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Master thesis

From cell to system

The role of battery cell manufacturers as system builders in
the Norwegian Lithium-Ion Battery Technological Innovation System

Alv Øidvin

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TIK Centre for Technology, Innovation and Culture
Faculty of Social Sciences

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Abstract

The transition to a low-carbon society is becoming increasingly important in the face of climate change. Lithium-ion batteries are central to this transition, essential for electric vehicles, green maritime vessels, and energy storage solutions. In Norway, three battery cell manufacturers, Beyonder, FREYR, and Morrow, aims to establish Norway as leading battery nation with a complete domestic battery value chain. This thesis investigates how these manufacturers engage in activities to strengthen and grow this value chain in Norway.

The thesis employs the Technological Innovation System (TIS) framework with the sub-theme of system building. An embedded single-case study design is utilised. The data collection consists of semi-structured interviews and secondary data such as press releases, the companies' fiscal reports, and company websites. The study reveals that the manufacturers simultaneously take on multiple system building activities, both independently with partners and in intermediary organisations, based on their available resources.

The empirical insights contribute to the under-researched TIS sub-theme of system building and refines its transferability. Ultimately, this thesis provides a comprehensive analysis of the activities undertaken by Beyonder, FREYR, and Morrow to build a sustainable lithium-ion battery industry in Norway within the broader context of climate change and decarbonisation of the energy supply.

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For Stig

Alv Øidvin
Oslo - May 2023

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List of abbreviations

BCM	Battery cell manufacturer
BESS	Battery energy storage system
BEV	Battery electric vehicle
CQP	Customer qualification plant
CRM	Critical raw material
DRC	Democratic Republic of Congo
EU	European Union
EU-SA	European Union Strategic Autonomy
GHG	Greenhouse gases
GWh/year	Gigawatt-hours per year
ICE	Internal combustion enegine
IPCEI	Important Project of Common European Interest
IRA	Inflation Reduction Act
LFP	Lithium Iron Phosphate
LIB	Lithium-ion battery
LiC	Lithium-ion capacitor
LMO	Lithium Manganese Oxide
LNMO	Lithium Nickel Manganese Spinel
NCA	Lithium Nickel Cobalt Aluminium Oxide
NGO	Non-Governmental Organisation
NMC	Lithium Nickel Manganese Cobalt Oxide
O&G	Oil and gas
R&D	Research and development
RBV	The resource-based view
SDG	Sustainable Development Goals
TIS	Technological Innovation System
UiA	University of Agder
UiS	University of Stavanger
UN	United Nations
W/kg	Watts per kilogram
Wh/kg	Watt-hours per kilogram

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Coal and oil will soon be depleted. Uranium is too dangerous. Geothermal and tidal control is too expensive. I know all that!

M. The Man With the Golden Gun (1974).

1 Introduction

Global warming, environmental degradation, and resource scarcity are global pressing issues often referred to as grand challenges. As these challenges have immense and pressing consequences for the world at large, the Paris Agreement and the United Nations (UN) sustainable development goals (SDG) put forth a range of ambitious measures to mitigate the glooming consequences ahead (IEA 2021a; UN n.d.). One of these measures relates to the goal of reducing global warming to 1.5 degrees Celsius. Countries are therefore striving to achieve net-zero emissions by 2050, as the emission of greenhouse gases (GHG) is considered the main driver behind global warming (IEA 2021a). This requires transitioning away from carbon-intensive energy sources to renewables, with the world thus facing the pressing need for a sustainable energy transition (Smil 2010).

The widespread and rapid diffusion of sustainable technologies are considered crucial by scholars for accelerating the energy transition (Markard 2018; Markard, Geels, and Raven 2020; Markard, Raven, and Truffer 2012). This thesis is focused on the technological realm of batteries, and more precisely the dominating battery technology of lithium-ion batteries (LIB). LIBs have already seen a widespread diffusion in battery electric vehicles (BEV), but the market is expected to expand to larger vehicles, maritime vessels, and energy storage solutions for the energy grid (GBA and WEF 2019). As the transport and energy sectors accounts for a substantial proportion of GHG emissions, batteries are thus considered an essential technology in the renewable energy mix (IEA 2021a). However, the market for batteries has far from consolidated, and the battery technology for certain applications still retains a variating degree of novelty to them (Campagnol, Pfeiffer, and Tryggestad 2022).

