapted from Urban Mine Platform: http://www.urbanmineplatform.eu/wasteflows/batteries/percentage*

Collection and sorting of spent LiBs

- **Need for safe handling and processing during the waste collection and storage.**

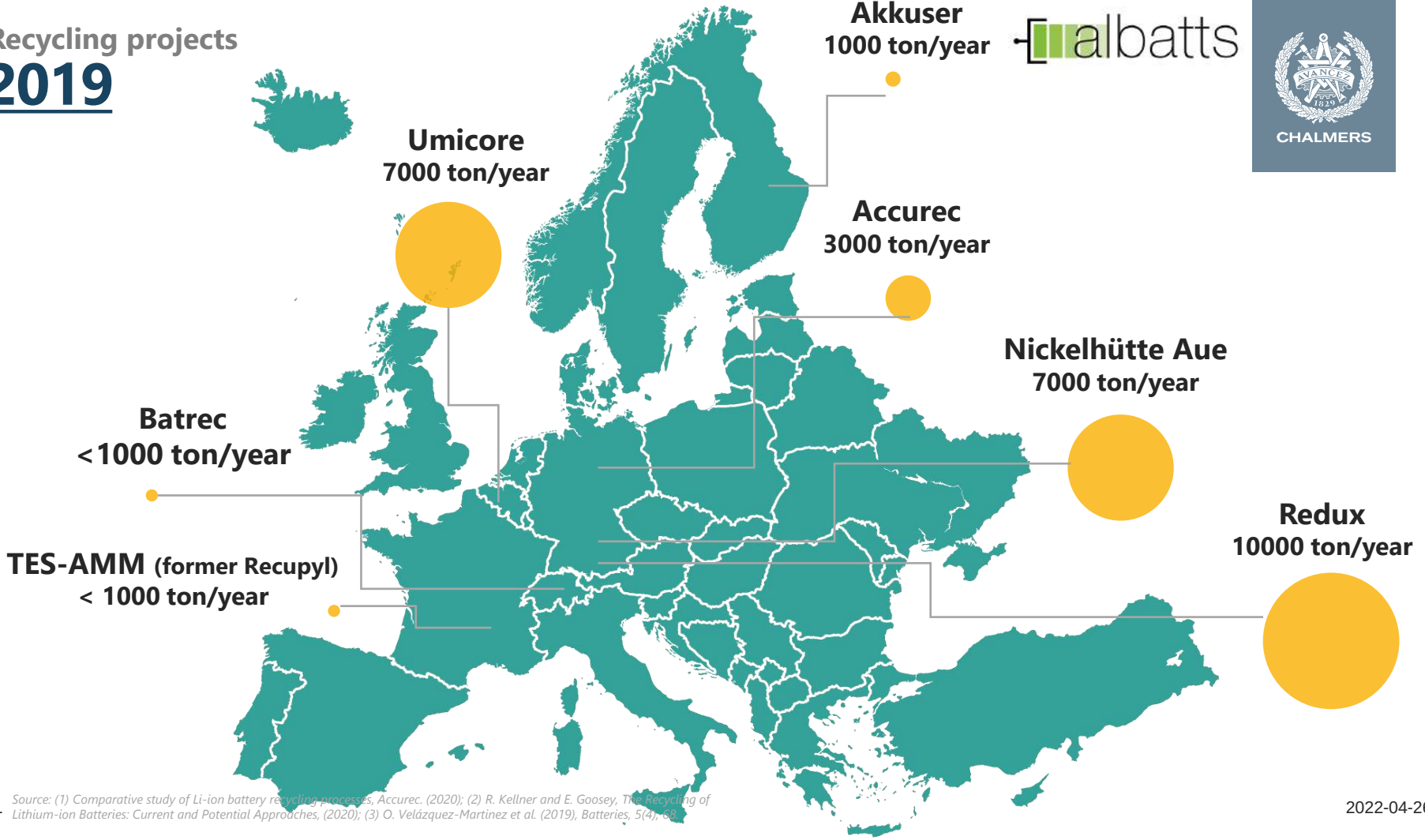
Battery labelling requirement



Source: J. Neumann (2021), Recycling of Lithium-Ion Batteries—Current State of the Art, Circular Economy, and Next Generation Recycling, Advanced Energy Materials, https://doi.org/10.1002/aenm.202102917

