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Batteries from Finland

FINAL REPORT

1.3.2019

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INTRODUCTION

This study is part of Business Finland Batteries from Finland activation project which aims at speeding up development of national battery ecosystem and creating a totally new industry sector to Finland.

Batteries from Finland -project is **enhancing the growth of knowledge basis** and **global competitiveness** along the entire battery value chain – from raw material production to battery cell production, battery applications and recycling.

The study was commissioned by Business Finland and jointly executed by Gaia Consulting and Spinverse.

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WHY FINLAND?

- Clean Energy
- Strong metallurgical knowhow
- Stable mineral supplies
- Long tradition in harsh use applications
- Stable Business Environment
- Competitive Workforce
- Safe society
- Vibrant startup scene
- Located Between East and West
- Reliable Infrastructure
- Innovation Champion

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Objectives

This study relates to the strategic aim to create in Finland a new battery industry ecosystem – in particular, giving a foundation to

CREATING	a globally competitive Li-ion battery industry business ecosystem in Finland
ENABLING	Finland to become a leading country in the Li-ion battery recycling know-how
INCREASING	the offering of the companies in Finland to feed the needs in the battery and energy storage market
CONNECTING	the Finnish organizations to international networks and growing markets
ATTRACTING	international Li-ion battery cell, component and chemicals manufacturers and their RDI-activities to Finland.

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Introduction to the work

Three main tasks in the work have been

1) the **background study** to create general view on the ongoing battery related activities in Finland, in the Nordics and in Europe and on potential partners to the battery ecosystem,

2) surveying the will and development needs of companies to act in the battery industry ecosystem, and

3) describing the success factors for a national battery industry ecosystem by identifying potential and value added of such an ecosystem.

The main working methods have been desktop study, interviews and workshops as well as utilization of digital platforms for internal team and external participant communication and engagement.

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Batteries in brief

PRIMARY BATTERIES

Small **single-use** batteries that used mostly in portable devices

SECONDARY BATTERIES

Rechargeable batteries used in e.g. automotive and industrial applications

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THE OVERALL BATTERY INDUSTRY SPACE

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Batteries a center piece in the energy transition

CLIMATE CHANGE

- The ongoing energy transition is driven by the climate targets outlined in Paris agreement (COP21) and e.g. EU regulatory frameworks.
- In the Paris Agreement, “central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius”.
- The Finnish Government Climate Strategy until 2030 outlines actions that will enable Finland to attain the Government Program and EU specified targets and to systematically set the course for achieving an 80–95% reduction in greenhouse gas emissions by 2050.

References:
The Clean Energy for All Europeans package
Ministry of Economic Affairs and Employment of Finland, Energy and climate strategy 2017

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Batteries a center piece in the energy transition

URBANISATION & MOBILITY

- The UN projects that by 2050 68 % of the world's populations live in urban environments.
- In Europe and the Nordics this figure will be even higher, and large portions of the future Nordic populations will live in large metropolitan regions.
- This will impact a wide spectra of people's daily lives, city planning, as well as product development and business model design.
- This will also bring along new mobility pressures, challenges and opportunities, also considering demographics and possibly shifting consumer behavior patterns.

Reference: World Urbanization Prospects: The 2018 Revision

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Batteries a center piece in the energy transition

POLLUTION REDUCTION

- Air pollution harms human health and the environment.
- Air pollutants comes from a range of both man-made and natural sources including burning of fossil fuels in electricity generation, and from transport, industry and households.
- Dense urban centra with increased vehicle mobility have led to an increase in poor air quality, affecting peoples' health on a daily basis.
- The increased use of electric vehicles is propelled forward by urbanization and urban densification.
- Electric vehicles present an alternative that does not produce harmful emissions for humans and nature as a mode of transport.

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General overview of the battery industry

MATERIALS

LITHIUM

85% of the global lithium production comes from Chile, Australia and China

4 companies control most of the mine output

NICKEL

1. most important metal in the cathode by mass, expected to be used more in Li-ion batteries as there is a trend on substituting cobalt with nickel

TOP largest producers include Australia and Philippines, Indonesia and Canada

COBALT

90% of cobalt mine supply produced as a by-product from copper or nickel mines

70% of the mined cobalt output is accounted by Democratic Republic of Kongo alone

KEY OBSERVATIONS

More minerals are required to sustain batteries and cells production

GLOBAL DEMAND, kt

(of which % of battery demand)

	Li	Co	Ni
2017	214 *(40%)*	136 *(30%)*	2 100 *(3-5%)*
2025	670-890 *(76-82%)*	222-272 *(50-60%)*	2 470 *(~23%)*

Reference: McKinsey & Company, 2018, Lithium and cobalt – a tale of two commodities

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General overview of the battery industry

CHEMICALS, CATHODE AND ANODE ACTIVE MATERIALS

Lithium hydroxide is preferred chemical for cathodes

Lithium hydroxide is produced from hard rock sources and is currently the preferred Li chemical for the long-range EV batteries. Other battery chemicals include nickel sulphate and cobalt sulphate and precursor materials such as metal hydroxides and cobalt oxides.

The demand for cathode active materials is rapidly increasing

Active materials used in cathodes have a huge impact on the battery properties and energy density. Share of Asian production is between 80% and 100% for each cathode material type, with China being the most significant producer.

The most commonly used active material types for anode are artificial and natural graphite

Natural graphite demand is expected to grow with the rate of 4% and need for artificial graphite with the rate of 15% a year.

KEY OBSERVATIONS

Demand for cathode active materials is rapidly increasing.

Cathode materials are critical for battery performance and cost.

Share of Asian production is between 80% and 100% for each cathode material type.

The share of Chinese production is significant.

Reference: McKinsey & Company, 2018, Lithium and cobalt – a tale of two commodities

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General overview of the battery industry

BATTERIES AND CELLS

In the past 25 years, global battery manufacturing volumes have increased significantly.