The Asian continent with China in the forefront is currently dominating the market for LIBs which is largely attributed to their substantial investments across the LIB value chain (Bradsher and Forsythe 2021; COM(2022) 643 final). The LIB value chain steps are tightly interconnected, which makes competition tough (Lebedeva, Persio, and Boon-Brett 2016). The immensely growing global demand for batteries have thus instigated other regions to pursue a build-up of their own LIB value chains to reduce dependency on third countries, while simultaneously striving to technologically and structurally reduce the value chain's negative environmental footprint (NFD 2022a; COM(2022) 643 final). Norway is one of many countries with an ambition to establish themselves as a "green battery nation" with a holistic domestic

LIB value chain, as put forth by the Norwegian government in the country's recently released battery strategy (NFD 2022b).

The pivotal step in the value chain is the manufacturing of LIB *cells*[1], and is connecting the upstream and the downstream part of the LIB value chain. The establishment of a holistic domestic LIB value chain is thus dependent on having battery cell manufacturers present (BCM) (Campagnol, Pfeiffer, and Tryggestad 2022). Three Norwegian companies, Beyonder, FREYR and Morrow have either commenced or are aiming to commence the building of so-called gigafactories in Norway, where they will manufacture LIB cells at scale. These three BCMs make out the focal interest of this thesis. The reason for this is as follows: They are young companies entering the pivotal step in a yet-to-be realised LIB value chain in a market which is yet-to-be consolidated. As BCMs are dependent on the successful integration of the entire LIB value chain in which they are situated in (Campagnol, Pfeiffer, and Tryggestad 2022), it is therefore of interest to investigate how they strategically work towards making that happen.

I will address this topic of interest through the theoretical lens of sustainability transitions studies. Sustainability transitions studies is an interdisciplinary field, rooted in the broader realm of innovation studies that aims to understand the complex dynamics behind sustainability transitions and how emerging technologies can accelerate these transitions (Köhler et al. 2019; Markard, Geels, and Raven 2020; Smith, Voß, and Grin 2010). There is a range of theoretical frameworks which sustainability transition scholars apply in empirical studies (Markard, Raven, and Truffer 2012). The applied theoretical framework for this thesis, namely the Technological Innovation System (TIS) framework, take a system perspective on sustainability transitions and focuses on the system dynamics surrounding a focal technology (Bergek et al. 2008; Bergek et al. 2015; Markard, Raven, and Truffer 2012). A highly influential elaboration to the TIS framework (Markard, Raven, and Truffer 2012). The functions approach considers a set of system-wide functions and how these functions' dynamics either drive or hinder the overall TIS performance (Bergek et al. 2008; Hekkert et al. 2007). I therefore find the TIS framework and the functions approach suitable to apply in this context, as this allows for studying the BCMs as actors in a broader LIB system and how their actions influence the system (Bergek et al. 2008). Thus, I define the Norwegian Lithium-Ion Battery Technological Innovation System, which is henceforth referred to as the Norwegian LIB TIS.

[1] Simply put, this is where raw materials and components are made into a functioning battery *cell*, which goes into a larger battery *pack* or *module*. This is explained in more detail in chapter two.

Given the inherently systemic perspective of the TIS framework, certain theoretical contributions have been put forth by scholars to facilitate more delineated and targeted TIS research (Bergek 2019; Köhler et al. 2019). Consequently, the analytical framework of this thesis is founded upon the TIS sub-theme of system building. System building enables the analysis of the strategic and deliberate actions undertaken by TIS actors to create (and/or co-create) system-wide resources that enhance the overall performance of the TIS (Musiolik and Markard 2011; Musiolik et al. 2020).

1.1 Research questions

I investigate the selected case with an empirical qualitative study. With the applied theoretical lens, I aim to answer the following two research questions (RQ):

> ***RQ 1:*** *How and why do the Norwegian battery cell manufacturers initiate system building activities in the Norwegian LIB TIS?*
>
> ***RQ 2:*** *How do these activities influence the Norwegian LIB TIS functions?*

To answer the research questions, the overall research project is built on an embedded single-case study research design, which is suitable for research aiming to answer "how" and "why" questions (Yin 2018). The qualitative data collection is done with a triangulation comprised of in-depth semi-structured interviews and secondary data sources.

