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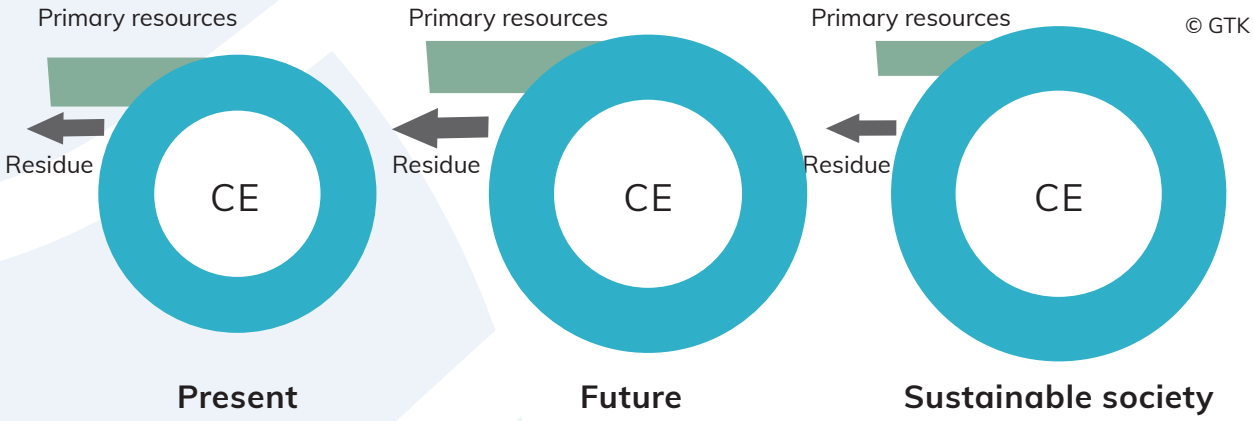
Raimo Lahtinen
Research Professor, Battery Minerals

Ferenc Molnár
Research Professor, Ore Geology

Pertti Sarala
Research Professor, Geochemical Exploration

Mineral economy solutions for Finland

Minerals are essential ingredients of advanced economies such as Finland, providing the raw materials for technological advances and products that sustain growth. The exploration for minerals has become increasingly difficult as the sources that are relatively easy to access have become globally exhausted or when available resources are from economically and politically unstable areas where it is difficult to sustain the exploitation of minerals. The uneven distribution of mineral resources in the Earth's crust also challenges the secure supply of modern and green technologies, as access to these resources has a considerable impact on the competitiveness of industrial production. The search for new mineral resources is going deeper underground and should turn to some still underexplored areas in politically and eco-



A conceptual diagram illustrating how the interplay between primary resources and the expanding circular economy (CE) might develop due to economic growth in emerging economies, which will increase the need for primary resources for decades until we reach a balance. The circular economy has also developed from an agrarian to an industrial, and then a high-tech socio-ecological regime on a historical scale, and this socio-metabolic evolution points towards to a new sustainable society with economically and environmentally more efficient use of primary and secondary raw materials.

nomically stable regions with a great potential for new discoveries, such as the Fennoscandian shield and other areas in the EU. At the same time, the exploitation of natural resources needs to take into account the environment and the people who live and work in the area. The majority of mineral deposits will have elevated social, environmental and governance risks in the future.

Following the circular economy model is currently considered as a promising way to reduce economic dependence on natural raw materials. However, the increasing population, undergoing industrial and urban transformations, will maintain the raw material demand at a high level for decades, which means that the exploitation of primary raw materials should increase during the coming decades. Therefore, despite the increasing role of recycling and substitution, new methods and technologies for modern exploration and mining should be developed. Furthermore, old mining areas that became sub-economic from the point of view of traditional technologies could be re-evaluated and revitalized by modern exploration considering the emerging needs of modern industry for unconventional metallic and non-metallic mineral resources.

Metal recycling as a resource

Closing the loop via recycling is an ultimate goal but includes technical and socio-economic complexities. The challenges include materials not being available for collection or not being properly collected, as well as the major material losses that exist along the recycling chain. The products used for metal scrap have become increasingly complex over time, and the functional recycling of minor metals is both technologically and economically challenging. The recycling industry has an important role to play in the provision of resources and economic growth, but on its own it cannot satisfy the global demand for materials.

"Primary and secondary resources should be considered as one combined system where the whole value chain from mineral exploration to effective recycling forms a sustainable circular economy".

Other sources, substitution, improved design and technological leaps

The reuse of old mine sites and tailings could be a potential source of traditional metals, and also of new metals and minerals listed in the EU's critical elements list. The substitution of critical raw materials is important, as it could reduce the potential consequences in the case of a supply disturbance. In an ideal

situation, we should develop bio-based and renewable materials to substitute primary resources. Improved design can reduce material use, increase the lifespan and improve recyclability. Technological leaps in energy production and storage, and a new socio-metabolic regime are targeted game-changers, but before these desired changes materialize, we are reliant on primary sources and circularity.