+25% Highest growth and major industry investments have focused on lithium-ion batteries: annual growth over 25% during 2010-2016

+4x Global battery manufacturing capacity expected to increase even 4-6 times by 2022 in comparison to 2017

400 GWh Global lithium-ion battery manufacturing expected to exceed 400 GWh by 2021 (now 150 GWh) with 73% of the global capacity concentrated in China

China China alone accounts for over a half of the global battery manufacturing market, followed by Japan and Korea

2 TWh Global demand for Li-ion batteries estimated to reach 2 TWh by 2040 (= 55 operational 35 GWh gigafactories)

KEY OBSERVATIONS

Capacity increase is needed to support energy transition and to ensure energy security in Europe.

China alone accounts for over 50% of the global battery manufacturing market.

Reference: Tsiropoulos, I., Tarvydas, D., Lebedeva, N., Li-ion batteries for mobility and stationary storage applications – Scenarios for costs and market growth, EUR 29440 EN, Publications Office of the European Union, Luxembourg, 2018, JRC113360

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General overview of the battery industry

APPLICATIONS

Batteries are used in a wide range of products and service offerings. The global battery sectors are developing and growing fast with the electric vehicle industry as a key driver.

The globally connected nature of the battery value chain means that supply chain stability, product and service innovation, and market access will continue to remain critical elements in company strategies and tactics.

> **Li-based technologies** are expected to remain in focus in the foreseeable future.
>
> A key competitive advantage is **battery cost**, and demand will be even better met as battery costs are being brought down.
>
> The market is underpinned by the **sustainability** theme in generating smarter and cleaner products, services, and combinations thereof.

KEY OBSERVATIONS

Central themes include

- Electric vehicle and marine demand
- New business models
- Renewable energy production and storage
- Cordless portable devices
- Digitalization
- Traceability

References:
Future of batteries, Arthur D. Little, 2018
The rise of the battery ecosystem, Prism 1, 2018, Arthur D. Little
Europe's World: Cities are partners for effective climate policy, 2018, Eurocities

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General overview of the battery industry

RECYCLING & REUSE

In addition to preventing battery waste altogether, two main themes are relevant within the space of batteries: reuse and recycling.

The amount of batteries ready for reuse and recycling is continuously increasing. China makes up observable portion of this growth – by 2025, recycled lithium may constitute 9% of the world's total lithium battery supply.

REUSE

makes more sense from a resource efficiency perspective than recycling, and thus the so-called **2nd life battery applications** are within an intense focus by many actors along the battery value chain.

RECYCLING

of batteries is **gaining traction across Europe,** driven by the expected growing demand for electric vehicles, and **European Commission's strategic action plans circular economy**.

Reference: Recycled lithium volumes still 'relatively low, https://recyclinginternational.com/, 2017 (accessed 24.1.2019)

KEY OBSERVATIONS

EU's Waste Framework Directive outlines priorities

- Waste prevention
- Preparing for re-use
- Recycling
- Recovery
- Disposal

A wide range of actors focus on developing so called battery 2nd life applications.

Large scale recycling still needs to gain traction.

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General overview of the battery industry

POLICY & REGULATORY FRAMEWORKS

EU has recognized the strategic importance of batteries in transitioning to a sustainable energy system, decarbonizing the transport sector and improving the competitiveness of EU industry.

The **Strategic Action Plan on Batteries** (COM(2018) 293), states that the development and production of batteries is a strategic imperative for Europe's clean energy transition and its automotive sector. This includes:

> **SECURING** access to raw materials
>
> **SUPPORTING** large-scale battery cell manufacturing
>
> **STRENGTHENING** EU research and innovation
>
> **DEVELOPING** competence in all parts of the value chain
>
> **AIMING** for the lowest possible environmental footprint

A number of directives and regulations relate to the battery industry value chain.

Reference: European Commission, Strategic action plan on batteries, COM (2018) 293

KEY OBSERVATION

EU's Strategic Action Plan on Batteries defines the development and production of batteries as a strategic imperative for Europe's clean energy transition and its automotive sector.

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General overview of the battery industry

EUROPEAN COMMISSION INITIATIVES

Horizon 2020 is funding battery related topics with a budget of €114 million in 2019 and with €20 million in 2020.

Continued work with the European Investment Bank (EIB) supports battery manufacturing projects through **public funding.**

A **large-scale research initiative** covering advanced battery technologies is also under preparation.

Upcoming establishment of a related **European Technology and Innovation platform** (ETIP) will advance battery research.

Important Projects of Common European Interest (IPCEI) might be set up as part of the Strategic Action Plan on Batteries.

KEY OBSERVATION

The European Commission is actively seeking a European role within the battery industry space and companies should actively engage in this development.

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CLOSER LOOKS AT ACTORS, KNOWHOW, NETWORKS AND INTEREST

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Key industrial actors

A wide range of Finnish, Nordic and European technology companies are integrating Li-ion batteries into their overall solutions.

Especially in case of large global companies, Li-ion battery technologies and products may become part of their core offering by acquisitions or by organic growth and recruitments.

Main actors are shown on the next slide.

