



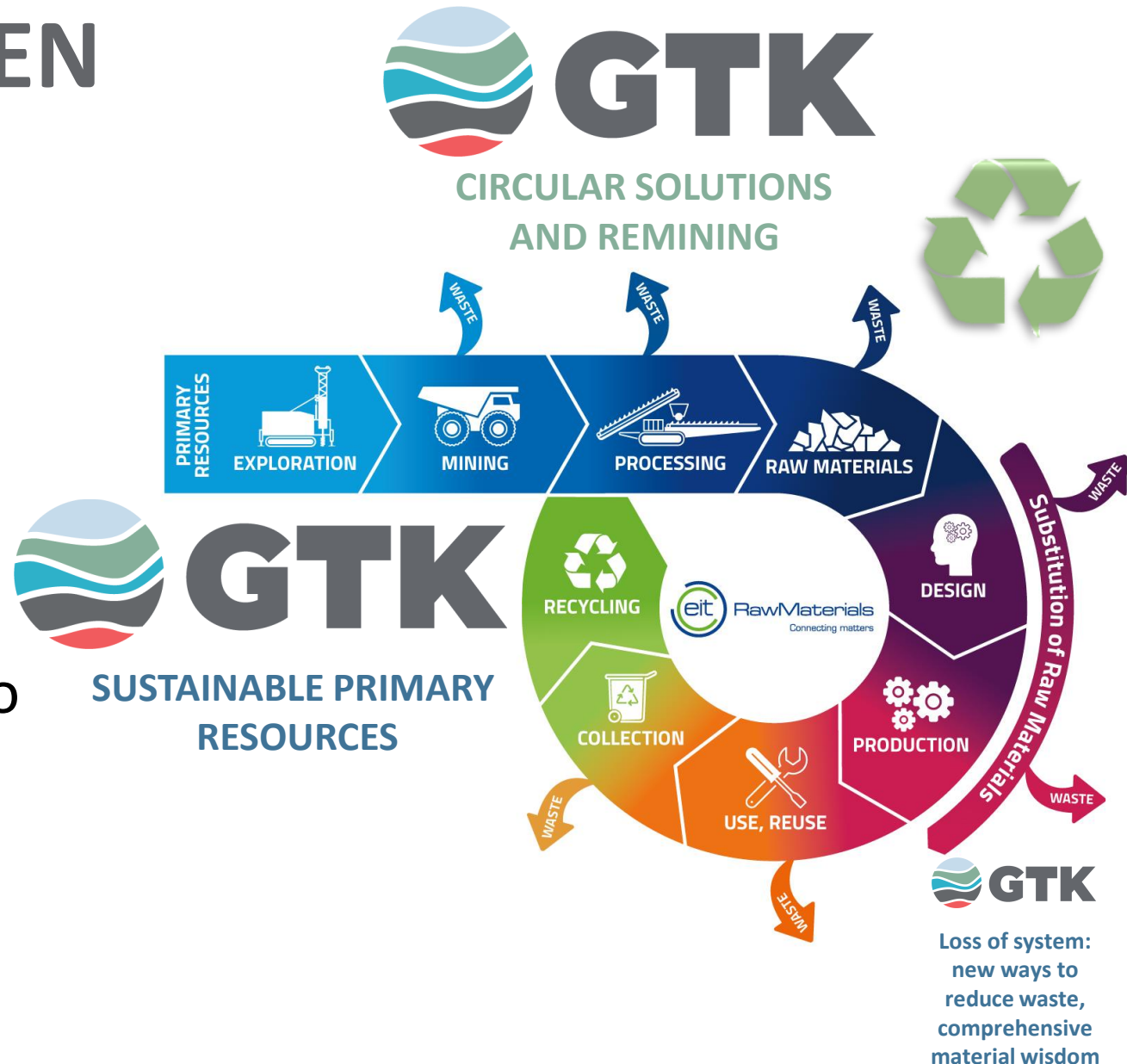
FINLAND'S ANSWER TO THE BATTERY METAL HYPE AND CIRCULAR ECOSYSTEM CHALLENGES

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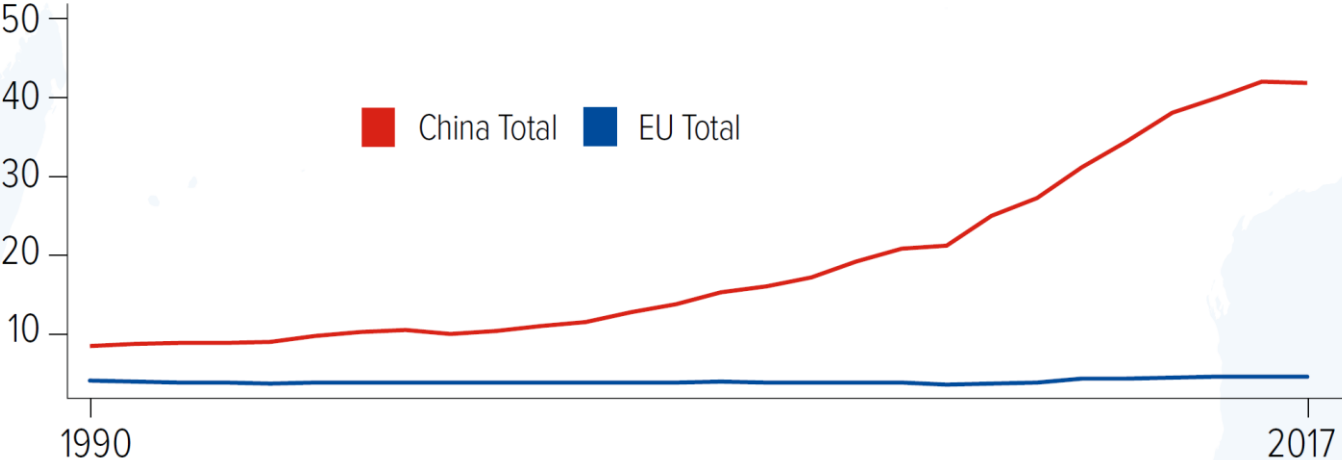
LIVING UP TO THE GREEN MOBILITY PROMISE

- Electric mobility builds on a promise of greenness
- Electrification requires unprecedented amounts of mineral raw materials -> research
- The raw material supply chain also has to deliver on the promise of environmental excellence
 - *Primary minerals*
 - *Circular economy*
 - *Re-mining possibilities*



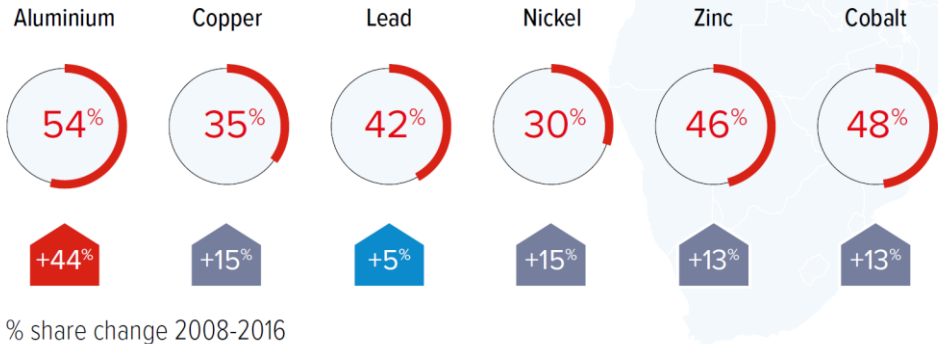
CAN EUROPE CATCH UP CHINA?

Production of Non-Ferrous Metals, EU vs China (Millions of tonnes)



China is dominating battery related commodities.

