Development of holistic Life Cycle Assessment (LCA) models of Critical Raw Materials (CRMs) to minimize waste and enhance the sustainability of the raw materials industry

Summary

This PhD project seeks to turn a problem into an opportunity, by developing and applying Life Cycle Assessment (LCA) tools to (1) minimize waste and (2) enhance sustainability and availability of critical raw materials. This PhD project will contribute to the raw materials industry's sustainability by proposing an innovative supply chain approach for strategic raw materials based on the valorization (recycling and secondary re-use) of industrial wastes. In this work, several processing routes of raw material waste (including overburdens and industrial mineral tailings) will be assessed for recycling into construction materials or chemical products. We will include input from several domestic and international industrial partners, who will provide sectoral expertise and share information about company activities in waste management. The research objective is to identify the environmental impact and sustainability potential of selected valorization routes using LCA, hot spot analysis and risk identification, creating a sustainability indicator. This work will significantly contribute to developing a quantitative decision support system for environmental, social and health impact assessment (ESHIA) aligned with the targets of the UN Sustainable Development Goals (SDGs).

Research field:	Environmental, marine and coastal technology
Supervisor:	Viktoria Voronova
Availability:	This position is available.
Offered by:	School of Engineering Department of Civil Engineering and Architecture
Application deadline:	Applications are accepted between June 01, 2025 00:00 and June 30, 2025 23:59 (Europe/Zurich)

Description

Main supervisor: Viktoria Voronova

Co-supervisor: Alan Henry Tkaczyk (University of Tartu)

The research

The raw materials industry is one of the Europe’s largest waste streams, generating vast quantities at 700 Mton/ year. The 2023 Amendment to the EU Waste Framework Directive requires enhanced recycling and will require the adoption of innovative technologies. Still, the EU industry is heavily reliant on raw material imports, and the energy transitions continue to increase demand for critical raw materials (CRMs).

A Euronews video and more information is available at: youtu.be/M2U9Z_TnyBk and valorwaste.ase.ro.

This project will holistically demonstrate the opportunities and challenges for the valorization of waste from the raw materials industry. This PhD project seeks to turn a problem into an opportunity, by developing and applying Life Cycle Assessment (LCA) tools to (1) minimize waste and (2) enhance sustainability and availability of CRMs. This PhD project will elaborate and assess an innovative supply chain for CRMs based on the valorization (recycling and secondary re-use) of industrial wastes.

In this work, several processing routes of raw material waste (including overburdens and industrial mineral tailings) will be assessed for recycling into construction materials or chemical products. We will include input from domestic and international industrial partners including VKG, Ragn-Sells, and SECIL, who will provide sectoral expertise and share information about company activities in waste management.

The case studies have been chosen to represent the whole stage of mining activities and different types of non-energy raw materials (see Fig. 1). The case studies include construction and demolition waste sites in Estonia, aluminium waste sites in Greece, and raw material and mining sites in Portugal, Türkiye, and Poland. Potential end-users of the recycled waste are also considered, including cement companies in France and Portugal, and chemical companies in Estonia (VKG) and Türkiye. This diversity of input materials and end users presents unique possibilities to achieve truly circular economy with minimized waste, complemented by quantitative LCA analysis.

Research aims

Research objective. Identification of the environmental impact and sustainability potential of selected valorization routes using LCA, hot spot analysis and risk identification, creating a sustainability indicator.

Impact. This work will significantly contribute to developing a quantitative decision support system for environmental, social and health impact assessment (ESHIA) aligned with the targets of the UN Sustainable Development Goals (SDGs).

Research methodology and holistic approach

This work applies LCA as a critical tool to assess the real impact of raw material waste production, prevention and reutilization. System Boundary definition and data quality will be critical, and will be based on analysis of defined waste characterization data, followed by a strict sampling case study, to evaluate valorization potential. A set demonstration scenario with recycled input materials will be implemented. The environmental impacts of the processes will be holistically assessed via LCA according to the ISO 1404x standard and EIA (environmental impact assessment) methodology. Focus on data reproducibility will ensure that the LCA findings are industrially relevant. This will be critical for identifying environmental hotspots along the value chain, for eco-designing the different stages of the valorization routes and solutions (i.e., industrial symbiosis), and ensuring that environmental, social and governance challenges are properly addressed.