1.2 Aims and objectives of the thesis

The LIB value chain in China and Asia is well established and has undergone extensive empirical examination[2]. In contrast, limited scholarly attention has been directed towards the emergence of LIB value chains in other regions. This research gap is to be expected, however, given the nascent and evolving phase of development of non-Asiatic LIB value chains. In an effort to address this research gap, I empirically investigate how the strategic involvement of Beyonder, FREYR, and Morrow as key value chain actors influence the performance of the entire LIB value chain. Through this investigation, I envisage to provide empirical insights that can contribute to bridging the aforementioned research gap. Furthermore, I aim to offer a valuable knowledge contribution which can aid the global expansion of the LIB industry and consequently accelerate the energy transition. In accordance with the applied theoretical framework, I aim to provide implications for how policy interventions can facilitate this.

[2] Stephan et al. (2017) and Stephan, Anadon, and Hoffmann (2021) provide useful overviews of existing research.

With regard to the applied theoretical literature, the TIS framework has been widely employed in a diverse range of empirical contexts (Köhler et al. 2019). The framework has thus been extensively examined, scrutinised, and refined. Conversely, the exploration of the system building concept as a sub-theme within the TIS framework remains a nascent concept, with system building studies to date admitting to several limitations (Fischer et al. 2022; Kukk, Moors, and Hekkert 2015; Musiolik, Markard, and Hekkert 2012; Musiolik et al. 2020). These limitations will be discussed further in the theoretical literature review in Chapter three. I aim to explicate the concept by applying it to a different technological domain, with a distinct temporal and spatial context, diverging from the cases in existing system building research. In that regard, I aim to potentially refine the concept and enhance its transferability[3] namely by analysing the BCMs' system building activities in the Norwegian LIB TIS.

1.3 Structural composition of the thesis

This thesis is structured as follows: Chapter two contains a detailed review of the empirical context. Climate change and the energy transition as a driving force for batteries are discussed. The LIB technology and the LIB value chain is elaborated upon, as well as the market situation now and its future growth trajectories. The Chapter also contains an introduction to the three BCMs. In Chapter three, I do a literature review on the theoretical framework I apply in this thesis. The TIS framework and the functions approach are reviewed before I direct the focus on reviewing literature on the system building concept. Chapter four consists of two sections. First, I define the analytical framework for the thesis. Second, I present a contextual framework in accordance with the theoretical literature to establish the boundaries of the Norwegian LIB TIS and to add analytical clarity. Chapter five concerns the methodological choices I have made throughout the research project. Research design, data collection, and analytical strategy is detailed alongside reflections on ethics and methodological limitations. I then present the findings in Chapter six, where I systematically elaborate on identified system building activities. Then, I provide a conceptual analysis in accordance with the analytical framework in Chapter seven, where the identified system building activities are further scrutinised. The thesis then rounds off with a discussion and concluding remarks in Chapter eight. The contributions of this thesis are discussed, overall limitations, and suggestions for future research.

[3] See Chapter 4 Methodology

2 Contextual background

The purpose of this Chapter is to provide a thorough review of the empirical context the case is situated in. This is to provide the reader a better understanding of the analysis. The content of the chapter is built on the preliminary literature study I conducted initially in this research project. First, the broader context of climate change and the energy transition is presented. Second, I do a brief technological review of the LIB technology. Third, an overview of the current situation and future projections for the LIB value chain is laid out in three levels: globally, in Europe, and in Norway. The chapter rounds off with a presentation of the three BCMs of interest, followed by a short contextual summary.

2.1 The energy transition

In wake of the 2015 Paris Agreement, the international treaty on climate change, more and more countries are pleading to reach net-zero emissions by 2050 to mitigate the many immense consequences of global warming and reduce the rise in worldwide temperature to 1.5 degrees Celsius (IEA 2021a). Furthermore, the member states of the UN have adopted 17 sustainable development goals (SDGs) functioning as a "shared blueprint for peace and prosperity for people and the planet, now and into the future" (UN n.d.). A part of reaching these ambitious and important goals involves the move away from carbon intensive energy sources which emit greenhouse gases, to renewable energy sources such as hydropower, hydrogen, bioenergy, wind, and solar (IEA 2021a). This requires radical and sustainable changes in modes of production and consumption, a so-called sustainability transition (Markard, Raven, and Truffer 2012). The energy transition in particular requires "change in the composition (structure) of primary energy supply, the gradual shift from a specific pattern of energy provision to a new state of an energy system" (Smil 2010, vii).

