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Battery Life Cycle Sustainability: a Qualitative Study on Life Cycle Assessment Process Development at IONCOR

International Business, Department of Marketing and International Business
Master's thesis

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Abstract

The purpose of this study is to examine the EU Battery Regulation 2023/1542 requirements for a battery carbon footprint, study how environmental regulations impact sustainability practice adoption, and how to implement new sustainability practices successfully. The aim is to propose a process which battery manufacturers can leverage when calculating a battery carbon footprint and provide information of successful implementation tools of internal sustainability drivers and Lewin’s planned approach and examine the impacts of environmental regulations.

An examination of the battery industry and its sustainability is conducted, after which the regulatory requirements for a battery carbon footprint from the EU Battery regulation 2023/1542 are described. This provides a background for the LCA process development to be developed on. To support a successful implementation, literature review of change management on regulatory impacts, internal sustainability drivers, and Lewin’s planned approach to change is presented. The literature review shows that regulations can positively impact the environmental performance of a company, while regulatory uncertainty negatively impacts the adoption of new sustainability practices. It also provides internal sustainability drivers and a change process to examine for applicability in the context of this thesis.

The results of the empirical action research study provide a process guide for a battery carbon footprint calculation, and tools for successful implementation. The findings show new insights to the existing literature as well. The findings of previous literature on the impacts of regulations are largely confirmed, with results showing positive impacts of environmental regulations on environmental performance and sustainability practice implementation, and negative impacts of regulatory uncertainty. The results also bring interesting additions to the internal sustainability drivers. Dependencies between the internal sustainability drivers are identified, providing new thoughts regarding the magnitude of each driver.

Keywords: life cycle assessment, battery, carbon footprint, internal sustainability drivers, environmental regulations, Lewin’s planned approach

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Tiivistelmä

Tämän tutkimuksen tarkoitus on tutkia EU Akkuasetuksen 2023/1542 vaatimuksia akun hiilijalanjäljen laskentaan, tutkia kuinka ympäristölainsäädännöt vaikuttavat vastuullisuustoimien käyttöönottoon, ja kuinka implementoida uusia vastuullisuustoimia onnistuneesti. Tavoitteena on tarjoa prosessimalli, mitä akkuvalmistajat pystyvät hyödyntämään laskiessaan akkujen hiilijalanjälkiä, tarjota informaatiota onnistuneen prosessikäyttöönoton saavuttamiseksi tutkimalla sisäisiä vastuullisuusajureita, sekä tutkia Lewinin järjestelmällistä lähestymistapaa muutokseen. Lisäksi tutkitaan ympäristölainsäädännön vaikutuksia uusien vastuullisuustoimien käyttöönotossa.

Akkuteollisuuden ja sen vastuullisuuden läpileikkaus, sekä EU:n Akkuasetuksen 2023/1542 asettamien akkujen hiilijalanjälkivaatimusten läpikäynti tarjoavat pohjan elinkaariarviointiprosessin kehittämiselle. Onnistuneen prosessikäyttöönoton saavuttamiseksi toteutetaan kirjallisuuskatsaus valituista muutosjohtamisen käsitteistä. Tutkielmassa tutkitaan lainsäädännöllisiä vaikutuksia, sisäisiä vastuullisuusajureita, sekä Lewinin muutosmallia. Kirjallisuuskatsaus osoittaa, että lainsäädäntö voi positiivisesti vaikuttaa yrityksen ympäristölliseen suorituskykyyn, kun taas lainsäädännöllinen epävarmuus vaikuttaa negatiivisesti uusien vastuullisuustoimien käyttöönottoon. Katsaus tarjoaa myös tietoa sisäisistä vastuullisuusajureista ja muutosmallin tutkittavaksi tutkielman kontekstissa.

Empiirisen tutkimuksen tulokset tarjoavat prosessiohjeen akkujen hiilijalanjäljen laskemiseen, sekä työkaluja onnistuneeseen käyttöönottoon. Löydökset tarjoavat uusia näkökulmia olemassa olevaan kirjallisuuteenkin. Olemassa olevan kirjallisuuden tunnistamat löydökset lainsäädännön vaikutuksista tunnistetaan myös tutkielmassa, kun tulokset osoittavat lainsäädännön kohentavan ympäristöllistä suorituskykyä, ja lainsäädännöllisen epävarmuuden tuovan negatiivisia vaikutuksia. Tulokset kuitenkin tarjoavat kirjallisuuteen myös uusia näkemyksiä. Riippuvuuksia olemassa olevien sisäisten vastuullisuusajurien välillä havainnoidaan, mikä tarjoaa uusia ajatuksia myös ajurien merkityksellisyysjärjestykseen.

Avainsanat: elinkaariarviointi, akku, hiilijalanjälki, sisäiset vastuullisuusajurit, ympäristölainsäädäntö, Lewinin muutosmalli

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List of abbreviations

Greenhouse gas (GHG)

Life cycle assessment (LCA)

Life cycle inventory (LCI)

Electric vehicle (EV)

Rules for the calculation of the Carbon Footprint of industrial Batteries without external storage (CFB-IND)

Bill of materials (BOM)

1 Introduction

1.1 Background

Climate change and global warming are two of the greatest risks to human society today. Lowering the global greenhouse gas (GHG) emissions is crucial in ensuring a safe future for humanity. Remarkable changes in production and consumption of goods and services are needed to achieve those reductions. It is likely that the global warming of 1,5˚C, which is the ideal goal of the UN Paris Agreement, in addition to the less strict goal of limiting it to 2˚C, is to be exceeded. But that does not mean that there is nothing to be done. (IPCC 2022.)

The global energy system, including both the physical infrastructure and societal systems and dynamics, is the largest source of CO2 emissions. (IPCC 2022, 618). This is due to the use of fossil fuels in energy production. In 2019, coal accounted for 34% of energy sector's CO2 emissions, followed by natural gas at 22% (IPCC 2022, 619). In the EU, production and use of energy accounts for more than 75% of EU's GHG emissions (European Commission – Energy and the Green Deal). To combat these emissions, a transition away from fossil fuels is required. Limiting global warming to below 2˚C demands an excessive transformation of the energy sector: "reductions in fossil fuel consumption, increased production of low- and zero carbon energy sources, and increased use of electricity and alternative energy carriers" (IPCC 2022, 615).

Using renewable energy sources is the most promising method in getting rid of fossil fuels (Olabi & Abdelkareem 2022). There has been a rise in renewable energy sources, like solar and wind power within the last decade, due to improved cost competitiveness and widespread support for low-carbon energy policies (Yang et al. 2024). There is still an issue on intermittent renewable energy sources, such as solar and wind energy. They must be used as they are available, or they will be lost. (Evans et al. 2012, 4141-4142.) This makes adequate energy storage system implementation crucial in adopting renewable energy in a large enough scale to replace fossil fuels.

Batteries are one of the energy storage options available. Batteries have especially been of interest in the effort to electrify vehicles. Traditional combustion engine road transport formed 71,7% of transport emissions in the EU in 2019 (European Parliament 6.12.2024). Battery electric vehicles (EVs), referring to fully electric vehicles, are shown to have lower GHG emissions compared to traditional combustion engine vehicles (da Costa et al. 2025). For EVs, Lithium-Ion batteries (LIBs) are deemed to be the most suitable of the currently available battery technologies. LIBs rose into the commercial market in the 1990s (Dunn et al. 2011, 930). Since then, they have become widespread, especially in EV applications. In 2016, 43% of LIBs produced were used in EVs (Li et al. 2018). These vehicles are not only cars, but electrification is active also in more heavy-duty vehicles, for example with buses and trucks. Due to batteries' significant role in the vehicle industry, this thesis focuses on industrial batteries aimed for heavy-duty and off-road vehicles. Batteries in that category can be used in various vehicles from vans to trucks to construction vehicles.

Though moving away from combustion engines to EVs seems attractive at first, batteries have their own issues. Battery value chains are long and multinational, hiding many sustainability issues within the various phases. Sustainability is defined here as meeting the needs of the present without compromising the future generations capability to fulfil their needs (World Commission on Environment and Development 1987). Sustainability is often separated into environmental, economic, and social sustainability (De Fine Licht & Folland 2019, 21). Environmental sustainability focuses on the maintenance of natural capital, for example upkeep of bodies of water, or limiting global warming. Economic sustainability refers to maintenance of capital, referring to a practice of preserving enough capital to enable continuous operations. (Goodland 1995, 3, 10.) Social sustainability is a more complex term, which lacks a definitive definition (De Fine Licht & Folland 2019, 22). It can refer to engaging in enhancing human well-being, solving social justice issues to name a few. In this thesis, social sustainability refers to efforts minimizing social issues present in the business environment, like modern slavery, inhumane working conditions, child labour etc. To study the battery life cycle and the issues within, a general life cycle of a large battery is presented in Figure 1.

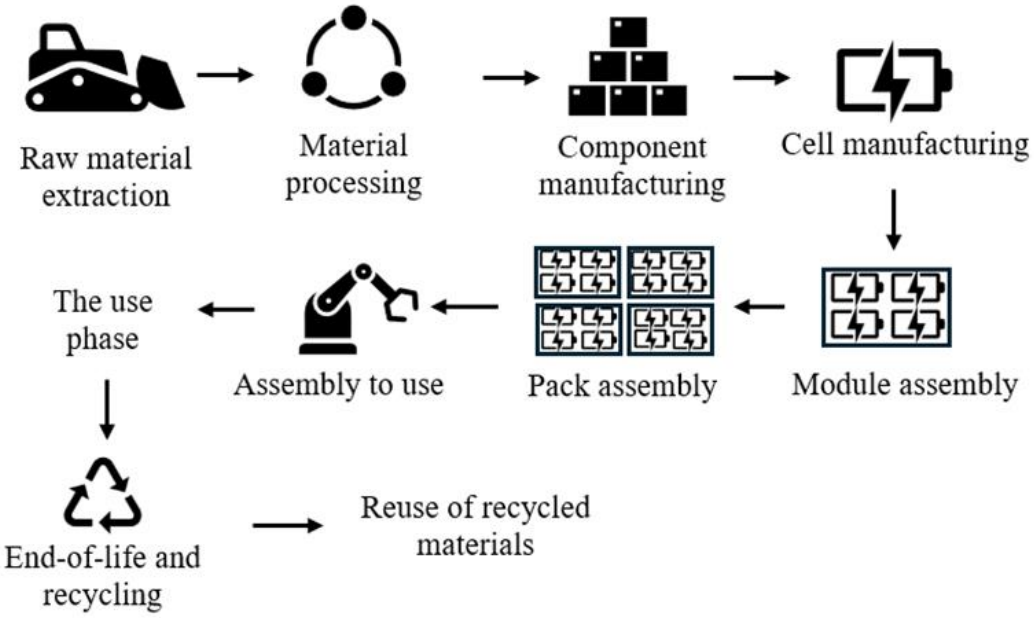


Figure 1 A generalised battery life cycle
Source: author's own creation

The battery life cycle begins with raw material extraction, which often raises issues on land-use conflicts and labour rights violations. After extraction, the raw materials are processed, manufactured to components and cells, and then cells to modules and packs. The manufacturing steps can be energy intensive and can involve flammable and toxic materials in the initial stages. (Niri et al. 2024, 3-5; Lebedeva & Boon-Berret 2016.) Then the finished battery products are assembled to their use cases, which can be inside various kinds of vehicles. The impact of the battery use phase is dependent on the battery user, as the impacts in this phase are tied to the energy source used to charge the battery. For example, the environmental impacts are bigger, if the battery is charged with energy coming from non-renewable energy sources, compared to a renewable energy source. After the use phase, the batteries enter their end-of-life stage, where they are often recycled. If batteries are not disposed of correctly, they can pollute the environment with hazardous and toxic materials, including heavy metals. However, some recycling processes pose their own issues, including lack of standardisation among batteries, creating technical and economic challenges for recyclers (Azimi & Chan 2024).

To tackle some of these issues within the battery industry, the EU has put into force the Battery Regulation EU 2023/1542, which sets requirements regarding the sustainability of batteries placed on the EU market, including carbon footprint for batteries. The regulation defines carbon footprint as the sum of GHG emissions and GHG removals in a battery, expressed as carbon dioxide equivalents. It is to be based on a Product Environmental Footprint (PEF) study, a life cycle assessment method, using the single impact category of climate change. The regulation demands batteries to be accompanied by a carbon footprint declaration for them to be able to be placed on the market. (Regulation of the European Parliament and of the Council 2023/1542). This makes calculating the environmental impact on climate change of batteries mandatory within the EU. This step towards transparency aims to lower the carbon emissions arising from battery life cycles, help design more sustainable batteries, and encourage customers to purchase batteries with lower carbon footprints. The regulation also covers a wider range of topics of the battery industry, aiming to cover the entire value chain of a battery to encourage a more circular battery industry.

To calculate the carbon footprint of a battery, a life cycle assessment calculation is to be performed. Life Cycle Assessment (LCA) is a tool which addresses the environmental aspects and potential impacts emerging from the entire life cycle of a product (ISO 2006, v). LCAs can be used to determine the environmental impacts of products in 16 different environmental impact categories, which include impacts like climate change, but also acidification, land use, and water use (European Commission - Product Environmental Footprint method). Carbon footprints often refer to an LCA calculation result from the climate change category, as is the case in this thesis. LCAs have been developed since the 1960s and have become increasingly standardized enhancing the strengths of the method. The strengths of the assessment lie in its quantitative and comparable nature and the life cycle perspective it takes. This ensures that the environmental burdens of certain life cycle stages or processes are not shifted to unintentionally create impacts on others. (Hauschild, Rosenbaum, Olsen 2018, 12–13.) LCAs can also be used in the eco-design process, which refers to product design that aims to enhance the sustainability of products and services, as it provides information about the environmental hotspots of the product. This links LCA to broader sustainability strategies involving enhancing product and supply chain sustainability.

This study aims to bring the LCA methodology and the contents of the EU Battery Regulation 2023/1542 regarding the carbon footprint to a practical level. This is done by developing a process for a battery carbon footprint calculation in a battery manufacturing company, with the methodology and guidance provided by EU. This study examines the available legal and methodological requirements of battery LCA’s, company capabilities in LCA implementation, opportunities and challenges arising in the value chains, and ways of successful process implementation. Studying the practical implications of LCA calculation projects is valuable, as LCAs require collaboration among various players in the battery value chain, which is needed to create more sustainable battery industry (Yang et al. 2021, 207).

To further study the change of practices at battery manufacturers arising from these requirements, a change management perspective is included in this thesis. Change management can be defined as “a process of actively reestablishing an organization's direction, structure, and capabilities to fulfil the changing needs of stakeholders”. (Moran & Brightman 2000, 66). Perspectives from the field of change management are chosen to be investigated further: Kurt Lewin’s Planned Approach to change, the role of external institutional impacts in sustainability practices adopted within a company, and the role of internal drivers in adopting sustainability practices. Kurt Lewin’s planned approach is chosen, as it provides an approach on how to implement change in an organization. It suggests the use of action research, which is determined suitable for the purpose of this study and chosen as the research method. External institutional impacts, specifically EU’s environmental regulations, are studied as impacting forces behind sustainability related changes in organizations. Policies are remarkably influential in sustainable development of the battery industry, making examining the EU’s largest battery regulation and its requirements valuable in determining its role in the development of the battery industry (Yang et al. 2021, 207). Complimenting the external impacts of the regulation, a look into the internal drivers of organizations in adoption of sustainable practices is taken along the lines identified by Lozano (2015).

This study is conducted as a commissioned work for IONOCR Oy, while the researcher is working there. This is done to bring the LCA methodologies and regulations to a practical level, by studying process development of an LCA calculation in a battery manufacturing company. The organization, IONCOR, is a Finnish battery solutions company, that offers modular battery platforms, systems supply, and contract manufacturing, operating in Finland and Germany.

1.2 Purpose of the study

Current research on the topic of battery life cycle assessments have focused on the results of various LCA calculations and how to reduce the identified environmental impacts (eg. Chen et. al 2022; Ellingsen et. al 2014). But there is not as much information on the practical implications of LCA processes that organizations must take into consideration when implementing LCA processes. This is a gap this study aims to contribute to. The results of this thesis can help practitioners in their development process for product LCA calculation. It also contributes to the academic research by showcasing the practical implementation process of a LCA calculation, and shedding light to how identified internal and external characteristics impact the adoption process of a new sustainability practice in an organization.

The purpose of this study is to examine what kind of a battery LCA process could be developed to satisfy the regulatory requirements, and how it can be implemented successfully by leveraging the Lewin's planned approach for change. The research has the following main objective: "**Develop a battery Life Cycle Assessment process for battery carbon footprint calculation, to support sustained organizational change to meet the needs of climate regulations**."

To support this, three sub-objectives are determined:

1. Approach the life cycle assessment from a perspective of a battery solution company to form a process to calculate the battery carbon footprint.
2. Assess the external institutional impacts of environmental regulations in sustainability practice implementation.
3. Ensure sustained change within an organization via examination of change management theories and the role of internal drivers in sustainability practice implementation in organizations.

The first sub-objective "Approach the life cycle assessment from a perspective of a battery solution company to form a process to calculate the battery carbon footprint" focuses on the life cycle assessment process development and the aim is to create a feasible life cycle assessment process for IONCOR. This objective aims to transfer the theoretical knowledge into a concrete implementable process for a business to use. It is achieved by conducting action research at IONCOR, where the researcher is working to create a functioning process for a battery carbon footprint calculation. During the time of this research, the company was actively working to create a battery carbon footprint for an upcoming product, in which the researcher assisted with her study and other work.

The second sub-objective "Assess the external institutional impacts of environmental regulations in sustainability practice implementation" investigates the regulatory requirements and how regulatory uncertainty impacts new sustainability practice adoption and implementation in companies. It is achieved by observing in the researcher's workplace and identifying when regulations impact situations or decisions made in the company. This is done by working on and observing the work around various sustainability topics relevant for the organization and identifying when regulations impact how, when, or by whom certain actions are conducted. For example, how the requirements of the Corporate Sustainability Reporting Directive impact the reporting process at IONCOR, by discussing the topic together with the sustainability team.

The third sub-objective “Ensure sustained change within an organization via examination of change management theories and the role of internal drivers in sustainability practice implementation in organizations.” aims to help with the implementation of the LCA process developed, and other sustainability practices. It is studied with Kurt Lewin’s Planned Approach to change to look how the approach could be leveraged in implementing a new sustainability practice within an organization, and with internal drivers for sustainability identified by Lozano (2015). Lozano and Haartman (2018, 520) suggest studying the role of the drivers in change management for sustainability. This will be studied in this research, as the drivers will be looked at how they can be leveraged in implementing a new sustainability process, which includes introducing more sustainability information into the organization.

1.3 Structure of the thesis

The structure of the thesis is as follows. In chapter 2, the battery industry, life cycle assessments, and the EU Battery Regulation 2023/1542 are presented in more detail, to provide a clear description of the research context. Also, a description of a battery product, from cell level to a finished battery pack is presented. This is done to help conceptualize the contents of a battery, which contribute to the carbon footprint. Chapter 3 includes the theoretical framework of the thesis on the chosen change management perspectives. It presents the role of external institutional impacts, regulatory uncertainty, internal drivers for sustainability, and Kurt Lewin’s planned approach to change.

After these chapters, Chapter 4 introduces the empirical research of the thesis. It includes the research design, data collection details, data analysis, ethical considerations of the research, and evaluation of the study. Chapter 5 then presents the findings of the empirical research. Chapter 6 provides the discussion of the results, theoretical and managerial implications, and the limitations and future research, and finally, chapter 7 includes a summary of the thesis.