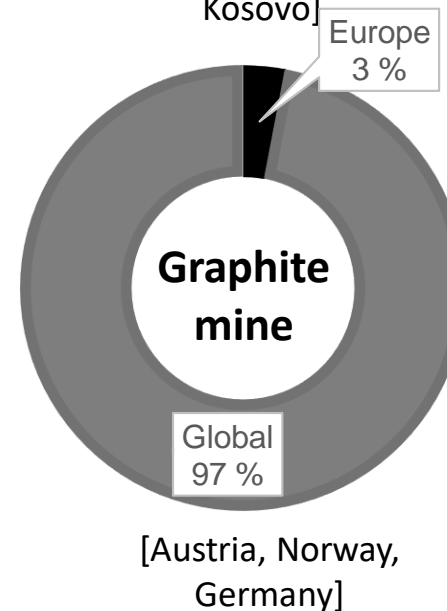
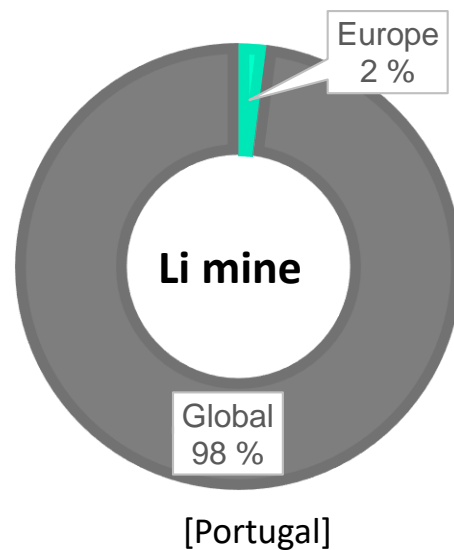
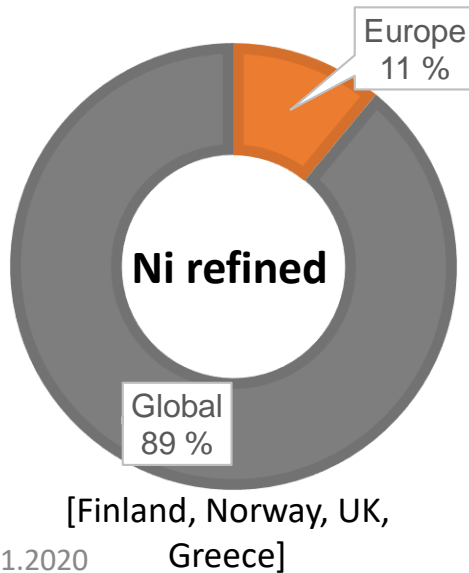
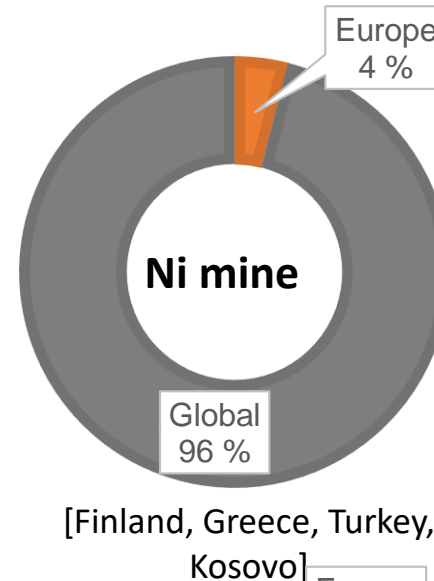
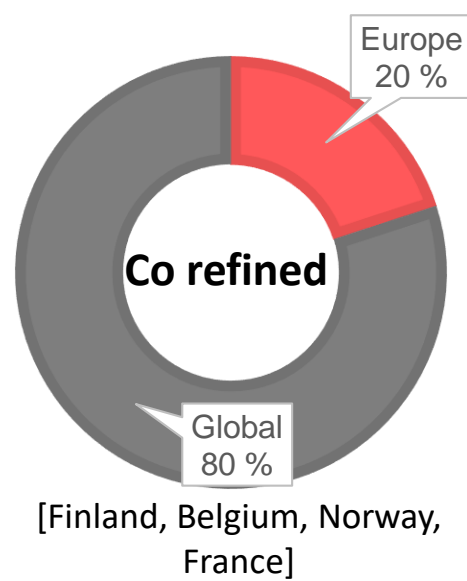
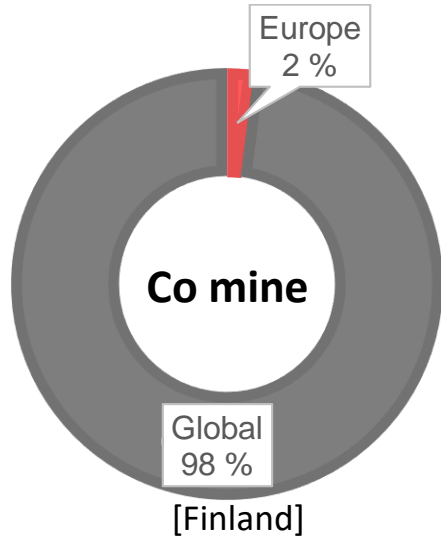
China's market dominance for non-ferrous metals (% share 2016)



Source: Taube, 2017

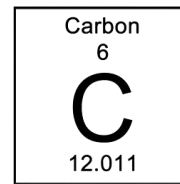
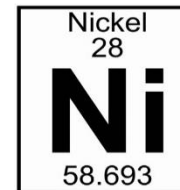
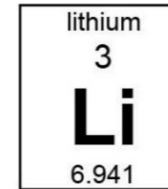
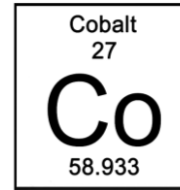
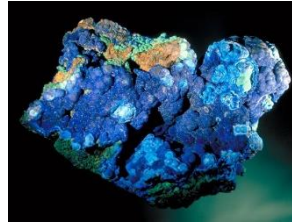
Sources: Institute for Climate Neutral Europe (IES); Vrije universitet Brussel (VUB) British Geological Survey

EUROPEAN BATTERY RAW MATERIALS

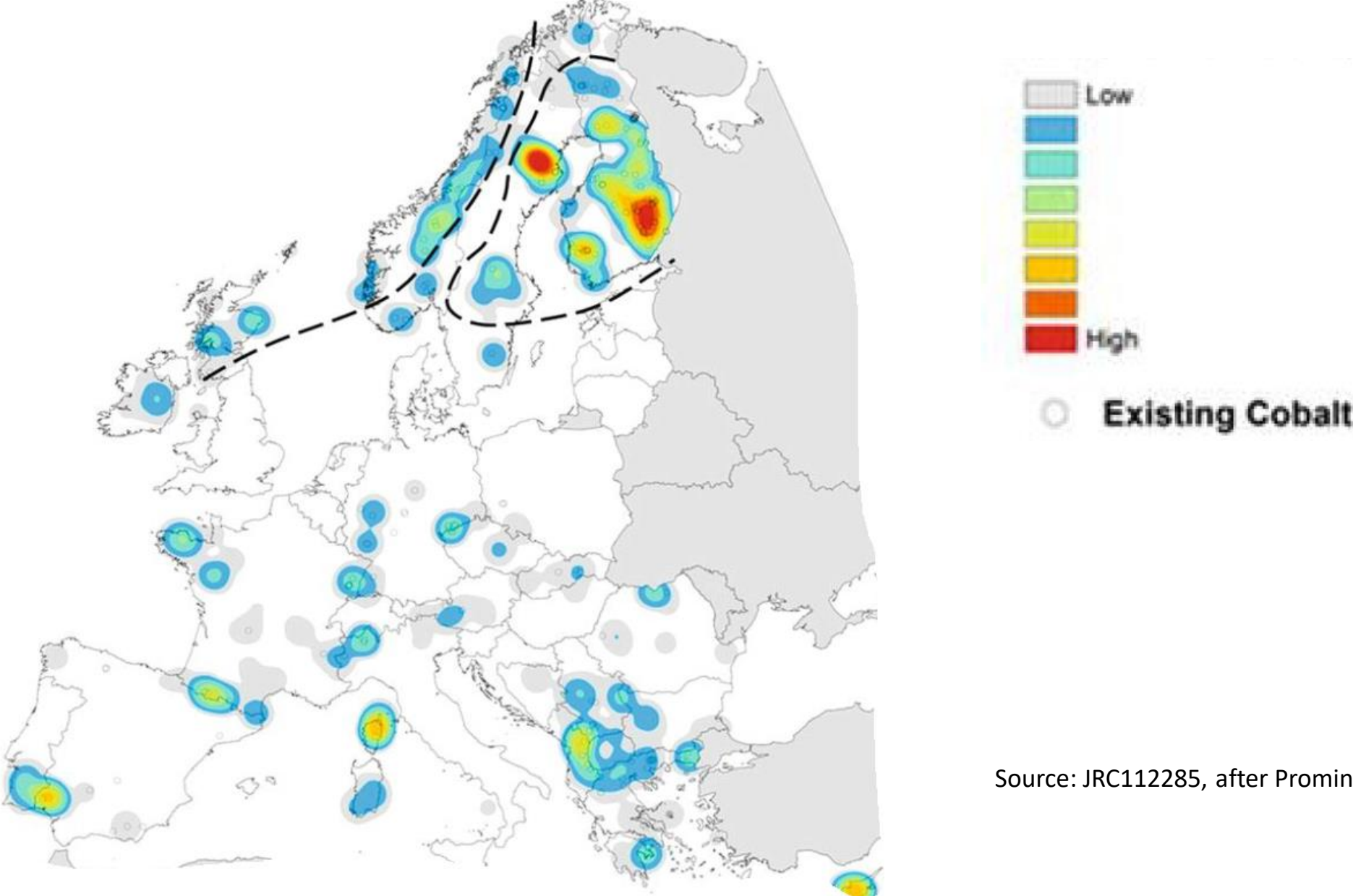


THE MAIN BATTERY METALS

- Cobalt (Co)
- Lithium (Li)
- Nickel (Ni)
- Graphite (C)
- Manganese (Mn)
- Copper (Cu)
- Aluminium (Al)

