BATCircle

Finland-based Circular Ecosystem of Battery Metals – **BATCircle**

Dear reader,

The Finland-based circular ecosystem of battery metals – BATCircle – started in March 2019. The first phase of BATCircle (referred to as BATCircle1.0) was successfully finished in April 2021 when BATCircle2.0 kicked off for the next three years. The consortium consists of the key research organisations and companies working in the field of battery metals in Finland and is coordinated by Aalto University. BATCircle research is mainly funded by Business Finland and included in their Smart Mobility and Batteries from Finland program as a flagship project. Together, the members cover a wide range of the domestic battery metals value chain with emphasis on battery minerals, metals refining, chemicals, active material preparation and battery recycling.

The aim of the ecosystem is to conduct high quality research at the academy-industry interface to increase competitiveness and the business potential of Finnish partners working in the battery metals sector. Furthermore, the aim is to enhance co-operation between research organisations and industry, to bring new feasible and sustainable solutions to the market. BATCircle has positively influenced Finnish collaboration in European research, with multiple new international research projects in the pipeline.

This brochure represents i) Motivation into batteries, ii) Batteries and Finland, iii) BATCircle1.0 consortium and research, iv) BATCircle2.0 consortium and research, and v) Batteries and European collaboration. Please visit our website (batcircle.aalto.fi) to find out more.

Research is needed to support the leap of electrification and battery metals are needed now more than ever. Welcome to join us for this journey with the Finland-based ecosystem!

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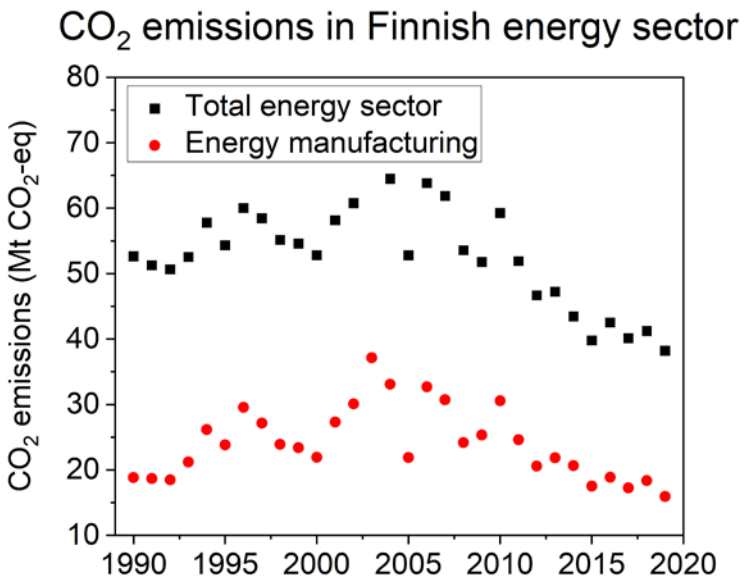
Motivation into batteries

Batteries are currently used in many application and will soon become ubiquitous in the daily life of most people. It has been fascinating to follow the rapid development of electrification during the last few years, with batteries playing a key role in enabling energy storage in various applications. The shift in consumers' interest from petrol Internal Combustion Engines vehicles to electric vehicles, and the general understanding of the necessity of this transition has increased substantially. The critical role battery metals is now better understood by all stake holders.

The Paris Agreement set a target of making batteries as well as the metals contained in them CO_2-free. Recycling batteries and refining battery materials for reuse is a step towards this target. We can also reduce our CO_2 load, for instance, by paying attention to the distances between production plants. The conditions for battery production in Finland are superb, as a sophisticated battery ecosystem is already in place and is developing further. Infrastructure for collecting and recycling batteries is already operating commercially. Moreover, the production plants and industrial assets are situated close together and could be optimized accordingly.

Another important consideration is that, in the future, the energy used for charging batteries should be produced in as environmentally friendly a way as possible. A current trend in the Finnish energy sector is the decrease in CO_2 emissions (see the figure below).