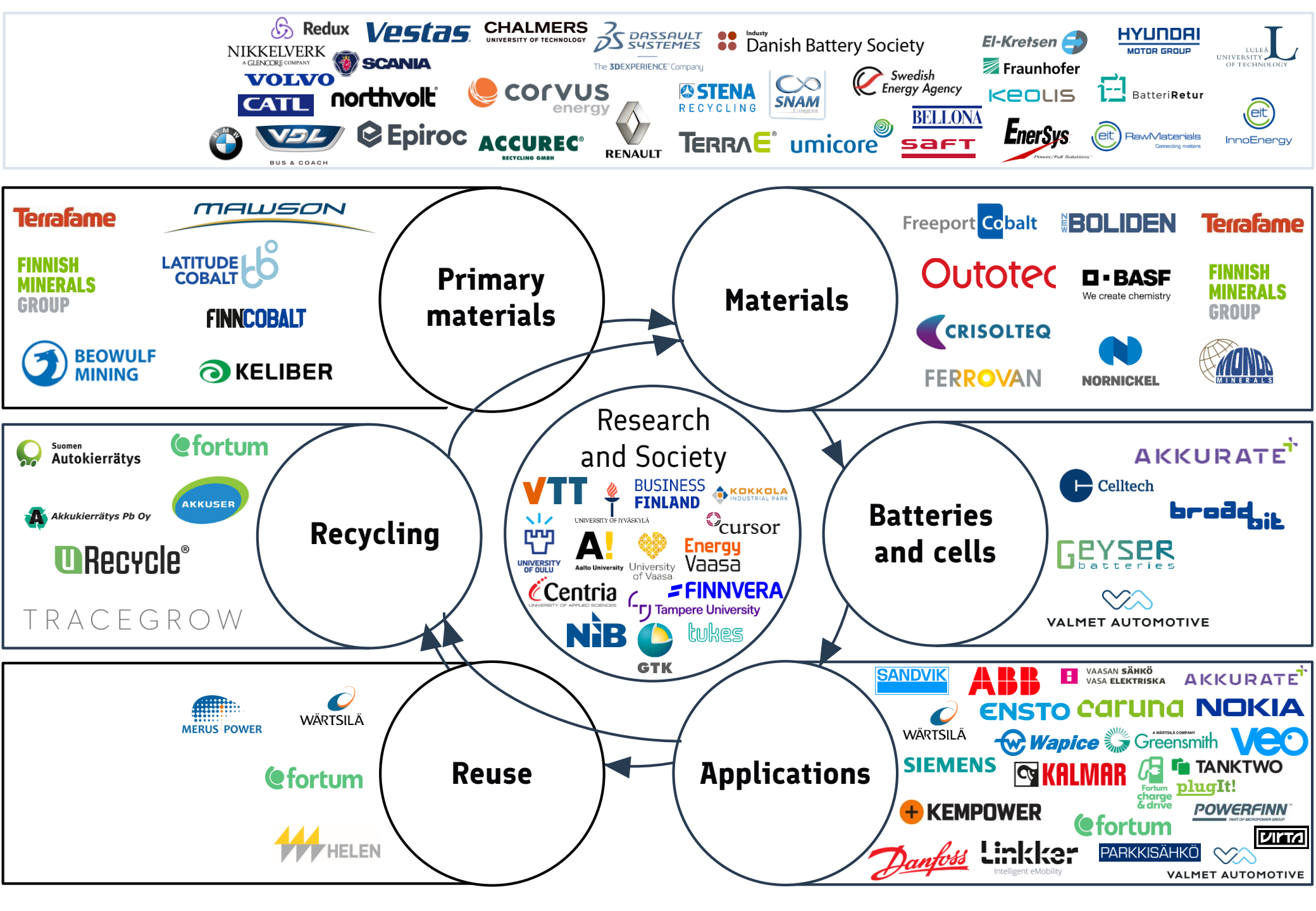
KEY OBSERVATIONS

Finnish mining presents ongoing activity.

There are interesting initiatives within battery cell manufacturing in Finland, although still no large scale operations.

Industrial companies integrate continuously batteries in applications.

Re-use and recycling is a core focus of many companies.


Primary materials
Materials
Batteries and cells
Applications
Reuse
Recycling
Research and Society

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Finland based companies in materials

EXAMPLE OF ACTIVITIES AND COMPETENCIES

- Current or planned production/refining of important battery minerals (lithium, cobalt, nickel)
- New mining planned with lithium and cobalt
- Planned activities in recovery of valuable substances for batteries from processing side streams
- Efforts in moving further in the value chain from mining to battery chemicals
- High level of knowledge in mining, processing and in some battery chemicals
- Solution provision for metal producers with knowhow on processing and hydrometallurgy

EXAMPLE OF ACTORS

- BASF
- Beowulf Mining
- Boliden
- CrisolteQ
- Ferrovan
- Finncobalt
- Finnish Minerals group
- Freeport cobalt
- Keliber
- Latitude 66
- Mawson Resources
- Mondo Minerals
- Nornickel Harjavalta
- Outotec
- Terrafame

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Finland based companies in batteries & cells

EXAMPLE OF ACTIVITIES AND COMPETENCIES

- Design and delivery of battery solutions for various battery needs
- Development of batteries for fast charging and short-range applications
- Development of new batteries using sodium-based chemistries
- Li-ion battery assembly side and production of battery pack systems
- No current large-scale battery cell manufacturing exists in Finland, although there have been efforts to attract large global battery cell manufacturers to locate their new cell manufacturing facilities in Finland
- The City of Varkaus and its business services agency Navitas focus on reopening the former European Batteries manufacturing facilities

EXAMPLE OF ACTORS

- BroadBit Batteries
- Celltech
- European Battery Technologies, City of Varkaus, Navitas
- Geyser Batteries
- GigaVaasa
- Valmet Automotive

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Finland based companies in applications

EXAMPLE OF ACTIVITIES AND COMPETENCIES

- Charging solutions for demanding conditions
- Digital applications for battery related operations. e.g. regenerative grid simulation that may be applied for car charging
- 2nd life battery applications that ties in with the wider automotive industry
- Using battery solutions to support grid stability
- Battery diagnostics and testing services
- Electric buses
- Energy storage and energy management solutions
- Development of heavy duty electronically powered vehicles
- Developing electric and Li-ion battery solutions for ferries and shipping

EXAMPLE OF ACTORS

- Akkurate
- Ensto
- Fortum
- Fortum Charge & Drive
- Kalmar
- Kempower
- Liikennevirta
- Linkker
- Merus Power
- Parkkisähkö
- PlugIt
- Sandvik
- TankTwo
- Wapice
- Virta
- Wärtsilä

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Finland based companies in recycling and reuse

EXAMPLE OF ACTIVITIES AND COMPETENCIES

RECYCLING

- Li-ion battery recycling operations, including new production capabilities to recycle EV and other low-cobalt Li-ion batteries
- Recycling services for EV and other industrial Li-ion batteries that includes safe transportation, dismantling and discharging of the batteries, recycling and reporting
- Producer coordination for electric vehicles Li-ion batteries
- Novel recycling creating micronutrient fertilizers using waste batteries as raw material

REUSE

- Development of battery second life uses with e.g. energy storage

EXAMPLE OF ACTORS

- Akkuser
- Fortum
- Suomen Autokierrätys
- Tracegrow
- uRecycle Group
- Wärtsilä

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Status of the Finnish know-how

EXAMPLE OF ACTIVITIES AND COMPETENCIES

Finland has strong know-how regarding exploration, mining, raw materials production, processing and refining due to the long history of mining.