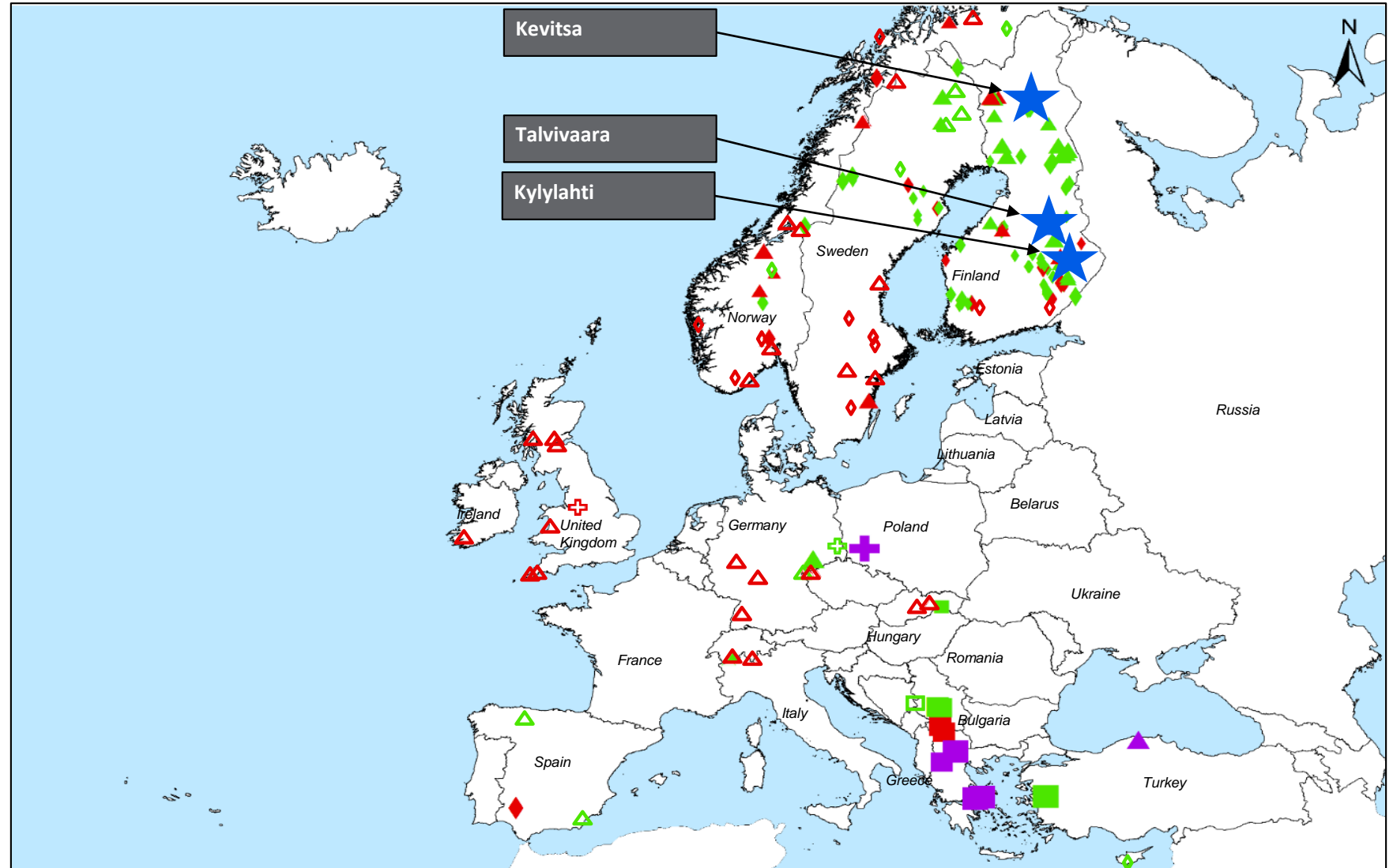
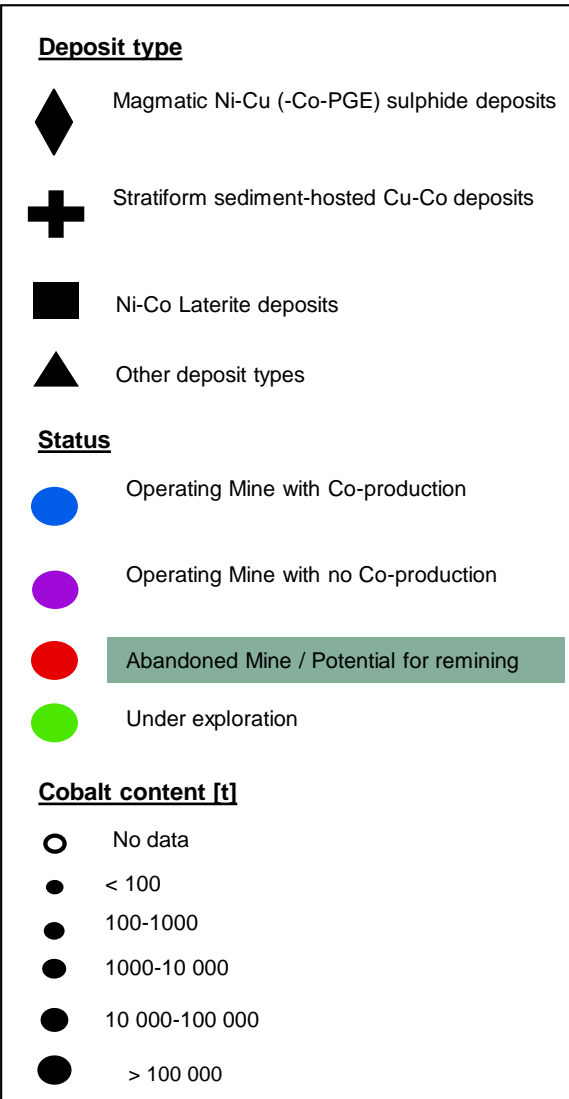