2 Battery life cycle assessment

2.1 Battery products and components

To provide a better understanding of the contents of a battery, this chapter showcases an overview of a general battery module and a battery pack. Figure 2 shows a simplified battery pack structure including a battery cell and module stages.

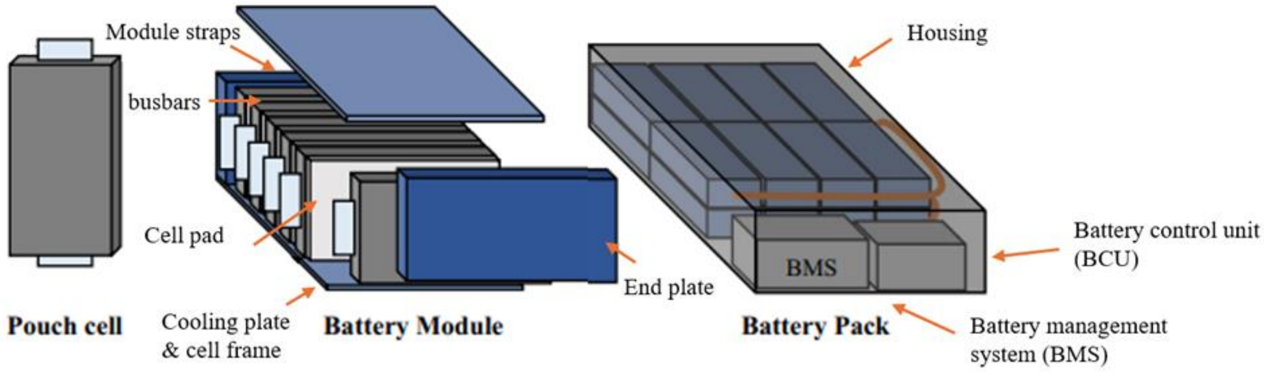


Figure 2 Battery cell, module and pack
Adapted from Choi et al. (2023)

Components of a battery are often combined to a part list, which is referred to as the bill of materials (BOM). A battery module consists of cells, cell pads, metal parts, cell management unit and plastic parts. Metal parts include endplates, busbars, and module straps. They are used to hold the module together. Plastic parts include end spacers and cell frames, also used in holding the module together. Cell pads are used with prismatic and pouch type cells to help put pressure on the cells, as they require pressure to function correctly. The cell management unit is an electronic part which provides cell data.

When assembling a battery pack, multiple battery modules are combined in a housing with a variety of parts to hold the pack together, electronic components, a battery management system, and often a battery cooling system. Battery management system is an electronic component, which controls the electric and thermal functions of a battery. There are also battery packs which are cell-to-pack. This refers to battery packs that do not include the module phase and instead cells are placed directly into the frame of a battery pack.

The most notable parts for the carbon footprint are the battery cells and metal components. Cells contain various materials which have a high carbon footprint and possible other sustainability-related issues. For example, cobalt is used in battery cells, and majority of global supply is mined in Democratic Republic of Congo (DRC). The DRC is the largest global source of cobalt and has suffered from deforestation, modern slavery, human trafficking and child labour (Earth Org 28.3.2023). Metal components are heavy, forming a large proportion of the battery. Also, aluminium and steel, which are used for parts like housing, busbars, and endplates, are energy intensive to produce and often high emitters of GHGs (Saevarsdottir et al. 2020, 298-299; Kim et al. 2022). These, and other sustainability issues are further discussed in chapter 2.2.

The battery type in focus in this thesis are industrial batteries. Industrial batteries are batteries specifically designed for industrial uses, for example in construction machinery, trucks, or buses.

2.2 Battery industry and sustainability

Increasing electricity demands have increased the demand for batteries as well. Batteries are one of the most used energy storage systems, LIBs being the most common battery chemistry for rechargeable batteries (Yang et al. 2021, 186). This can be credited to a remarkable cost reduction of 90% since 2010, higher energy density, and long lifetimes. LIBs are most used in EV application in the global energy sector. (International Energy Agency 2024a, 18, 20.) Batteries are credited to be in a crucial position in the green transition and enhancing energy security. Utilizing batteries in the renewable energy sector helps lower dependencies on imported fossil fuels, increasing not only the share of renewable energy, but also domestic energy independency of nations (International Energy Agency 2024a, 19.) Batteries can and shall be included in the energy transition, but the inherent sustainability issues of the battery industry need to be addressed.

The life cycle of LIBs poses often social risks in the supply chains like child labour, corruption, occupational toxics and hazards, and poverty, and environmental impacts in manufacturing, use and recycling phases, like high GHG emissions, hazardous waste and human toxicity, particle pollution formation, and mineral resource depletion (Thies et al. 2019, 295; Oliveira et al. 2015, 358-359). The impacts of each life cycle stage to environmental and social impacts varies based on the battery's chemistry. Even within LIBs, there is a variety of different battery cell chemistries, for example lithium nickel manganese cobalt (NMC) and lithium iron phosphate (LFP) cells. Chemistries with high contents of nickel, the critical minerals processing is the largest source of emissions, accounting for 55 %, while for LFP, the same process accounts only for 35 % of emissions (International Energy Agency 2024b, 15). This makes cell chemistry information important, as battery cell manufacturing is one of the most crucial elements contributing to battery life cycle assessments (Ellingsen et al. 2014, 117).

Environmental issues start in the raw material extraction and pre-processing. Batteries often require materials that the EU has declared as critical raw materials; lithium, cobalt, manganese, and natural graphite (Rajaeifar et al. 2022). Critical raw materials refer to non-energy, non-agricultural raw materials central to European industries and key in enabling the path to meet the political goals set by the EU, including the European Green Deal. The critical raw material status is determined with calculations on economic importance and supply risk. (European Commission 2023, 1). On average, a typical EV LIB contains 8-10kg lithium, 10-14 kg of cobalt, 30-40kg of nickel, 20-25kg of manganese, and 60-70 kg of graphite (Pol 2025, 2553). Extraction of Lithium for battery cells is energy and water intensive, can cause water pollution, and harm biodiversity (Wanger 2021, 204-205). Lithium mining and refining poses high risks of health and safety issues, freedom of association and collective bargain, and medium risk on child labour, working hours, prevention and mitigation or armed conflicts, and corruption. (Jose et al. 2025, 2294-2295). This is relevant to all LIBs, regardless of the specific cell chemistry being used. Cobalt is another mineral that comes with a variety of issues. Cobalt mining and refining include high risks of child labour, issues regarding working hours, fair salary, health and safety, equal opportunities and discrimination, prevention and mitigation of armed conflicts, corruption, and forced labour. It also poses medium risks on freedom of association and collective bargaining. (Jose et al. 2025, 2294-2295.).

Production of battery cell materials (nickel, cobalt, and lithium) is the largest contributor of carbon emissions in the entire battery production chain (Chen et al. 2022). The issues around extraction of these raw materials does not end with these presented above. There are great risks regarding supply chain risks, as these materials are in high demand, leading to possible issues of availability and extraction is concentrated partly on conflict areas (Xu et al. 2020). For example, Russia is one of the major extractors and refiners of nickel (Yang et al. 2022). The battery industry is expected to grow exponentially in the upcoming decades; the demand of these materials is expected to grow with it. This creates demands of expansions of existing extraction, additional resource discovery, and increased use of recycling. (Xu et al. 2020.)

Moving from the processing of raw materials into manufacturing of batteries and components. Battery cells are the most impactful component sustainability wise. Manufacturing battery cells involves being in contact with toxic materials, energy-intensive processes, and the recycling rate is often low. (Dühnen et al. 2020.) Another notable component type are metal parts, especially aluminium parts. Aluminium is used in various parts, including battery cells, and the battery casings which cover finished battery packs. As metallic aluminium does not naturally occur in nature, production of aluminium requires always complex processing for it to be used properly. Manufacturing of aluminium is estimated to contribute to almost 2 % of global carbon emissions due to its energy-intensive processes. Aluminium has also one of the fastest growing demands out of metals. In addition to the growing needs, aluminium's manufacturing is concentrated in China, which produces 57 % of primary aluminium. (Saevarsdottir et al. 2020, 297-299.)

Another important metal is steel. Steel is often used in structural components and as it is a heavier material, it forms an accountable part of a battery. Steel is completely recyclable, making it a friendly material for circular economy (Broadbent 2016, 1660). Use of recycled and decarbonised steel is a way to reduce the environmental impacts of batteries. But there are still issues with recycling steel, including the question of availability, and cost fluctuation due to political instability (Yellishetty et al. 2011, 655-656).

After the production of battery components, comes the battery assembly. This phase's impacts are dependent on the energy and heating usage in the assembling facility (Dühnen et al. 2020). This shows that there are opportunities to lower carbon emissions with switching into renewable energy in battery assembly.

In the use stage of the battery, the used energy makes a remarkable impact for the carbon emissions of a battery (Das et al. 2024, 78). This makes use of renewable energy an effective way to lower the carbon emissions of a battery. Though, this is in the hands of the end user of the battery, not the manufacturer of the battery or the vehicle the battery is placed in. This is also the reason why EU has left the use phase out of the scope for battery carbon footprints.

When LIBs meet the end-of-life phase, they need to be disposed of properly, or the batteries will cause more environmental damage due to the toxic materials used in them. Also, not returning battery materials into use via recycling is worsening the resource depletion of these materials. (Azimi & Chan 2024.) Improper landfill or incineration can generate health risks and fire hazards in municipal waste facilities (Arshad et al. 2022). But recycling of batteries does also contribute to carbon emissions. Transportation, preparation of batteries, and energy intensive recycling processes lower the environmental benefits gained from recycling (Baum et al. 2022, 715) These make developing green recycling methods critical in enhancing the sustainability of batteries.

All of these stages have aspects which can increase the carbon footprint of a battery, but they also include opportunities to lower it. The next subchapter investigates what the method for the carbon footprint calculation, the life cycle assessment, is.

2.3 Life cycle assessment

Life cycle assessment emerged as a concept from the life-cycle-oriented methods in the 1960s (Hauschild et al. 2018, 18). Since the 1990s, the standardization of life cycle assessment has evolved and currently, two international standards guide the majority of LCA work: "ISO 14040 (2006) Environmental management – Life cycle assessment – Principles and framework, and ISO 14044 (2006) Environmental management – Life cycle assessment – Requirements and guidelines" (Guinée et al. 2011, 91).

LCAs analyse the whole life cycle of a product covering a variety of impacts coming from those life cycle stages. It is characterised by its adoption of a life cycle perspective, coverage of a variety of environmental issues, quantitative approach, and scientific background. (Hauschild & Rosenbaum 2018, 12-13.) Strengths of LCA are (1) comprehensiveness of life cycle perspective and coverage of environmental issues and (2) the use of "best estimate" principle. LCAs can provide valuable knowledge on identifying the opportunities to increase products environmental performance in various life cycle phases, provide information for industry, government, and non-government organizations decision making, in choosing relevant indicators of environmental performance, and marketing (ISO 2006, 9). The ISO 14040/44 is the most known and widely used LCA method available. The structure of the method is presented in Figure 3.

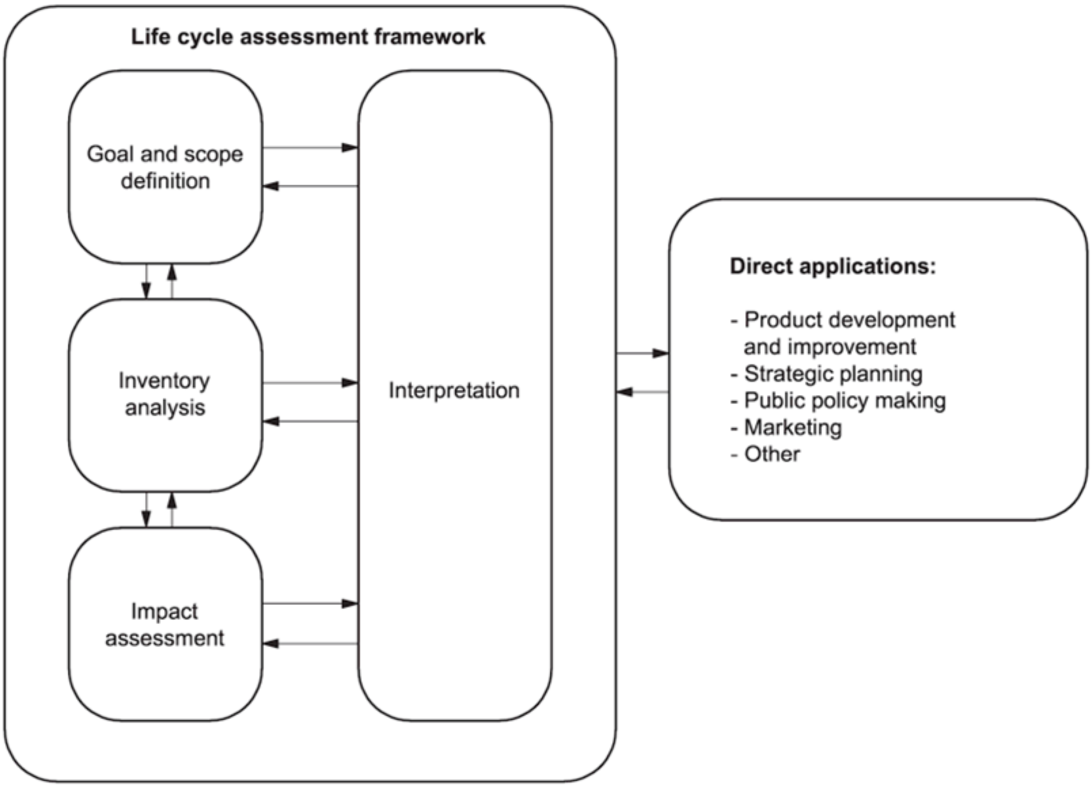


Figure 3 Phases of an LCA study

From ISO 14040:2006 Environmental Management. Life cycle assessment. Principles and framework (2006)

An LCA study based on ISO 14040/44 has four phases: “goal and scope definition, inventory analysis, impact assessment, and interpretation”. In the goal and scope definition phase, the system boundaries and level of detail for the study are set. Inventory analysis consists of collecting process level data for the calculations and forming the collected data into Life Cycle Inventories (LCI), which combines the exchanges of elementary, waste and product flows (Regulation of the European Parliament and of the Council 2023/1542). In the impacts assessment phase, the magnitude and significance of potential environmental impacts of a product are evaluated. In the case of calculating a carbon footprint, this means combining the collected process level data into the carbon footprint of the product. In the interpretation phase these results from the inventory analysis and impact assessment are evaluated within the defined scope to reach conclusions and recommendations. LCA results can be used as a tool in various topics, like product development, strategic planning, and marketing. The life cycles stages covered by the ISO 14040/44 method include every phase from cradle-to-grave, referring to life cycles from raw materials extraction through production, use, end-of-life treatment, recycling and final disposal (ISO 2006, 9). This method has been largely used in academic research on battery LCA.

In addition to these international standards, the EU has published its own LCA methods, which build upon the ISO standards. Product Environmental Footprint (PEF) method and Product Environmental Footprint Category rules (PEFCR) further develop and improve the reproducibility, comparability and verifiability of the results of specific product groups. The PEF method also adds an additional step into the process: verification and validation. Currently, the PEFCR for batteries and accumulators is in revision. (European Commission - Product Environmental Footprint method.) The battery carbon footprint required by the EU Battery Regulation 2023/1542, builds on the PEF and PECFR methods.

2.4 EU Battery Regulation 2023/1542

In 2023, the EU Battery Regulation 2023/1542 entered into force, with gradual implementation. The regulation is a part of the EU's Green Deal, introducing elements like the digital battery passport, extended producer responsibility, battery due diligence, and battery carbon footprint requirements. It is the first piece of EU legislation to take the entire life-cycle approach addressing sourcing, manufacturing, use and recycling of batteries, under a single law (European Commission 17.8.2023). The battery regulation applies to all battery categories: portable batteries, starting, lighting, and ignition batteries, light means of transportation batteries, EV batteries, and industrial batteries. Table 1 presents the most relevant chapters of the regulation for this thesis.

Table 1 EU Battery Regulation 2023/1542 chapters and topics

Chapters	Articles	Relevance to life cycle assessment
Chapter II Sustainability and safety requirements	Articles 6-12	Includes the requirements for carbon footprint
Chapter VII Obligations of economic operators as regards battery due diligence policies	Articles 47-53	Due Diligence risk management can benefit from LCA results
Chapter IX Digital battery passport	Articles 77-78	The carbon footprint is a required part of battery passport

The regulation aims to cover the entire value chain of a battery to enhance the circularity of batteries within the EU market, making the carbon footprint a central part of it, as it addresses the emissions coming from each life cycle stage of a battery.

The regulation includes a variety of obligations to various actors across the value chain. Since this thesis focuses on the life cycle assessment process of a battery, the regulation is tackled here with that perspective in mind. The regulation and carbon footprint calculation rules, described in the following subchapter, introduce few terms with specific definitions, which are defined here in Table 2.

Table 2 EU Battery Regulation and LCA calculation rules specific term definitions

Term	Definition	Source
Activity data	"Information associated with processes in LCI modelling."	Battery Regulation 2023/1542
Battery manufacturer	"Natural or legal person manufacturing batteries or has a battery designed or manufactured and markets that battery under its own name or trademark, or puts it into service for own purposes."	Battery Regulation 2023/1542
Company-specific dataset	"A dataset compiled with company-specific data. Dataset is a document or file with life cycle information of a specified product or other reference such as a process, covering its quantitative life cycle inventory or its carbon footprint."	Andreasi Bassi et al. 2025, 66.
Economic operator	"Covers the manufacturer, authorised representative, importer, distributor, fulfilment service provider, and other legal or natural person subject to obligations to the manufacture of batteries, making them available or placing them on the market, or putting them into service."	Battery Regulation 2023/1542
Elementary flow	"Materials or energy entering the system under study that have been drawn from the environment without human transformation, or materials or energy leaving the system without further human transformation."	Andreasi Bassi et al. 2025, 66.
Life cycle inventory (LCI) dataset	"Document or a file with life cycle information on a specified product, process etc. Covering descriptive metadata and quantitative life cycle inventor."	Andreasi Bassi et al. 2025, 67.
Life cycle inventory (LCI)	"Combined set of exchanges of elementary, waste and product flows in an LCI dataset."	Battery Regulation 2023/1542
Secondary data	"Data not from a specific process within the supply chain of the company completing a carbon footprint study."	Andreasi Bassi et al. 2025, 66.

The table provides the term, its definition and its source. The terms relate to the carbon footprint calculations and defining their meanings is important to understand the requirements for the carbon footprint calculation.

2.4.1 EU Battery Regulation requirements for battery carbon footprint

The requirements for the battery carbon footprint are largely determined in Article 7 and Annex II of the Battery Regulation 2023/1542. Additionally, the EU is in the process of publishing implementing and delegated acts providing more detailed rules for carbon footprint calculations. Article 7 demands that:

> “...for electric vehicle batteries, rechargeable industrial batteries with capacity greater than 2 kWh, and LMT batteries a carbon footprint declaration shall be drawn up for each battery model per manufacturing plant”.

This declaration shall include at least the following information (Regulation of the European Parliament and of the Council 2023/1542):

- “Administrative information about the manufacturer
- Information about the battery model
- Information about the geographic location of the battery manufacturing plant
- The carbon footprint of the battery, calculated as kg of carbon dioxide equivalent per one kWh of the total energy provided by the battery over its expected service life
- The carbon footprint of the battery differentiated according to the life cycle stages described in point 4 of Annex II
- The identification number of the EU declaration of conformity of the battery
- A web link giving access to a public version of the study supporting the carbon footprint”

According to the EU Battery Regulation, the battery life cycle consists of four life cycle stages. These stages and the processes involved can be seen in Table 3.