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Take a look at the Paris Agreement

unfccc.int/sites/default/files/english_paris_agreement.pdf

Photo: Valeria Azovskaya

Batteries and Finland

On a global scale, Finland plays a major role in battery production. A special source of interest for the battery industry operators is our ready-made battery infrastructure. Our bedrock contains many minerals required for the manufacture of batteries, such as cobalt, nickel and lithium. Finland also boasts a high level of research and production expertise, not to mention a fertile ground for the collaboration of businesses and research facilities.

The national battery strategy, which lays the ground rules for the development of battery production in Finland, is aimed at increasing the competitiveness and growth of research and production in the field, both nationally and internationally. In the last few years, several players have invested heavily in Finland, for example, in battery chemical and material production, further reinforcing the whole sector's growth prospects.

Photo: Valeria Azovskaya

Take a look at Finland's national battery strategy

julkaisut.valtioneuvosto.fi/bitstream/handle/10024/162685/TEM_2021_6.pdf?sequence=1&isAllowed=y

The most significant and potential ore deposits in Finland

Some of the latest significant news in Finland-based battery sector

Terrafame is producing battery grade nickel and cobalt sulfates at Sotkamo.

Keliber is aiming to start mining and refining Finnish lithium hydroxide at Kaustinen.

Umicore is expanding its battery material production capacity in Kokkola.

Stora Enso and Northvolt cooperate to plan the production of lignin-based hard carbon anode materials at Kotka.

BASF will start pCAM production in Harjavalta.

Valmet Automotive has started battery production in Salo and Uusikaupunki.

Fortum will start hydrometallurgical battery recycling process in Harjavalta 2023.

Research activities

BATCircle members are involved in many other big EU research projects in batteries such as BATTRACE, ENICON, RESPECT, RESTART, SOLID and HiQ-CARB.

SCI-MAT PLATFORM

LUT University

Sustainable Circularity of Inorganic Materials, multidisciplinary research platform

The SCI-MAT platform solves complex societal challenges in the circularity of inorganic materials utilizing mechanical and hydrometallurgical processes. Business models and sustainability (social, environmental, economic) are also in the focus.

» lut.fi/sci-mat

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LUT University | Clean energy, water and air are life-giving resources for which we at LUT University seek new solutions with our expertise in technology and business. We help society and businesses in their sustainable renewal. Our international community consists of 6 500 members. Our campuses are in Lappeenranta and Lahti, Finland.

BATCircle1.0 consortium and research

Photo:
Valeria Azovskaya

BATCircle1.0 was a 2-year project, the operating period of which started in spring 2019. The consortium comprised 23 businesses, 2 municipalities and 6 research organisations. Open research was implemented by Aalto University, University of Oulu, University of Eastern Finland, LUT University, Geological Survey of Finland (GTK) and VTT Technical Research Centre of Finland. The research was largely focused on cobalt-rich batteries. The objective was to improve cooperation between battery companies and research organisations by introducing added value to the entire battery value chain. In total, the project included seven work packages, covering the whole battery production value chain from enriching minerals and recycling batteries to assessing the opportunities provided through business.

One of the things discovered in the BATCircle1.0 project was that the carbon footprint of the recycling process was 70% of the carbon footprint of primary production. The ability to salvage the aluminium contained in a battery would reduce the carbon footprint by up to 50% compared to the current state of affairs.

WP1 Sustainable primary resources

WP2 Value addition in metals production

WP3 Recycling of batteries

WP4 Tailored precursors and active electrode materials

WP5 Business potential

WP6 Project management

WP7 European network

BATCircle1.0 in numbers

Over **40** talks and interviews given related to BATCircle and Finnish battery value chain