PREDICTED COBALT DENSITY IN EUROPE

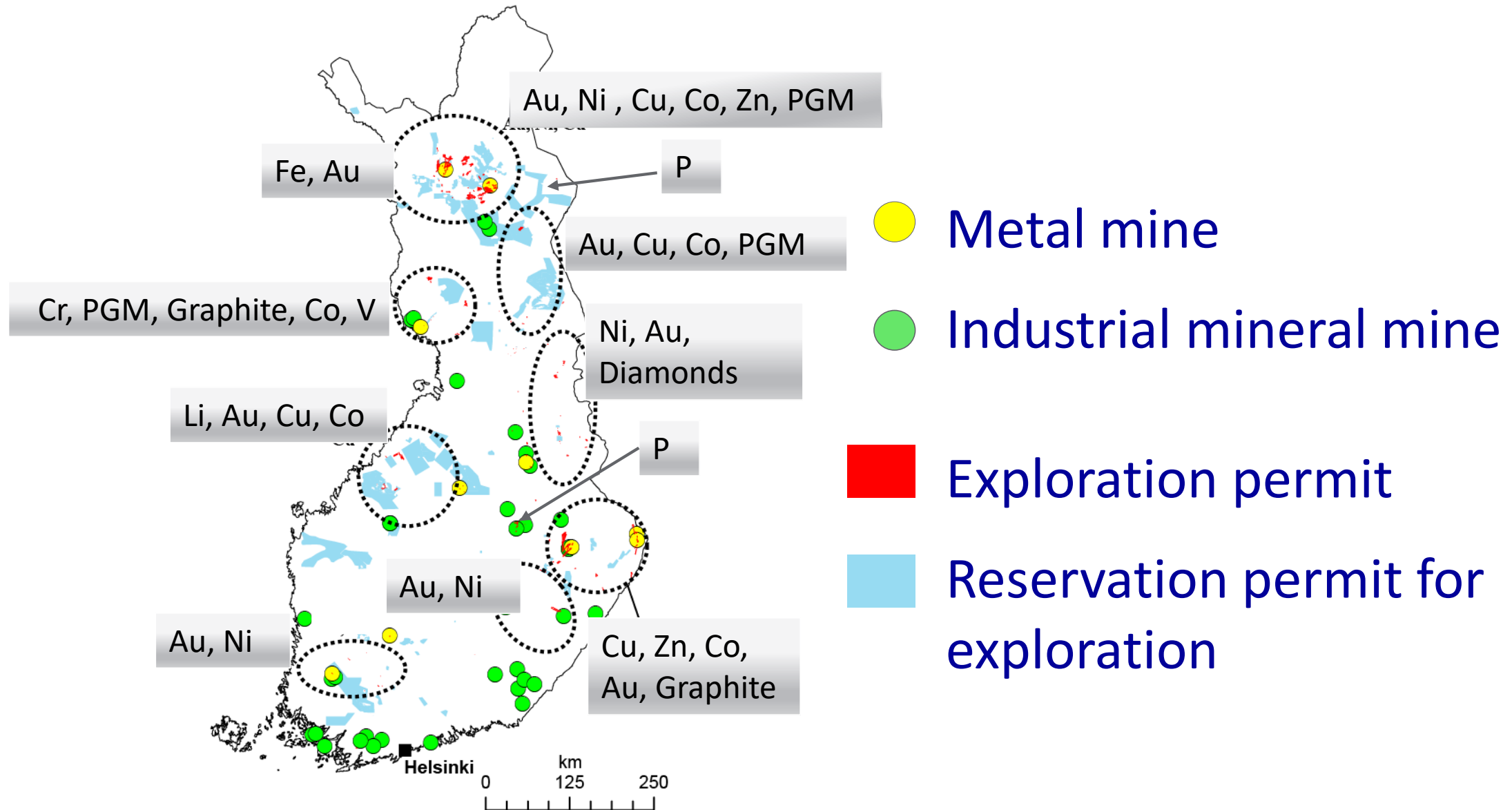


Source: JRC112285, after Promine2015

PRIMARY COBALT DEPOSITS AND RESOURCES IN EUROPE



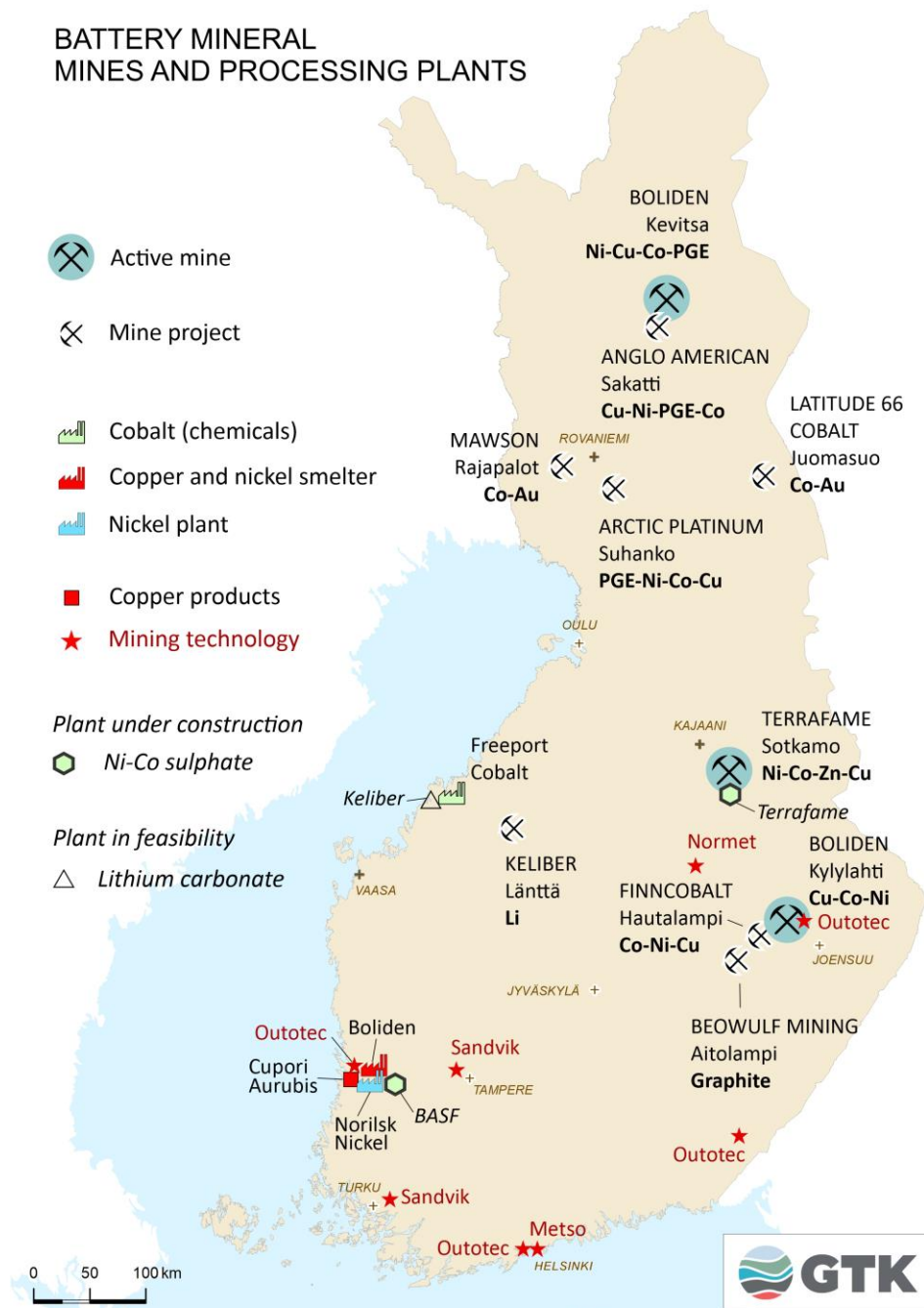
TENEMENTS AND EXPLORATION TARGETS



BATTERY CLUSTER

- 🌐 Leading expert
- 🌐 Battery mineral research and solutions
- 🌐 Innovations
- 🌐 Exploration concepts
- 🌐 Battery minerals

- *Exploration: Mineral systems, exploration focus point*
- *Processing: Material characterization*
- *Raw materials: Main and side product material know how*
- *Sustainable growth: Usage forecast, environmental view, social license to operate*



MINING IN FINLAND

Active mines in Finland 2019

- Finland is currently the only EU country producing Cr, Co and P and is also the largest producer of PGM and Au