Table 3 Battery life cycle stages

From Regulation of the European Parliament and of the Council 2023/1542)

Life cycle stage	Process involved
Raw-material acquisition and pre-processing	Includes mining and other relevant sourcing, pre-processing and transport of active materials, up to the manufacturing of battery cells and battery components (active materials, separator, electrolyte, casings, active and passive battery components) and electric or electronic components
Main product production	Assembly of battery cells and assembly of batteries with the battery cells and the electric or electronic components
Distribution	Transport to the point of sale
End of life and recycling	Collection, dismantling and recycling

The first life cycle stage is raw material acquisition and pre-processing. This stage covers the collection of natural resources and their pre-processing up until they are used in various components, all transportation of raw materials and intermediate products before main product production, and the production of all materials or intermediate products not covered by the main product production. Main product production includes production of cathodes, anodes, and electrolytes, battery cell production, assembly of battery modules and packs, and transportation of intermediate products to their use site. Distribution covers the transportation of battery products from the manufacturer to the point of placing the battery on the market. End of life and recycling is the last step, including transport of waste batteries, battery dismantling, recycling of battery components, and energy recovery and disposal of waste fractions. (Andreasi Bassi et al. 2025, 20-21.)

The processes included in the EU battery carbon footprint calculation does differ from the ISO 14040 method, mainly by excluding the use phase of the battery from the calculations. This is done since the use phase is not under direct influence of the battery manufacturer. There are also two processes excluded from the life cycle of a battery: "manufacturing of equipment for the assembly and recycling of batteries, and the battery assembly process using the original equipment manufacturer (OEM) system components."

The carbon declaration shall apply from 12 months after the date of entry into force of the delegated or the implementing act for that battery category. In addition to a carbon footprint declaration, the EU will declare carbon footprint performance classes, which help to identify batteries with lower carbon footprints, and maximum carbon footprint thresholds. Batteries shall be accompanied by a label communicating the carbon footprint performance class they belong into. Performance class requirements shall apply 18 months after entry of force of the delegated act for each battery category. Maximum allowable carbon footprint thresholds for batteries will be introduced by the EU based on the relative distribution of carbon footprint values of batteries on the market, the progress in reducing the carbon footprint of batteries, and the actual and potential contribution to EU objectives on sustainability and climate neutrality. The thresholds will apply for each battery category 18 months after the entry into force of the delegated or implementing act. (Regulation of the European Parliament and of the Council 2023/1542)

2.4.2 Calculation of the life cycle carbon footprint

No delegated or implementing acts have been published yet at the time of writing this thesis in Spring 2026. What has been published, are "Rules for the calculation of the Carbon Footprint of industrial Batteries without external storage (CFB-IND)" and "Rules for the calculation of the Carbon Footprint of Electric Vehicle Batteries (CFB-EV) Final draft". The rules for calculation operates as methodological guideline for carbon footprint calculation and basis for the enforcement of Article 7 of Regulation (EU) 2023/1542. (Andreasi Bassi et el. 2023, 1; Andreasi Bassi et el.

2025, 3.) Regarding the calculation of EV batteries, the EU has a draft delegated act, but this is delayed. The EU should have adopted a delegated and an implementing act setting out the methodology and format of the carbon footprint by 18th of February 2024 for EV batteries and 18th of February 2025 for industrial batteries. There is no further information available on when it will move forward from the draft stage. The calculation method in the draft act is based on the rules for the calculation of the Carbon Footprint of Electric Vehicle Batteries (CFB-EV) Final draft. This makes it difficult for companies to prepare for the requirements, as the timeline and final requirements are not published. As industrial batteries are the focus of this thesis and the guidance is mainly taken from the CFB-IND, as it provides the guidelines for that battery category.

The CFB-IND provides a system boundary, which defines the parts of the life cycle that are included in the calculation, for a general industrial battery. A simplified version is presented in Figure 4.

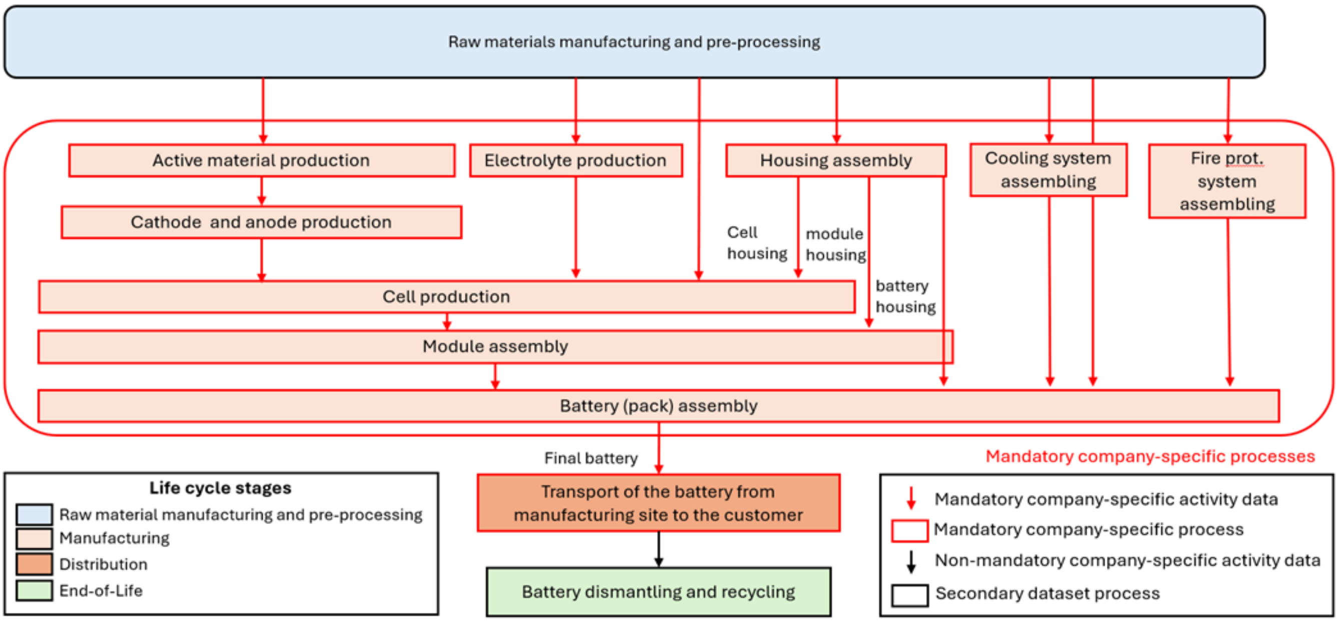


Figure 4 Simplified system boundaries for a battery carbon footprint calculation

Figure adapted and simplified from Andreasi Bassi et al. (2025)

Data required for the carbon footprint calculation is separated into mandatory and non-mandatory company-specific processes, and secondary dataset processes. Mandatory processes include processes after raw materials manufacturing and pre-processing, up until the transportation of the finished battery. Secondary dataset processes are raw materials manufacturing and pre-processing, and battery dismantling and recycling. Non-mandatory processes are further separated into most relevant and non-most relevant processes. Most relevant processes include production of certain cathode active material precursors (cobalt, nickel, iron, lithium, cadmium, lead, and vanadium), production of certain anode active material precursors (lithium, titanium, nickel, cadmium, lead, rare earths, sodium metal, silicon, graphite and hard carbon precursors), production of certain electrolytes, and production of copper, aluminium, and steel. Cathodes and anodes are responsible for the charging and discharging of batteries. Corresponding datasets are to be used for each process type. For input data, the data must include the following parameters: specification of the input or output, such as the name of the input, primary, the supplier, and country of origin, unit, LCI data per kg main output product, LCI data source, collection method or methods, and timespan, and LCI data collection date. For outputs, direct emissions and waste streams must be recorded. For transportation, primary data for the weight, distance and transportation method shall be collected.

Company-specific dataset refers to a quantitative life cycle inventory of a specific product or process in the form of a LCI or its carbon footprint. Company-specific means that the data must be primary data collected from the company in question. For example, for battery cells, the data needs to be gathered from the battery cell manufacturers operations. Complete LCI refers to an annual life cycle information of a product, site or a process, covering all material and energy inputs, auxiliaries and other materials inputs, transport distances and means of transportation, elementary flows, and material outputs. (Andreasi Bassi et al. 2025, 30, 66-67.) According to the system boundary, mandatory company-specific data shall be used for main product production and distribution life cycle stages. It shall be collected according to one of three ways (Andreasi Bassi et al. 2025, 26):

- “Suppliers provide manufacturers complete LCI of the process, including elementary flows, energy consumption, input material, and recycled content.
- Suppliers provide the manufacturer with a company-specific dataset of the process.
- Suppliers provide the complete LCI of the process to a third party, who comprise the LCI into a company specific dataset of the process, which is then forwarded to the manufacturer.”

Non-mandatory company-specific activity data is to be collected for the raw material acquisition and pre-processing life cycle stage. This means, that for these processes company-specific data or secondary data from the European Platform on LCA, or from the Life Cycle Data Network may be used (Andreasi Bassi et al. 2025, 27-28). For the end-of-life, default battery recycling process is to be used, but the data for collection and transportation of batteries is to be collected similarly to other transportation data. According to the extended producer responsibility, the responsibility for the collection and transportation falls under producer organizations.

In conclusion, primary data is required from processes part of the main product production, transportation data and distribution. Primary or secondary data may be used for raw material extraction and pre-processing, including production of copper, aluminium, and steel, and for the end-of-life stage. In addition, a supporting study of the carbon footprint calculation shall be conducted. The supporting study will have two versions: public and a non-public version. It provides metadata of the calculation and technical information of the battery.

2.4.3 Other notable battery regulation 2023/1542 chapters and articles

Most notable other chapter in the regulation for the carbon footprint calculation is Chapter IX, Digital Battery Passport. This chapter details the requirements for the digital battery passport which shall be present as a QR code in each light means of transportation battery, industrial battery with capacity greater than 2 kWh, and EV battery placed on the market. The battery passport is mandatory to these batteries from 18th of February 2027 onward.

The passport consists of information regarding to the battery model and information of the individual battery. The carbon footprint information is one of the attributes required in the battery passport. The carbon footprint declaration is to be public information, which means that anyone can access this information via the QR code accompanying the battery in question. The digital product passport is the platform the carbon footprint will be available to the public. The passport combines majority of the requirements presented in the regulation to be presented via the passport QR code added to every battery.

On top of the digital product passport, another notable chapter from the carbon footprint calculation viewpoint of the regulation is chapter VII "obligations of economic operators as regards battery due diligence policies".

Chapter VII consists of the obligations for battery due diligence. According to the regulation, economic operators who place batteries on the market, must fulfil battery due diligence obligations. These obligations include: adopting and communicating to suppliers and the public the company battery due diligence policy regarding raw materials, incorporating in the battery due diligence policy standards consistent with internationally recognized due diligence instruments, structure the internal management system to support the battery due diligence policy, operate a system of controls and transparency in the supply chain, incorporate battery due diligence policy into contracts and agreements with suppliers, and establish a grievance mechanism. The raw materials included in the battery due diligence are cobalt, natural graphite, lithium, nickel, and chemical compounds based on these materials necessary for manufacturing the active materials of batteries. (Regulation of the European Parliament and of the Council 2023/1542.)

Regarding the carbon footprint, the most relevant part of the due diligence obligations is the risk management obligations. Economic operators shall identify and address the risk of adverse impacts in its supply chains. These risks are separated into three categories: a) environmental, climate and human health, b) human rights, labour rights, and industrial relations, and c) community life, including indigenous peoples. The first category includes pollution to air, water, and soil, which are included in the carbon footprint calculation, as carbon emissions are considered a pollution. These risks can be assessed leveraging the life cycle carbon footprint and its description of emissions coming from each of the life cycles.

Understanding the requirements for a battery LCA is important, but to ensure a process is implemented successfully in the target organization, examining internal and external impacts is valuable. These are investigated in the next chapter.

3 Adoption and implementation of new sustainability practices

To support the understanding and adoption of the life cycle assessment process, three change management perspectives are included in this thesis: role or regulations in new sustainability practice adaptation, internal sustainability drivers, and Lewin’s planned approach to change. Deepening the understanding of external institutional impacts and their role in driving change in an organization is used to help define the impacts of the EU Battery Regulation in the motivations and adoption of life cycle assessment. Internal drivers compliment the external institutional impacts by shedding light to the organization's own capabilities in implementing new sustainability practices. Kurt Lewin’s planned approach to change is taken as the theoretical framework for change implementation in a company. Kurt Lewin was a highly appreciated psychology researcher focusing on finding solutions for social conflicts, especially directed towards minority or disadvantaged groups (Burnes 2004, 978). Later, his work has been widely used in organizational change, and he is mostly known for his three-step model, which is part of his planned approach. Lewin’s work will be mainly looked through the revisitation of Burnes in his publications from 2004 and 2020, as the planned approach is handled together, rather than examining the components individually.

3.1 Role of regulations in new sustainability practice adoption

Organizations are deemed to be impacted by three types of forces: normative, mimetic, and coercive (DiMaggio & Powell 1983, 150). Normative pressures refer to market pressures for an organization to be seen as legitimate in the eyes of partners. Mimetic forces are created by the pressure to “mimic” successful competitors in the market. Coercive forces are the pressures to adopt practices demanded by regulatory or other groups. (Adebanjo 2016, 997).

External institutional impacts fall under the coercive forces, as they are demanded by groups like regulatory bodies. The increasing visibility of sustainability issues has created regulatory initiatives to control the negative impacts of production and consumption of goods and services, especially within the EU, where the European Green Deal, aims to reach climate neutrality by 2050 (European Council 2025). The strategy consists of a variety of regulations and directives created by the EU, including corporate sustainability due diligence, circular economy acts, net-zero industry acts, and renewable energy acts. The battery regulation 2023/1542 is part of the European Green Deal as well. The green deal is an example of environmental legislation, which is the focused legislation type in this study.

Regulations and incentives have been identified to have a positive correlation to environmental performance, partly mediated by eco-design, as illustrated in Figure 5 (Zailani et al. 2012, 735).

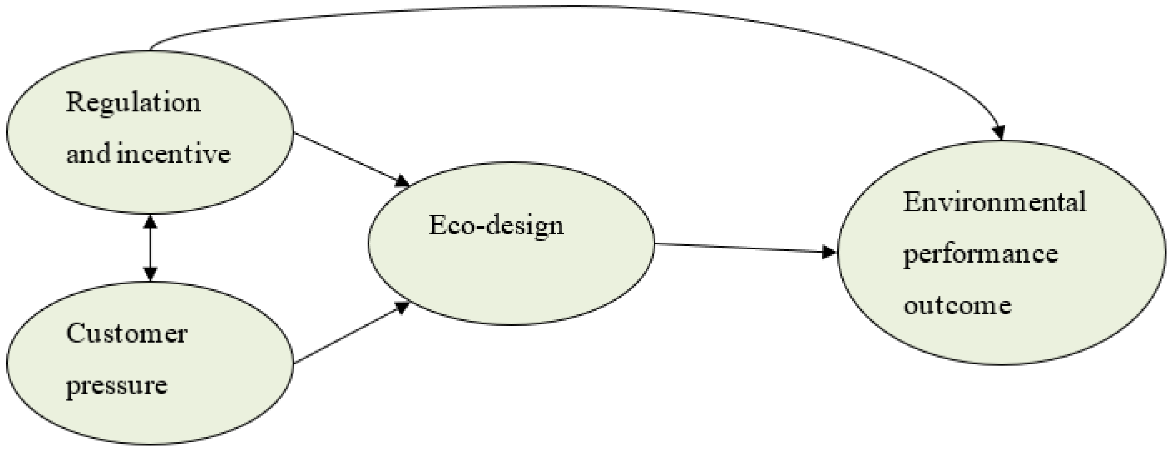


Figure 5 Regulation and incentive impacting eco-design and environmental performance
From Zailani et al. (2012)

Eco-design is also impacted by customer pressure, which is positively correlated with regulation and incentive. Regulation and incentives include regulatory drivers, governmental environmental regulations, and threat of non-compliance with regulations, and incentives, like financial incentives from governments and organizations, parent company standards, and governmental environmental inspections (Zailani et al. 2012). Out of these, government incentives have been identified to be more effective in eco-design, especially when they are in the form of financial incentives (de Medeiros et al. 2022). Similar results were found by other authors, like Adebanjo et al. (2016) who studied the role of external pressures on adopting sustainable management practices and environmental performance, both of which were found to be positively affected by external pressures, which include the regulatory pressures, and other stakeholder pressures. Trevlopoulos et al. (2017) also identified that environmental regulations impact environmental performance positively. Even though they were able to prove that complying with environmental regulations increases the environmental performance of a company, they were unable to find linkages between environmental regulations and economic performance.

In addition, the role of regulatory uncertainty is studied. Regulatory uncertainty is defined as decision maker's inability to predict the future of the regulatory environment (Rodriguez Lopez et al. 2017, 93). Regulatory uncertainty plays a significant role especially when it comes to the natural environment. Even though issues around the topic are acknowledged, politicians are slow to respond to them (Marcus et al. 2011, 6). Rodriguez Lopez et al. (2017) studied the role of regulatory uncertainty and perceived regulatory uncertainty on likelihood of investing in measures that decrease the GHG emissions. They found that when companies perceive that the uncertainties they face cannot be reduced, they slow down their investments in those measures. This means that whenever decision makers are uncertain of the regulatory environment around a sustainability topic, they are less likely to adopt sustainability practices in their organizations. Regulatory uncertainty is a relevant topic in relation to the EU battery regulation and the carbon footprint calculation, as the EU has exceeded some deadlines for implementing and delegated acts regarding adoption of some legal requirements. For example, there is no information on the current timeline of implementing/delegated acts for carbon footprint calculation for industrial batteries. There is also evidence that EU is currently backing down with some of its environmental regulations. For example, in March and December 2025, the EU announced that they will narrow the scope and simplify the contents of the Corporate Sustainability Reporting Directive (Council of the EU 9.12.2025).

In this study, the role of regulatory institutional pressures on sustainability practice implementation is assessed. The battery regulation, which is the main regulatory pressure studied, demands battery producers to fulfil certain sustainability requirements. This study aims to look further into the impact of regulatory pressure on sustainability practice adoption, and what other, voluntary actions are being done and what motivates them, to form a picture on the role of regulations in adopting sustainable practices.

3.2 Internal sustainability drivers

Implementing sustainability practices is not only impacted by external actors, but organizations also have internal drivers, which encourage engaging in sustainability practices. The impacts of internal characteristics have been widely studied in previous literature. Different viewpoints have been taken in previous literature, for example circular economy, and specific industries. Internal sustainability drivers aim to explain why companies engage in certain sustainability practices. In this study, one set of drivers for investigation, was chosen. The internal sustainability drivers examined here are drivers identified by Lozano (2015) and reinforced by Lozano and Haartman (2018). This set was chosen, as it is deemed most suitable for examination in the organization in scope of this thesis, and it is not limited to any certain aspect of sustainability, as it aims to bring a holistic view for the drivers of corporate sustainability. Corporate sustainability is defined as companies' activities which proactively aim to contribute to sustainability, including environmental, social, and economic dimensions in both short and long-term view (Lozano 2015, 33). Lozano (2015) and Lozano and Haartman (2018) identified nine internal drivers separated into three categories, affecting corporate social responsibility in organizations presented in Table 4.