Recycling projects

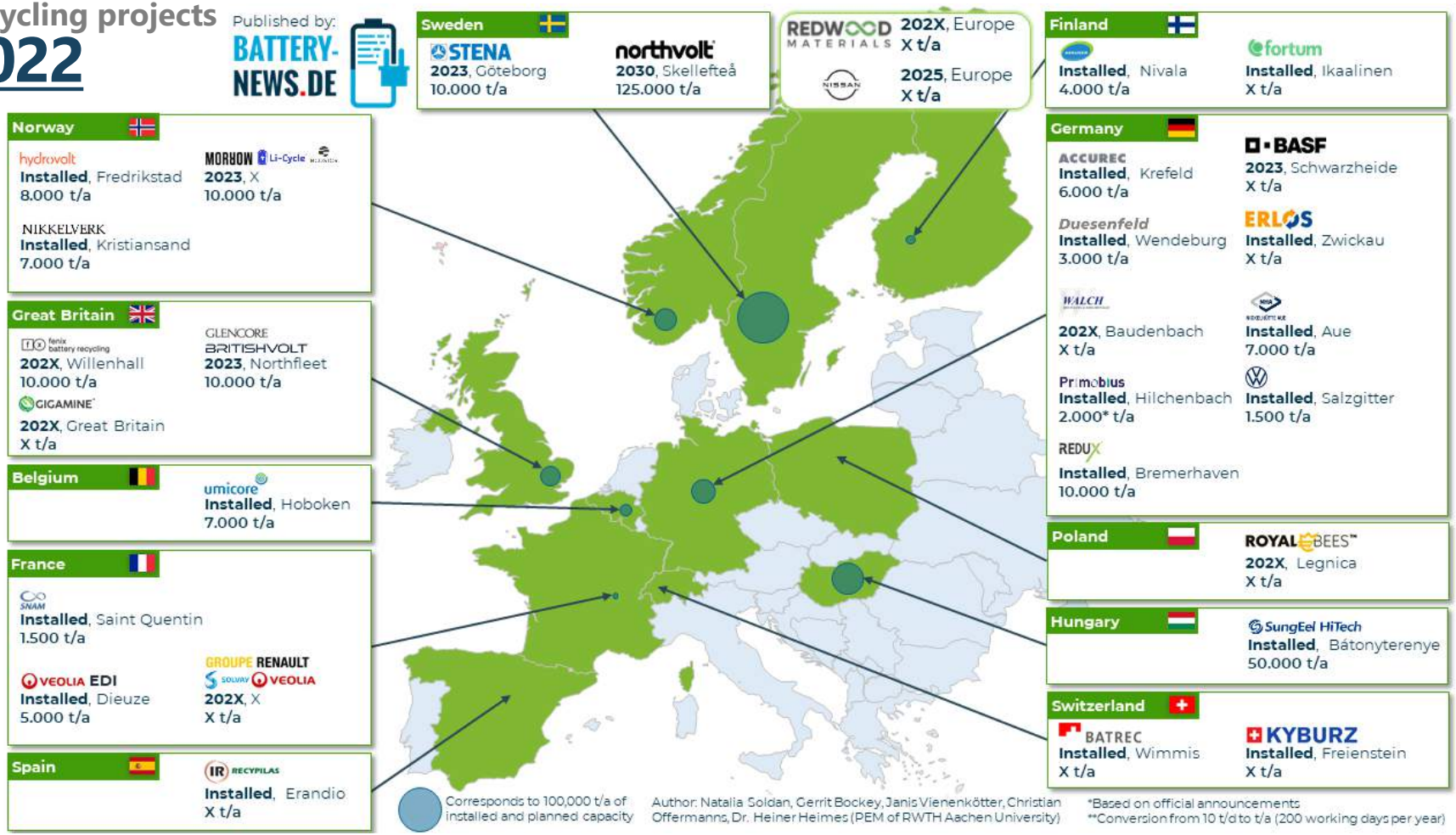
2019



Source: (1) Comparative study of Li-ion battery recycling processes, Accurec. (2020); (2) R. Kellner and E. Goosey, The Recycling of Lithium-ion Batteries: Current and Potential Approaches, (2020); (3) O. Velázquez-Martinez et al. (2019), Batteries, 5(4), 68.

