Critical Materials in Circular Economy of Cities

Academy Programme 2022–2025

Programme memorandum

ACADEMY OF FINLAND

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1. Rationale and background

The global economy and the associated megatrend of urbanisation are driving demand for natural resources. For purposes of the functionality of cities, it is essential to secure access to critical materials not only for households, buildings and infrastructures, but also for high technology products. Equally important is that these critical materials are reclaimed for recycling and reuse towards the end of the product lifecycle. Reliable and secure access to the metals needed in ICT and new environmental and energy technology applications is paramount. The batteries used in electric cars, the panels used in solar energy production and the high-power permanent magnets used in wind energy production all include rare earth metals that are classified as critical or elements that otherwise are crucial to future sustainable development or circular economy.

Difficulties in accessing these strategically important metals and other elements may stem from different reasons. Mineral resources may be scarce or concentrated in geographically problematic areas (e.g. rare earth metals, phosphorus or cobalt), the use of metals relative to identified natural resources may be increasing exponentially with the development of new applications (cobalt, silver), or it may only be possible to reclaim metals from the by-products of base metal production (e.g. indium, gallium).

In some critical and technology metals, recycling is not economically viable because of the potentially small quantities present in certain products (lithium, indium). So-called conflict minerals and their ores, such as tin, tantalum, tungsten and gold, have also gained increasing public and legislative focus. These minerals, too, are extensively used in high technology products.

Europe is dependent on imported metals. Given the high concentration of metal production, availability and price trends are a potential source of serious vulnerabilities. For instance, China is the absolute world leader in rare earth metals, with a world market share in excess of 90%. China is also the world's leading producer of permanent magnets. The leading global sources of palladium and platinum are Russia and South Africa, while the world's cobalt reserves are largely concentrated in the Democratic Republic of Congo. Apart from rare metals, another material on the European Commission's list of critical raw materials is phosphorus, which is regarded as high-risk because of issues with substitutability, access and extraction. More than 90% of all phosphorus used in the European Union is imported. Not only in Finland but across the EU, there is a growing recognition of the key strategic importance and business potential of critical metals and their value chains.

The European Union's aim is to secure unhindered, sustainable and affordable access to raw materials. The European mining industry is unable to secure the raw materials required by all technologies. Furthermore, current recycling levels are inadequate to satisfy EU demand for critical raw materials. Efficient metal recycling is therefore paramount to the security of raw

material supply. In particular, poor raw material substitutability and the low recycling rate currently present an increasing production risk. The European Union maintains and updates a list of critical raw materials, which is subject to review every three years. The number of raw materials rated as critical has increased with every update. The 2020 list identifies 30 critical raw materials, most of which are metals. In the space of just six years, the number of items on the list has increased by ten.

One way of trying to secure access to the raw materials needed in production is urban mining, that is, recovering usable metals from urban waste. Electronics waste often has several times higher concentrations of certain metals than crude ore (e.g. copper, gold, platinum, palladium and silver in circuit boards), and indeed urban mining can be a more cost-effective method of recovery than primary ore mining. On the other hand, certain products contain only very small quantities of certain technology metals (e.g. indium in flat screens, cobalt in circuit boards), and therefore large amounts of elements are lost in recycling processes. In these cases, new innovations and business models are needed to enhance the economic viability of recovery. The efficient recovery of metals also requires new and better methods for analysing and processing waste from urban energy technology. Cities should play a more prominent role in establishing an effective circular economy chain and in ensuring that all critical materials are recovered and recycled.

The effective reuse of materials recovered from urban structures (buildings, community infrastructure, including underground cabling and piping, electrical and electronics waste) requires an understanding of the functionality of cities and the composition of different materials, and active measures to influence planning and decision-making systems. A key challenge for research is to determine how specific elements can be reclaimed from very different kinds of waste materials in an environmentally friendly and economically viable way, or how otherwise to organise materials recycling and reuse. Effective circular economy is central to sustainable development.

A common problem of materials recycling is its scale, which is not always large enough to allow for economic viability. On the other hand, in response to the demands of active consumers, companies are realigning their business models and investing in recycling, at the same time as urban planning is contributing to support more efficient recycling. Circular economy calls for the introduction of new technologies, products and recycling mechanisms as well as new business models.

2. Objectives

The Academy Programme's primary objectives are to

- produce new scientific information in the programme's thematic areas
- steer research towards areas of application that are relevant to circular economy in cities
- increase high-level research with a view to facilitating the development of circular economy in cities.