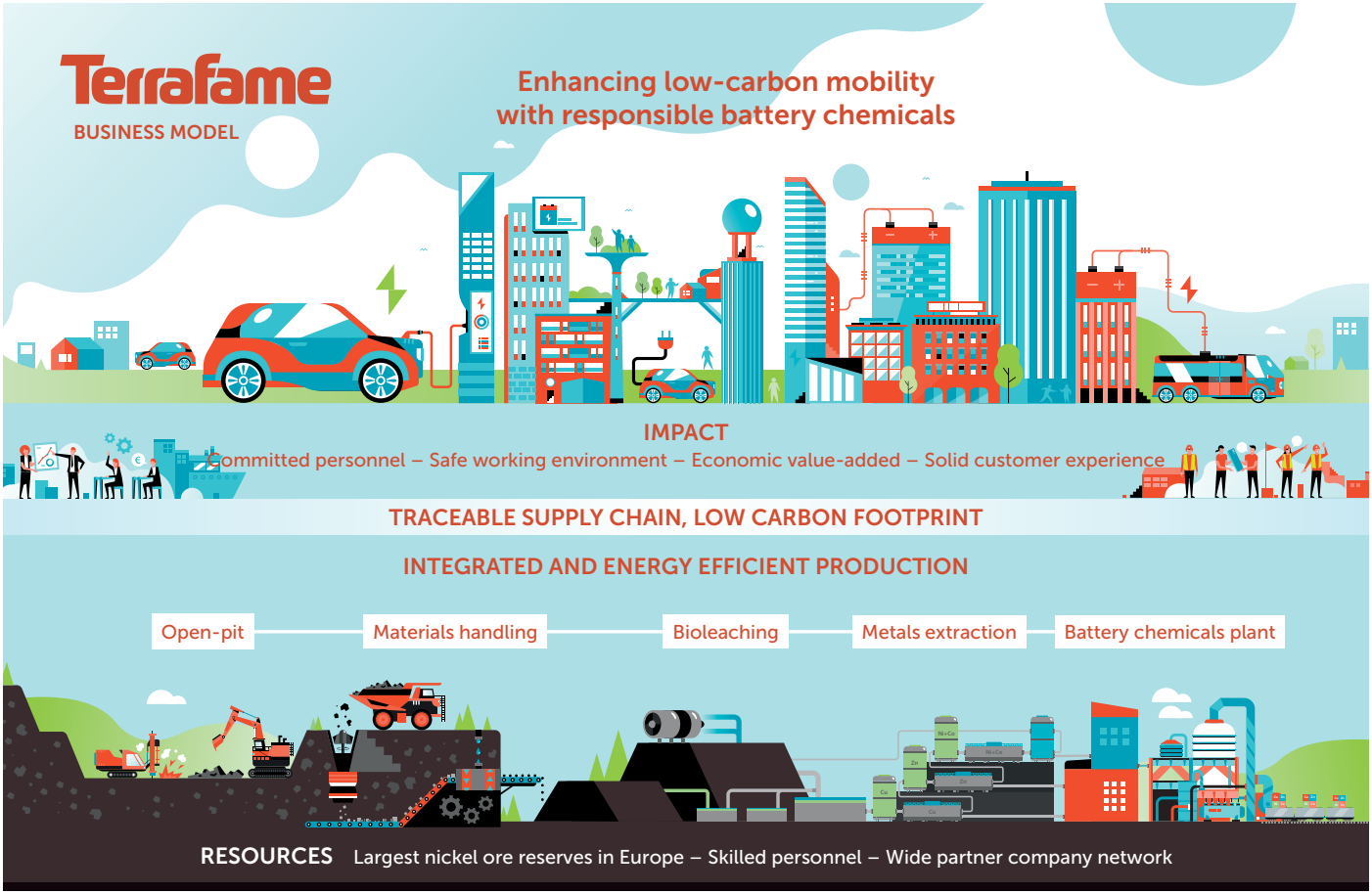
30 published Theses

39 peer-reviewed publications (~25 manuscripts submitted or to be submitted to peer-review)

13 technical reports

41 conference reports

7 magazine articles



Terrafame's purpose is to enhance low-carbon mobility with responsible battery chemicals

Our production process is unique.

It begins in our own mine and ends with battery chemicals, all this integrated on one industrial site.

We participate in the fight against climate change.

Our energy-efficient production chain provides customers with battery chemicals that have a markedly smaller carbon footprint compared to the industry average.

Sustainability is at the core of our strategy.

We are committed to diminishing the environmental impact of our operations as well as enhancing sustainable development and circular economy.

We are part of developing the battery strategy

at European and Finnish level by contributing to various research initiatives such as the BATCircle 1.0 and 2.0 projects coordinated by Aalto University and the European IPCEI-programme.