Batteries are considered a critical enabler for achieving the energy transition and reaching the net-zero goal by 2050 (IEA 2021a). A report by the Global Battery Alliance and the World Economic Forum explains how (GBA and WEF 2019). The biggest opportunity lies in transportation, where batteries are critical in the move from internal combustion engines (ICE) vehicles to battery electric vehicles (BEV). A similar contribution can be made in the decarbonisation of maritime vessels and aircrafts. Additionally, batteries have the potential to store energy generated from renewable energy sources such as wind and solar, technologies which are challenged by their intermittency in energy production. This solution is called battery energy storage systems (BESS). BESSs are dispatchable and can be used to distribute electricity in the energy grid when wind and solar inputs are low, contributing to a more stable and "green grid". Moreover, BESSs can make it easier to achieve a decentralised energy grid and it might reduce the need for grid expansions. For example, buildings and industrial sites may store excess energy in BESSs and use it later when they need it. Furthermore, BESSs can be provided to areas where conventional energy supply is challenging or non-existent, thus having the potential to meet an array of SDGs by providing electricity to the 850 million people not having access to it today, among other things.

In sum, batteries have the potential to fundamentally contribute to transforming the transportation and energy sectors, which today accounts for around 75 per cent of GHG emissions (IEA 2021a). It is estimated that the successful integration and diffusion of batteries will enable a 30 per cent reduction of the total required GHG emissions in these sectors (GBA and WEF 2019). However, the battery value chain is facing several ~~sustainability~~ challenges related to its carbon footprint, resource scarcity and social issues. I will return to these issues in section 2.3. The battery technology itself must also move forward should the goals be reached. Thus, a brief technological review is presented below.

2.2 Technological review of the lithium-ion battery

The LIB has been established as the most dominant battery technology due to its wide applicability and several key compositional features that allows for high energy density and power density (Beard 2019). Energy density and power density is the two most often used concepts to measure a battery cell's performance (Linden, Reddy, and Beard 2019). Energy density is the energy (watt-hours) a battery cell can *store* per kilogram it weighs (Wh/kg). Power density is the power (watts) a battery cell can *generate* per kilogram it weighs (W/kg). To illustrate the difference, Minos (2023) draw a useful analogy to a draining pool: "Energy density is similar to the size of the pool, while power density is comparable to draining the pool as quickly as possible".

The origins of lithium-based batteries go all the way back to the 1960s, but it remained a novel technology until 1990, when Sony launched their production of LIB cells with a carbon based anode (Xie and Lu 2020). The LIB cell then quickly commercialised and diffused, and has over the span of the last 30 years tripled in effect and been applied in an array of applications (Beard 2019). The rapid diffusion of BEVs and the potential batteries have in other applications, has skyrocketed the demand for LIBs in the last years (GBA and WEF 2019). The current market situation and future trajectories are further elaborated upon in the next section. The remainder of this section explains the composition and electrochemical processes of a LIB cell. This is by no means an exhaustive technological walkthrough. I nevertheless find it sufficient to provide a coherent understanding in the context of this thesis.

The terms “battery” and “cell” are used interchangeably in literature referring to battery cells. To avoid confusion or ambiguity, it is therefore important to clarify that a *cell* is the basic electrochemical unit, while a *battery* can consist of one or many cells (Linden, Reddy, and Beard 2019). Furthermore, a battery as such is considered a finished product, whereas battery cells are stacked and enclosed in a battery *pack* (or case) together with a circuit board and other ancillary components. A LIB cell configuration can take on different shapes depending on intended application and required qualities (Beard 2019). The configuration can be either cylindrical, prismatic or pouch shaped (see Figure 1).

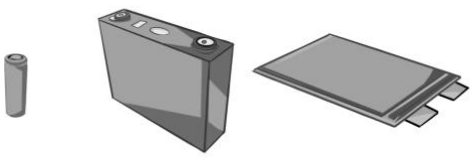

Figure 1. Different cell configurations (NFD 2022b, 34).