Companies have a good level of understanding in integrating Li-ion batteries into an overall solution, especially when related to traditionally strong Finnish industrial segments.

Expertise in battery recycling in general is at a good level, and different actors have developed their own IP portfolios.

Battery second life knowhow has been advanced via e.g. partnerships and acquisitions.

Research and education activities includes:

1) Li-ion battery small-scale production line and testing,
2) Li-ion battery health and degradation mechanisms,
3) Battery technology education module, and
4) Li-ion battery testing and characterization of battery cells, modules and packs

EXAMPLE OF ACTORS

- Aalto University
- Centria University of Applied Sciences
- Geological Survey of Finland (GTK)
- Kokkola University consortium Chydenius
- Metropolia University of Applied Sciences
- Tampere University of Applied Sciences
- Turku University of Applied Sciences
- University of Eastern Finland
- University of Helsinki
- University of Oulu
- University of Turku
- Vaasa University
- VTT

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Examples of battery related networks

European Battery Alliance aims to create a competitive manufacturing value chain in Europe with sustainable battery cells at its core.

InnoEnergy is supported by the European Institute of Innovation and Technology. One InnoEnergy thematic area is Energy Storage.

Recharge promotes the value of rechargeable batteries and represents the interests of all its members in the chain of battery life.

ALISTORE ERI is a federative research structure funded though academic member contributions and 12 companies.

EIT RawMaterials is a network-type organisation with the vision to develop raw materials into a major strength for Europe.

EnergyVaasa is a Finland based Nordic hub for energy technology, bringing together more than 140 businesses in the energy industry.

Future Battery Ecosystem Project is a Finland based initiative aiming to create business opportunities within the battery industry from a circular economy perspective.

BATCircle combines 20+ companies, cities and research organizations to improve battery recycling and the manufacturing processes of mining & metals industries and battery chemicals.

OBSERVATIONS AND BENEFITS OF NETWORKS

- The number of Li-ion battery related networks has increased during the past 5-~~7~~ years in Finland, the Nordics and in Europe.
- Network participation can open new doors, and allow for 1) exchanging information, 2) making new or keeping up professional contacts, and 3) enabling commercial activity and creating new services and/or products.

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Interest & attractiveness

\+ COMPANIES (55%) and ORGANIZATIONS (88%) currently active within the Li-ion battery value chain in Finland are **very interested** in joining a Finnish Battery Ecosystem

81% The attractiveness of Finland as operational environment for COMPANIES currently active within the Li-ion battery value chain in Finland was mainly considered as **somewhat attractive** or **attractive** covering together 81% of the company representative answers.

19% The remaining COMPANY interviewees thought that Finland is **very attractive** as operational environment for the Li-ion battery industry within their own active part of the value chain.

89% of active ORGANIZATIONS in Finland see Finland as **attractive** or **very attractive** as an operational environment.

KEY COMPONENTS OF ATTRACTIVENESS

\+ Business Finland funding and projects

\+ General technical know-how

\+ Mineral resources

\+ Cheap clean power

\+ Existing resource base

\+ Advanced process industry

\- Industry size in Finland

\- Investment environment

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LOOKING FORWARD

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Towards a Nordic Green Smart Battery

- The Nordic region is a unique and highly integrated area, even on industrial scale via e.g. a common electricity market.
- Many companies are already present in one or more of the Nordic countries, and trade and exchange has historically been strong.
- Examples of clear overlaps between Finland and other Nordic countries include: Marine, Mining, Heavy duty, Energy storage, Battery second life applications, and Renewable energy production.
- Nordic electricity production as measured per CO2/kWh is very attractive from a sustainability point-of-view.
- A number of themes highlight the close affinity between the countries e.g. traceability, responsibility and environmental sustainability.
- Listed to the right are eight key focus areas that make up a starting point for considering a development towards a Nordic Green Smart Battery.

KEY FOCUS AREAS

- Technology and manufacturing
- Traceability and data management
- Economic viability
- Competence
- Collaboration
- Regulation and standardization
- Safety
- Public policy

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Towards a Nordic Green Smart Battery

TECHNOLOGY AND MANUFACTURING

- Lithium-ion is the main battery technology adopted by the EV industry
- Due to the decreasing cost trend, lithium-ion is replacing lead-acid batteries in a variety of end applications
- Transition to post-lithium-ion technologies not expected before 2030
- Lithium-ion will remain the dominant battery chemistry next 10 years
- Recognized need to lower European and national dependency on e.g. Asian battery producers to strengthen the competitiveness of European industry at large
- Infrastructure should be considered at a higher system level in order to accommodate integration of all needed aspects of the value chain

KEY FOCUS AREAS

- **Technology and manufacturing**
- Traceability data management
- Economic viability
- Competence
- Collaboration
- Regulation and standardization
- Safety
- Public policy

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Towards a Nordic Green Smart Battery

TRACEABILITY AND DATA MANAGEMENT

- Traceability is a tool for battery life-cycle management and digitalization can provide enabling technologies for its realization.
- Traceability of raw materials can enhance sustainability and responsibility issues connected to materials production and thus give competitive advantage.
- Within the area of traceability, digitalization could improve recycling, open up new recycling or second use business models, and advance consumer awareness.
- Systematic collection of battery information is still in its cradle, and there is a question of who in the end owns the data.
- Finland is globally known for its competence and knowhow in IT and digital solutions, and embracing digitalization on a wider scale could provide a more comprehensive competitive advantage for Finnish companies.