Recycling projects 2022

Published by: BATTERY-NEWS.DE



Recycling approaches

Mechanical pre-treatment

Steel | Plastic | Al | Cu | Electrolyte

Akkuser, Finland
Batrec, Switzerland

Recovered | Not-recovered

REDUX, Germany
Accurec, Germany

Thermal pre-treatment

Plastic | Electrolyte

Umicore, Belgium,
Nickelhutte, Germany

Pyrometallurgical processing

Fe | Ni | Co | Cu

Li | Mn | Al | Electrolyte

Hydrometallurgical processing

Fe | Ni | Co | Cu

Li | Mn | Al | Electrolyte

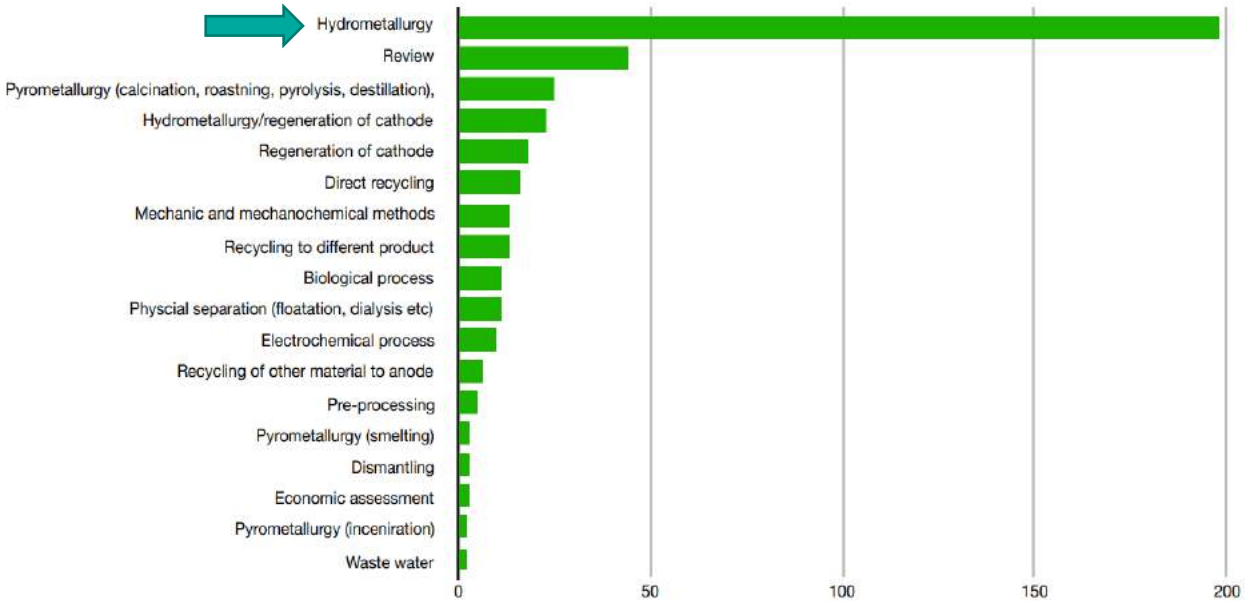
Northvolt, Sweden
Fortum, Finland
Eramet, France

Alternatives to pyrometallurgy are being implemented

Source: M. Petranikova (2021), technical presentation; F. Larouche, Progress and Status of Hydrometallurgical and Direct Recycling of Li-Ion Batteries and Beyond, Materials (Basel), 13(3), 801, (2020).