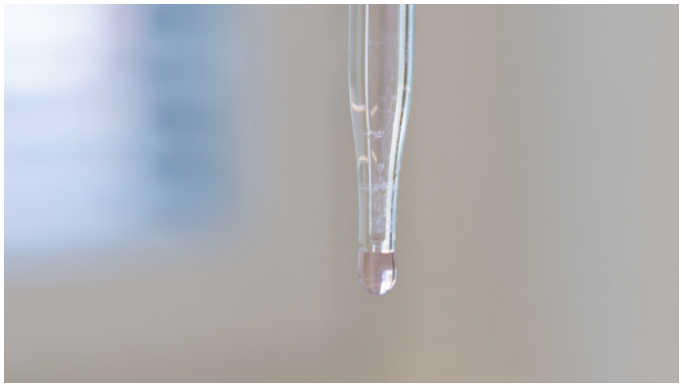
Terrafame www.terrafame.com

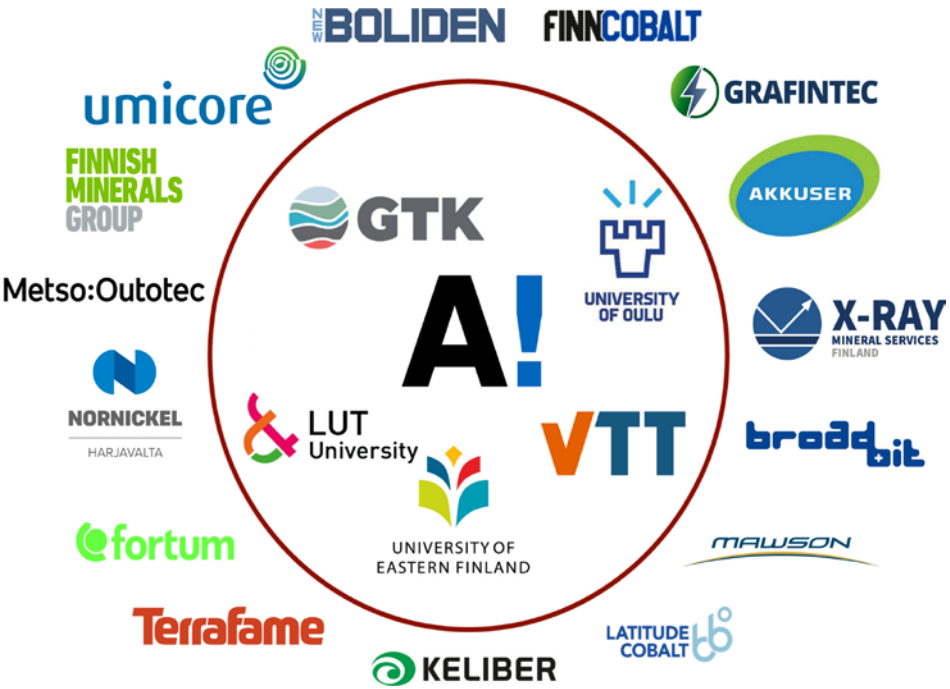
BATCircle2.0 consortium and research

BATCircle2.0 will continue from where the previous project ended, researching battery metals and the recycling of batteries. The main emphasis of R&D is on batteries with a high nickel content. Due to their higher efficencies these batteries will predominate in future markets. The 3-year project is organised by Aalto University. There are altogether 6 research organisations and 15 companies involved in the project. The project's overall budget is in the region of EUR 19 million.

The goal is to unearth methods that will create added value for Finnish battery sector operators and, in that way, help to strengthen Finland's position on a global scale. This will be achieved by (1) more efficient characterisation and utilisation of the domestic mineral resources; (2) improving the metal refining processes at multiple points along the value chain, up to the active electrode materials; (3) recycling battery metals; (4) improving cooperation between companies and research organisations; as well as (5) increasing understanding of circularity in the context of battery materials. Additionally, BATCircle is active in European collaboration, aiming at fostering truly collaborative international joint research actions.