KEY FOCUS AREAS

- Technology and manufacturing
- **Traceability data management**
- Economic viability
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Towards a Nordic Green Smart Battery

ECONOMIC VIABILITY

- Client needs and specifications along with price are important decision factors in whether a European green Li-ion battery could be an economically viable concept.
- For general public, an important driver in the area of Li-ion batteries is response to more climate-friendly and safer living.
- Because of the doubts on willingness to pay, many call for advancing the sustainability aspects through regulatory instruments.
- The automobile industry determines and drives the overall business dynamic and development.

KEY FOCUS AREAS

- Technology and manufacturing
- Traceability data management
- **Economic viability**
- Competence
- Collaboration
- Regulation and standardization
- Safety
- Public policy

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Towards a Nordic Green Smart Battery

COMPETENCE

+ Key advantages of Finland include the proximity of raw materials and the availability of low-carbon energy at a competitive price
+ Mineral deposits, activities as well as competences in mining, processing and refining give Finland a good position in Europe
+ Strong know-how in applications related to harsh environments and in solutions for energy storage
+ High-level expertise related to chemicals and processing
+ Finnish know-how and engineering experience in digital solutions offer opportunities for wide value creation
+ Robotics and automation process expertise offers opportunities when designing automated Li-ion battery manufacturing facilities

- Lack in skills and understanding of (cathode) active materials, cell technology and manufacturing processes, one of the main barriers for cell and battery production both in Finland and Europe
- Lack of competence and technology base in electrochemical processes
- Finland needs to get a foothold on next generation batteries – multidisciplinary competence is recognized as important
- Value chain understanding of the general public is considered inadequate
- Tightened university resources are a challenge and there are worries on how to assure an adequate amount and level of research and education

KEY FOCUS AREAS

- Technology and manufacturing
- Traceability data management
- Economic viability
- **Competence**
- Collaboration
- Regulation and standardization
- Safety
- Public policy

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Towards a Nordic Green Smart Battery

COLLABORATION

- Clear understanding of the Li-ion battery related vision and goals is needed on national level
- The Nordic countries should focus on strong common position
- There are bilateral and multilateral spheres of cooperation between different Nordic countries based on common points of interest and priorities
- Clear consensus from companies and organizations both in Finland and in other Nordic countries that Nordic cooperation should be supported through political will and a high-level collaboration agreements
- Cooperation is seen necessary for the ability to impact decision-making at the EU level

KEY FOCUS AREAS

- Technology and manufacturing
- Traceability data management
- Economic viability
- Competence
- **Collaboration**
- Regulation and standardization
- Safety
- Public policy

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Towards a Nordic Green Smart Battery

REGULATION AND STANDARDIZATION

- Within the frame of climate targets, batteries should be seen an enabler of a clean energy transition
- Finland has a stable and predictable regulatory environment that is favorable to industry and business but is however lacking sufficient policy frameworks and political will to encourage a wider adoption of CO2 neutral technologies
- When it comes to waste lithium-ion batteries, the Finnish regulatory and legal environment should be harmonized with that of the Nordic and European environments
- Regulation and standardization have very important roles in future battery related solutions and value chains
- Standardization on a Li-ion battery level might be a sensitive topic, but there is movement towards defining the performance of e.g. a green battery

KEY FOCUS AREAS

- Technology and manufacturing
- Traceability data management
- Economic viability
- Competence
- Collaboration
- **Regulation and standardization**
- Safety
- Public policy

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Towards a Nordic Green Smart Battery

SAFETY

- Battery safety, reliability and performance are key articulated priorities of companies along the entire value chain
- Battery safety also relates to those who are engaged in actual vehicle usage or energy storage development, such as energy producers and/or property/building owners
- From a value chain perspective battery safety includes not only physical management, such as, reception, transport, storage, disassembly, and re-processing, but also immaterial aspects such as reporting, keeping track of battery health issues, and software simulation

KEY FOCUS AREAS

- Technology and manufacturing
- Traceability data management
- Economic viability
- Competence
- Collaboration
- Regulation and standardization
- **Safety**
- Public policy

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Towards a Nordic Green Smart Battery

PUBLIC POLICY

- Raw material security: there is rising concerns regarding the access to the raw materials needed by the European industry
- China has made series of long-term strategies for ensuring its economic security and access to raw materials and thus plays an important role in this matter
- The role of the government is paramount from public policy perspective
- Slow permitting processes are seen as a challenge especially in mining but also in construction of manufacturing facilities
- Cross-border cooperation requires mapping and alignment of public policy aims and ambitions

KEY FOCUS AREAS

- Technology and manufacturing
- Traceability data management
- Economic viability
- Competence
- Collaboration
- Regulation and standardization
- Safety
- **Public policy**


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IDENTIFIED ECOSYSTEM THEMES

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Identified ecosystem themes

Six main ecosystem themes were identified following a co-creation focused participatory process in three workshops held during the autumn of 2018 and January of 2019.

The **main question** in outlining these themes was,

> "Where can we in Finland create and add value in the European and global battery space?"

The ecosystem themes relate to **all aspects of the value chain**, and a cross-sectorial approach is needed in navigating forward in the Finnish, European and global industrial landscapes.

Some ecosystem themes engage the entire value chain, whereas others see their highest added value and relevance within a more limited scope.

IDENTIFIED THEMES

- Developing battery applications for harsh use
- Battery raw materials and chemicals
- Battery system engineering
- Battery safety
- Large scale recycling of lithium batteries
- Traceability in the value chain

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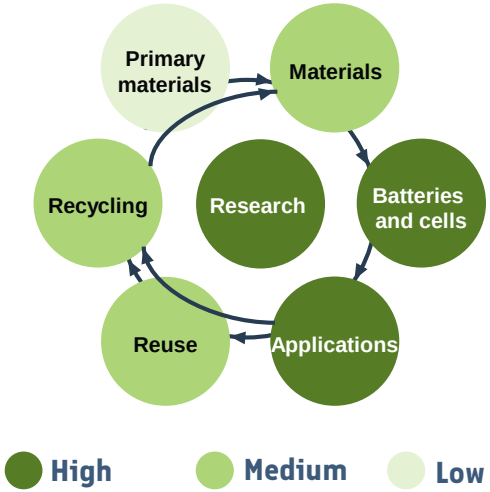
Developing battery applications for harsh use