Table 4 Internal sustainability drivers

From Lozano and Haartman (2018)

Driver	Magnitude	Category
Proactive leadership	1st	Leadership
Moral and ethical obligations	2nd	Culture
Organizational culture	3rd	Culture
Business case	4th	Economic
Precautionary principle	5th	Economic and culture
Avoiding risk	6th	Economic
Sustainability champions	7th	Leadership
Economic considerations	8th	Economic
Demands from employees about the organization’s sustainability efforts	9th	Culture

The drivers are, in the order of magnitude; Proactive leadership, moral and ethical obligations to contribute to sustainability, organizational culture, business case, precautionary principle, avoiding risk, sustainability champions, economic considerations, and demands from employees. They can also be separated into three categories: economic, culture, and leadership. Business case, precautionary principle, avoiding risk, and economic considerations fall under economic category. Precautionary principle, company culture, moral and ethical obligation to contribute to sustainability, and demands from employees are under culture. Proactive leadership, and sustainability champions form the leadership category. (Lozano & Haartman 2018, 512.).

Economic category includes drivers which are motivated by economic benefits. Business case here refers to the relation between sustainability and economic performance. When engaging with sustainability provides a positive business case, or not engaging in it brings a negative business case, it is seen as an internal driver for sustainability. Avoiding risk links to this, as some risks, like reputational risks, can be tackled by engaging with sustainable practices. Economic considerations refer to improvement in performance, profit and growth, and reducing costs while improving efficiency and reducing waste. (Lozano 2015, 36, 40.)

Culture category focuses on the drivers arising from how the people in the organization operate. Organizational culture refers to beliefs, values, ideas, and attitudes shared within an organization, guiding the behaviour of the members. Organizational green culture, which is a culture encouraging green behaviour, has been proven to have a positive impact for green innovation and environmental performance. Organizational green culture increased employees felt involvement with environmental issues. (Wang 2019, 667, 670.) This makes organizational culture a powerful driver to leverage for sustainability, as it can make employees feel more connected to the topic. Demands from employees for corporate sustainability actions is the second culture driver. It has the lowest magnitude of the internal drivers.

Precautionary principle, which belongs to both economic and culture categories, is defined as a requirement to take precautionary measures when threats of harm towards human or the environment arise. It comprises four components: “taking preventative action when faced with uncertainty, shifting the burden of proof to the supporter of an activity, exploring a range of alternatives to possibly harmful actions, and increasing public participation in decision making.” (Kriebel et al. 2001, 871.) Precautionary actions are to be taken even if there is no conclusive scientific proof which links it to environmental damage. “Its purpose is to encourage and oblige decision makers to consider the harmful effects of their activities before pursuing them.” (Cameron & Abouchar 1991, 2.)

Leadership is the third category. Proactive leadership was identified as the most important internal driver of sustainability By Lozano and Haartman (2018). “Leadership for sustainability has been identified to require reading and predicting through complexity, thinking through complex problems, engage groups in dynamic adaptive organisational change, and managing emotions appropriately” (Metcalf & Benn 2013, 381). Sustainability champions refer to individuals who attempt to create change towards sustainability in their organizations or in the wider context. In companies, sustainability champions can help to turn environmental issues into successful innovations and practices. (Anderson & Bateman 2000, 548-549.) They can be people in the leadership positions, but they can also be anyone within the organization.

This study aims to identify whether these drivers are present in the company and how they can be leveraged in the process of implementing a new sustainability process. Next, the last part of the theoretical framework studied in this thesis is presented, Lewin’s planned approach to change.

3.3 Kurt Lewin’s planned approach to change

Lewin’s planned approach is investigated in this study to ensure a sustained change in the adoption of the LCA process in the company. It consists of four main elements: field theory, group dynamics, action research, and the three-step model. The most notable one credited to Lewin is the three step model and it has often been separated from the context of the other three elements. This is not how it was intended to be done, instead all the four elements are to be used together. (Burnes 2004, 981.) This is why the planned approach is studied as a whole, instead of focusing solely on the three-step model in this study, and why the planned approach is examined here through Burnes' two publications from 2004 and 2020.

The first component is field theory. According to it, human behaviour originates from the forces affecting person or a group, forming their life space or field where behaviour happens (Burnes 2020, 35). Any behaviour or change in the life space depends on the state of the field at that time (Lewin 1943, 294). Meaning, that to alter human behaviour, the field needs to be altered. In the context of changing people's tasks in an organisation, before aiming to alter specific workers behaviour, a change in the working environment shall be done. This change should be encouraging of this desired behaviour. In this thesis context, this refers to an aim to alter the organizational atmosphere to be more open to the new LCA process.

Group dynamics is the second component. Group dynamics emphasizes the importance of studying group behaviour, instead of individual behaviour, as individuals are under group pressure to conform. It also notes that understanding a group's internal dynamic is not enough, but to successfully commit people to change, the members need to be engaged in the change process (Burnes 2004, 983). Group dynamics closely supports the field theory and provides further reasoning to focus on changing the environment, before aiming for individual behaviour change. But it also emphasizes using an interactive change process and committing people into the process of change itself to sustain the results. In this thesis, group dynamics is taken into consideration in by engaging the target group in the change process.

The interactive nature to the change process required by group dynamics is achieved by leveraging the action research method, developed by Lewin. With action research, Lewin aims to find answers to three questions: "1. What is the present situation? 2. What are the dangers? 3. And most important of all, what shall we do?" (Lewin 1946, 201). It emphasizes that for change to happen, it needs actions aimed at achieving that change, and that successful action is based on correctly analysing the situation, identifying all the alternative solutions, and finally choosing the most appropriate one. Action research is to be performed on a group level, engaging the individuals in a group the change is desired to make in and aim to understand the forces impacting the behaviour of the said group. (Burnes 2004, 983-984.) Action research also allows the research to have two types of research objectives, a more practical objective, and a more theoretical objective (Lewin 1946, 34, 36). This makes action research not only useful for practical issues, but also a method which can be used in academic research.

The most known feature of the planned approach is the three-step model, illustrated in its most used form in Figure 6. Lewin did not originally aim it to be used for organizational change, but it has cemented its role in organizational change management regardless. (Burnes 2004, 985).

Figure 6 Basic three step model of change
From Burnes (2020)

The first step of the three-step model is unfreeze. This refers to the destabilization of the existing balance of behaviour. Destabilization is needed to ensure the previous behaviour is unlearnt. To successfully unfreeze a status quo, the group need to be given confirming information that the status quo is no longer valid and ensure that they feel safe from loss and humiliation, before they can accept the situation and reject their old behaviours. (Schein 1996, 60-61). The second step is moving. It refers to the iterative process of trial-and-error process of identifying and evaluating all possible options to move to a more valid set of behaviour. This is to be done via the action research method together with the group members to ensure they are participating in the change. (Burnes 2004, 985-986.) The final step is refreezing. This is the effort to stabilize the new set of behaviours identified in the moving step, to prevent regression from the previous ways of doing. To ensure a successful refreezing, the group norms and routines must be transformed as well. (Burns 2004, 986.) If those stay the same, it is easier for the participants to fall back into the behaviours used previously with the norms and routines. Burnes (2020) combined the elements Lewin created into the Lewin's planned approach, presented in Figure 7.

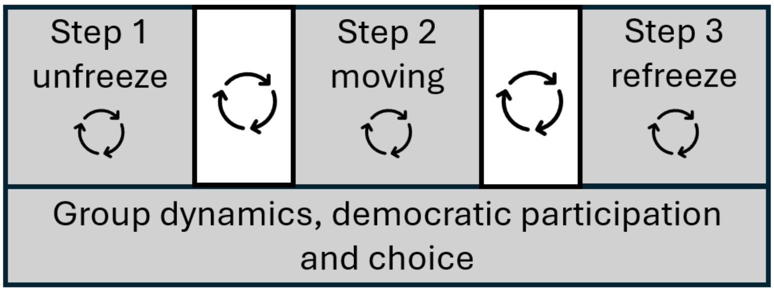


Figure 7 Lewin's planned approach

From Burnes (2020)

As mentioned, Burnes (2020) combined the previously discussed elements into a single diagram showcasing their connections. The bar below, including group dynamics, democratic participation and choice, showcases how these elements run behind the three-step model. The circle arrows within and between the steps display the iterative nature of the process, emphasizing that it is not straightforward change from the beginning stage to the end.

Lewin's planned approach revolves highly around participatory research done within the group that the change is implemented in. Lewin intents this to be achieved via action research, which is the chosen research method of this thesis. The research approach is further defined in chapter 4. Before moving to the methodology, a synthesis of the theoretical framework of this thesis is presented.

3.4 Synthesis of the theoretical framework

Chapters 3.1-3.3 provide the theoretical frameworks used in this thesis. This chapter is a synthesis of the theoretical frameworks and situates them into the context of battery industry and life cycle assessment process adoption. The combined theories described in this chapter, shown in Figure 8, define how a new sustainability practice can be successfully implemented.

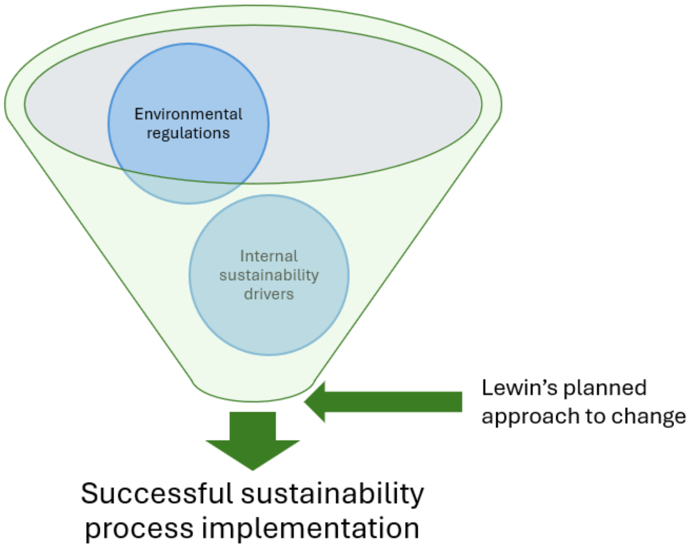


Figure 8 Influencers for a successful sustainability practice implementation

Author's own creation

The impacts of environmental regulations can set the general baseline for a new sustainability practice is to be built upon. This is a more general baseline due to regulations' wide impacts, while the internal sustainability drivers focus on the organization specific aspects for sustainability practice implementation. They determine the organization's capabilities characteristics which affect process implementation. Together they form the context to which a new process needs to be implemented. The process can then be implemented in an organization using the Lewin's planned approach to change (Burnes 2020).

Chapter 3.1 Provides the framework of regulatory impacts in sustainability process adoption. This includes positive impact of regulations in implementation and the impacts of customer pressure to regulations by Zailani et al. (2012), and the proposed negative impact of regulatory uncertainty by Rodriguez Lopez et al. (2017). Studying the external impacts of regulations provides a background of the context in which a change is required.

Internal drivers in chapter 3.2 are studied in support of the external regulatory impacts. Internal drivers identified by Lozano (2015) and further elaborated by Lozano and Haartman (2018) provide insights on what concepts embedded in an organization aid sustainability. The internal drivers bring the organization specific context to a process implementation to showcase the organizational environment and attitude towards sustainability and change. These drivers help to form the organization specific context in which the change needs to be performed.

Chapter 3.3 introduces the concept of the Lewin's planned approach. The Planned approach is a well-known framework for human behaviour change created by Kurt Lewin in the first half of the 20th century (Burnes 2004; Burnes 2020). The planned approach provides a guide of how a change process can be implemented successfully to fulfil the regulatory requirements and leverage the internal sustainability drivers in the process. Together these components form the context and tools which help and guide the implementation of a new sustainability practice in an organization.

4 Methodology

This chapter introduces the methodology used in this study. First, the research context is introduced, including a description of the company in which the research is performed. After that, the chosen research approach is described and justified. Then, the data collection method and data analysis method are presented. Lastly, the ethical considerations and data evaluation are discussed, to provide a comprehensive picture of the study.

4.1 Research context

This research is performed at IONCOR Oy, a Finnish battery solutions company, assembling EV and industrial batteries for B2B vehicle and industrial sector. The company assembles batteries in three plants in two countries, in Salo and Uusikaupunki in Finland and in Kirchardt in Germany. In addition, they have office locations in Helsinki, Turku, and Münich. The company offers their own modular battery platform products, system supply, and contract manufacturing. IONCOR employs around 1000 employees in two countries and has produced over 3 million batteries between 2019 and 2025 (IONCOR – Who we are 2025).

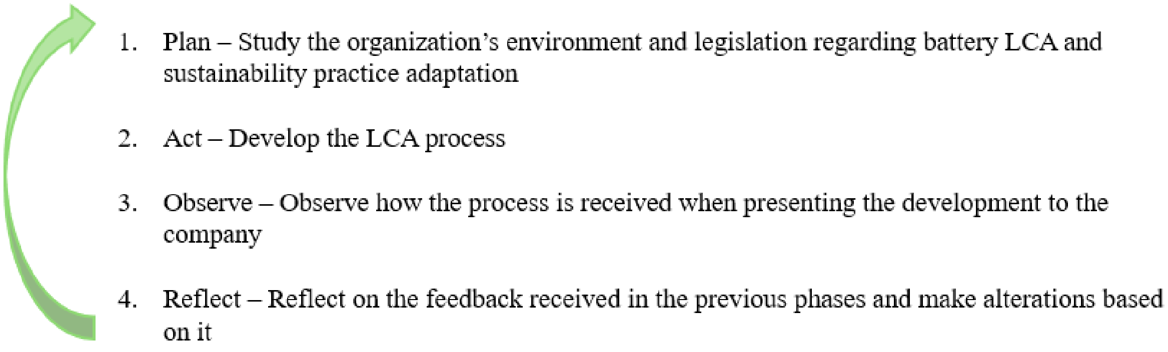
IONCOR's operations fall under the requirements of the EU battery regulation 2023/1542. For their own modular battery platform products, IONCOR must calculate the carbon footprint according to the EU requirements and fulfil the other requirements of the regulation as well. The company communicates that sustainability is a crucial mission in its operations. This makes studying the role of external institutional impacts in the company interesting.

4.2 Research approach

The chosen research method for a study should be relevant in answering the research questions defined for the study, making the research questions the dictating part for the method choice (Eriksson 2015, 27). The research objectives of this study, aim to develop a life cycle assessment process in a company, how it is to be adopted and adapted accordingly, and why the process is developed the way it is by studying external and internal factors affecting it. These objectives align with the qualitative action research method. Qualitative research approaches are concerned with interpretation and understanding of phenomena. Action research is deemed a suitable method, when research is related to describing an unfolding series of actions taking place in a certain group, or understanding the process of change, development or improvement of some actual problem. (Eriksson 2015, 193-194.) To be more exact, participatory action research is the method chosen for this research. It emphasizes the two aims of research: improvement of and finding solutions to a problem, and the involvement of the researcher in the activity. (Eriksson 2015, 195). It also ties with Lewin's view, that action research is something that the group under the study shall be offered the opportunity to participate in the research as well, to ensure more successful research (Burnes 2004, 984).

It is important to note that research is not conducted in a vacuum. Instead, it is placed in the real world, where research is under the influence of paradigms, telling researchers what is important, legitimate, and reasonable. At the end, that guides the researcher to an understanding of knowledge and how it is formed (Patton 2015, 89). This makes it valuable for a researcher to determine under which paradigm their study is conducted. This study follows the paradigm of pragmatism. Pragmatism focuses on seeking practical and useful answers that solve or provide direction to address real life problems. According to pragmatism, there is no objective truth, because all acts and their consequences are dependent on the situation they happen in (Morgan 2017, 26). The context dependency of action research does not create objective truths, therefore supporting the pragmatic view of knowledge creation.

The role of the researcher in action research can be described as a facilitator (Stringer & Aragón 2020, 24-25). It is reflected in this research, as the researcher will help identify and address the current situation regarding the LCA process and develop a plan of an LCA process to be implemented. She is actively facilitating the process development and motivating the groups in the organization to partake in the process development and eventually in the actual process. The basic action research model in Figure 9 acts as the spine of the research process.



1. Plan – Study the organization's environment and legislation regarding battery LCA and sustainability practice adaptation
2. Act – Develop the LCA process
3. Observe – Observe how the process is received when presenting the development to the company
4. Reflect – Reflect on the feedback received in the previous phases and make alterations based on it

Figure 9 The basic action research model with research specifications

Adapted from Costello (2011)

The model presents four phases in the action research process, plan, act, observe, and reflect. In the plan phase of this study, the researcher went through academic research on the topic of life cycle assessments and EU sustainability regulations related to the battery industry and sustainability. She also studied the current situation within the company to determine how the LCA process development shall be approached and unfreezing the current situation to allow space for the upcoming LCA process. The unfreezing was conducted by approaching persons relevant for the LCA and informing them of the upcoming regulatory requirements regarding it. She ensured that everyone understood that the process is new and under development, aiming to provide a safe environment for the participants to include the new LCA practice in their work and not feel humiliation or fear that they have done their work incorrectly in the past. In this phase she also familiarised herself with the internal drivers of sustainability and observed their presence in the company, and the opportunities to leverage them in later stages. She continued this observation across the period of data collection for this study.

Act phase consists of working towards the development of a LCA process together with the company and presenting the process to be tested. The act phase actions were based on the data acquired in the previous phase. Though it was not a linear move from the plan to action, but rather an iterative process, where the researcher was collecting information and developing the process simultaneously while receiving new information. In the act phase, she aimed to engage the participants of the LCA process in the development.

The observation happened by presenting the process to her team for approval to be used later by the company. Reflect phase consisted of hearing what works and what does not and then investigate how the process could be enhanced in the future. This part of process was iterative, like the previous ones, and observation and reflection happened simultaneously with other steps and each other.

The action research model is in line with the circular nature of research processes, especially qualitative research processes (Eriksson 2015, 31). The data collection of this research, which happened in all the phases described above, focused on understanding the needs for an LCA process to be implemented, as well as the external motivations and internal capabilities impacting practice adoption and implementation. The data collection methods are described in more detail in the following subchapter.

4.3 Data collection

Majority of the qualitative data used in this thesis were primary data collected within IONCOR. The researcher partook in product carbon footprint calculation work within the company, while also supported in ensuring compliance with other parts of the EU battery regulation 2023/1542. The data were collected based on the work of the researcher, and other employees of the company. Three interviews were held with persons outside of the company, working in companies which are part of the battery value chain. Collected forms of data are presented in Table 5.

Table 5 Data collection methods

Collected by the researcher	Form of data
Yes	Research diary
Yes	Meeting notes and recordings
Yes	Interviews with battery value chain partners

Primary data are in the form of a research diary, meeting notes and recordings, and interviews with battery value chain partners. These meetings and the notes taken in them have provided the researcher wider understanding of the starting situation at IONCOR, readiness for data collection both inside the company and in the value chain, and mapping for key persons for the process. Some secondary data inside the company was collected, but after data collection period ended, it did not offer insights that were not already collected by primary data.

Action research can be referred to as an inquiry with people, rather than research on people (Eriksson 2015, 165). This is reflected in the data collection of this research, where a large portion of the data has been collected by discussing with various people at IONCOR and then reflecting on those discussions, and the LCA development work conducted by the researcher, in her research diary.