Furthermore, the social and operational objectives are to

- steer research towards resolving problems central to the research themes and to facilitate the mass-scale application of these solutions
- steer research towards the goals of the UN Sustainable Development Agenda 2030
- set up multidisciplinary research teams and national and international networks of research collaboration
- promote the networking and mobility of doctoral candidates and researchers
- strengthen the cooperation and international competitiveness of academia and industry and to enhance urban vitality
- promote open science and research.

3. Thematic areas

Cross-disciplinary cooperation is encouraged in all thematic areas under the Academy Programme.

3.1. Flows of critical materials in circular economy

The first theme is concerned with the occurrence of critical elements and the chemical composition and properties of material flows in different matrices, and with developing economically viable and sustainable processes for the beneficiation, separation, recovery and purification of critical elements. Specific research subjects may include the circular economy of electronics,

permanent magnets, batteries or solar cells, or the separation of valuable elements or compounds from wastewater, sludge or combustion residues from landfill waste. This subject may be addressed from the vantage point of process development and modelling, value creation in recycling, or from a systems theory or industrial ecology perspective.

Research questions relevant to circular economy and critical materials in this theme include the following:

- In what kind of matrices are critical elements found?
- How to develop economically viable metal beneficiation, separation, recovery and purification processes?
- What kinds of technological, economic and other solutions can help secure access to the raw materials needed for the production of electronics, permanent magnets, batteries or solar cells, for instance?
- How can material flows of the circular economy be modelled?

3.2. High technology products and services in circular economy

The second theme is focused on product design and concept development that supports reuse and recycling and that allows for the optimum recovery of different materials at the end of the product lifecycle. Ultimately the aim is to minimise the non-recyclable footprint of products. New product and service solutions generate added value for different groups of stakeholders. Research questions relevant to circular economy and critical materials in this theme include the following:

- What kinds of new products and services can be developed in line with the principles of sustainable development?
- How is the ownership of new products determined?
- What kinds of business models should be developed?
- What kinds of circularity-based delivery chains should be built?
- How should regulation be developed in order to support circular economy innovation?

3.3. Cooperation and governance of circular economy actors

Cities attract an accumulation of many different kinds of materials, which may have economic significance for urban residents and other stakeholders. Research questions relevant to circular economy and critical materials in this theme include the following:

- What kind of new cooperation and organisation is needed among different stakeholders?
- What methods of economic and strategic influence could be applied to steer and encourage different stakeholders?
- How can the public, private and third sector contribute to sustainable value creation?
- What kinds of local, national and international institutional arrangements could help to promote the desired course of development?

3.4. Circular economy and urbanisation

The focus in this theme ranges from researching flows, processes and materials through to cities as platforms for various productive activities. Urbanisation opens up new angles for studying processes of change and transition in functional circular economy structures. The city is approached as an accumulation of materials and a functional entity, considering its structures and connections both within the urban region, between different regions and at a global level. Apart from a deeper understanding of consumer behaviour, new information is needed about the interaction of people and the environment, urban everyday life and the vulnerability of society. The research theme also comprises legislative reforms that influence the operation and administration of cities. The aim is to gain a deeper understanding of the functionality of cities and urban regions and their role as circular economy platforms. Research questions relevant to circular economy and critical materials in this theme include the following:

- What kinds of physical, immaterial and functional structures and processes in cities support the reserves and flows of urban circular economy?
- How is the city structured and organised as a built environment, space and platform of regional circular economy?
- How do people's ways of organising themselves, their networks and material flows change?
- How does circular economy as a strategic urban governance issue connect with the city's other strategic operations?
- What kinds of risks can flow from circular economy and critical materials processes?
- What are the implications of these changes for the circulation of materials and for administrative and business solutions?

Applications to the programme are particularly encouraged from projects that combine natural sciences, engineering and social sciences research. Applicants are recommended to take special note of the systemic nature of

circular economy in cities. Projects may apply natural science and engineering methods to study both the structures and processes of urban circular economy and critical materials. The programme especially encourages interdisciplinary and cross-disciplinary teams that will be able to examine circular economy in cities both from the point of view of recyclable critical metals, entrepreneurship and organisation and from the point of view of societal institutions (legislation, culture, political decision-making, public governance).

4. Impact of programme

In order to reduce the consumption of non-renewable natural resources and to lower CO2 emissions caused by increasing mining operations and the manufacture of metals, it is necessary to take positive action to develop the recycling of materials, starting from the collection of electronic waste through to the recovery and reuse of critical raw materials. The development of recycling processes will also enable the recovery of several metals that are currently not recycled at all. There is particularly large untapped potential in the area of battery recycling.