Value chain relevance



Overall scoping and theme components

- Focusing on product development and life-cycle design and modelling
- Developing chemistries for harsh environments
- Advancing knowhow and education

Key drivers and needs

- Climate strategies of both private and public sectors organisations
- Environmental requirements
- Piloting, testing and showcasing of solutions
- Knowhow and expertise e.g. within system integration

Needed partners and Nordic dimension

- Partners needed across the value chain, including those in: Battery chemistry developers, Module engineering, Thermal management, Battery Management System Developers, Pack engineering; and also Universities and End users
- Joint ventures between different Nordic actors should be considered, for example within collaboration around process know-how, cooperation on pilot projects and establishing testbeds/testing environments

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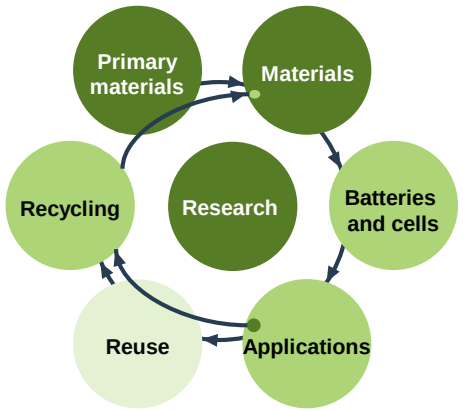
Battery raw materials and chemicals

Value chain relevance



Overall scoping and theme components

- Securing access to raw materials & raw materials supply within the EU
- Sustainability and resource efficiency including utilising industrial side streams
- Further value creation through processing raw materials to battery chemicals
- Climbing the value chain (attracting active material producers to Finland)

Key drivers and needs

- Rapidly increasing need for certain raw materials (Co, Li, Ni)
- Volatile material prices and limited access to raw materials
- Need for attractive value proposition to companies operating in Finland (regulations, taxation and subsidies)

Needed partners and Nordic dimension

- Strong partnerships throughout the value chain to stay competitive in future where vertically integrated ecosystems compete
- Geological surveys, mines, processing solution providers, refineries/battery chemical producers, active material producers, research institutes, universities and other educational institutes, governmental organisations

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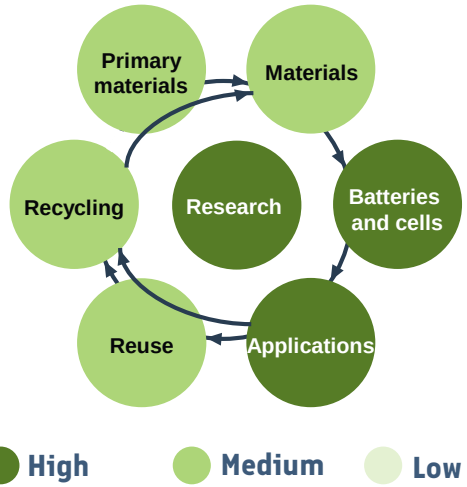
Battery system engineering

Value chain relevance



Overall scoping and theme components

- System level battery pack design & integration, incl. power system engineering
- Battery monitoring systems (BMS), testing and simulation
- Common platforms
- Tailoring for specific applications

Key drivers and needs

- Safety and reliability of battery systems
- Battery life cycle and performance management and optimization
- Standards and regulation
- Digitalization

Needed partners and Nordic dimension

- Cell and battery manufacturers
- BMS, battery diagnostics and testing providers
- System integrators, manufacturing and assembly partners for application
- Strong existing competence in digital solutions and data-driven business in the Nordics

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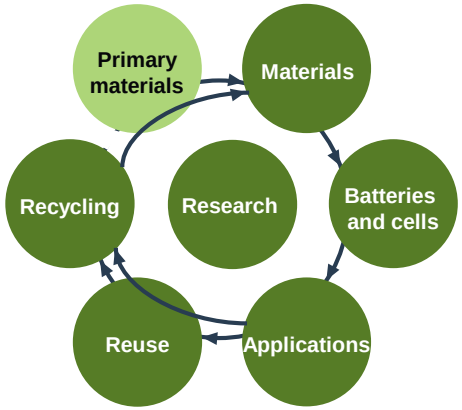
Battery safety

Value chain relevance



Overall scoping and theme components

- Battery reliability and safety are imperatives, as is proper use in applications
- Standardization is a key parameter, and could cover more safety aspects
- Technology innovation, e.g. vis-à-vis next generation batteries, will be important to develop also from a safety perspective

Key drivers and needs

- Clearly defined environmental and end-user regulations and requirements
- Public image of application e.g. an unfortunate incident can hurt many actors
- Digital solutions in battery safety applications
- Safe logistics

Needed partners and Nordic dimension

- Battery safety is a cross-cutting theme that needs careful and active presence and participation of all actors throughout the value chain, public and private actors alike.
- The theme battery safety should be integrated into networks e.g. Battery 2030+ initiative in Sweden and European Battery Alliance
- Needed partners could also include e.g. Norwegian regulators where especially the overall EV market is more advanced from a utilization point of view.

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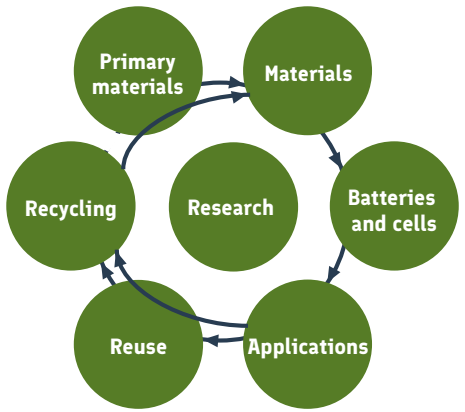
Large scale recycling of lithium batteries

Value chain relevance



Overall scoping and theme components

- Recycling of critical materials for battery manufacturing, and related business models and frameworks for large scale recycling
- Developing overall material value
- Developing collection, logistics and transportation chains