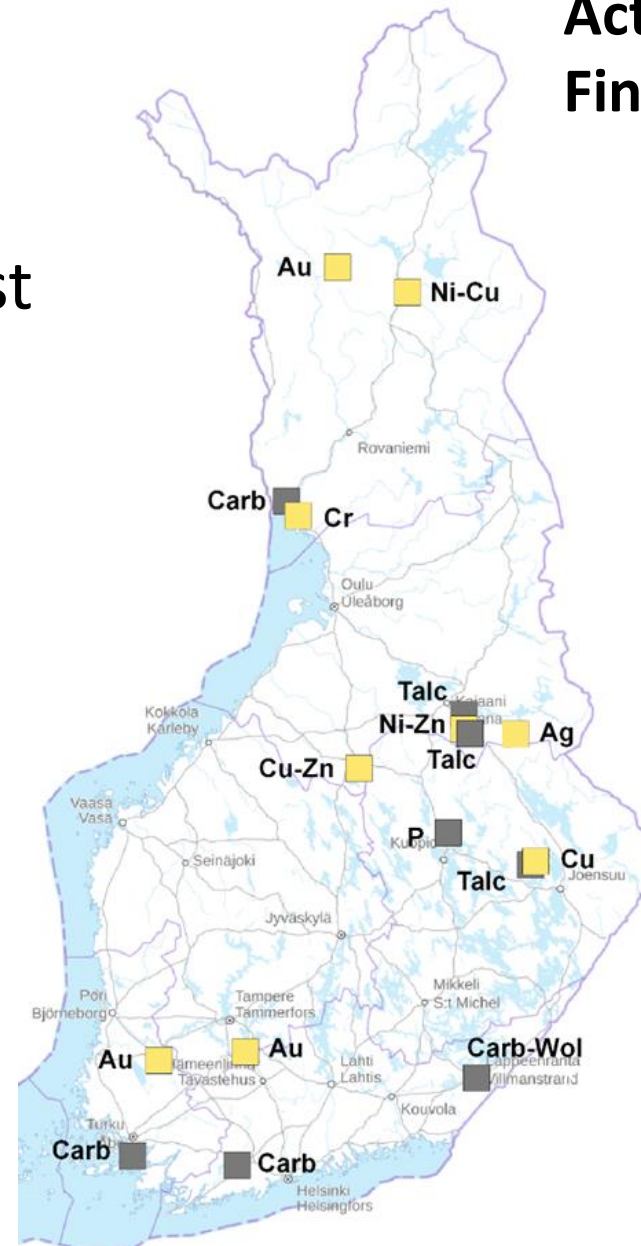
Outotec



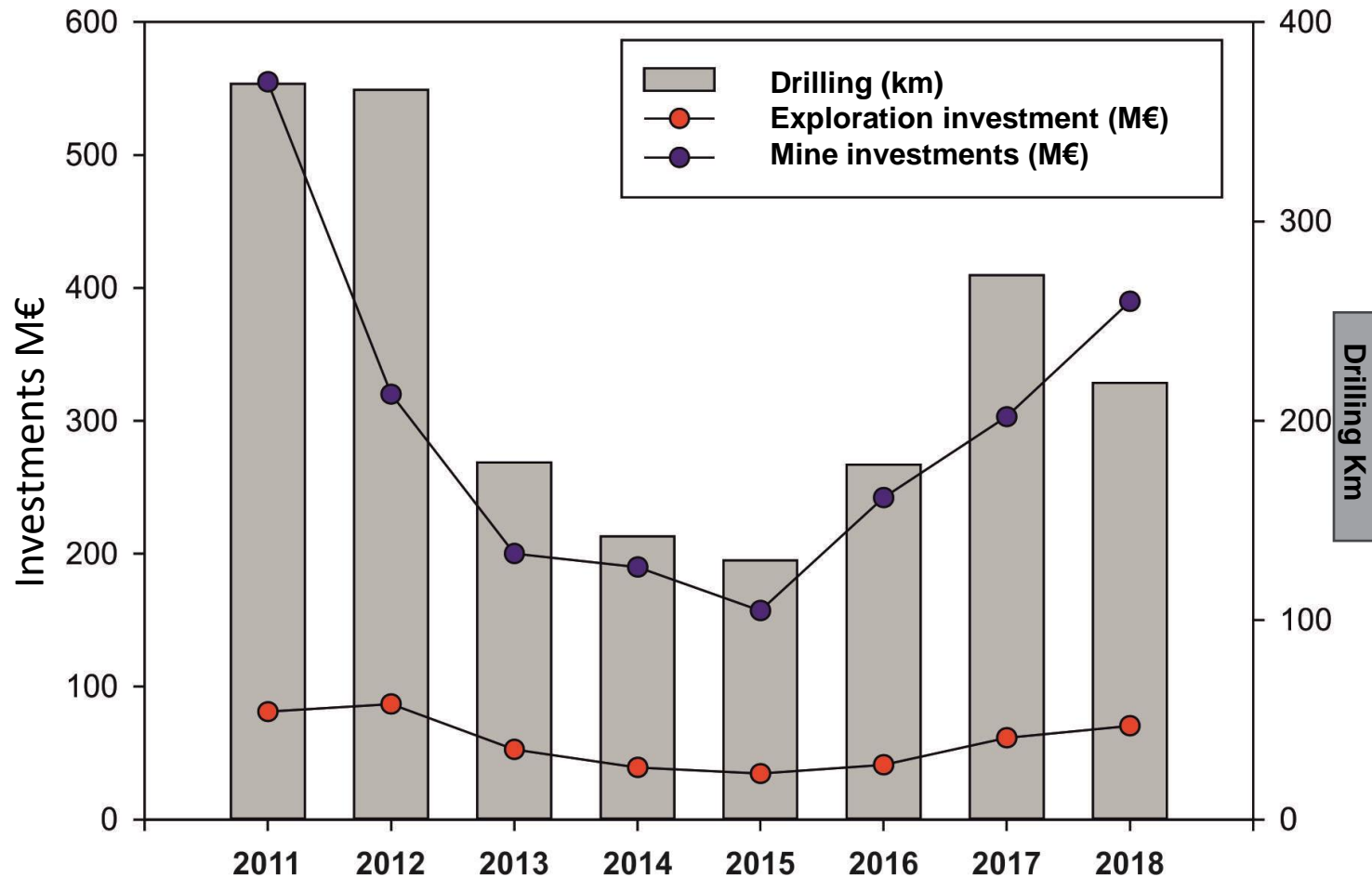
normet
FOR TOUGH JOBS

 metso

SANDVIK
Rock Tools



EXPLORATION AND MINING INVESTMENTS

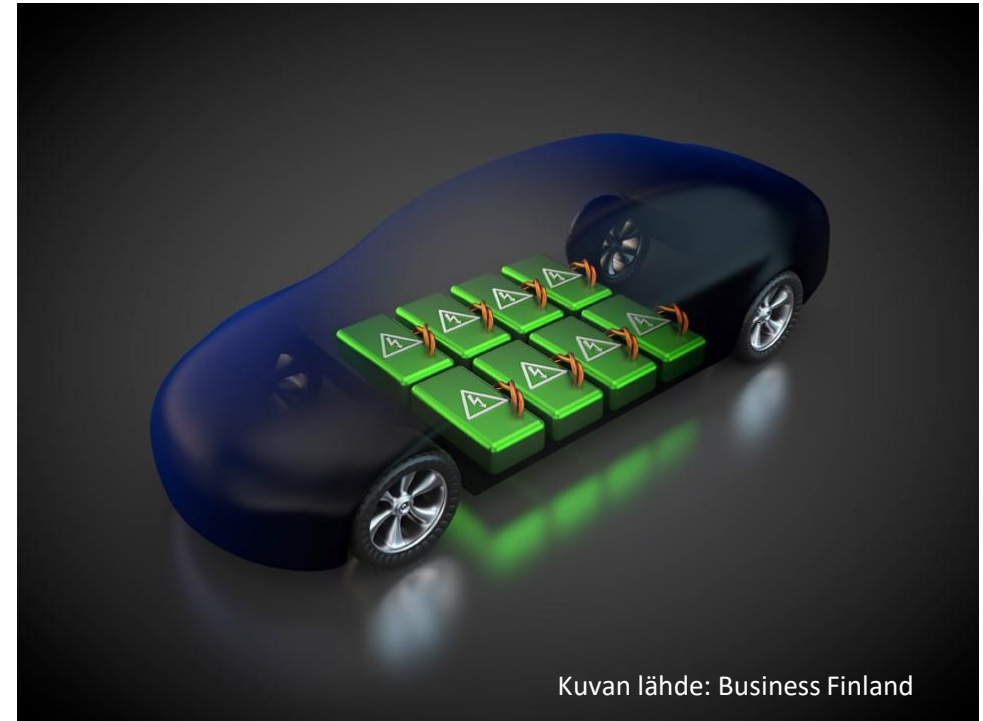


- Investments in exploration and mining have increased since 2015.

- GTK runs (2019–2022) project: Evaluation of the potential of battery metals (cobalt, lithium and flake graphite)

INVESTMENTS INTO MINE PRODUCTION AND BATTERY CLUSTER DEVELOPMENT IN FINLAND

- 🌐 Terrafame: 240 M€ in **nickel- and cobalt sulphate factory**
- 🌐 BASF: **battery chemical factory**
- 🌐 Boliden: 80 M€ in capacity increase in the Kevitsa Co-Ni-Cu-PGE-Au mine
- 🌐 Boliden: 150M€ to new **diesel electric haulage trucks** to Kevitsa mine.
- 🌐 Outokumpu Chrome: 250 M€ in **deepening the mine** down to 1 Km in Kemi.

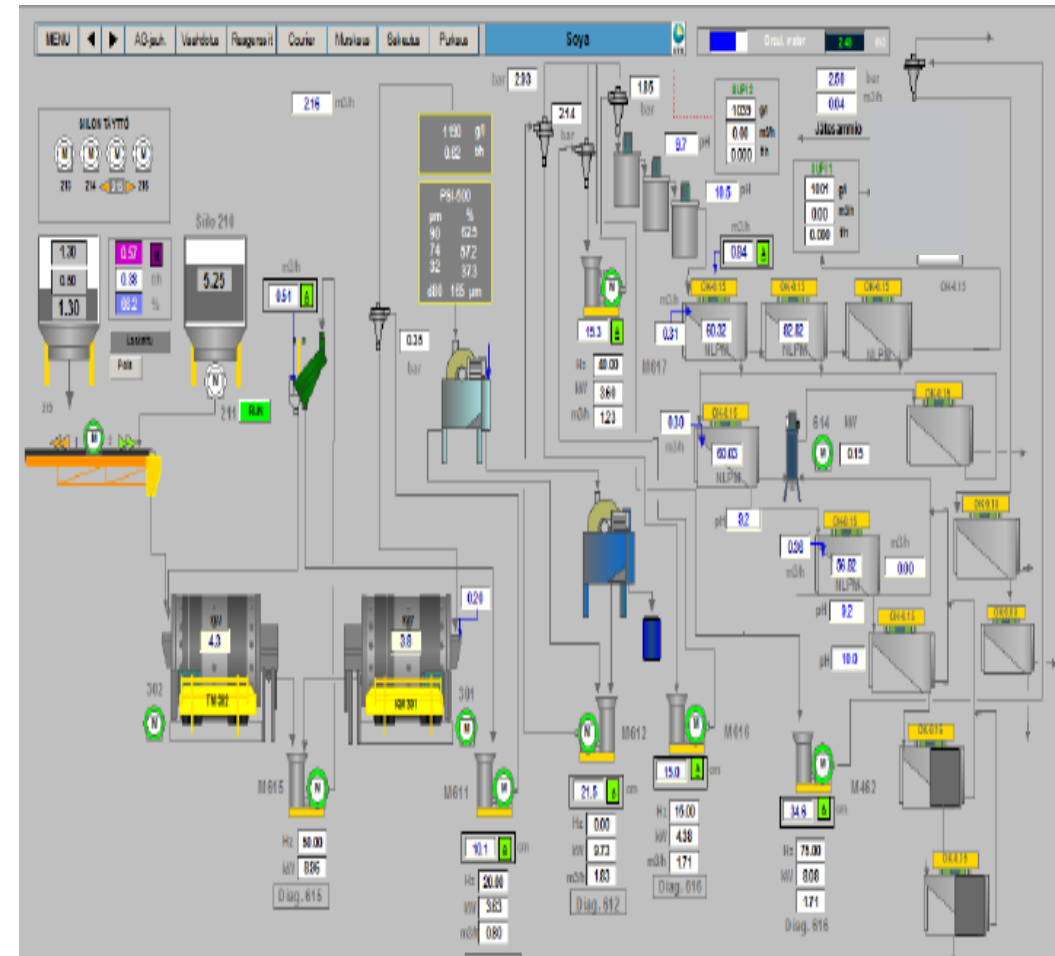


HOW CAN THE MINING OPERATIONS PARTICIPATE IN CIRCULAR ECONOMY?