The research conducted in the programme will provide a foundation for future reuse and waste recycling solutions and create new industrial and commercial opportunities. Circular economy offers a genuine competitive advantage for Finland in key priority areas such as the manufacture of metals.

5. Timetable and funding

The Academy Programme is funded and coordinated by the Academy of Finland. The Academy Board has set the programme's funding budget at 8 million euros. Funding will be provided to individual projects and consortium projects for a maximum of four years. The funding period for the 2021 call starts on 1 January 2022 and ends no later than 31 December 2025.

6. Actions by other funding agencies

The importance of the subject area covered in the programme is well recognised in Finland. Business Finland's Bio and Circular Finland programme (2018–2022) is designed to support the growth and internationalisation of Finnish companies in the bioeconomy and circular economy areas and to provide guidance and advice for the application of EU funding. Ultimately, the aim is to increase Finnish exports of bioeconomy and circular economy solutions. The development of new innovations is supported across various

circular economy sectors, particularly in new textiles and construction applications. In 2019, Business Finland granted funding worth around 10 million euros to the BATCircle consortium (Finland-based Circular Ecosystem of Battery Metals). Administered by Aalto University, the consortium's mission is to develop manufacturing processes in the mining industry, metals industry and battery chemicals, and to increase the recycling of lithium-ion batteries. Its goal is to strengthen cooperation between companies and research organisations in Finland and to find new business opportunities. The Academy Programme will start at the same time as the Business Finland programme ends.

The Finnish Innovation Fund Sitra is continuing its award-winning work to advance circular economy take-up. Sitra is mainly concerned with determining the impacts of a large-scale circular economy transition and identifying the necessary steps to achieve that transition; understanding the system-level environmental impacts of digitalisation; creating an operating environment that encourages circular economy practice; and accelerating the global transition particularly through trade and investment agreements and development banks.

Circular economy and materials efficiency figure prominently in the Ministry of Economic Affairs and Employment's priority area of "Bioeconomy and cleantech". The Ministry awards grants for the promotion of innovative circular economy solutions. Funding is granted out of an appropriation of 1,000,000 euros. Projects must be scheduled for completion by 30 June 2022.

Within the European Union, research and innovation in the circular economy field is promoted through EIT RawMaterials, a Knowledge and Innovation Community (KIC) funded by the European Institute of Innovation and Technology (EIT). EIT RawMaterials supports innovation and entrepreneurship and aims to enhance cooperation between universities, research institutes and business.

The European Commission adopted its new Circular Economy Action Plan on 11 March 2020. This is one of the main building blocks of the "European Green Deal", the EU's new programme for sustainable growth. Building on an earlier plan published in 2015, the new Circular Economy Action Plan outlines initiatives along the entire lifecycle of products with a view to modernising and changing our economy and at the same time protecting the environment. The purpose is to give consumers access to long-lasting products and to make sure they can fully engage in the circular economy and benefit from the positive changes it creates.

The EU's From Farm to Fork strategy is intended to promote circular economy, and the Commission's communication on critical raw materials supports the present Academy Programme. The communication "Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability" was published on 3 September 2020.

One of the visions of the EU Research and Innovation Framework Programme Horizon Europe (2021–2027) is to achieve the goals of sustainable development across the European Union. All pillars of the framework programme are geared to sustainable development, as are at least four of the programme's mission areas. Research and innovation calls will be opened at a later date under the framework programme

M-ERA.NET 3 was launched in 2020. Focused mainly on materials science, its themes include both circular economy and batteries. The Academy of Finland is involved in the M-ERA.NET 3 network.

The importance of the Academy Programme's subject area is also recognised by the OECD, which published a report on "The Circular Economy in Cities and Regions" on 4 November 2020. Cities will play a pivotal role in the transition from a linear to a circular economy. The synthesis report builds on the findings from 51 cities, one of which is Umeå in Sweden. Liv Öberg introduced Umeå's circular economy at an exploratory workshop hosted by the Academy of Finland on 27 August 2020.

7. Contacts and more information

This programme memorandum is available as a PDF download on the Acaemy of Finland's website.

- Saila Seppo, Programme Manager, tel. +358 295 335 109
- Risto Vilkko, Programme Manager, tel. +358 295 335 136

Our email addresses are in the format firstname.lastname(at)aka.fi.

Postal address:

Academy of Finland

PO Box 131 (Hakaniemenranta 6)

FI-00531 Helsinki