Key drivers and needs

- Circular economy and resource efficiency are key drivers
- There could be a real need for large scale battery industry recycling activity to be located close to collection and/or primary production
- Producer responsibility in EU law

Needed partners and Nordic dimension

- Partner with the Nordic value chain, where there might be actors who wish to make use of batteries for recycling
- Electric network companies and/or application developers (who could re-use batteries in grid operations)
- Large scale recycling requires large CAPEX, and hence also financial strong partners and careful value chain integration

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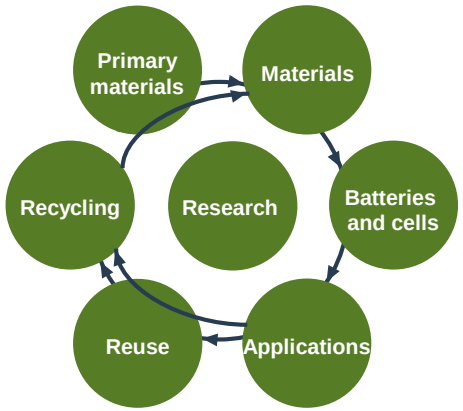
Traceability in the value chain

Value chain relevance



Overall scoping and theme components

- Tracing materials in the value chain (linking to green batteries concept)
- Trace and collect information on environmental footprint and social acceptance
- Consumer acceptance, reputation
- Traceability of transportation and storage

Key drivers and needs

- Need to improve the competitiveness of Nordic/EU countries
- Demand for 1) social acceptance and life cycle analysis 2) safety, tracking conditions for transportation 3) info on environmental footprint (CO2, chemical, water etc.)

Needed partners and Nordic dimension

- Nordic and European industry forerunners in sustainability (within the whole value chain from materials to recycling)
- IT companies and SMEs
- Commitment of the players in global value chain needed in later phases

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CONCLUSIONS

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Readiness for creating battery related ecosystems in Finland

Strengths	Weaknesses
• Strong competence in mining and processing, automation and digital technologies • Reliable, cheap and relatively clean electricity • Stable regulatory and political environment • Good price-quality ratio and supply reliability • Good R&D, innovation and research environment • Long industrial tradition within harsh environment applications: marine, heavy duty, energy storage, and digitalization	• Finland is perceived as a remote location • Insufficient cooperation and information exchange • Perceived lack of competence, know-how and experience in cell design and manufacturing • Not strong automobile industry, vs. Europe at large • Slow permitting processes • Lack of Finnish investors • Information asymmetry, at least in the public sphere

Opportunities	Threats
• Global demand for battery materials will grow • Recycling is a future must, but needs development • Digitalization is an enabler • Responsibility and traceability • Energy mix is still at good level in Finland considering CO_2/kWh • Linking Finland to European ecosystems • New battery technologies	• Strict regulations on logistics related to cells • Dominance of Asia/China/Korea • Is Finland/Europe moving too late? • Is our value proposition attractive enough for global cell and battery producers?

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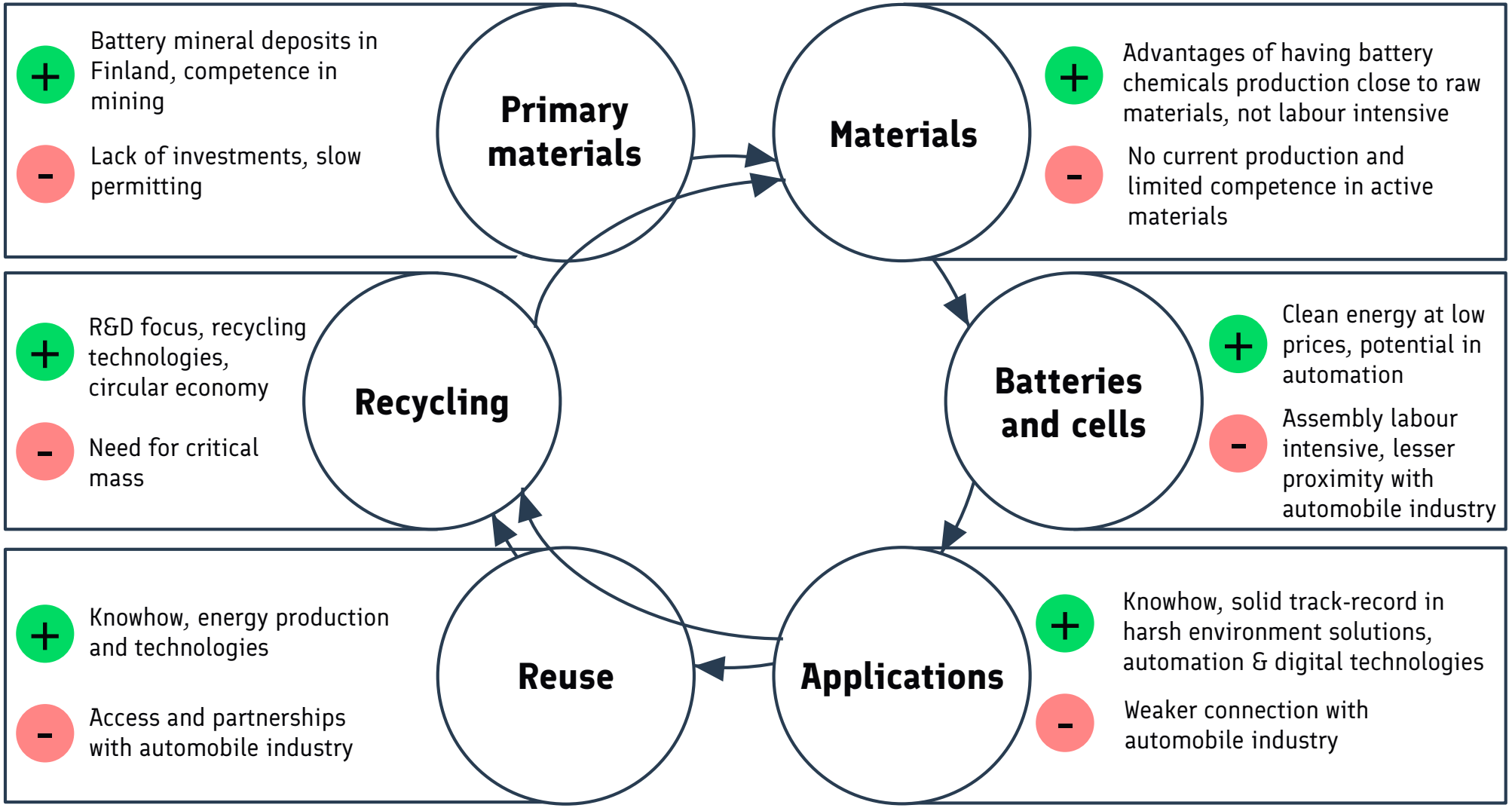
Status of the Finnish readiness