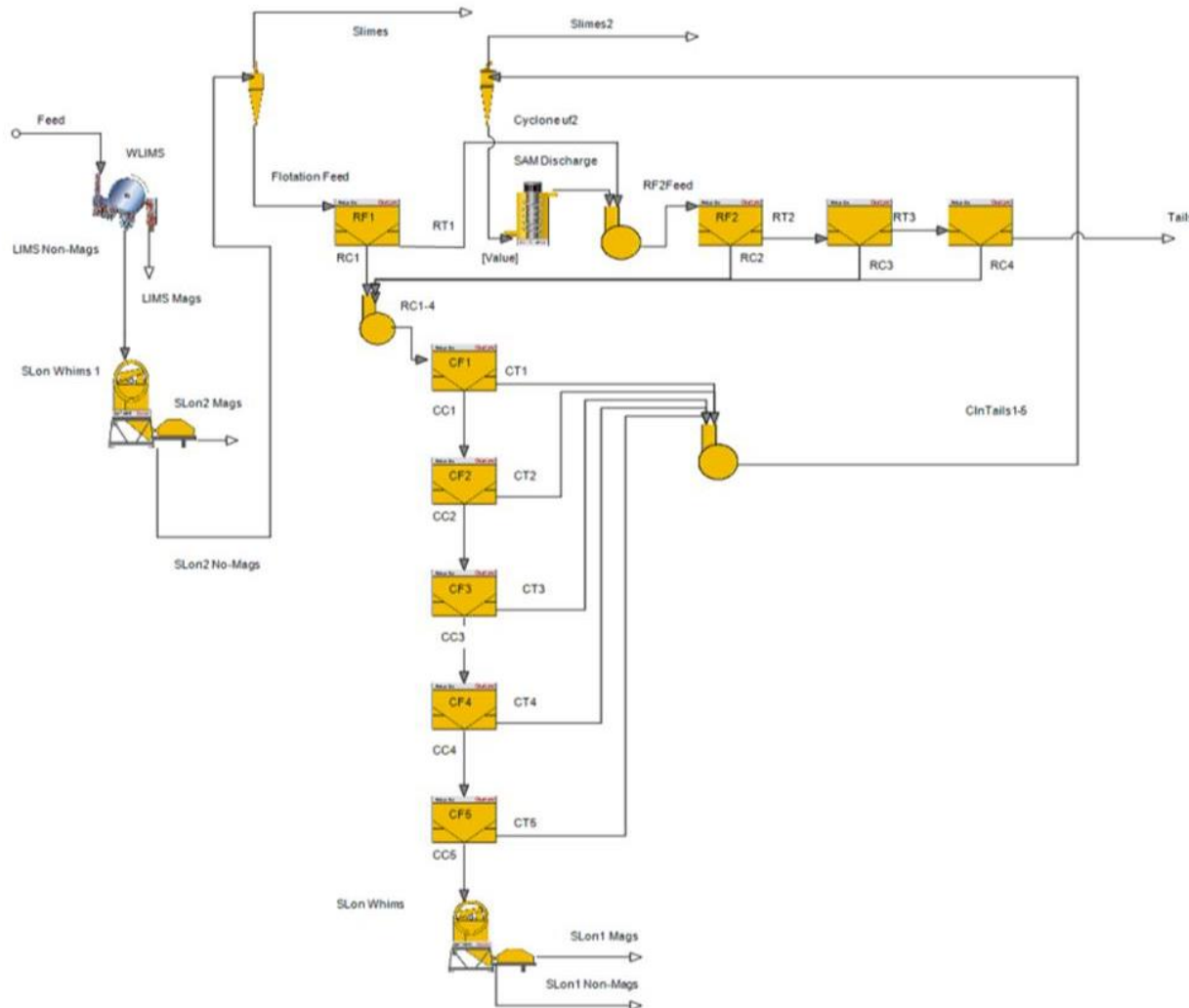
- Prevent minerals ending up as waste
 - *Improved or alternative/additional processing*
 - *Lower cutoff*
- Extend reserves
 - *Mine lifespan, brown fields and deep mine exploration*
- Usage of waste
 - *Utilize waste rock*
 - *Reprocess tailings and waste rock for raw materials*
- Deep extensions adding mine life e.g. Pyhäsalmi (Zn) and Kemi (Cr)
- Designing processing flow sheet (**GTK Mintec**), mine management according to BAT

GTK MINTEC: COMPLETE MATERIAL MANAGEMENT FROM THE START

- Mineral processing flow sheet development for ores, geomaterials and old tailings materials (remining) and more
- Designing complete utilization of the crushed and ground ore:
 - *Primary commodities: Ni, Co, Cu, Fe, Au, Zn, PGE..*
 - *Future and marginal commodities*
 - *Earth construction materials: bricks, blocks...*
 - *Final tailored waste fractions: Ceramics, 3D etc*
 - *Recent example: Otanmäki Ilmenite tailings*



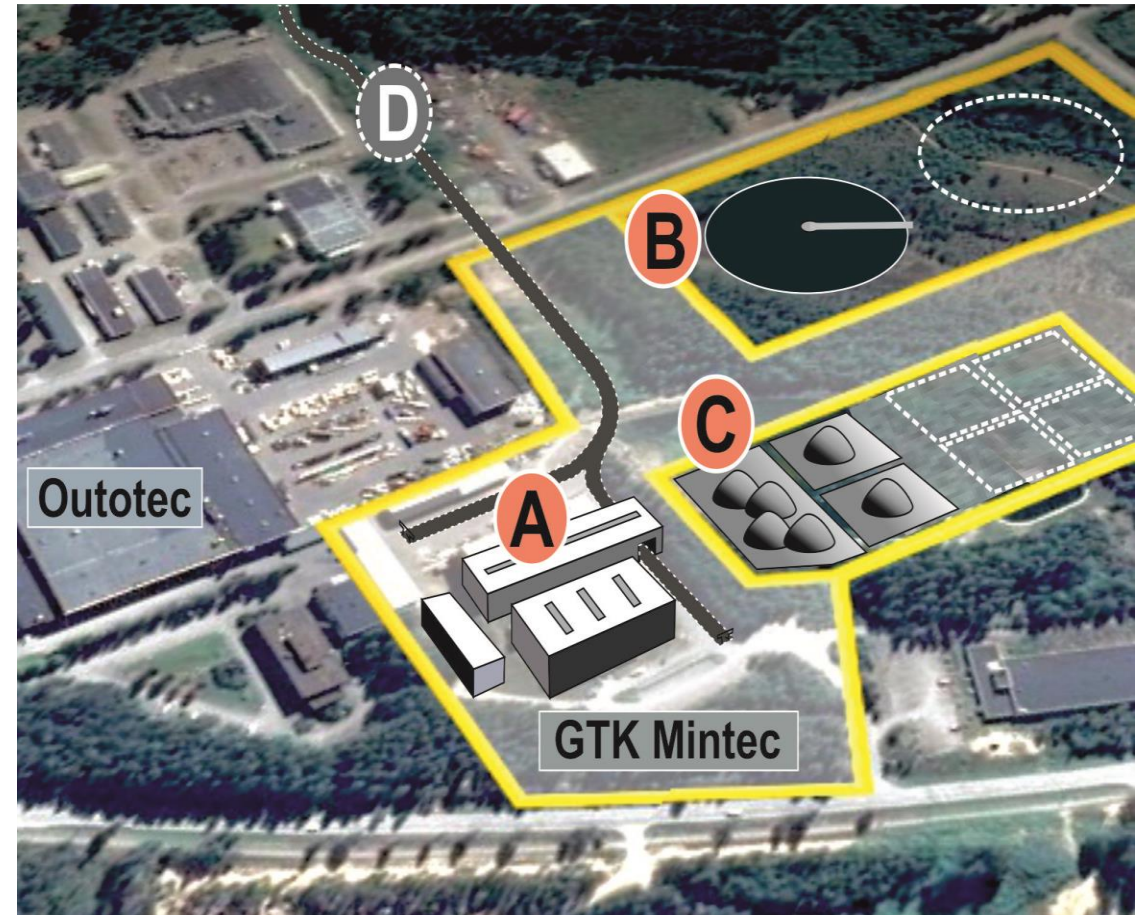
YARA SOKLI PHOSPHATE ORE: MAGNETIC SEPARATION THAT REDUCES THE AMOUNT OF FLOTATED ORE



- New process for the low grade ore type
- HI magnetic separation as a pre-concentration phase for LIMS non-magnetic fraction before the flotation phase
- Between 20-40 % of the feed mass was reduced in early stage with acceptable P_2O_5 recovery loss
- P_2O_5 feed grade for flotation raised by 30%
- **Less beneficiation chemicals and water needed in flotation** -> reduction of the environmental impact