In this research, the action research was conducted by the researcher contacting persons identified important in the adoption of the LCA process. These persons were either identified by the researcher, or other members of the sustainability team. Sometimes the people contacted also provided a follow-up contact relevant to another aspect for the LCA process. The researcher contacted these persons mainly via email, inviting them to a meeting to discuss adoption of an LCA process, this research, and their role in the upcoming process. The meetings were mainly 30-minute online meetings that were recorded with the consent of the participant. In total, around 15 persons participated in the research within IONCOR. The researcher introduced herself as an employee of

IONCOR, who is also conducting research simultaneously while working at IONCOR. This decision was made, as it was important for the company to collect information of the readiness for an LCA process adaptation. Practically it meant that the researcher held the necessary conversations within the company to determine its readiness for process implementations as an employee first, but when received the consent to use the conversations in this study, also acted as a researcher.

When introducing the topic of the research, the focus was on the LCA process development. This was chosen as the approach as it showed the practical use of the study for the persons involved, increasing the likelihood for them wishing to participate. The importance of adopting an LCA process was emphasized due to it being a regulatory requirement. The change management perspective was still included in the introduction of the topic, but as it was less practical for the participants, it was not the focus. For the change management data, explicit discussions were rarely held. Some conversations on the impacts of regulations were held, but largely they came up when discussing other topics for this study. For example, when discussing the logistics data collection and decreasing the emissions from logistics, the internal sustainability drivers rose up. The topics in the discussions with the participants largely focused on the LCA readiness and process development, and the regulatory impacts, as they were the most practical topics for the employees at IONCOR.

Majority of the meetings were specifically set up for discussions on LCA development. Often, in the meetings, the researcher was offered information on who to talk to next about the topic in question, forming connections between the various meetings. Sometimes, only one meeting with a person was held, but also with some people, multiple meetings were held in series to discuss the next steps to take with the topic. This was common when collecting data for LCA process development, as information of for example key persons came gradually and sometimes one person had to be contacted about more than one topic.

The entries to the research diary were often written right after these meetings including the researcher’s reflections of the meeting. Other entries were written after the researcher had worked independently on the topic. To separate the two roles of the researcher (researcher and an employee), she kept two separate diaries. The first research diary was used as data for this research, and the other was to document the thesis process on matters like theoretical framework development, and decisions on structure. The second diary is not used as data in the research but was used more as a tool for the researcher to stay on top of the research process.

Three external interviews were also conducted. They were held with people from other organizations within the battery value chain. The aim of the interviews was to get a better picture of the data collection readiness of companies working in the value chains of the battery industry. As the battery regulation demands primary data from some of these activities, the readiness of these actors plays a remarkable role in the execution of LCA data collection. Even though providing this information to a battery manufacturer within EU is mandatory for the supplier to provide their products or services within the EU, looking closer into the value chain's readiness was deemed valuable. This is due to the regulation being relatively new and not being entirely applied into practice at the time of this thesis. Table 6 presents the people interviewed:

Table 6 Interviewed companies

Interviewed	Company/position	Interview details
Interviewee A	Logistics company	Online interview
Interviewee B	Upstream metal component manufacturer	Online interview
Interviewee C	Battery industry specialist	Online interview

Choosing the interviewees was done based on the most important parts of the life cycle for the carbon footprint. Logistics company was chosen as transport is included in multiple life cycle stages (main product production, distribution, end-of-life). Metal components manufacturer was chosen due to the remarkable part of the battery mass being comprised of metal components, making them a large contributor to the carbon footprint. Thirdly, a battery industry specialist was interviewed regarding the end-of-life part of the life cycle, and the impacts of the battery regulation. There was an aim to interview a battery cell manufacturer, but it turned out to be not viable for this thesis, due to the sensitive nature of battery cell manufacturing. The interviews were semi structured. The questions presented in Appendix 1 were forwarded to the interviewees before the interview, to ensure they had time to prepare for the interview beforehand. The interviews were held via Microsoft Teams, as people interviewed were located across Finland. Time scheduled per interview was 30 minutes to 60 minutes.

After the data are collected, they are to be analysed, so conclusions can be drawn. The data analysis process of this study is described in in the following subchapter.

4.4 Data analysis

The data analysis in this thesis is done using qualitative content analysis. This approach was chosen, as it allows the systematic and objective analysis of data in various forms of text (Tuomi & Sarajärvi 2018). This is important, as the data collected in this study are in various forms of text, and using this approach allows the researcher to analyse all data with the same method. Qualitative content analysis organizes the information for it to be used to form conclusions. This often draws criticism towards the method, if the organized data itself is presented as the results, with no conclusions drawn from it (Tuomi & Sarajärvi 2018). This makes it important for the researcher to form their own conclusions based on the analysed data. The researcher actively ensured that the organized data in this study was used to form conclusions that are presented as the results, instead of the organized information, resulting in the findings chapter being organized based on the conclusions, not the identified themes.

Qualitative content analysis is done in this study by using an inductive data driven qualitative content analysis. The analysis can be separated into three steps: (1) reduction of data, (2) categorization of data, and (3) abstraction. (Tuomi & Sarajärvi 2018.) Using the data-driven approach allowed the researcher to analyse the data on LCA better, as it allowed for a more open analysis of the data compared to a theory driven qualitative content analysis.

The data analysis followed the process of the data driven analysis presented by Tuomi and Sarajärvi (2018). Figure 10 shows the process and focus of the analysis.

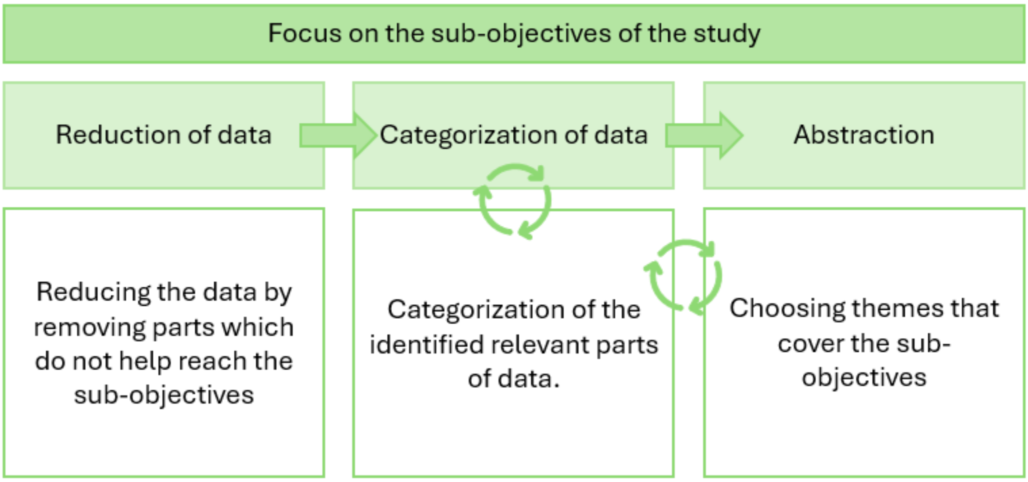


Figure 10 Structure of the data analysis

Author’s own creation

The analysis begins with transferring materials not yet in text form, referring to recorded meetings, are transcribed into text format. After all the data converted into text, they are read multiple times and most valuable parts of the data were highlighted and subsequently transferred to a separate document removing unnecessary information from the data. In the second phase, the highlighted and transferred data is categorized into categories, relating them to the sub-objectives of this study. Categories were then combined until they formed themes. This is the third step, abstraction. The language used in the data is formed into theoretical concepts and conclusions, but the route to the original data needs to still be visible (Tuomi & Sarajärvi 2018). Through the entire analysis process, the researcher focused on the sub-objective of the study. This was done to ensure all sub-objectives are covered, and also keeping the focus on the right topics, as the data collected covered also other topics, which are not as relevant for this study. When reducing the data, reductions happened based on whether the parts of data reduced contain important information important for reaching the sub-objectives of the study. If the content provided information related to any of the sub-objectives, it was kept in for the next steps of the analysis. In the categorization step, the sub-objectives guided the categorization, and the researcher focused on creating categories which cover all three sub-objectives. Categorization was not a liner process, but a rather iterative one. As the researcher analysed the data, the focus areas became clearer, specifying the focus points to certain topics, like data collection capabilities and difficulties, instead of focusing solely on difficulties. The categories were revisited multiple times to ensure their applicability. After categorization, the themes were formed with the focus on creating themes for each sub-objective. This step was not linear either, and some themes were changed and altered multiple times, even going back to re-categorizing them as well. For example, regarding LCA readiness, the topic was categorized and abstracted many times before settling with the final abstraction of three themes, internal development needs, sustainability and LCA knowledge, and data collection capabilities and difficulties. An example of analysing one simplified expression is presented in Table 7.

Table 7 Example of an analysis process for one simplified expression

Simplified expression	Categorization	Abstraction	Sub-objective
There seems to be a business case for sustainability, but it would require investing more resources.	Sustainability business case	Impacts of internal sustainability drivers	Ensure sustained change within an organization via examination of change management theories and the role of internal drivers in sustainability practice implementation in organizations.
	More resources needed	Internal development needs	Approach the life cycle assessment from a perspective of a battery solution company to form a process to calculate the battery carbon footprint.

The data was analysed in two phases. First, the data on LCA readiness in the company and in the value, chain was analysed. After analysing the readiness, the researcher continued the development of the process by incorporating the readiness information gathered and analysed in the first phase. The second phase consisted of analysing the rest of the data, including the development of the LCA process, assessing internal sustainability drivers and external regulatory impacts, and the suitability of Lewin's planned approach. After the data analysis, the researcher started to form findings based on the analysed data, presented in chapter 5.

After the first analysis phase, the results of the readiness were presented by the researcher to her team. This was done to engage the target group into the change process and create a more comprehensive understanding of the readiness, to begin the development of the LCA process internally.

The data analysis phases identified the following themes: internal development needs, sustainability and LCA knowledge, data collection capabilities and difficulties, regulations' negative impacts for sustainability practice adaptation, regulations and other stakeholders, purpose of sustainability regulations, sustainability as a competitive edge, and impacts of internal sustainability drivers. The justifications of these themes are presented in the following subchapters detailing the two phases of analysis.

4.4.1 First data analysis phase

The data analysed in the first phase included the interview data, and data collected inside the company on data collection readiness, including both data from meetings and research diary material.

Data-driven analysis in this research followed the guidance provided by Tuomi and Sarajärvi (2018). The researcher did the first steps of the analysis by transcribing the recorded interviews and meetings regarding the topic, familiarised herself with the material, simplified the expressions, and started to identify the similarities and most important parts of the interviews and meetings, by categorizing them. She also went through the categorised material multiple times, aiming to identify the themes based on the categories and simplified expressions. This was done by focusing on the topics most relevant in identifying the capabilities to perform LCA. For example, what data is being collected now, and what is not, to identify where development is required to perform an LCA in the company. Before abstraction, the researcher presented the categorized data to her supervisor and team member in the sustainability team, to receive feedback on the categorization. There were no major changes made based on this discussion.

After categorization of the data, the research started to abstract the data to form themes. As the analysis is data driven, there are no pre-determined themes from literature, and the abstraction happened by the researcher combining similar categories into themes, as guided by the process described by Tuomi and Sarajärvi (2018). The key themes identified in the analysis of LCA readiness are internal development needs, data collection difficulties and capabilities, and LCA knowledge. These themes were identified, as they cover the positive and negative readiness (data that is collected and data that is not being collected) including the level of LCA and sustainability knowledge in the company, and the required internal development to perform a successful LCA in the company.

After the analysis, the researcher went through the analysed information and moved to develop the proposed LCA process, which will be presented in chapter 5.1. After this, the second phase of the analysis was performed by the researcher.

4.4.2 Second data analysis phase

The second phase of data analysis was conducted via the same process of qualitative content analysis as the first analysis phase, excluding showing the categorized information to her team. This part of data analysis was conducted after the analysis of the LCA readiness data, as the analysis of that material impacted the focus of this analysis, due to readiness impacting the approach in developing the proposed process, which happened partially between the two analysis phases. The final proposed process was formed after all data was analysed. When analysing the data on this subject, the focus was on identifying possibilities to leverage internal drivers of sustainability in the adoption and adaptation of the LCA process, the role of regulations, and the assessing the fit of Lewin’s planned approach in the development and implementation of the LCA process.

The structure of this analysis followed closely the description in the beginning of chapter 4.5. The data was transcribed, simplified expressions formed, then categorized and abstracted. The themes that rose from this part of the analysis are delayed regulations, regulations and other stakeholders, purpose of sustainability regulations, and impacts of internal sustainability drivers. They were identified, as they showcase the various ways sustainability regulations affect businesses and decision makers, and combines the findings regarding the internal sustainability drivers. Impacts of internal sustainability drivers is a very high-level theme, but it was the most logical thematization of the internal drivers, as each driver has its own role and abstracting them into separate themes would not serve the purpose of the drivers in this thesis. Their impacts are described in more detail in chapter 5.3. The dimensions of sustainability regulations were abstracted into separate themes, which was due to the topics around sustainability regulations covering more than just the impacts of the implemented regulations.

4.5 Ethical considerations

Ethical principles govern all research activities, regardless of research method or paradigm. Research ethics shape the way research is conducted and reported, and it is in a crucial position in increasing the credibility of research. (Eriksson 2015, 63.) The key ethical obligations of a researcher are respect towards people involved and affected by the research, and do no harm (Kemmis et al. 2014, 159).

One of the most common ethical considerations in research ethics is the role of the researcher. Regarding the role of a researcher in action research, the role and the degree which they involve themselves in the organization studied in the research should be mutually agreed upon during the research process. (Eriksson 2015, 65, 166). This thesis is conducted as a commission to IONCOR Oy. The researcher is working part time in the company during the research period and a written agreement on it has been signed detailing for example the thesis topic, timeline, publication and confidentiality. The researcher is in an active role in the organization, and her work aims to understand the issue of life cycle assessment process development, how to develop a process applicable for the organization, and how to ensure the process is working. This role was agreed upon with the supervisor of the researcher within IONCOR Oy. This fits into one of the relationships between researcher and the participant described in Eriksson (2015, 65)

> "The researcher can actively participate in activities and enable changes to take place, perhaps also making changes, as facilitator, change agent or enabler. Those researched are collaborators in research".

In these kinds of researcher-participant relationships, the researcher does not only need to consider the contractual approach, a written agreement between the two parties, but also additional obligations. These obligations include guarding the anonymity of participants and create a trusting relationship that does not break during the research, as in long research periods, the researcher and participants can form stronger relationships than other methods of research, for example with single interviews (Schwandt 2015, 93; Eriksson 2015, 65). The research period of this study was multiple months, from September 2025 to February 2026, and the researcher collaborated with the participants on other work topics as well, as she worked in the company at the same time. This enhanced the relationship between the researcher and the participants, making trust even more important.

It is important to notice that when action research is conducted in the researcher's own organization, the role duality needs to be taken into consideration. Role duality refers to the multiple roles that a researcher has, when they are researching within their own organization and how they interact with the role of a researcher. (Coghlan 2019, 77; 80.) In the case of this study, the two roles of the researcher are researcher and an employee, a member of the sustainability team in the organisation. This dual role posed challenges to separate the researcher from the employee. This was especially important as the researcher used her observations and notes as data, which made keeping voluntary consent with the participants in the organization crucial. She tackled this issue with informing participants each time she was collecting data and mentioned that she is taking notes of the discussions she is participating in, separating the moments when she acted as a researcher on top of a sustainability team member.

Ensuring consent and voluntary participation are another critical ethical consideration in research (Eriksson 2015, 71). Every participant in this study was provided an informative description of the study, presented in Appendix 2, why the person is being asked to participate in the research, and emphasizing the voluntary nature of participation in the study. It was clearly informed that the researcher is conducting research for her master's thesis, but that the results are also to be applied within the organization in the form of a new process. She emphasized that even though the information is to be used in the company as well, participation in the research is voluntary, and the person can decide to give the researcher the information they need for their work, but to decline for it to be used in the research. This was done to ensure that every participant understood the purpose of the research, and that participation in the study is voluntary. Voluntary participation is especially important in situations where the research context can make the participants feel that they cannot withdraw from the study (Eriksson 2015, 71). As many of the participants in the study were employed by the commissioning company, there is a risk that some of the participants could feel that way. The researcher offered the participants an opportunity to ask further questions before giving or not giving their consent to participate in the study. She also offered them an opportunity to discuss the topic the researcher had in mind, and after the discussion decide whether they give their consent to use the information in the thesis. The researcher approached the participants by herself, or with a colleague on the same level in the organization, without the presence of supervisors. This was done to make it easier for participants to deny participation if they wish to do so.

Hand in hand with voluntary participation comes informed consent. It refers to research participants' right to know how they are being researched, the nature and purpose of the research, the risks and benefits of participation, and the right to withdraw at any point in time (Schwandt 2015, 156). To provide the participants with this information, every participant was provided with a description of the study, including research purpose and involved parties, research methods, research timeline, voluntary nature of participation, why they specifically were asked to participate in the research, data privacy and data management information, and the right to withdraw from the research later. Participants within IONCOR were forwarded the notice in Appendix 2, while participants outside IONCOR, were forwarded the notice in Appendix 3. This appendix is in Finnish, as the notice was forwarded in Finnish.

One other ethical consideration arising from conducting action research in researcher’s own organization is preunderstanding. It refers to people’s knowledge, insights, and experience before they begin their research project (Gummesson 2000, 57). As an insider in an organization, the researcher already has preunderstanding of organizational culture and structure. This is an advantage and a disadvantage at the same time. The researcher can for example talk with the people in the organization using the language familiar to them. This might make it more difficult to stand back and assess and critique the organization. The researcher should also realize that even though they might understand how their team or department works, they might not know how other parts of the organization function. This was taken into consideration in this study by discussing more freely with the participants, offering them a chance to show how their department or team functions and how the topics in question are handled. This was extremely important in collecting information for the LCA process development, as the participants will be the persons responsible for conducting the parts of the process designed. The researcher offered the participants a space to showcase how their teams and departments operate, instead of focusing on the ways her own team operates and trying to combine those ways.

To combat the challenges, the researcher focused on reflecting on her insights on her own preunderstandings, and different roles, while also ensuring that trust between her and the participants of the study remains. She also kept two different research diaries to help identify and understand her two roles: the researcher and the person working on the LCA topic. The first diary was used as part of data collection, and it includes her thoughts, inquiries, and reflections on the work within the organization. The other diary is more focused on the research process, theory discussions, and decision-making reflection.

AI has been used in this thesis in the transcription of recorded data material. The service used is transcribe.utu. The researcher listened the recorded interviews and manually corrected the transcriptions after transcribing them with the software. No other AI tools were used in this thesis.

4.6 Data evaluation

To evaluate the quality of this research, the criteria on ‘trustworthiness’ created by Guba (1981) are used. As this research relies on pragmatism, where the researcher and the participants create jointly understandings, this criterion is used in evaluating the quality of this research. The four criteria presented by Guba (1981, 79-80) are: (1) credibility, (2) transferability, (3) dependability, and (4) conformability.

Credibility refers to the evaluation of the truthfulness of the results presented, (Guba 1981, 79-80). The topic of the research and the industry with the study is conducted, were already familiar to the researcher, as she had worked at IONCOR before beginning with this research. This shows prolonged engagement at the site, aiming to minimize distortions in the research arising from participants wariness of the researcher’s presence (Guba 1981, 84). The name of the organization being publicly available also increases the credibility, as it shows that the organization is real and the information whether this study has been conducted in the organization can be checked. The researcher also collected and stored the data materials used in the research to make it possible to review them later. Credibility can be increased with transparency regarding research ethics, and this has been covered in extent in the previous chapter 4.5.

Transferability refers to evaluation of the results applicability to other contexts, similar to the context of the original research (Guba 1981, 81). By nature, action research is always tied to the specific context within which it has been conducted, limiting the transferability of this study. The results of a similar study conducted in another organization might produce results that are different to the ones presented in this research, but with high dependability, the study should be able to be repeated in another context.