Critical raw materials for energy transition

A current paradigm is where non-renewable fossil fuels are replaced by renewables, many of which require critical raw materials and metals to manufacture. Wind turbines and solar energy are examples of the need; these modern technologies still require a sustainable supply of classical base metals (e.g. Cu, Ni) and numerous other metals and minerals, many of which (e.g. REE, Li, Co) are critical in the EU. The historical use of these latter materials has been limited and the amounts of possibly recyclable and substitutable resources are low. It will probably take 10–30 years before the secondary resources are an important resource to supply the growing need for these materials. Thus, for the transition period, primary resources form the main input of these critical raw materials to the circular economy.

Globalization, supply security and traceability

During the past few years, we have seen changes in the discussion from global markets and free trade as the ultimate solution for raw material supply towards a more complex approach. There is growing concern about raw material monopolies (e.g., REE and China), as well as the dumping of scrap materials for recycling, and increased awareness of global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"The transition from a linear, primary material dominated to a circular, secondary material dominated economy for most critical raw materials in energy transition will take decades."

environmental impacts. Moreover, responsible sourcing is a key issue in producing certificated and traceable raw materials. In particular, the use of a dominant marketing position and targeting towards domination of the whole value chain (primary and secondary resources, and products) is very troubling for a country like Finland or the EU as a whole. Thus, we must create a supply security buffer of the critical raw materials (CRM) needed by our industry. The EU published its fourth list of 30 CRMs in 2020 and launched the European Raw Materials Alliance (ERMA) in September 2020. The ERMA is an industrial alliance dedicated to


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"Critical raw material resources, and the related infrastructure and knowledge base in Finland and the EU, are needed to secure future industrial competitiveness"

securing the sustainable supply of raw materials in Europe, and Finland as a CRM-potential country is an important partner in increasing the resilience of the EU in CRM.

Exploration

Exploration and discoveries are feeding the raw material value chain, and further discoveries will facilitate raw material supply and sustainability in Finland and Europe. In addition to the geology of a country or an economic region, the main challenges in exploration are access to land and the need to make socially and environmentally acceptable discoveries. Surface outcropping deposits still exist but are in many cases covered by surficial cover. In Finland, more than 96% of the land area bedrock is unexposed. In addition, we have to look deep, especially in areas having proven resources. Thus, in current and future exploration, we need deeper penetration, better resolution and better targeting, including the implementation of innovative disruptive technology and sustainable exploration practices.

However, it should be kept in mind that despite favourable geological and socio-economic conditions, only about 0.1% of exploration projects are able to produce exploitable mineral resources. Nevertheless, even failed exploration programs produce knowledge that could be useful for designing more successful exploration projects and for the development of new research and exploration technologies. Another issue is that it may take a decade from discovery to exploitation in the case of an important (large resources) mineral deposit. Sustainability of the mineral raw material supply should also consider innovative knowledge and technological development, as well as time factors and the high economic risk associated with mineral exploration. Sustainability also requires the reduction of these risk factors as much as possible. For example, the geological risk could be reduced if we have better capacities for the collection of geological information and the interpretation of geological databases.


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"Exploration is key to securing a sustainable mineral supply chain."


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"GTK's mineral economy activities should facilitate the change towards ***Exploration 4.0****"*

GTK's role in battery minerals value chain

Europe has set a goal to reach climate neutrality by 2050, and Finland is targeting carbon neutrality by 2035. Electric batteries are a key component of the ongoing and growing energy transition away from fossil fuels towards low CO2 emission renewable energy sources. Finland has made initiatives in the development of a national battery ecosystem and eventually creating a totally new industry sector in Finland. To strengthen this development, the government has formulated a national battery strategy with the ambitious goal of creating a knowledge basis and global competitiveness along the entire battery value chain, especially in sustainable battery manufacturing and recycling. One key point in the battery minerals value chain is the production of raw materials and how to provide raw material security in Finland and in the EU, both now and in the future. GTK has taken on this challenge, and one of its four focus areas (FA) for the strategy period 2020–2023 is "Battery minerals".

One of the ultimate goals of GTK is to sustain responsible resource development for future generations in Finland. This is based on framework geoscience, critical to the overall management of our raw material resources, including the subsurface structure and knowledge of earth systems through time. We have to be an active partner in creating a scientific and innovative ecosystem as a basis for business development along the raw material value chain.

Enhance the discovery potential of ore and industrial mineral resources

Towards Exploration 4.0

- GTK provides information, expertise and services to the exploration and mining industry
- Plays a leading role in of innovative development of large data handling, new expertise and methods for the exploration and mining industry
- GTK offers a 3D Finland platform (crustal to belt scale)
- Increase in investments and decrease in exploration costs
- More acceptable discoveries by evaluation of Social License to Operate (SLO) in targeting
- Material cycles and circular economy

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