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RECOMMENDATIONS

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Recommendations

1. The concept of **Green Smart Battery** is an added value that Nordic countries should pursue to deliver together and also take an active role in developing the required platforms and methodologies.

   The concept of traceability should be built as an integral part of the Nordic Green Smart battery.

   Digital tools should be used as means to build competitiveness for the concept.

2. Finland must **maintain and develop its current strengths** as a spring-board for future innovation, development and growth.

   Adequate investment should be allocated towards next generation battery technologies.

3. A **holistic, systems engineering approach** is needed for the development of high-performance batteries meeting the tough requirements of specific applications.

   Relevant competences should be built based on active partnering/collaboration between large and small companies where relevant players are systematically brought together.

KEY HIGHLIGHTS

- A Nordic Green Smart battery would add value
- Strengths include: mining, raw materials production and processing
- Next generation battery technologies need investments
- Nordic countries should jointly work on EU level

ACTION

- Feasibility study on potential of a Nordic Smart Green Battery, to gain understanding on business potential

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Recommendations

4 The battery field needs **highly multi-disciplinary** competences in education at universities, lower educational institutions, as well as in companies.

There is a need to strengthen the image and branding of the field to attract both new talents and key experts.

5 The know-how that Finland has on developing **industrial products used in harsh environmental conditions**, such as marine and heavy-duty equipment and vehicles, should be leveraged in the area of batteries.

Digitalization should be used as a tool to take a systemic and data driven approach to ensure competitiveness.

Foster innovation in business model development.

Support the creation of joint ventures between different Nordic actors, as well as cooperation of pilot projects.

KEY HIGHLIGHTS

- The battery industry needs to show its relevance in contributing to smart and sustainable societies
- Finland must enhance companies and research institutions to connect and engage with foreign actors
- The Nordic countries present natural point of connection
- The image of the battery industry needs to be refreshed to attract talents

ACTION

- Establish well-defined innovation ecosystem projects

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Recommendations

6 **Mineral potential mapping** in Finland should be carried out in more detail covering also deeper deposits.

As different stakeholders are acquiring mineral resources throughout the world, it is important to consider how the ownership of the deposits found in Finland will remain inside EU.

7 The potential and prerequisites for establishing **cell manufacturing** in Finland should be assessed.

This should include analysis of different scenarios for how to secure access to high-quality battery cells with competitive prices and delivery times.

KEY HIGHLIGHTS

- The Finnish mineral deposits must benefit Finland
- Mineral mapping should focus also on deeper deposits
- National subsidy regimes must be re-visited and possibly improved

ACTION

- Map Finnish mineral deposits at deeper depths
- Assess the potential and prerequisites for establishing cell manufacturing in Finland

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Recommendations

8 As a **cross-sectional theme, battery safety** needs to be an integrated component of all battery related products and services.

Integrate battery safety as an educational component in academic and vocational education and training.

Support the integration of digital solutions within the overall theme of battery safety, e.g. in remote surveillance, diagnostics and IoT.

9 **Large scale** European/Finnish **recycling** of lithium batteries requires a concerted effort by all actors in the value chain, both public and private.

Initiate and finance a critical mass study of side and waste stream utilization potential, including business development opportunities.

Assess the viability of the battery 2nd life model, value chain and its possible disruption potential.

KEY HIGHLIGHTS

- Battery safety is an imperative
- Large scale recycling of lithium batteries needs concerted action

ACTION

- Establish a working group that drives and advances safety standardization and develop appropriate testing methodologies
- Initiate a critical mass study of side and waste stream utilization potential of lithium, including business opportunities
- Assess the prerequisites and potential for establishing large-scale recycling

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Recommendations

10 A national level **networking forum** coordinated by Business Finland's 'Batteries from Finland' –program or similar should be organized and developed further.

Assess prerequisites for establishing an interest group for battery ecosystem stakeholders in Finland with an aim to protect the interests of Finnish stakeholders and communicate with international networks.

11 Finland must **nurture its relations with other countries** but become much bolder in creating prerequisites for companies and research institutions to connect and engage with foreign actors.

Universities, research institutions and governmental bodies have a big role that may under no circumstances be under-estimated.

KEY HIGHLIGHTS

- Active dialogue, effective networking and knowledge sharing are building blocks for the future
- Finland must boldly engage with various foreign counterparts
- The Nordic is a natural starting point, and national priorities a good ground for cooperation

ACTION

- Business Finland should initiate a national battery networking forum

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Recommendations

12 **Nordic cooperation** should be actively pursued at national and governmental levels.

Governmental policy and national priorities must be recognized, so that common areas of interest can be jointly advanced.

When feasible and relevant also Nordic cross-border companies should be encouraged to advance Nordic cooperation, for example in being supported executing pilots and creating testbeds for new innovation and solutions.

13 An **active role** should be taken **in the Strategic Forum for Important Projects of Common European Interest (IPCEI)** related to batteries to boost the competitiveness of Finland.

The Finnish Government should take an active role in supporting battery-related activities, e.g. through participating in high-level meetings, allocating R&D funding and invest-in activities.

KEY HIGHLIGHTS

- The values of channels such as IPCEI must be recognized and leveraged
- The Finnish Government must assume its role in the battery industry space and advance the interests of Finland based companies and other organizations and institutions when needed

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THANK YOU!

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