Dependability refers to the repeatability of the study, meaning the researcher has to offer information to the readers that showcases the logical, traceable, and documented research process (Guba 1981, 80-81; Eriksson 2015, 307). The nature of action research makes the research process and its reporting not straightforward, as it is a very iterative process, interrupting the logical reporting flow (Eriksson 2015, 170). This is combatted by the systematic approach of action research presented in chapter 4.1. With the help of the action research’s systematic execution presented earlier in figure 9, the reporting has been conducted as logically as possible. Despite the systematic approach, it did not prevent the study from being iterative. The data analysis was conducted in the described manner of Tuomi and Sarajärvi (2018) on qualitative content analysis. The researcher reported the data analysis process in detail, showcasing how and why certain decisions were made, and themes identified in the analysis process. This increases the transparency of the process, making it more clear to the reader how the reported findings were discovered from the data. Appendix 1 also presents the interview questions used in the interviews, providing evidence on the basic structure of the interviews held.

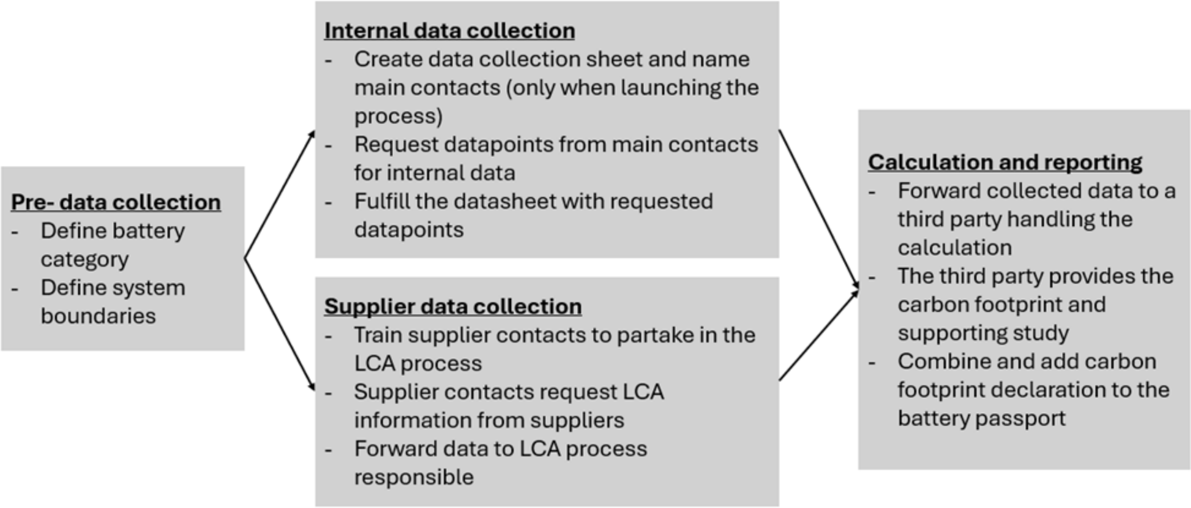
Confirmability ensures that the inquiries and results are real, not the imagination of the researcher, and the linkages between findings and interpretation is understood by the readers. (Guba 1981, 80-81; Eriksson 2015, 307). The academic research for this study is comprehensive and connects to the findings identified in the empirical study. The researcher also engaged in various reflective exercises when keeping her research diary and when analysing the data used. Detailed description of the data analysis process also increases the confirmability, as it provides linkages and support between the findings and their interpretation, by providing background for the findings. Appendices 2 and 3 showcase the information sent to participants, providing evidence that the participants, who have provided data for this study, have been aware of the purpose and aim of the study.

5 Empirical findings

This chapter consists of the presentation of the empirical findings of this study. This chapter is constructed to answer the sub-objectives of this study. First in chapters 5.1 and 5.2, the proposed model for an LCA process adapted for a battery manufacturer with a smaller variety of products and the readiness for the process implementation at IONCOR, answering to the sub-objective “Approach the life cycle assessment from a perspective of a battery solution company to form a process to calculate the battery carbon footprint”. After that, in chapter 5.3, the tools for successful process implementation in an organization are explored, covering the sub-objective “Ensure sustained change within an organization via examination of change management theories and the role of internal drivers in sustainability practice implementation in organizations”. Lastly, sub-objective “Assess the external institutional impacts of environmental regulations in sustainability practice implementation.” is explored in chapter 5.4.

5.1 Proposed LCA process for a battery manufacturer

Examining the regulatory requirements and guidance, and collecting empirical data at IONCOR, helped to develop a process for an LCA satisfying the regulatory requirements and internal capabilities. The proposed process for a battery LCA calculation conducted at a battery manufacturer is presented here in Figure 11.



Pre- data collection
- Define battery category
- Define system boundaries

Internal data collection
- Create data collection sheet and name main contacts (only when launching the process)
- Request datapoints from main contacts for internal data
- Fulfill the datasheet with requested datapoints

Supplier data collection
- Train supplier contacts to partake in the LCA process
- Supplier contacts request LCA information from suppliers
- Forward data to LCA process responsible

Calculation and reporting
- Forward collected data to a third party handling the calculation
- The third party provides the carbon footprint and supporting study
- Combine and add carbon footprint declaration to the battery passport

Figure 11 Proposed LCA process for a battery carbon footprint calculation

Author’s own creation

Based on the regulatory requirements, calculation rules created by the EU, and empirical data collected at IONCOR, the following process for an LCA calculation at a battery manufacturer is presented above. The process has four steps: pre-data collection, internal data collection, supplier data collection, and calculation and reporting. The first step, the pre-data collection, consists of defining the scope of the study by defining the battery category and system boundaries. The system boundaries are partially set by the calculation rules, presented in Figure 4 in chapter 2.4.2. In addition, a general cut-off of 1 % of battery mass is allowed, which is to be defined here in the pre-data collection phase. This is because the cut-offs impact the amount of data required from suppliers in the following data collection phase. Battery category also needs to be defined here, as it has impacts in the calculation process, as there are small differences between EV and industrial batteries, and between different kinds of industrial batteries.

After the scope is defined, comes data collection. Internal and supplier data collection can happen simultaneously, as collecting either of the datapoints before the other is not required. Internal data, which consists of data from the company's own production, and data for the supporting study shall be collected to a datasheet handled by the team responsible for the life cycle assessment, for example a sustainability team. The data collection sheet is developed by the team responsible of the process when a battery carbon footprint is calculated for the first time in the company. The data collection sheet must include all requirements defined in the calculation rules for EV batteries or industrial batteries, depending on the battery in question. Then the main contacts for each datapoint are also to be named during the first round of battery carbon footprint calculation. This means appointing persons with the access to required datapoints to deliver the data to the process responsible when requested. For example, energy consumption can be collected from a contact in maintenance, who has access to the software which holds the information. This is done due to one single team rarely having access to all required datapoints without assistance from other teams. The datasheet itself, where the required information is combined, is not forwarded to the contacts, only the datapoint request. This is done to minimize issues arising from sharing a single datasheet, like accidentally editing information another person has added previously, or creating multiple copies of the datasheet. Sharing only the data request also removes the need to train multiple people to edit the datasheet properly.

Supplier data is largely requested by direct sourcing department, as they are often the main contacts for the various suppliers of battery components. The logistics department might be relevant when requiring data from logistics partners; in cases they are the main contact to those partners. Data is requested by forwarding the suppliers the requirements for datasets, and requesting the suppliers to deliver the data, and required documentation to the battery manufacturer. A datasheet can be leveraged in supplier data collection as well, to provide a consistent way for suppliers to deliver a complete LCI. Crucial part in successfully collecting supplier data, is ensuring that people contacting the suppliers are well informed of the requirements and can answer questions suppliers might pose to them.

After collecting data both internally and from suppliers, it shall be forwarded for calculation. In the case of a battery manufacturer who is not producing large quantities of different products, the process proposes that the calculation part is outsourced to a third party. Outsourcing the calculation to a third party requires less resources, as the actual calculation process requires a software and accessing databases for secondary data, which both require money and human resources. For a company producing a smaller variety of batteries, outsourcing the calculation process is a relevant option and it is the suggested approach in this process. After the third party has calculated the carbon footprint and created the supporting study, the information is used to satisfy the labelling requirements of the EU battery regulation. According to the regulation, all EV and industrial batteries with capacity greater than 2 kWh shall be accompanied with a label indicating the carbon footprint and the carbon footprint performance class. The carbon footprint declaration is also to be included in the digital battery passport. (Regulation of the European Parliament and of the Council 2023/1542.)

5.2 Readiness to adopt the LCA process at IONCOR

This chapter examines the readiness at IONCOR and among value chain partners, to adopt the LCA process proposed above. This readiness analysis is specific to IONCOR, and readiness might be different in other battery manufacturers. The readiness a value chains is also limited, as interviewing cell manufacturers wasn’t viable.

IONCOR has a background in contract manufacturing and a limited background on designing and manufacturing its own products. Due to this, there is little to no previous experience on conducting LCAs within the company. Some individual employees have knowledge of LCA on a more general level, but not extensive knowledge on battery LCAs. One battery carbon footprint calculation has been performed previously as a consulting project few years ago, but the person responsible for that project no longer works in the company. This limited the available knowledge of that project and its success. The calculations in that project were not aligned with the currently published EU calculation rules as they were not available at the time.

The main two findings regarding readiness for data collection and LCA calculation at IONCOR and in the value chain are presented here in Table 8, in connection with the themes identified in the data analysis phase of this study.

Table 8 Main findings regarding LCA readiness

Themes	Findings	Overview of the findings
Internal development needs. Sustainability and LCA knowledge. Data collection capabilities and difficulties.	Internal data collection readiness is good regarding datapoints, but internal development is required for the entire LCA process to run smoothly.	Required internal datapoints are already being collected within the company. There aren't enough resources to perform the calculation part of a LCA. There is a need to develop a well-planned process to ensure smooth data collection for both internal datapoints and requesting suppliers for data. Knowledge of LCA and product carbon footprint varies within the company, levelling the knowledge is required for a smooth process implementation.
	Value chain data collection readiness is good in Finland; challenges arise when partners are located outside of Finland.	Finnish value chain partners have good capabilities to collect and provide required data. Difficulties are encountered when sub-contractors and non-Finnish partners are included in the transportation journeys for transport data. When importing and exporting products to and from Finland, foreign partners used and non-road transport are always used, which can lead to some data gaps. There are difficulties to get access to battery cell information, as the industry is highly secretive.

The readiness within IONCOR was conducted by attending meetings on the topic, discussing with various employees in the company, and via observations.

The first finding discusses the internal readiness at IONCOR. It suggests that the overall readiness at IONCOR and in the value chain is at a level which can satisfy the datapoint requirements for the LCA calculation. The required data is collected, and no new data collection methods are required but can be added to enhance the accuracy of the data collected. This is discussed more in the following paragraphs. Readiness for the data collection process itself, both internal and from value chain partners, requires some development. This means that there is no established process for data collection and not all relevant employees are aware of the requirements. This needs to be developed to ensure that all affected by the process, are aware of what is expected of them

According to the currently published rules for carbon footprint calculation for industrial batteries, the following data for company-specific datasets must be collected: material inputs that end up in the product (bill of materials (BOM)), energy production and consumption, auxiliary and any other material inputs required for the manufacturing process, transportation distances and means of components to the plant and of finished products to the customer, all elementary flows, and all material outputs (Andreasi Bassi et al. 2025, 30).

The BOM shall always be known before the LCA process can start, as it is used to define the cut-off rules. Due to this, the BOM is always present for the data collection phase. Energy consumption must be known for both electricity and heating. At IONCOR, both are known at plant level. This is an acceptable level of detail, as mass-based allocation can be used to determine the production line level energy consumption. Mass-based allocation is to be done by identifying the mass of the product in question from the entire produced mass of products in that plant. The electricity consumption data could be collected also per production line, to determine the consumption of electricity to produce the product in scope with more accuracy.

Water consumption, like energy consumption, is measured on plant level. In the battery assembly, no water is being used in the actual production in the plants. Water is being used in air moisture control and air conditioning. There is only one water meter in the plant, which includes the sanitary water used in the office spaces located in the same building. This makes separating the water consumption of the production from the consumption of offices in the same building nearly impossible. To enhance the data accuracy of water consumption, IONCOR could consider installing a separate water meter to the production side of the facility to collect water consumption linked to the actual production processes.

Chemicals and auxiliary materials used in production are tracked in the company per plant, but tracking per production line is going to be included in the upcoming years. Transportation data is received from logistics partners, as it is not possible to collect the required transportation data (transport distances and means) without input from the logistics partners. The company is receiving that data from the partners, but the level of information is dependent on the logistics partner.

Development is most required in how the collected datapoints are requested and delivered to be included in the calculation process. The data collection involves a variety of different functions within the company, making it important to ensure all these functions are up to the status of the process and minimize the risk of the data collection falling onto a single person's workload. This can be achieved by clearly defining the responsibilities of each participant. For example, naming the main contacts for each internally collected datapoint.

Regarding the data collected from suppliers, there is a similar need for development. Main contacts need to be named and a method of data delivering needs to be specified. How the data is delivered can be determined in the company for both internal and supplier data, the most important thing is to ensure every main contact is aware of their responsibilities. Also, comprehensive instructions can be created and forwarded to the suppliers, to minimize risk of not receiving data from suppliers due to low knowledge level of the topic at the supplier end.

Readiness in the value chain was researched by interviewing battery industry’s value chain partners on metal component production, logistics, and downstream, as well as discussing within the company regarding previous experiences with collecting sustainability data from various value chain partners. There was an attempt to gather information on the battery cells via interview, but the sensitive nature of cell manufacturing business lead into a situation in which this research was unable to gain contact with cell suppliers to gather information on their data readiness. There is a possibility that cell suppliers have the required data, as it is required if cell suppliers wish to sell their product within the EU. Various cell suppliers also provide general information on their websites regarding preparations for the battery passport demanded by the EU. This would suggest that cell suppliers are prepared or preparing to share carbon footprint data and it is assumed here in this study, that battery cell suppliers would be able to share required data to European customers, like IONCOR. But there was no opportunity to confirm this clearly with a cell supplier.

From suppliers, the battery manufacturer needs to receive either a full LCI of the processes for the component they are supplying or a company-specific dataset of the process, which refers to an LCA of that component. From logistics partners, the transportation means and distances are required. For the end-of-life, the transportation of waste batteries from the application to the treatment location, and recycling are included. Recycling is calculated with averages presented by the EU, unless the manufacturer has a company-specific recycling process at a commercial scale for the battery product in scope (Andreasi Bassi 2025, 38). The transportation of batteries from application to treatment is likely excluded from environmental impacts, as it is excluded in the draft delegated act for calculation of EV batteries carbon footprint, and in the calculation rules for industrial batteries, environmental impacts of pre-treatment of waste batteries is excluded (European Commission 2023; Andreasi Bassi 2025, 21).

The findings suggest that the readiness in the value chain is good in Finland, but more complex outside of Finland. For components, the required data readiness is good in Finnish companies. Interviewee B told that they have been engaging with product level carbon footprint calculations previously and they are prepared to provide required data for the battery carbon footprint calculation. Regarding component data, it is still important to recognize whether there has been any sub-contracting for the component, because the emissions of sub-contractors might not always be included. There are opportunities to collaborate with Finnish partners according to the previous experiences within IONCOR, compared to partners outside of Finland. This would suggest that even in cases where the partner would not be as prepared as interviewee B, there are opportunities to work together with suppliers to deliver the required information to a battery manufacturer.

For transportation data, transportation includes both the transport of components to the production site, and the distribution transportation from the production site to the customer. As mentioned earlier, a battery manufacturer does not collect transportation data themselves, but it is instead received from the logistics partners. The level of detail is dependent on the logistics partner. A Finnish logistics company (Interviewee A) was interviewed to research the readiness of logistics companies. According to them, the road transport part of transporting can be collected well by the logistics company themselves, including the actual weight and transportation means. The data is collected on shipment level.

The difficulties in transportation data collection arrive when sub-contractors are used, because they might not always have as developed data collection capabilities, and when other forms of transportations are used. Finland can be viewed as an island in logistics viewpoint, due to everything needing to be either transported via airplane or ship from abroad. This forces components to be transported with at least two different methods to each time they are being delivered from abroad. Interviewee A told that logistics companies can request the required data from their partners, but especially from partners located outside of Finland can pose some difficulties and not every partner can deliver everything. This means there can be some data gaps in transportation. As transportation data can be either primary or secondary data, these gaps are not critical, as those gaps can be covered with secondary datasets if needed. The rules for calculating the battery carbon footprint for either EV or industrial batteries do no forbid using primary and secondary data together.

In conclusion, there are not any identified major gaps in data readiness based on the analysis. There might be some gaps in the battery cell data readiness, but this research was unable to identify them. For the LCA process to run smoothly in the company, developments are required establishing the new responsibilities of main contacts for internal and supplier data. The next subchapter discusses the various tools which can be used in new sustainability practice implementation.

5.3 Tools to implement sustainability practices successfully

There are two major findings regarding successful implementation of a sustainability practice in an organization: 1) Sustainability drivers identified by Lozano (2015) are dependent on the existence of the other drivers, and 2) Implementation of Lewin's planned approach requires focussing separate change processes for different teams. Table 9 presents the findings regarding the implementation of the proposed LCA process.

Table 9 Findings regarding successful process implementation

Themes	Findings	Overview of the findings
Impacts of internal sustainability drivers. LCA and sustainability knowledge. internal development needs.	Sustainability drivers identified by Lozano (2015) are dependent on the existence of the other drivers.	Organizational culture is an underlying driver behind the other identified drivers. Sustainability champions help to decrease the resistance to sustainability work. Precautionary principle is used as a reasoning behind adopting new sustainability practices. To achieve proactive leadership, which positively impacts sustainability, it needs to be committed to sustainability work. Business case for sustainability is required to commit leadership into engaging with sustainability and minimize the negative impact of economic considerations. Demands from employees show that there is an expectation in the organization that it should engage in sustainability. Avoiding risk can exist without other drivers, but its positive impacts are limited.
	Implementation of Lewin's planned approach requires separate change processes for different teams.	For a change impacting the organization on a larger scale, but differently in various teams, the change process could be executed separately for the organization and with each team affected. For change required by regulations, ensuring choice might be difficult.

The sustainability drivers and their role in new sustainability practice implementation were studied. The major findings focus on the relationship between the drivers, and how they can be dependent on each other. Majority of the drivers act as positive drivers, but some were also identified to act as barriers. The drivers are not purely positive or negative, but instead their impact is determined by the existence/lack of other drivers. Next, the drivers and their relationships are described based on the research data.

Organizational culture is an underlying driver, as it allows sustainability work to happen in an organization. If the culture is not open to sustainability, resources would not be allocated to that work or new practice adoption. It enables the existence of the other sustainability drivers. For example, at IONCOR, the researcher's work in identifying the LCA data collection readiness was easy, as the organization was welcoming to the development of this process and the researcher was given the resources needed to conduct work for the LCA. Without positive atmosphere around new sustainability practice adoption, the development of the process would have been more difficult, and the other drivers might not have been there.

This organizational culture welcoming to sustainability can be enhanced with the help of sustainability champions and embedding the thought of precautionary principle. By creating more sustainability champions, the organization has more knowledge and capabilities to adopt new practices, as there are more employees working towards sustainability in various functions. At IONCOR, increasing the amount of sustainability champions is seen as valuable, as it creates more "sustainability specialists" across various departments, enhancing the thought that sustainability affects not only the employees officially working with the topic, but instead the whole organization.