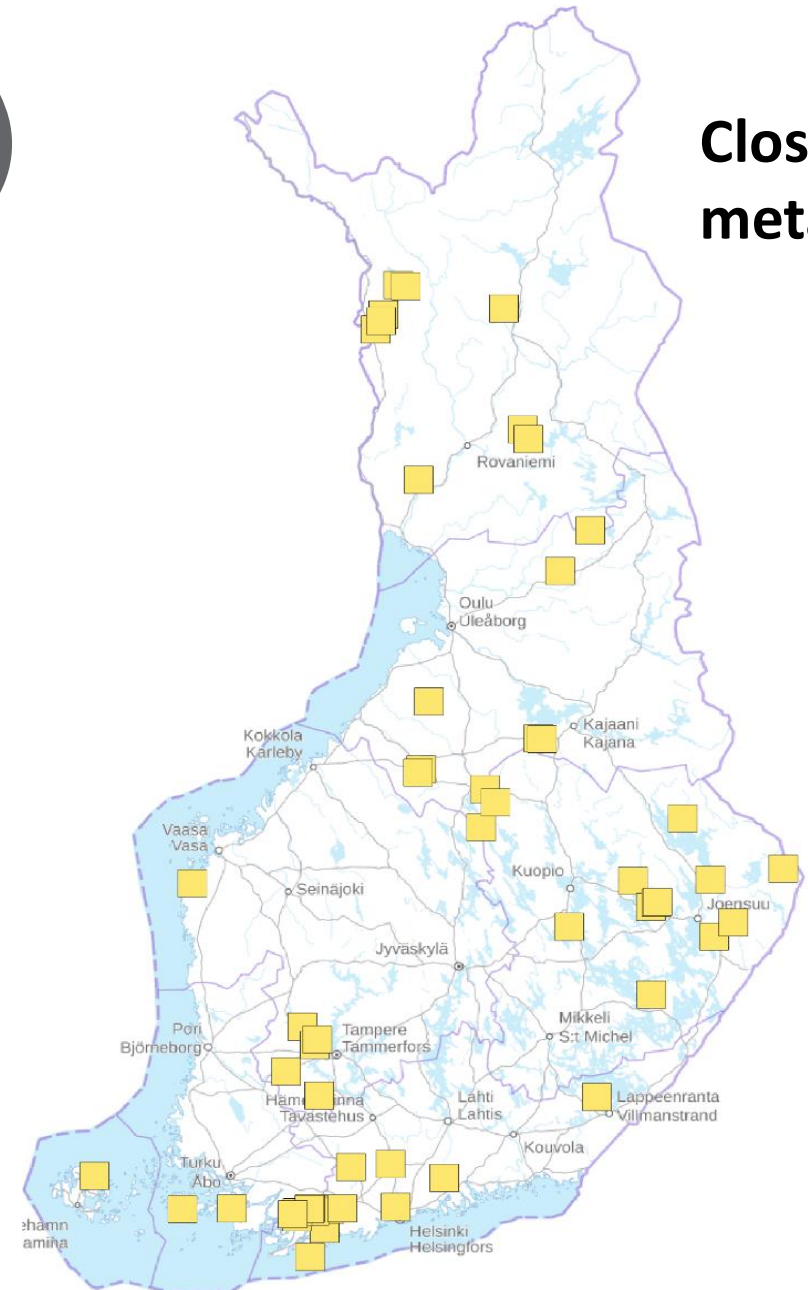
SOLUTIONS FOR THE TAILORED WASTES

- "SMART" tailing facility
- Tailored, optimized final waste types
- Cost effective when included in the processing scheme from the start
- Detailed environmental and geotechnical characterization of the optimized wastes
- Selection of best management methods for low cost and small footprint
- Water recovery for recycling
- Technology supplier collaboration



MINE TAILINGS (REMINING)

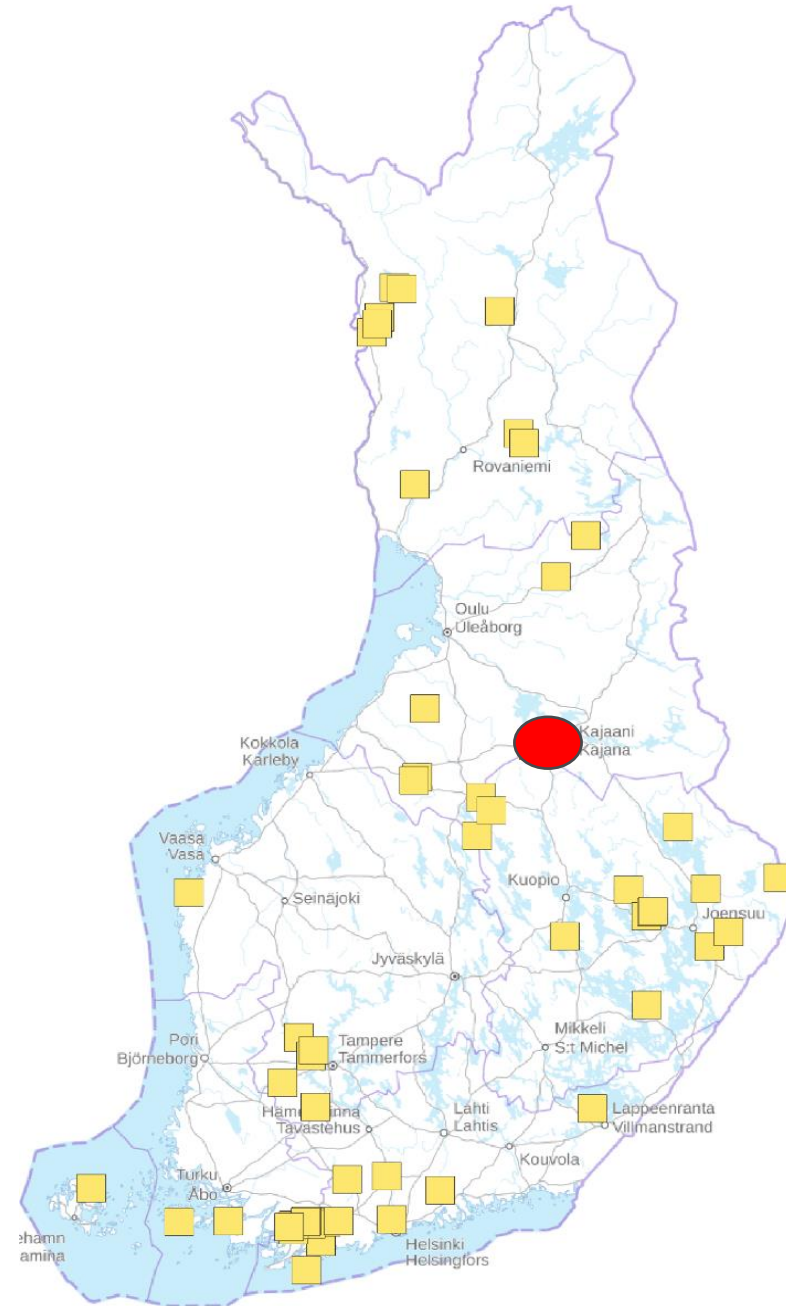
- 30 + closed mines
- Commodities: Au, Cu, Co, Fe, Ti, Mo, Ni, S, Pb, REE, V, W, Zn
- Most of these mines were in operation at some stage during 1950-1980
- Projects ongoing investigating the possibility to reprocess the tailings



OTANMÄKI MINE

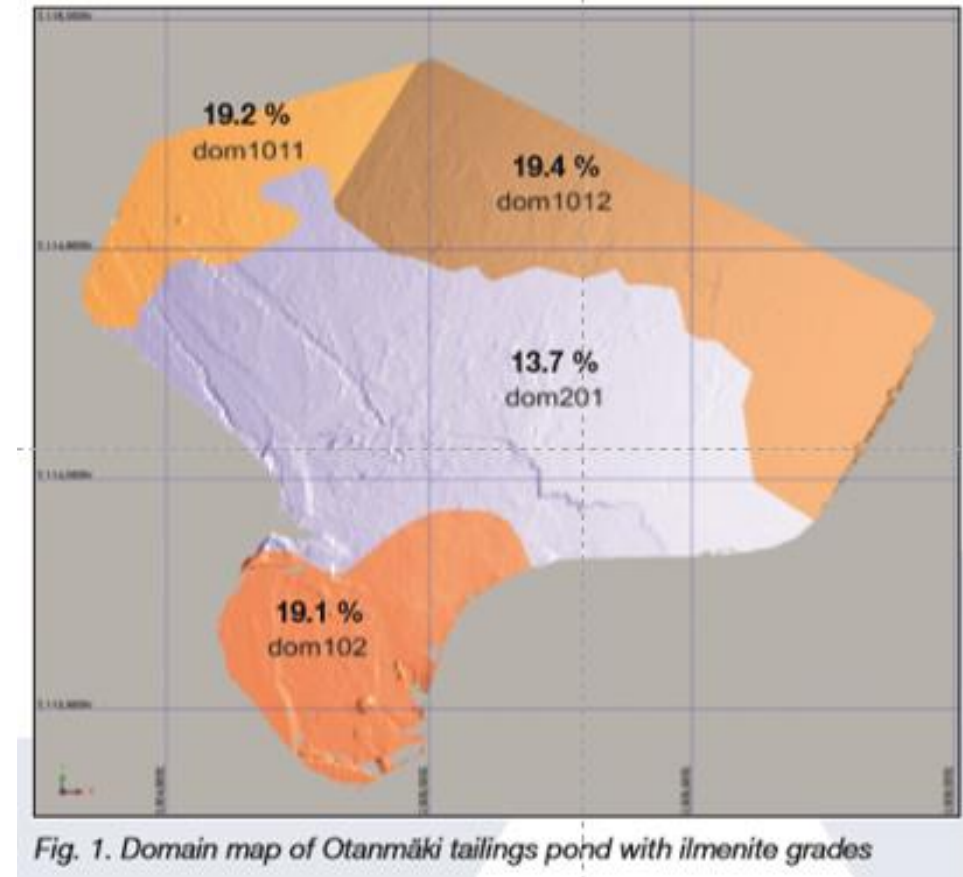
- Produced Fe-V-Ti-S 1953- 1985
- Magnetite and ilmenite ore
- Otanmäki Mine Oy is planning to reprocess the tailings
- Significant amounts of ilmenite still in the tailings