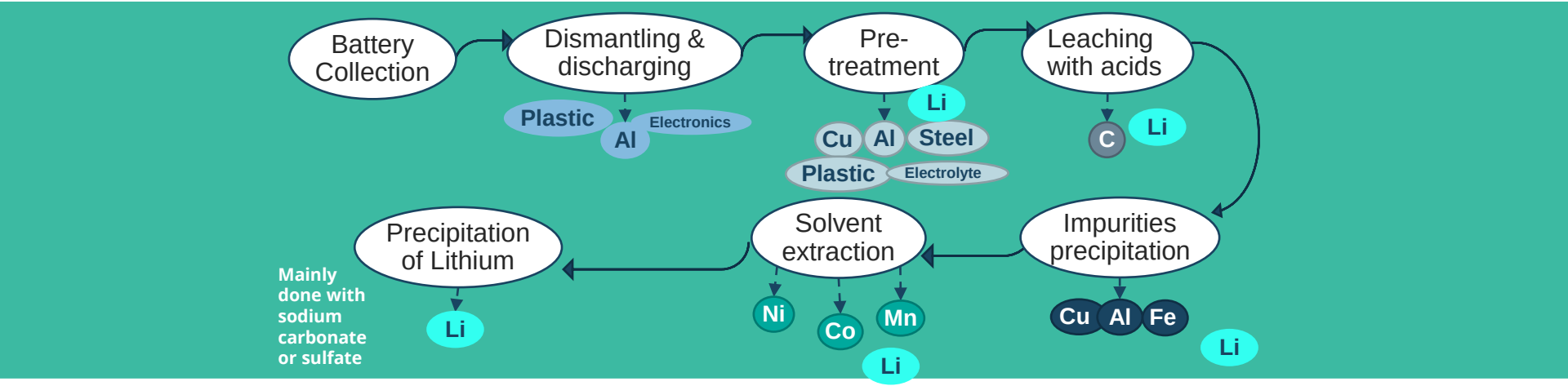
Recycling approaches

Focus of published research about recycling of LiBs (from 2003):



Source: Melin, H.E., 2019. State-of-the-art in reuse and recycling of lithium-ion batteries – A research review. London. Available on: https://www.energimyndigheten.se/globalassets/forskning--innovation/overgripande/state-of-the-art-in-reuse-and-recycling-of-lithium-ion-batteries-2019.pdf

Recycling flowsheet: Hydrometallurgy



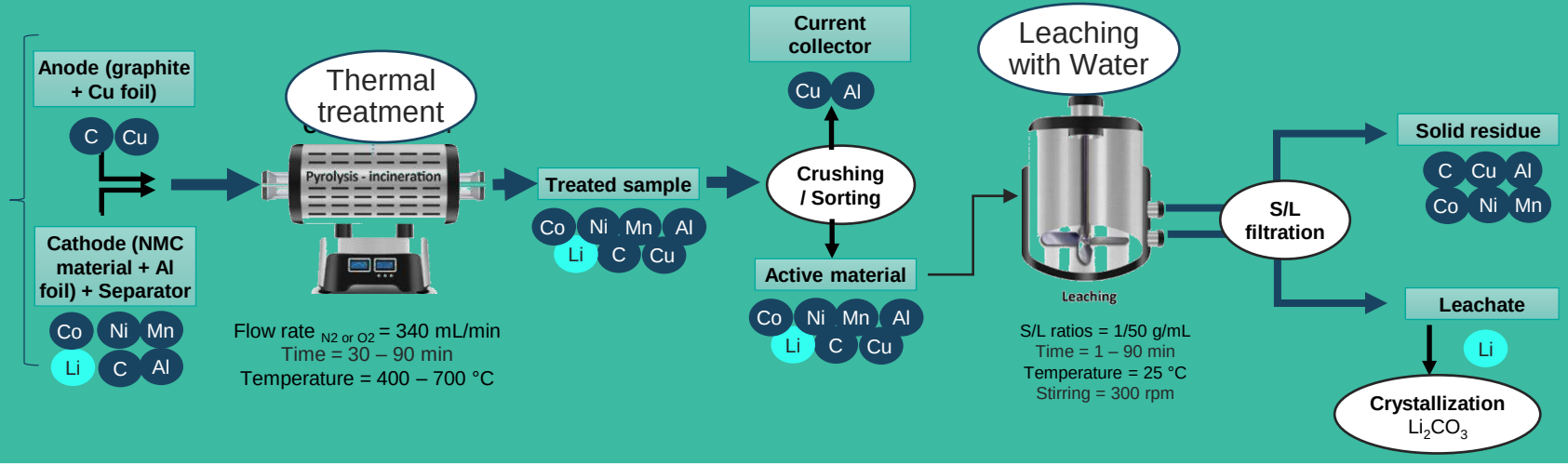
Challenges:

- Recovery of **organic components** – electrolyte, binder, separator, presence of fluorine
- **Leaching** – need for reducing agents, challenges related to the presence of graphite – could it be reused? It is a critical raw material
- **Precipitation** – consumption of sodium hydroxide, removal of impurities as hydroxides, difficulties in filtration
- **Lithium: Critical material recovered at the end of the process → Losses**

Research activity ongoing at Chalmers

- Improve the Li recovery rate from **3% to 95%** using Reducing thermal treatment followed by early-stage water leaching to produce battery grade Li_2CO_3 - purity of 99.95%.