Proactive leadership is identified as the most valuable driver to enhance sustainability work by Lozano (2015). This research identified that to create a more proactive leadership regarding sustainability, the leadership needs to be committed to sustainability work. One way to do this, is to provide a business case for sustainability. It is a keyway to create commitment, as economic considerations can be a remarkable barrier for sustainability practice implementation. Many sustainability actions might not get adopted, due to their monetary costs. For example, logistics can be decarbonized if transportation methods are switched from combustion engines to electric or switching the fuels to biodiesel. But, as this comes with increased logistics costs, it might not be considered as a viable opportunity without commitment from the leadership for decarbonization. This makes providing a viable business case for sustainability practice implementation a powerful tool to impact how sustainability work is seen in organizations.

Avoiding risk is another complex driver. It can drive adoption of new sustainability practices even in the absence of the business case. But then those sustainability practices are done to avoid risks, like non-compliance with regulations or damage to reputation, so they stay in the minimal requirements for sustainability. For example, ensuring compliance with the requirement to produce a battery carbon footprint, but then not leveraging the results to increase the sustainability of future product. Moral and ethical obligations were not present in the data collected in this study, so its relationship to other drivers was not examined.

To successfully adopt new sustainability practices covering more than the minimum requirements set by legislation, the organizational culture thus needs to be open towards sustainability. The organization should also have active sustainability champions across various departments and encourage new champions to emerge if none are present at the time. A business case for sustainability is also required to commit leadership to sustainability, as it enables proactive leadership, and motivations to do more than just avoid risks.

The second finding regarding successful implementation focused on the actual process of change. The Lewin's planned approach process by Burnes (2020) was examined in the context of the LCA process implementation at IONCOR. The research shows that some modifications to the approach can be done to ensure a process which requires different input from various teams to be implemented successfully. The modifications are presented in Figure 12.

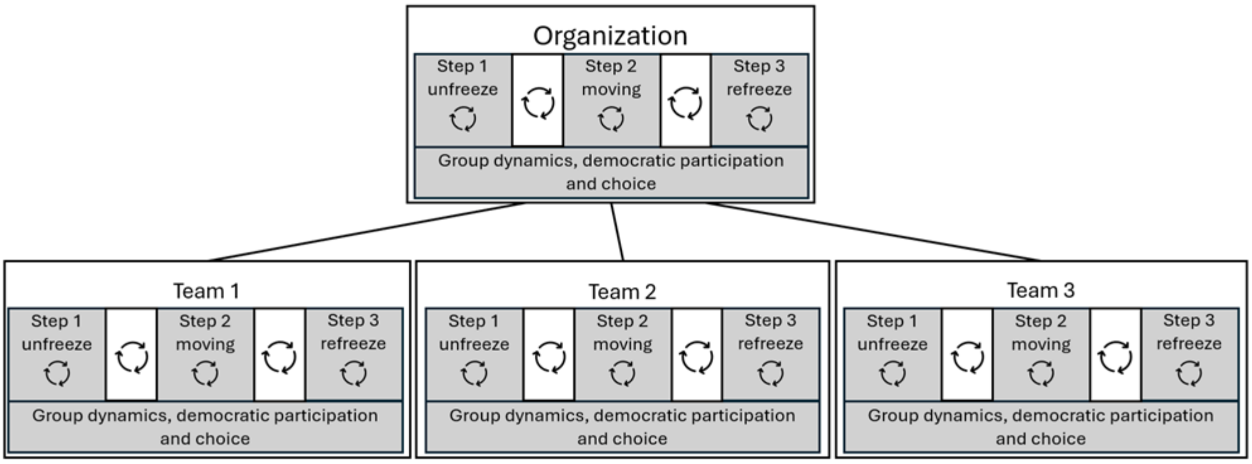


Figure 12 Proposed version of the planned approach
Adapted from Burnes (2020) with author's own edits

The modification suggested in this research is to go through the change process multiple times within the organization. The process is to be done in the entire organization, but also separately in the impacted teams. This is to ensure that the teams are aware of the requirements specific to their work, not just on a more general organizational level. For example, changes required from a sourcing team are different compared to changes required from the sustainability team. If these team specific changes do not get successfully implemented, the organization might not be able to successfully adopt new practices requiring inputs from various teams. In the case of the LCA process implementation, if supplier data is not collected correctly, the LCA process cannot be finished according to the requirements. Still, it is not enough to only inform of the affected teams, but the entire organization needs to be aware, as the new practice can have indirect impacts for other teams. For example, product development might not be required for the calculation process itself, but the results might impact their work as well, making it important for them to be aware that there is a new process.

The contents of the approach are not criticized in this study, but the role of choice might pose issues. This is due to the battery carbon footprint calculation being a regulatory requirement, leaving no room for a person to choose whether to participate in the process or not. It is kept in the model, as Burnes (2020) stated choice to be the voluntary participation aspect of action research.

In the case of LCA process implementation, separate change processes need to be conducted for those responsible of data collection and delivering data to the LCA process responsible. As the data collection is the most important part for the battery manufacturer, this is the step which requires most changes in the company.

5.4 Role of regulations in sustainability practice implementation

Based on the data analysis, the key findings of the impacts of regulations on sustainability practice implementation are the following: (1) sustainability regulations increase the validity of sustainability as an important business factor (2) sustainability regulations bring up the industry sustainability average, (3) EU regulations “force” EU companies to use sustainability as their competitive advantage, (4) impact of customer pressures is dependent on the industry in question, (5) uncertainty of EU sustainability regulation implementation questions the validity of the regulations and importance of sustainability, and (6) Delayed regulations is interfering with preparation for sustainability practice implementation. An overview of the findings is presented in Table 10.

Table 10 Main findings regarding regulatory impacts

Themes	Findings	Overview of the findings
Regulations’ negative impacts for sustainability practice adaptation.	Sustainability regulations increase the validity of sustainability as an important business factor.	Regulatory requirements have more power compared to specialists on the topic.
Regulations and other stakeholders. Sustainability as a competitive edge.	Sustainability regulations bring up the industry sustainability average.	EU sustainability regulations do not cover the most cutting-edge practices. The aim is to get industries on the same average level of sustainability.
	EU regulations “force” EU companies to use sustainability as their competitive advantage.	EU companies cannot use price competition against companies outside of the EU. EU sustainability compliance pushes companies to make sustainability a priority and a competitive edge, creating a business case for it.

Impact of customer pressures is dependent on the industry in question.	B2B businesses regulations often require more sustainability actions than customers require. In industries like automotive, the big industry players have often impacted the regulations to suit them.
Uncertainty of EU sustainability regulation implementation questions the validity of the regulations and importance of sustainability.	Regulatory uncertainty lowers the validity and credibility of EU sustainability regulations. Companies size down their sustainability teams when uncertainties arise among sustainability regulations.
Delayed regulations interfere with preparation for sustainability practice implementation.	When regulations' implementation delays without notice of when it will come out, preparing for it becomes more difficult.

The first four findings relate to EU's environmental regulations' role in sustainability practice adoption and environmental performance. The last two findings discuss the role of EU regulatory uncertainty in sustainability practice adoption in companies.

The first finding, sustainability regulations increase the validity of sustainability as an important business factor, showcases that regulations help to push the sustainability topics covered by the regulations. Often sustainability is not seen as a business-critical topic, until legislation covers that topic. Sustainability regulations are used as reasoning to adopt a sustainability practice in an organization by sustainability specialists. Without the push from regulations, some sustainability practices would likely not be adopted such widely among companies.

The second finding, sustainability regulations bring up the industry sustainability average, refers to how the expectations of companies' sustainability practices and contributions increase when the sustainability regulations cover a broader range of activities. A good example of this is the sustainability reporting, which is now an expectation that companies have an annual sustainability report, even though the Corporate Sustainability Reporting Directive (CSRD) demands complying reporting only from the largest companies in the EU. As discussed in the previous finding, without these regulatory requirements, they would likely not be adopted or expected to be adopted by the customers or society in such a wide scope. Together the regulations elevate the requirements and expectations of sustainability practices. Also, the regulations do not often cover the most cutting-edge sustainability practices, as the aim is to increase the sustainability average, not introduce most impactful sustainability practices.

The data also shows in the third finding that regulations alter the way companies use sustainability as a competitive edge. As companies within EU are unable to lower their prices to compete with non-EU companies due to legislation covering topics like environmental protection and labour rights, they might see competing with sustainability as a valuable option.

The fourth finding, impact of customer pressures is dependent on the industry in question, focuses on the relationship between customer pressure and regulations. The data shows that the industry within which a company operates influences the impact of regulations and customer pressures. In business to consumer industries, customer preferences and pressures regarding sustainability have more influence and companies need to satisfy customer preferences. In business to business, the customers do not hold sustainability as high of a priority as consumers often do. This makes regulations more impactful for business-to-business companies. Also, in industries like automotive, where large industry players have an outsized impact on the regulatory environment via lobbying, these customers can be impacting greatly the contents of the sustainability regulations, making their preferences already present in the regulations.

The last two findings, "uncertainty of EU sustainability regulation implementation questions the validity of the regulations and importance of sustainability" and "Delayed regulations interferes with preparation for sustainability practice implementation" suggest that there are issues within execution of these EU sustainability regulations. Changes in the regulatory requirements and timelines for adoption show companies that EU is not as reliable with its sustainability regulations, which questions the validity of these sustainability practices in the eyes of business leaders. It is also difficult for sustainability specialists and others working on the topic to ensure that they are complying with the requirements, when there is no certainty over what the requirements will be, and when they need to be implemented. When companies cannot be sure that the regulations are entering into force at a certain point of time in the way expected, they cannot prepare well, and risk of non-compliance can rise. If a company prepares for a regulation expecting it to enter into force as described initially, if changes are made, they risk losing resources by preparing for something that was not needed. But if they do not prepare at all due to uncertainty, when the regulations enter to force, they might be in a hurry to comply with it. In the next chapter, these findings are discussed further and connected to the theoretical frameworks of this study.

6 Discussion and contributions

6.1 Discussion

This study examined how a battery manufacturer can satisfy the requirements of the EU Battery Regulation 2023/1542 regarding the carbon footprint requirements and how the process proposed can be implemented successfully by examining the internal sustainability drivers identified by Lozano (2015) and Kurt Lewin's planned approach to change, presented by Burnes (2020). Also, the impacts of sustainability regulations in the adoption of new sustainability practices were examined, with the focus on identifying the impacts of environmental regulations, but also the impact of regulatory uncertainty. Based on the empirical findings, a simple process consisting of four steps, pre-data collection, data collection, calculation, and reporting was proposed. Relationships between the internal sustainability drivers by Lozano (2015) were identified, and their impacts for new sustainability practice implementation seems to be dependent on the existence of each other. Environmental regulations were identified to have both positive and negative impacts in the adoption of new sustainability practices. These findings are now combined with the theoretical frameworks discussed previously in this study

There is very little previous literature on the LCA process development for the battery industry, which could have guided the process development in this study. The majority of LCA research has focused on analysing the results of the LCAs, instead of focusing how it is conducted, as the ISO 14040/14044 method is so widely used. The methodology for the EU compliant battery carbon footprint is quite detailed for industrial batteries, in the CFB-IND by Andreasi Bassi et al. (2025). This leaves little to no adaptation possibilities to adapt the methodology itself, but how the process shall be conducted in organizations, is left for companies to determine. For example, how responsibilities shall be shared, how the data shall be forwarded and stored, and who will conduct the calculation itself. The proposed process in this study provides companies steps which to take to determine the carbon footprint of their batteries. The empirical findings suggested the use of a third party for the calculation of the carbon footprint, while the data collection is the largest part conducted by the battery manufacturer itself, guiding the focus of the process to that part. The data collection requirements are quite well determined, so those are not included in the proposed model, but instead the structure of the data collection is suggested, as it can be conducted multiple ways for both internal and supplier data. As the scope and system boundaries is also defined already for the industrial battery carbon footprint in the CFB-IND by Andreasi Bassi et al. (2025), the manufacturer does not need to determine that by themselves either, except for the cut-offs.

Regarding the adoption of the proposed model, the empirical findings point to two focus areas: data collection readiness, and receptiveness for a new sustainability practice. The manufacturer must collect all the required datapoints, and the people appointed responsibilities of the process, must be aware of their new responsibilities and understand the importance of the process. Using the carbon footprint any further than to ensure compliance with the EU Battery Regulation 2023/1542 is not required, however the carbon footprint can be leveraged in for example eco-design efforts, benchmarking, and other marketing and product development practices. The battery manufacturer might consider using the results in these or other ways to enhance other sustainability work in the organization.

In the adoption of an LCA process, internal sustainability drivers by Lozano (2015) can be used to ensure organizations' internal capabilities are leveraged for a successful implementation. Lozano (2015) identified nine drivers: proactive leadership, moral and ethical obligations, organizational culture, business case, precautionary principle, avoiding risk, sustainability champions, economic considerations, and demands from employees about the organization's sustainability efforts. The drivers were further studied by Lozano and Haartman (2018), examining their importance and categorizing them into three categories: economic, culture, and leadership. The empirical findings in this study show relationships between these drivers, further examining their impacts for sustainability. Eight out of the nine drivers were identified in the data collected in this study, the excluded driver being the moral and ethical obligations.

Organizational culture was determined to be an underlying driver enabling the existence of other drivers. This aligns with the previous literature on organizational green culture, which can change existing ways of thinking in an organization, and assist in transforming strategies into actions within an organization (Wang 2019, 667). Findings on sustainability champions and precautionary principle show that they can be leveraged due to organizational culture and they can be used to enhance the organizational culture to be more open to sustainability. The relationship between organizational culture and sustainability champions is supported by the notion that organizational green culture can enhance the experienced involvement to environmental issues for employees, increasing the likelihood of them becoming sustainability champions (Wang 2019, 667). Embedding the thought of precautionary principle on the other hand, can help guide the development of activities in the organization, as it forces the decision makers to consider the environmental impacts of the organization's activities before implementing them. Organizational green culture can leverage the use of precautionary principle, as organizational green culture can help management to allocate resources to environmental action (Wang 2019, 668). This ties to the role of proactive leadership in sustainability practice adaptation.

According to Lozano and Haartman (2018) proactive leadership is the most impactful internal driver for sustainability. The findings of this research also support the importance of proactive leadership for new sustainability practice adaptation. This study also identified that the leadership must be committed to sustainability, before proactive leadership can take place. One way this commitment can be achieved, is to provide a business case for sustainability. This is due to the findings suggesting that economic considerations regarding the costs of engaging with sustainability can prevent managers from adopting new sustainability practices. As Wang (2019, 668) points out, organizations without organizational green culture might have limited resources useable for sustainability, which leads to inability to invest into sustainability. This connects organizational culture again to another driver as an enabler. Business case in the findings was determined to be an important way to reduce the barrier arising from economic considerations. Unlike Lozano and Haartman identified (2018), economic considerations did not arise as a positive driver in the empirical data of this study. Economic considerations are deemed to be a barrier, rather than a driver, as engaging with new sustainability practices is seen to increase costs, instead of lowering them, contradicting the previous findings of Lozano and Haartman (2018). Though this is not unheard of. For example, in Álvarez Jaramillo et al. (2019) study, high initial capital costs of implementing sustainability practices was one of the most mentioned barriers for sustainability adaptation in small and medium size enterprises.

The last connected driver is demands from employees about the organization’s sustainability efforts. For employees to have demands for sustainability efforts, they would think that the organization should engage in sustainability, which might arise from an expectation based on previous engagement to sustainability, or the employees own expectations. If demands rise from previous engagement to sustainability, it would mean that the organization has previously been open to and already adopted some sustainability measures.

Avoiding risk is the last examined driver, but it was deemed to be more separate from the others, as it does not need the presence of organizational culture to drive for sustainability engagement. Avoiding risk can relate to avoiding negative consequences from non-compliance to legislation, or reputational risks, due to visible unsustainable practices. Avoiding risk does not encourage companies to engage any further sustainability actions than what is required to be compliant with regulations or avoid reputational risks.

Kurt Lewin’s planned approach was the second sustainability practice implementation tool examined in this research. It was studied using the revisited framework presented by Burnes (2020) and examining how it might be applicable for LCA practice adoption in a company. The findings suggest going through the process multiple times, using it separately to each affected team, and to the organization. The findings do not disagree with the contents of the planned approach, expect the role of “choice” is pondered. As the battery carbon footprint must be calculated, to comply with EU legislation, how “choice” can be ensured. Choice in the model refers to the voluntary participation in the action research, which is the method to approach the change process (Burnes 2020, 40). In the context of this study, the informed and voluntary consent was received from the participant of the study. But, when conducting this process in an organization, by the organization, to introduce a practice required by legislation, it might be difficult to ensure voluntary participation.

This leads the discussion into the impacts of regulations on sustainability practice adoption. Sustainability regulations can be seen to positively impact the sustainability development in companies, as they increase the validity of sustainability as a business factor, and bring up the industry average for sustainability. But sustainability regulations do not only bring positive impacts, they also negatively impact sustainability adoption. Uncertainty around regulations questions the validity and importance of sustainability, and delayed implementation interferes with preparation for compliance.

According to Zailani et al. (2012, 735), regulations and incentives have a positive impact on eco-design adaptation. Based on the empirical findings, this is true, when the practices are mainstream practices, as the EU regulations do not cover cutting edge sustainability practices.

The findings show that the industry within which a company operates influences the impact of regulations and customer pressures. In business-to-business industries, like the industrial and EV battery industry, the customers do not hold sustainability as high of a priority. This makes regulations more impactful for business-to-business companies. In industries like automotive, where large industry players have an outsized impact on the regulatory environment via lobbying, these customers can be impacting greatly the contents of the sustainability regulations, making their preferences already present in the regulations. This finding supports Zailani et al. (2012) finding on the relationship between customer pressure and regulations.

The second positive aspect of environmental regulations pointed out in this study is how environmental regulations help push sustainability topics they cover and increase the validity of sustainability as an important business factor. Companies might not adopt certain sustainability practices if they were not required by legislation, and regulatory coverage increases the viewed importance of the topic in the eyes of decision makers. This supports the Zailani et al. (2012) finding, that regulations and incentives positively impact eco-design.

EU regulations are mandatory to follow by companies operating within the EU. When companies wish to operate within the EU, they encounter a variety of regulations guiding how companies shall operate. For example, regarding the environment, treatment of workers, and reporting standards. Due to these regulations, companies within the EU are almost “forced” to make sustainability their competitive edge. Companies within the EU cannot compete in price competitions, as they are not able to exploit and underpay workers in their operations. As they are already forced to comply with a variety of sustainability regulations, making it a competitive edge and a priority can be seen as a reasonable option to differentiate the business from competitors coming from outside of the EU. This is an example of how environmental regulations impact the environmental performance of companies, as suggested by Zailani et al. (2012).

The negative impacts of environmental regulations rising in this study are linked to regulatory uncertainty and delayed regulations. When regulatory uncertainty around sustainability topics arise, companies are likely to size down their sustainability teams. This reflects that the company is less interested in investing in sustainability, as they employ less people focusing on those practices. This supports the findings of Rodriguez Lopez et al. (2017), that regulatory uncertainty prevents companies from investing into measures decreasing the GHG emissions. When the validity of sustainability goes down due to uncertainty, it has a clear impact in the ways companies are investing in sustainability practices. For the last few years, there has been push from the EU to bring out environmental regulations, but now they have started to take some of them back. For example, in November 2025, the EU ruled that the CSRD will only apply to companies with over 1750 employees and a net annual turnover of over 450 million euros and be much lighter in content than it was first introduced. Also, the due diligence obligations would only be applicable for non-EU companies and EU companies with more than 5000 employees and an annual net turnover of over 1,5 billion euros. (European Parliament 13.11.2025.) This shows that the EU can alter the environmental regulations even after they have been implemented, lowering their credibility.