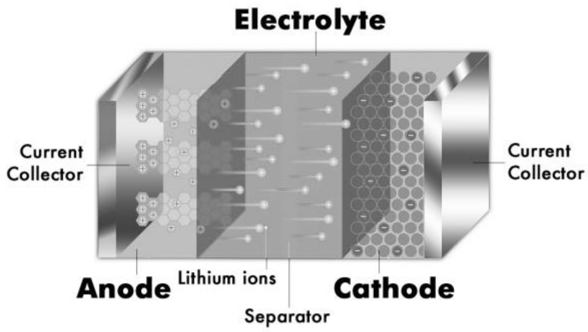

Figure 2. Lithium-ion cell (UL Research Institutes 2021)

The internal composition of the LIB cell is illustrated in Figure 2. Its three main components are the anode, the cathode, and the electrolyte (Linden, Reddy, and Beard 2019). The anode and cathode are the negative and positive electrodes, where the lithium is stored together with other materials. The electrolyte is most often a liquid, serving as an ionic conductor. This means that it allows for the lithium-ions to be transferred between the electrodes. The separator lets the lithium-ions through, while separating the electrodes from each other. The electrodes are connected to current collectors (or foils). When the battery cell is being charged or discharged, an electric current is carried between the battery and the energy source or application, respectively. When the battery cell is being charged, lithium-ions are released from the cathode and moves over to the anode. Simultaneously, electrons move opposite to the lithium-ions through the current collectors and further through the external circuit, thus creating an electrical current. The opposite takes place when the battery cell is discharging. It is this flow of electrons that helps to power the application (UL Research Institutes 2021). In other words, when the battery cell is cycled, that is charged and discharged, the lithium-ions “rocks” back and forth between the anode and cathode (Dahn and Ehrlich 2019, 757). Therefore, as an analogy, LIBs are often referred to as rocking chair batteries.

Beside lithium being an obvious ingredient in a LIB cell, several other raw materials also go into it. Depending on which lithium-ion based battery type is being manufactured, other raw materials typically include cobalt, nickel, manganese, aluminium, titan, graphitic carbon, copper and silicon (Dahn and Ehrlich 2019). Table 1 lists the most common LIB types on the market. Beside those, there are several promising technologies which will improve performance, which are yet to be commercialised. Examples include technologies replacing the liquid electrolyte with solid or semi-solid materials, and alternative electrode materials (Beard 2019). Furthermore, the Lithium Nickel Manganese Oxide (LNMO) battery is by many considered the next-generation LIB as it has a superior energy density and low material cost potential (Wu, Maier, and Yu 2020). However, LNMO still suffers with a poor life cycle, which must be overcome for it to commercialise and diffuse. There are also novel lithium-free technologies in development, but LIBs is expected to be the dominant battery technology well beyond 2030 (COM(2022) 643 final).

Table 1. The most common lithium-ion battery types

Abbr.	Description	Comment
NMC	Lithium Nickel Manganese Cobalt Oxide	Dominant in vehicles
LFP	Lithium Iron Phosphate	Dominant in BESSs
NCA	Lithium Nickel Cobalt Aluminium Oxide	
LMO	Lithium Manganese Oxide	

2.3 The lithium-ion battery value chain

The global LIB value chain is vast and complex. As the previous section illustrates, the LIB technology is a multi-component technology, and the material input is provided by a range of stakeholders across the globe (Stephan, Anadon, and Hoffmann 2021). A comprehensive review is therefore complex and furthermore inexpedient in the context of this thesis. Nevertheless, it is important to provide an overall understanding of the different steps of the value chain, the interrelatedness between them, and challenges therein. That is the purpose of this section. A common division of the LIB value chain is illustrated in Figure 3 (Lebedeva, Persio, and Boon-Brett 2016).

Figure 3. The lithium-ion battery value chain (Lebedeva, Persio, and Boon-Brett 2016)..

2.3.1 Upstream

The upstream part of the value chain consists of mining of raw materials, refining of the raw materials, and the making of them into active materials (components) for LIB cell production. The raw materials are extracted from the ground, usually in large industrial mines. A pressing issue here is the dependence on raw materials with scarce availability, so-called critical raw materials (CRM) (COM(2014) 297 final). The LIB cell ingredients cobalt, graphitic carbon and silicon are all listed as such (Lebedeva, Persio, and Boon-Brett 2016). The scarce availability can halt the diffusion of LIB applications and other low-carbon technologies as well, as the world shifts from a “fuel-intensive” to a “material-intensive” energy system (IEA 2021b, 28). Furthermore, the spatial natural occurrence of the raw materials adds complexities to the value chain. For example, The Democratic Republic of Congo (DRC) supplies 70% of the world’s cobalt (Pattisson and Firdaus 2021). Not only is the DRC close to having a monopoly on the supply of a CRM, the country has been accused of severe human rights violations of miners and other workers in the sector (Pattisson 2021). These issues drive the push for technologies replacing or reducing the need for CRMs in batteries[4].