Responsibilities and (foreseen) tasks

Applicants should fulfil the following requirements:

- A master's degree in engineering or science, with a focus on environmental, construction, chemical, geological or closely related topics.
- Strong interest in LCA, EIA, or sustainability metrics.
- Interest in data analysis and computational modelling.
- Very good proficiency in spoken and written English language.
- Willingness to travel to international and domestic project meetings.

The following experience is beneficial:

- Experience with LCA tools and software (e.g., SimaPro, GaBi, openLCA).
- Familiarity with EIA processes, sustainability indicators, or environmental reporting.
- Practical or industrial experience in environmental, construction, chemical, geological or closely related sectors.
- Proficiency in computer programming in Python or other languages.
- Proficiency in scientific communication and writing.
- Basic skills or willingness to learn Estonian language.

We offer:

- **The opportunity to work on an interdisciplinary and internationally attractive research topic.**
- **Joint Supervision and Expertise**: The PhD position is offered in cooperation between Tallinn University of Technology (TalTech) and University of Tartu, combining TalTech's strengths in life cycle analysis and industrial engineering with the University of Tartu's expertise in environmental science and sustainable resource management.
- **Access to Dual Research Environments**: Candidates will benefit from access to facilities, research networks, and academic resources at both universities, fostering interdisciplinary collaboration and a broad academic experience.
- **Industry-Linked Research with European Scope**: The project is integrated into a pan-European research network, providing opportunities to collaborate with industry partners and contribute to high-impact case studies across Estonia, Portugal, Türkiye, and Poland.

About the department

This PhD project will include a cooperation between two universities: Tallinn University of Technology (TalTech) and the University of Tartu (UTARTU). The home base for the project will be TalTech, and the PhD degree will be awarded by TalTech upon successful completion of the project and doctoral requirements.

At TalTech, the Department of Civil Engineering and Architecture, within the School of Engineering covers research and education in the fields of architecture, building structures, construction processes, near zero energy buildings, structural and fluid mechanics, road construction, geodesy and water and environmental engineering. Within the De-

partment, the Water and Environmental Engineering (WEE) research group performs research on life cycle assessment (LCA), impacts of climate change, water quality and treatment of municipal and industrial waste and waste waters. The WEE research group has long-term experience in conducting life cycle assessments and calculating the carbon footprint of various products and materials. The WEE laboratory offers the capability to measure the physical and chemical parameters of wastewater and assess the biodegradability of various bioplastics. The research group has developed several educational materials on LCA and sustainability topics in waste management. The research group actively participates in national and European Union research projects, including Horizon Europe, Interreg, Erasmus+, LIFE, and EuropeAid.

At UTARTU, the Institute of Technology focuses on research and education in the following areas: environmental technologies, biomedical technologies, intelligent materials and systems. Within the Institute, the research group of Associate Professor Alan Tkaczyk investigates valorization of industrial residues, environmental impacts, sustainable resource management, and naturally occurring radioactive material. As a cooperation between UTARTU and KTH, the research group developed and implemented a novel NORM-LCA methodology on the topic “A framework for including enhanced exposure to Naturally Occurring Radioactive Materials (NORM) in LCA.” For the last decade, the research group has investigated circular economy issues associated with valorization of bauxite residue, a byproduct of the metals industry. The research group is highly active in international and domestic research, including having participated in ten European Union (Horizon Europe, H2020, FP7) project and three Estonian Research Council projects on environmental topics.

(Additional information)

For further information, please contact:

1. Dr. Viktoria Voronova (e-mail: viktoria.voronova@taltech.ee)
2. Associate Professor Alan Tkaczyk (e-mail: alan@ut.ee)

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