This would suggest that regulatory uncertainty acts as a moderator between environmental regulations and environmental performance of a company in the model proposed by Zailani et al. (2012), presented in Figure 5. It weakens the relationship between regulations and incentives and environmental performance. In addition to regulatory uncertainty, delays in the implementation of regulatory requirements impact adoption of sustainability requirements. When companies are not certain of the timeline and specific requirements due to delays in the implementation of regulations, their capabilities to prepare are worse, and uncertainty increases. Regarding the battery regulation, there is no certain knowledge of when the carbon footprint declarations need to be finished, as the delegated acts are delayed and no information about when they will eventually come out, is not available. This puts companies in a difficult position, where they need to prepare for the requirements, but they are not entirely sure of the contents of the requirements, or when they need to be compliant with them.

6.2 Theoretical contribution

The main objective of this study was to develop a battery Life Cycle Assessment process for battery carbon footprint calculation, to support sustained organizational change to meet the needs of climate regulations. For successful implementation, internal sustainability drivers identified Lozano (2015) and Lozano and Haartman (2018) and Lewin's planned approach to change revisited by Burnes (2020) were examined. The purpose of examining these tools was to identify how they can be used in implementing a new sustainability practice. In addition, the impacts of EU environmental regulations were investigated with the viewpoint from Zailani et al. (2012) on regulations impact on eco-design and environmental performance, and Rodriguez Lopez et al. (2017) study on the impacts of regulatory uncertainty on adoption of sustainability practices.

A process for a battery life cycle assessment was proposed in the study. There has not been a similar process proposal in previous literature, as the requirements by EU for the battery carbon footprint are quite recent, and previous literature focuses on analysing the results of battery carbon footprints calculated with methods like the ISO14040/14044. This makes the proposed process new in the academic literature in the field of battery LCAs.

The results of the study support the identified drivers of Lozano and Haartman (2018). The results also add to the academic literature by presenting results of the relationships of the drivers, pointing out the interdependence of these drivers. The results show that organizational culture acts as a base for other drivers to exist. This contradicts the order of magnitude of the internal drivers, that Lozano and Haartman (2018) identified in their research. According to them, proactive leadership is the most influential driver, but the results of this study argue that the order of magnitude of the drivers might vary and be dependent of the other drivers. The findings of this study do support the existence of the identified drivers, but do question can they exist alone, or do they require co-existence of other drivers before they can be leveraged. As organizational culture is deemed to be the underlying driver enabling the existence of the other drivers, it can be argued that its' magnitude can be higher than what Lozano and Haartman (2018) originally identified. Similarly, the original magnitude of proactive leadership can be questioned. Lozano and Haartman (2018) identified it as the driver with highest magnitude, but this study shows that proactive leadership is not only dependent on the organizational culture, but also on commitment from leadership, which can require the presence of a business case for sustainability. This shows that proactive leadership is not an individual driver, but it rather depends on the existence of multiple other drivers.

Lewin's planned approach was examined in this study to see whether it can be used in the adoption of new sustainability practices. The results suggest that the approach might be beneficial to conduct separately with impacted teams, on top of together with the organization. The results show that the approach is a valuable tool in managing successful change within organizations. The role of choice was identified cause possible issues when implementing practices that are mandatory due to legal requirements. As some practices are required by legislation, choice can't be implemented as well as for practices which are not implemented due to regulatory requirements.

The findings in this study regarding the impacts of environmental regulations' impacts on sustainability practice adaptation support the framework of Zailani et al. (2012). Regulations positively impact the environmental performance of companies, by increasing the industry average and the validity of sustainability as a valuable business topic. The findings also support previous findings of Rodriguez Lopez et al. (2017) that regulatory uncertainty negatively impacts the willingness to invest into sustainability practices. In the discussions, the regulatory uncertainty is proposed to act as a moderator in the framework of Zailani et al. (2012).

6.3 Managerial contribution

As the EU Battery Regulation poses new requirements on the methodology for the LCA, it does not strictly follow previous LCA methods, like ISO 14040/14044 or EU PEF and PEFCR methods. This makes studying the possible process for the calculations valuable for specialists working on the topic. In addition, the closer examination of the internal sustainability drivers in situations of adopting new sustainability practices can guide the decision-makers to implement the processes more smoothly in their organizations. Studying the impacts of regulations in the context of sustainability practices can increase understanding on the purpose, aim, and the consequences of uncertain and delayed regulations on compliance preparation and the validity of sustainability in the eyes of decision-makers.

The proposed process in chapter 5.1. provides sustainability specialists in battery manufacturing companies a guideline on how to approach conducting a battery LCA. It is aimed for companies that do not produce large varieties of different products, but rather for companies with a couple of different products in the production line at the same time. It complements the methodological guidelines for calculation of battery carbon footprints, by focusing on which part of the process needs to be done, how, and when. It leaves room for adaptation, for example it does not guide what kind of a data collection sheet needs to be created, as different formats might serve different organizations better. This allows companies to adopt the process, but tailor it to fit their own organization, readiness, and capabilities.

This study also provides more tools to ensure successful implementation of new sustainability practices, by examining the internal sustainability drivers and revisited Lewin's planned approach. Decision makers can analyse whether certain drivers are present in their organization and aim to leverage them in the implementation process. They also might think of acquiring new drivers via the presented relationships between the examined drivers. The results might help managers to determine why certain drivers are not present in the organization and guide development to enable drivers that are deemed valuable to include in an organization. Managers can also leverage the revisited Lewin's planned approach, when implementing a practice impacting various teams/departments. The revisited approach offers a framework which focused on each affected team separately, providing more support and participation from the affected employees, enhancing their awareness and ownership of the process. This helps minimize the risk of the practice receiving a negative reception, as the persons affected have been participating in the change process.

Lastly, managers can also use the results on the impacts of regulatory requirements in determining the impacts of new environmental regulations on their companies' operations. This can proof useful in situations where new environmental regulations are introduced, and organizations need to identify their impacts on their operations. The findings guide to the categories of impacts from positive, new practices to negative ones, impacting the validity of sustainability in a negative way. The findings can help managers to be more ready to face the possible impacts and mitigate the negative ones if necessary.

6.4 Limitations and future research

This study was conducted as action research in a specific organizational context. That limits the generalization of the results, as they are dependent on the organization. The results found in this organization might not be applicable in other organizations. For example, the relationships of the internal sustainability drivers were identified in the context of IONCOR, and a wider examination could be beneficial to determine how commonly the relations between the drivers are present. This provides space for future research, where the topics researched in this study could be examined on a wider scope, including more than one organization in the study.

The readiness of cell suppliers was not determined in this research, due to the sensitive nature of the cell manufacturing. This could be a potential future research topic as well, as the cells form a remarkable part of the carbon footprint, as previous literature suggests. Also, the EU did not publish the final implementing acts for the calculation of carbon footprint for industrial or EV batteries, which means there might be some changes compared to the rules published at the moment of writing this thesis in Spring 2026.

During the research period of this study, no LCA were performed according to the methodological guidance and the proposed process. To determine how applicable the proposed process is, this should be tested in future research, to identify possible issues and opportunities for development.

Regarding the impacts of internal drivers, the results are based on the observations of the researcher within IONCOR. To further determine the relationships between the drivers, further research can be useful. Various organizations could be included, and other data collection methods, like interviews or quantitative methods, might provide better context to how the drivers impact each other in organizations.

7 Summary

The purpose of this study was to examine the EU Battery Regulation 2023/1542 requirements for a battery carbon footprint, study how environmental regulations impact sustainability practice adoption, and how to implement new sustainability practices successfully. The aim was to propose a process which battery manufacturers can leverage when calculating a battery carbon footprint and provide information of successful implementation tools and examine the impacts of environmental regulations.

First, an examination of the battery industry and its sustainability was conducted, after which the regulatory requirements for a battery carbon footprint from the EU Battery regulation 2023/1542 were described. This provided a background for the LCA process development to be developed on. To support a successful implementation, literature review of change management on regulatory impacts, internal sustainability drivers, and Lewin's planned approach to change were presented. This provided the thesis with academic background, to which to compare the results of the empirical study conducted in the commissioning company. The literature review showed that regulations can positively impact the environmental performance of a company, while regulatory uncertainty negatively impacts the adoption of new sustainability practices. It also provided internal sustainability drivers and a change process to examine for applicability in the context of this thesis.

The results of the empirical action research study provided a process guide for a battery carbon footprint calculation, and tools for successful implementation. The findings provided new insights to the existing literature as well. The findings of previous literature on the impacts of regulations were largely confirmed, with results showing positive impacts of environmental regulations on environmental performance and sustainability practice implementation, and negative impacts of regulatory uncertainty. The study also provided interesting additions to the internal sustainability drivers. Dependencies between the internal sustainability drivers were identified, providing new thoughts regarding the magnitude of each driver. Lastly, it is good to note that as this study was conducted as action research in a specific organization, further research is recommended to confirm the transferability of the results of the study.

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Appendices

Appendix 1 Questions of semi-structured interviews

Questions of the semi-structured interviews

- What is your current job description?
- How familiar are you with life cycle assessment?

Description of the EU Battery Regulation 2023/1542 data requirements for that specific value chain partner is given.

- Are you currently collecting suitable data?
    - If no, is it possible for you to collect this kind of data
    - If yes, are you able to share that data to be used in life cycle assessment calculations?
    - If partly yes, which kind of data is collectable, and which is not?
    - If no or partly yes, why are you not able to collect the data required?
    - In what format are you collecting this data?

Appendix 2 Notice and consent of this study for participants inside IONCOR

The following notice of the study was forwarded to the participants of this study inside IONCOR to ask for consent.

Notice of the study *Battery life cycle sustainability: a qualitative study on Life Cycle Assessment process development at IONCOR.*

Please let me know whether you wish to participate in the data collection via responding to this email. Participation is entirely voluntary.

I am now writing a master’s thesis at Turku School of Economics for my master's degree in international business, commissioned by IONCOR. The topic of the thesis is development of a life cycle assessment process at IONCOR. The objective of the study is to examine battery life cycle process development according to requirements of EU Battery Regulation 2023/1542. In addition, the study aims to investigate the impacts of EU regulation on businesses’ sustainability practices, and internal sustainability drivers.

The study is conducted as action research, which means I work in the commissioning company IONCOR. Action research consists or research diaries, meeting notes, the work conducted at IONCOR, and interviews.

For you, this means that with your consent, I will make notes/ record meetings on the topic. Each time before collecting data, I will inform the participants that I will use this opportunity to collect data for my study. At any point, you can withdraw your consent, even if you now give general consent to collect data.

Direct data will not be shown in the master’s thesis, including names or personal information. Possible recordings are transcribed and destroyed afterwards.

Data collection period lasts from September 2025 to April 2026 according to preliminary schedule. If the schedule changes, you will be informed.

You can access the privacy notice and data management plan via links provided, if you wish to examine them. **If you have any questions, I am happy to answer them.**

If you give your consent to data collection, please respond to this email. If you do not wish to participate, please let me know as soon as possible.

Appendix 3 Notice and consent of this study for participants outside of IONCOR

TIEDOTE TUTKIMUKSESTA

Tutkimuksen nimi

Battery life cycle sustainability: a qualitative study on life cycle assessment process development at IONCOR

Pyyntö osallistua tutkimukseen

Tutkimuksen tavoite:

Tutkimuksen tavoitteena on tutkia akkujen elinkariarviointiprosessin (life cycle assessment) kehittämistä EU:n Akkuasetuksen 2023/1542 antamien vaatimusten mukaiseksi. Lisäksi tutkimuksessa pyritään tutkimaan EU lainsäädännön vaikutuksia yrityksen toimintaan.

Keitä tutkimukseen kutsutaan mukaan ja miksi olette valikoituneet haastateltavaksi tähän tutkimukseen:

Tutkimus toteutetaan toimeksiantona IONCOR Oylle. Tutkimukseen kutsutaan IONCOR Oy:n työntekijöitä, sekä IONCOR Oy:n kanssa toimivien yritysten työntekijöitä.

Arvio tutkimukseen osallistuvista henkilöistä:

Tutkimukseen osallistuu noin 20 henkilöä IONCOR Oy:n sisältä, sekä tavoitteellisesti muutamia IONCOR Oyn ulkopuolisista henkilöitä

Osallistumisen vapaaehtoisuus

Tähän tutkimukseen osallistuminen on vapaaehtoista. Voitte kieltäytyä osallistumasta tutkimukseen tai peruuttaa suostumuksenne syytä ilmoittamatta, milloin tahansa tutkimuksen aikana ilman, että siitä aiheutuu Teille minkäänlaisia kielteisiä seuraamuksia. Jos päätätte peruuttaa suostumuksenne, peruutukseen mennessä jo kerättyä aineistoa käytetään tutkimustarkoitukseen anonymisoituna ja luottamuksellisesti.

Lukekaa rauhassa tämä tiedote. Jos Teillä on kysyttävää, voitte olla yhteydessä tutkijaan, jonka yhteystiedot löytyvät asiakirjan lopusta. Jos päätätte osallistua tutkimukseen, Teitä pyydetään allekirjoittamaan oheinen suostumus.

Tutkimuksen toteuttaja

Tämän tutkimuksen toteuttamisesta vastaa Turun yliopiston kauppakorkeakoulun kansainvälisen liiketoiminnan pääaineopiskelija Emmi Somero. Lisäksi tutkimus tehdään toimeksiantona IONCOR Oy:lle, mutta yritys ei kuitenkaan vastaa opinnäytetutkimuksen suorituksesta.

Tutkimuksen rekisterinpitäjä on Emmi Somero, joka vastaa tutkimuksen yhteydessä tapahtuvan henkilötietojen käsittelyn lainmukaisuudesta. Tieteellisessä tutkimuksessa henkilötietojen käsittely perustuu yliopistolaissa annettuun tehtävään ja sillä toteutetaan yleistä etua.

Tutkimusmenetelmä

Tutkimuksessa hyödynnetään toimintatutkimusta, eli tutkimuksen tekijä toteuttaa tutkimusta työskentelemällä toimintatutkimuksen kohdeyritykselle, eli tässä tilanteessa IONCOR Oylle.

Toimintatutkimus koostuu tutkimuspäiväkirjasta, tapaamismuistiinpanoista, IONCOR Oyssä toteutetusta työskentelystä, sekä haastatteluista.

Haastattelujen kesto on keskimäärin yksi tunti.

Haastattelujen tavoitteena on saada informaatiota IONCOR Oyn arvoketjuissa tapahtuvasta hiilidioksidipäästödatan keräämisestä ja vaatimustenmukaisuudesta EU:n Akkuasetuksen 2023/1542 kanssa. Haastattelu on puolistrukturoitu, eli haastattelijalla on kysymyksiä esiteltyyn aihepiiriin liittyen, mutta keskustelu ei ole sidottu pelkästään näihin kysymyksiin.

Haastateltavan luvalla, haastattelut äänitetään ja litteroidaan tekstiksi.

Tutkimuksesta mahdollisesti aiheutuvat haitat ja epämukavuudet

Haastattelun voi halutessaan keskeyttää milloin tahansa. Tarvittaessa, esimerkiksi haastattelun herättäessä ahdistusta, voitte ottaa yhteyttä esimerkiksi Mieli RY:hyn. Voitte myös pyytää haastattelijalta ohjausta tarvitsemanne avun piiriin.

Tietojen luottamuksellisuus ja tietosuoja

Tutkimuksessa henkilöllisyytenne on ainoastaan tutkijan tiedossa, ja tutkija on pro gradu-tutkielman tekijänä salassapitovelvollinen. Kaikkia Teistä kerättäviä tietoja käsitellään luottamuksellisesti, eikä tietojanne voida tunnistaa tutkimukseen liittyvistä tutkimustuloksista, selvityksistä tai julkaisuista.

Tutkimusrekisteriin tallennetaan vain tutkimuksen tarkoituksen kannalta välttämättömiä henkilötietoja. Tutkija ei anna teidän nimeänne tai yhteystietojanne ulkopuolisille. Tutkimustuloksissa ja muissa asiakirjoissa Teihin viitataan vain tunnistekoodilla, esimerkiksi nimikirjaimin tai pseudonyymillä. Rekisteriä säilytetään Turun yliopistossa, kunnes tutkimus on päättynyt. Rekisteritietoja ja tutkimustietoja säilytetään erikseen.

Jos päätätte peruuttaa suostumuksenne, peruuttamiseen mennessä kerättyä aineistoa käytetään tutkimuksessa anonymisoituna ja luottamuksellisesti.

Tutkimuksen kustannukset ja rahoitus

Tutkimukseen osallistuminen on Teille maksutonta. Tutkimuksesta ei makseta palkkiota, eikä tutkimukseen osallistumisesta aiheutuvia mahdollisia ansionmenetyksiä tai matkakustannuksia korvata.

Tutkimuksen rahoituksesta vastaa tutkija, sekä IONCOR Oy.

Lisätietoja

Jos Teillä on kysyttävää tutkimuksesta, voitte olla yhteydessä tutkijaan. Hänen kanssaan voitte keskustella kaikista tutkimuksen aikana mahdollisesti ilmenneistä kysymyksistä ja muista mieltänne askarruttavista asioista.

Yhteystiedot:

Emmi Somero, emmi.j.somero@utu.fi, 0443602177

SUOSTUMUS TOIMINTATUTKIMUKSEEN

Minua on pyydetty osallistumaan pro gradu-tutkimukseen ”Battery life cycle sustainability: a qualitative study on life cycle assessment process development at IONCOR”.

Olen perehtynyt tutkimustiedotteeseen ja saanut riittävästi tietoa tutkimuksesta ja sen yhteydessä suoritettavasta tietojen keräämisestä, käsittelystä ja luovuttamisesta.

Selvitykset antoi Emmi Somero.

Minulla on ollut riittävästi aikaa harkita tutkimukseen osallistumista.

Ymmärrän, että tähän tutkimukseen osallistuminen on vapaaehtoista. Minulla on oikeus, milloin tahansa tutkimuksen aikana ja syytä ilmoittamatta, keskeyttää tutkimukseen osallistuminen.

Suostumuksen peruuttamisesta ei aiheudu minulle kielteisiä seuraamuksia. Olen tietoinen siitä, että suostumuksen peruuttamiseen mennessä kerättyjä tietoja käytetään osana tutkimusaineistoa, anonymisoituna ja luottamuksellisesti. Ymmärrän, että minuun voidaan olla yhteydessä jatkotutkimusten osalta.

Vahvistan vapaaehtoisen suostumuksen haastateltavaksi osallistumalla tutkimukseen vastaamalla sähköpostiin, jonka yhteydessä tiedote ja suostumuslomake on lähetetty, sekä merkitsemällä alle suostumukseni.

Suostun osallistumaan tutkimukseen ☐

______________________________ ______________________________

Allekirjoitus *Päiväys*

____

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Email (suostumuksen tallentamista ja mahdollista myöhempää yhteydenottoa varten)

SUOSTUMUKSEN VASTAANOTTAJA

______________________________ ______________________________

______________________________ ______________________________

Emmi Somero *Päiväys*

Alkuperäinen allekirjoitettu asiakirja jää tutkimusryhmän arkistoon. Suostumusta osallistua tutkimukseen säilytetään tietoturvallisesti niin kauan kuin aineisto on tunnisteellisessa muodossa.

Kopio suostumuksesta lähetetään osallistujalle ensisijaisesti sähköpostite. Tarvittaessa myös osallistuja voi pyytää paperikopiota.