**Closed
metal mines**



REMINING FOR SUSTAINABILITY

- Old TMFs hold an untapped potential for battery and other innovation metals
- Remining can greatly enhance sustainability if done right
- Must be based on detailed mineralogical characterization: geometallurgy
- Tailored processing flow sheets
- Full material utilization similar to primary ores



OTANMÄKI MINE

Otanmäki tailings pond ilmenite project

JORC2012-compliant mineral resource of ca. 10 Mt of tailings sand containing on average 16% of ilmenite

Mineral resource estimate for the Otanmäki Tailings Project
December, 2018

Category	Cut-Off TiO ₂ %	Mt	Grade	Grade
			(% TiO ₂)	(% FeTiO ₃)
INDICATED	4	9.8	7.9	15.96
TOTAL	4	9.8	7.9	15.96

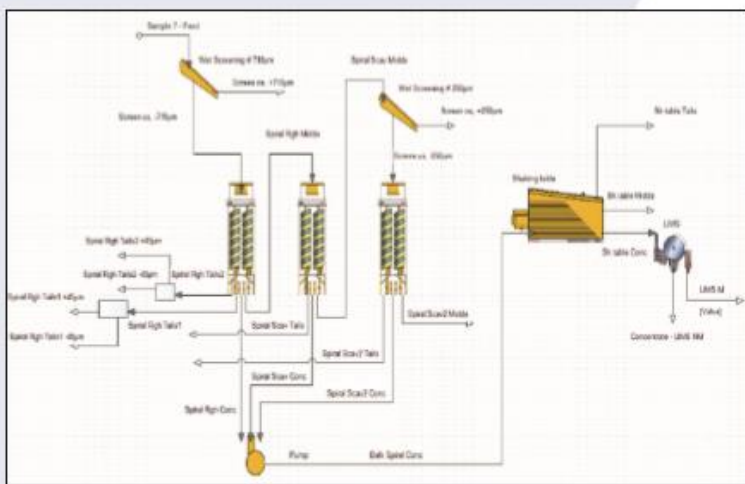


Fig. 2. Processing flow sheet (GTK, Mintec 2018)

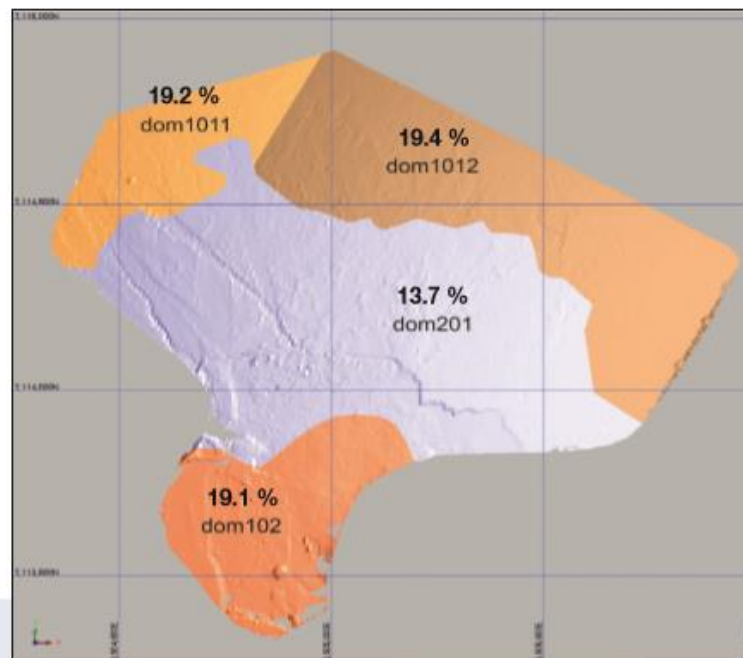


Fig. 1. Domain map of Otanmäki tailings pond with ilmenite grades

- Recovery of ilmenite with simple gravity based processing
- Planned processing of 1.1 Mt of tailings sand per year producing 100 000 tons of ilmenite per year.
- Total production time estimated ca. 7 years.
- Ilmenite production from Otanmäki mine starts before the end of tailings sand processing.

the end of tailings sand processing.

REMINING

Similar process development tests have been done for e.g.:

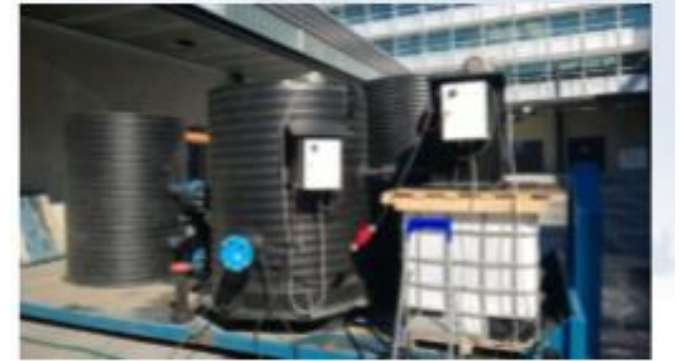
- Ni, Cu, Co, PGE
- Spodume
- Wollastonite

Remining outcome:

- Vanadium: Vanadium-Redox-batteries (V2O5)
- Titanium: Lithium Titanate Batteries (Li₂TiO₃)
- Fe, Pigments

MANAGE YOUR VALUABLE WATERS

- Increase process water recirculation but maintain processing results
- Less water to TMF
- Tailored water quality for different parts of the process
- Water treatment design, on-site piloting, new treatment methods
- Water management for the whole site
- Discharge management



GUIDES FOR ENVIRONMENTAL MANAGEMENT OF EXTRACTIVE INDUSTRY

- **Under preparation:**
 - *Guide for the Best Available Techniques Reference Document for the Management of Waste from Extractive Industries (MWEI-BREF)*
 - *Guidebook for the Planning and construction of environmental protection structures for mining*
 - *Guidebook for the Assessment of the remediation need for the closed and abandoned mining waste areas*
- **Previously published e.g:**
 - *Best Environmental Practices for Metal Mining*
 - *Mine Closure Handbook*
 - *Environmental Impact Assessment Procedure for Mining Projects in Finland*
 - *Defining Mining Waste as 'Inert'*
 - *Environmental Risk Assessment for Metal Mines*
 - *Good Practices in Assessment of the Environmental Impacts of Mining Projects*

CONCLUSIONS

- 🌐 The European commission have commenced actions to secure the battery industry in the EU but Asia is far ahead and Europe has to work hard to catch up.
- 🌐 The electrification will change and increase the need for primary raw materials
- 🌐 Battery hype and circular economy requires lots of collaboration between research community and the technology developers
- 🌐 Finland has got the opportunity to enhance the battery cluster growth by building on existing strengths.
- 🌐 GTK focuses on battery- and critical minerals as well as on circular economy solutions in its new strategy.
- 🌐 **GTK has expertise and solutions from the exploration to mine closure**

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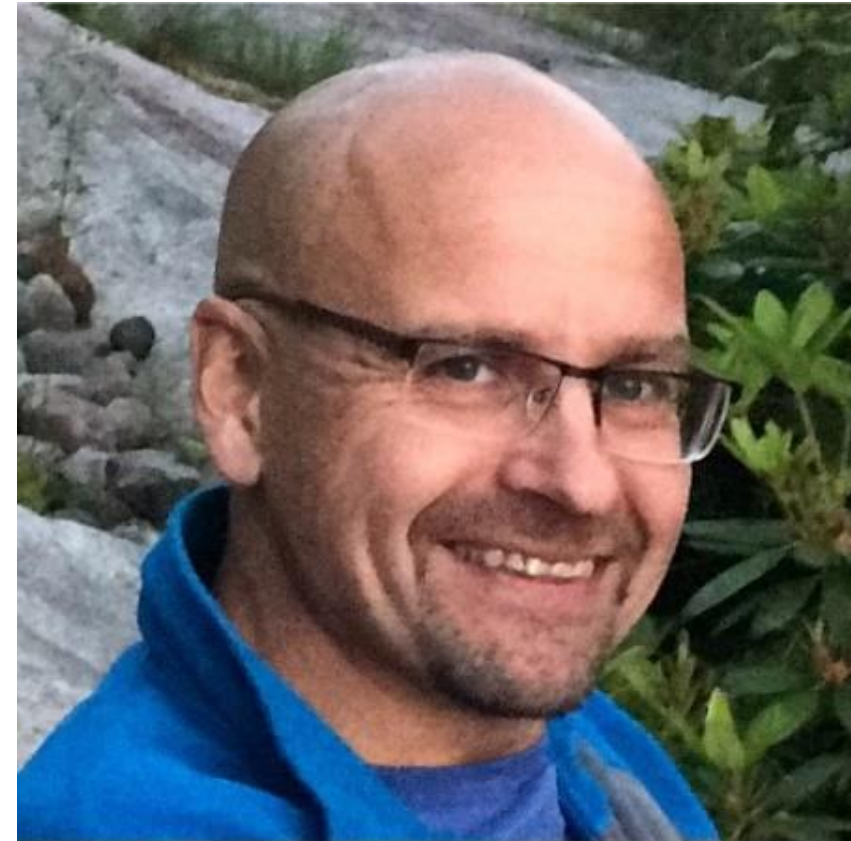
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