The BATCircle2.0 project involves battery companies and research facilities. Additionally, BATCircle2.0 has a dedicated advisory board by stakeholders. >





VTT

Sustainable growth awaits

VTT is your partner in developing process and recycling innovations for battery metal industry. We are one of Europe's leading applied research companies and solve major challenges through scientific and technological means.

Interested? Find more at VTT world:

www.vttresearch.com/en/vtt-world

beyond the obvious

BATCircle2.0 consortium and research

Work packages

BATCircle2.0 open research consists of five technical work packages (WP1–WP5), project management work package (WP6) and one for European co-operation (WP7). The subjects of research include cutting emissions, refining materials as well as the circular economy of batteries. The aim during the project is to increase cooperation both at national and international levels.

WP1

Battery minerals exploration and responsible mining

The first work package is focused on the earliest stage of the battery life cycle. The aim is to determine a unique integrated prospectivity approach for new resources and improved battery mineral prospecting methods. Additionally, data mining and statistical findings of potential locations combined with geological structure models are developed.

The research in WP1–WP5 includes the whole life cycle of battery metals and minerals from production to recycling.

WP2

Enhanced battery materials recycling

This work package solves the challenges related to the recycling of battery materials to meet the continuously increasing demand of battery metals. The objective is to form data-driven classification of batteries by non-destructive means. The leaching phenomena of real EV battery waste are investigated aiming to improve recovery and recycling of currently non- or under-recovered elements (graphite, Li, impurities) present in the battery waste. In this WP, the interest is in developing dynamic modelling for SX process optimisation, new methods for battery metals recovery as well as membrane separation unit processes enhancing hydrometallurgical LIB recycling.

WP3

Advanced minerals and metals processing

This work package considers the crucial phase of battery life cycle prior to manufacturing actual battery materials. The aim is to produce high purity graphite products from primary resources. Pyrometallurgical processes are developed for LIB treatment and integration into primary processing. The environmental impacts (LCA) of lithium from virgin vs. multimetal recycled raw materials are studied. Battery raw materials are integrated into primary hydrometallurgical processing and the most promising raw materials into bench scale piloting.

WP4

State-of-the-art battery materials

The 4th work package deals with the anodic and cathodic battery materials. The aim is to increase the knowledge of synthesising the precursors as well as anode and cathode active materials up to pilot-scale. Additionally, the use of secondary material flows and purity requirements in the synthesis of active electrode materials is investigated.

WP5

Circular battery materials value system

This work package aims to increase understanding of circularity in the context of battery materials. Engineering parameters are developed to support circular technologies, and mineral characterisation standards are defined for Li, Co and Ni. Circularity aspects are identified to support the Finnish battery ecosystem.

WP6

Project management

The project is organised and managed by Aalto university.

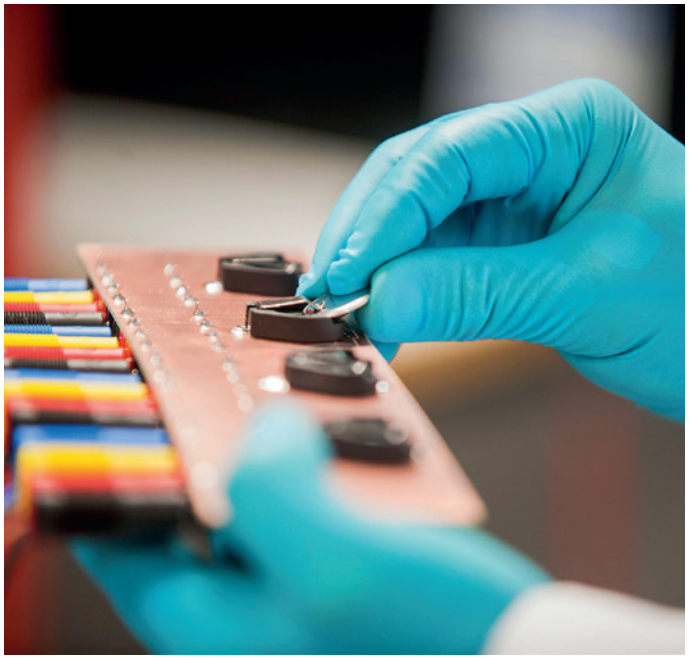
WP7

European network

Collaboration with EU level companies and research organisations.