2.3.2 Midstream (LIB cell manufacturing)

The midstream part of the value chain encompasses the activity Beyonder, FREYR and Morrow undertakes, namely manufacturing the LIB cell. This step is where the value chain begins to move away from process manufacturing to discrete manufacturing (NFD 2022a)[5]. Moreover, it is considered the pivotal part of the value chain, as it is estimated that it accounts for between 40-46 per cent of the value added by 2030 (Campagnol, Pfeiffer, and Tryggestad 2022; GBA and WEF 2019). Additionally, off all the steps in the value chain, battery cell manufacturing sees the highest amount of employment (GBA and WEF 2019). The key part this step has is also reflected in how turnover in the whole value chain is measured, which is done in terms of capacity of LIB cells made annually (NFD 2022a). This corresponds with the

[4] However, ethical dilemmas arise to whether withdrawing from countries like the DRC due to human rights violations is the best move. Some argue that it could cause even more social issues in the country, and thus argue that a better supervision of the lithium mining industry in the DRC should be strived for, as opposed to withdrawing entirely (Pattisson 2021).

[5] Manufacturing battery cells starts with advanced electrochemical processes, but during the many manufacturing steps it gradually moves towards discrete manufacturing, as individual units (cells) are the final output.

aforementioned energy density definition but aggregated and put in terms of gigawatt hours per year (GWh/year). Consequently, this is also how the capacity of an individual LIB cell factory is measured.

The conventional LIB cell manufacturing process is capital intensive, complex and consists of many labour- and energy intensive steps (NFD 2022a). This makes LIB cell manufacturing costly. Moreover, the intensive use of energy is problematic when the energy input is from high-carbon sources such as coal and natural gas, which is mostly the case in factories currently in operation. Furthermore, downstream actors have stringent qualification criteria for the batteries they use, so BCMs must often test and validate their product and technology in a pilot line. Pilot lines can reach NOK billions in cost, and BCMs usually have to carry the risk themselves.

2.3.3 Downstream

As described in the previous section, finished battery cells go into packs. A battery management system is put in, which allows for monitoring and controlling of the packs (also referred to as battery systems) (Lebedeva, Persio, and Boon-Brett 2016). As with individual cells, packs are tailored to the application they go into. Application is the next step, where the packs are put into either BEVs, BESSs, maritime vessels, and so on. After the pack reaches its end of life and is not considered waste, it is either repurposed or recycled. Repurposed means that, for example, a BEV battery pack can serve as a private BESS after its performance becomes unsatisfactory for the vehicle it was in originally. Recycling of batteries has become increasingly important factor in making the value chain sustainable, in part because of CRM reuse (GBA and WEF 2019). However, the current conventional process suffers from poor cost- and recycling efficiency[6] (Lebedeva, Persio, and Boon-Brett 2016).

2.4 Current situation and future projections

2.4.1 Globally

Today’s battery demand is focused on China, the EU and the United States., mainly driven by the sales of BEVs (Business Sweden 2023). The Chinese government has meticulously pushed to become the dominant country in the global market, enforcing a soft regulatory treatment and heavily subsidising the sector (Bradsher and Forsythe 2021). As of 2022, China controls 80 per cent of the world’s capacity in LIB raw material refining, 60 per cent of its cell production and

[6] Recycling efficiency is not a standardised term, but usually refers to the percentage of a raw material suitable for reuse when the recycling process is done (Lebedeva, Persio, and Boon-Brett 2016).

60 per cent of its active material manufacturing (COM(2022) 643 final). The Chinese company CATL alone controls around 30 per cent of the global market for EV batteries, much thanks to a strong focus on vertical integration[7] (Pattisson and Firdaus 2021). Furthermore, Chinese-owned companies control 70 per cent of the mining sector in the DRC, which is by many considered a driving force for the aforementioned human rights violations there (Pattisson 2021).