Energimyndigheten
Project number 52009-1



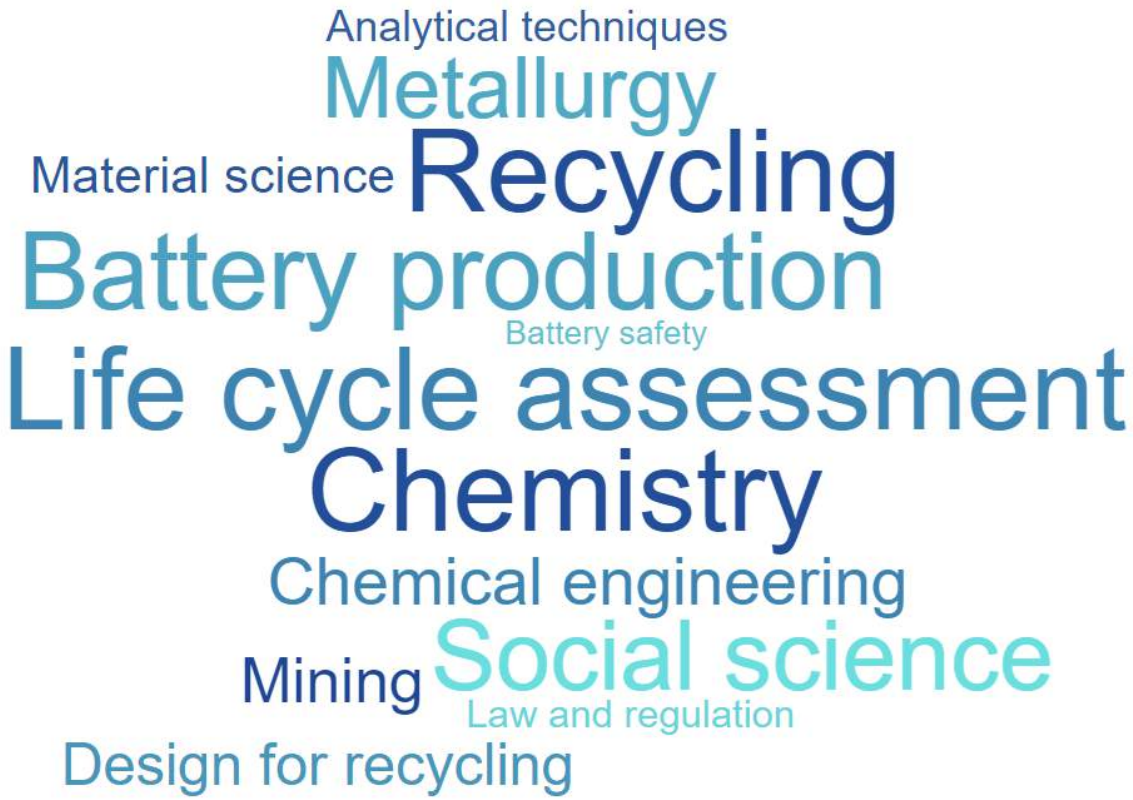
Actual main objectives:

- **Maximize the Li conversion, from salts and oxides present in the LiBs, to lithium carbonate**
- Minimize the waste generation via utilization of recovered carbon from batteries – lower production of solid residues

Skills and competences:

Holistic and Multidisciplinary

2022-04-26


Analytical techniques
Metallurgy
Material science
Recycling
Battery production
Battery safety
Life cycle assessment
Chemistry
Chemical engineering
Mining
Social science
Law and regulation
Design for recycling

Thank you for your attention!

Léa Rouquette, malea@chalmers.se
Nathália Vieceli, nathalia.vieceli@chalmers.se