UNIVERSITY OF OULU

Battery chemistry research since 2007



Batteries and European collaboration

Some of the big research questions considered relate to mineral resources and their sustainable utilisation, metals refining to battery grade materials, battery recycling, development of new active materials, as well as life cycle analysis and the environmental impacts of all linked processes.

As many of these research questions are global; BATCircle has also been active on the international stage through collaboration in several European research projects and in identifying the future R&D needs of the EU in the field of battery raw materials and recycling – more than ever, an attitude of "working together for the common good" is needed.

The Batteries European Partnership Association (BEPA) was formed in late 2020 to strengthen

Cobalt sulphate solution samples as extracted and separated from leachate.

co-operation between European battery industry and research with several Finnish representatives appointed. Also, Finland was selected to lead Working Group 2 of Batteries Europe “Raw materials and recycling”.

Let’s make Finland into the no. 1 country in sustainable battery operations!

BATCircle helps to create and develop battery operations. Please join us – both domestic and global cooperation is needed more than ever!

See Batteries Europe Road map 2020 in raw materials and recycling.

energy.ec.europa.eu/system/files/2021-12/vol-2-009.pdf

A! Aalto University School of Chemical Engineering

Future world runs on green chemistry. Be a part of it!

Study Sustainable Metals Processing

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- Recycling and Separation Technologies
- Material Properties of Metals

IMPACT

- Sustainable Development
- Mitigate CO_2 Emissions
- Develop Battery Recycling

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- Production Manager
- Sustainability Specialist

Apply to the Master’s Programme in Chemical, Biochemical and Materials Engineering – Sustainable Metals Processing at Aalto University! More information: aalto.fi/SMP

Battery material research at University of Eastern (UEF) Finland FINE laboratory

General

Li-ion battery material synthesis and characterization is carried out UEF FINE laboratory in Kuopio campus. We a specialized in gas phase synthesis and high temperature annealing of cathode and anode materials in Li-ion and next generation batteries. We are carrying out basic and applied research and we offer services to industry and other organisations.

Synthesis methods

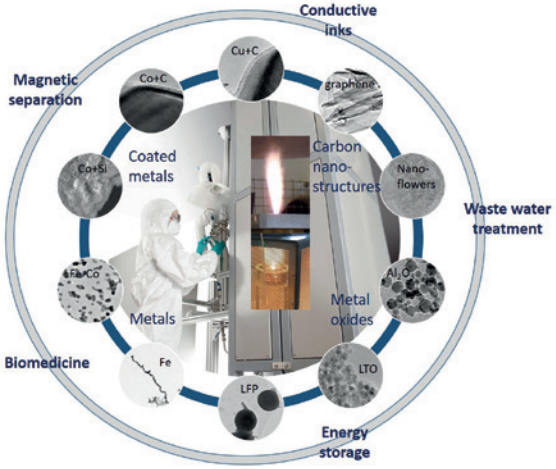
Our synthesis methods include:

1. Spray drying and Spray pyrolysis
- synthesis of metal oxides, doped metal oxides and composition materials
- particles from nano- to micrometer size can be produced
- particle composition and properties are tightly linked to the precursor solution that contain either dissolved or suspended reagents

2. Flame synthesis
- synthesis of metal oxide and doped metal oxide nanoparticles using high temperature oxidizing flame
- laboratory and pilot scale production up to 1.5 kg/h

3. Chemical vapour synthesis
- production of wide range of nanomaterials including zero valent iron and iron oxides and coated particles
- particles for magnetic and medical applications

4. Induction annealing
- production of carbon nanostructures including graphene, carbon nanoflowers, carbon nanodotd and graphite
- high temperature synthesis up to 2600 C



Examples of Li-ion active electrode material production

Anode materials: Lithium titanate (LTO), mineral- and bio-based graphite, carbon coated silicon nanoparticles.

Cathode materials: Lithium metal oxides and phosphates NMC, LMO, LFP, LCO.

At UEF we have also novel physico-chemical and electrochemical material characterization methods in use.

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