However, the Chinese dominance is due to many factors expected to decrease over the next decade. The most prominent factor is demand, which is forecasted to drastically grow both because of increased BEV market penetration and the diffusion of battery technology in the other aforementioned applications. Global projections varies depending on when the reports were made and the methodologies behind them (NFD 2022a), but one of the most recent reports on the matter estimates the global LIB cell capacity to pass seven GWh/year by 2030 (BMI 2022), compared to 282 GWh/year in 2020 (Business Sweden 2023). It is in other words a matter of massive upscaling of production, instigating a so-called "battery arms race" between countries and regions (Pattisson and Firdaus 2021). So, recent estimations indicate that China's market dominance will decrease to around 69 per cent by 2030, while Europe's is expected to reach around 15 per cent (BMI 2022). There are also other factors driving a spatial diversification of the market, which is suitable to illustrate in a European context.

2.4.2 Europe

In addition to being a signee of the Paris Agreement, the EU is actively taking measures to accelerate a European green transition through strategies and policies like the European Green Deal and the Fit-for-55 package. In relation to these, the EU is set to ban sales of ICE vehicles by 2035, making electric mobility Europe's main driver of demand for batteries (COM(2022) 643 final). The EU Strategic Action Plan on Batteries of 2019 thus puts forward an ambition of securing a mostly self-sufficient and sustainable European battery value chain, including efforts to improve recyclability (COM(2019) 176 final). Doing so is deemed crucial to prevent an irreversible material and technological dependence on third countries, and China in particular. This can in turn be tied to the EUs Strategic Autonomy initiative (EU-SA) (NFD 2022a), which aims to make Europe resilient on being dependent on third countries in general.

[7] Vertical integration: One company controls a number of steps along the value chain (Pattisson and Firdaus 2021).

EU-SA has gained momentum in recent years due to two important events (COM(2022) 643 final). First, value chain shocks caused by the COVID-19 pandemic disrupted supply from third countries and lead to a 15 per cent increase in LIB cell prices year-over-year in 2022[8]. Second, the geopolitical situation in wake of Russia's war on Ukraine made Europe cut its ties to Russian natural gas supply, intensifying the already ongoing European energy crisis. The "REPowerEU" plan was instigated as a direct response to the war, with the aim to increase Europe's energy independence, thus drastically accelerating the European energy transition (COM(2022) 230 final). This boosts the demand for grid-integrated BESSs, with an expected 80-160 GWh installed capacity by 2030 (COM(2022) 643 final).

Based on announced battery initiatives, Europe is currently underway to provide 69 per cent of its own demand by 2025, and 89 per cent by 2030 (COM(2022) 643 final). This means that Europe will still be dependent on imports from third countries, should not further initiatives be put in motion (EBA 2021). Some of the announced initiatives are Norwegian in origin, and the Norwegian government has further ambitions of making Norway a leading European battery nation across the value chain (NFD 2022b).

2.4.3 Norway

Norway's Battery Strategy was released in 2022 by the Norwegian government as a response to the context described above[9], and it states a vision for Norway to "*develop a complete and profitable battery value chain, stretching from sustainable mineral extraction to battery recycling. Norway will be an attractive host country for profitable activity along the entire battery value chain and attract major battery investments and gigafactories*" (NFD 2022b, 12).

The strategy is linked to the broader Green Industrial Initiative, where the ambition is to establish Norway as a leading nation in several sustainable industries boosting the energy transition[10] (NFD 2022c). This will include creation of new and attractive jobs, increased mainland investments, and a boost in exports. The Green Industrial Initiative highlights that Norway is in the forefront in Europe regarding access to land, infrastructure, renewable energy and expertise (NFD 2022c). Renewable energy is cheap compared to other countries, and

[8] This reversed the long-term trend of decreasing prices in the years before (COM(2022) 643 final).

[9] Norway is not an EU member but has close ties to the union through the European Economic Area agreement (EEA), energy market linkages, and various other political/trade links/agreements. Norway is therefore both directly and indirectly connected to the EU/European context laid out in this Chapter.

[10] Some of the other industries encompassed by the Green Industrial Initiative include offshore wind, hydrogen, and carbon capture storage (NFD 2022c).

projections estimate it to stay that way well into the future. There are already a number of companies extracting and refining raw materials for LIB cells in Norway, and they do so with almost 100 per cent renewable energy (NFD 2022a). When it comes to expertise, Norway has a long history with process industries, where the country has been paving the way for advanced automation. These strengths can drastically reduce costs across the battery value chain and potentially contribute to making Norway's GHG emissions from battery manufacturing Europe's lowest (NFD 2022a).

Norway has been a leading nation in the adoption of BEVs. It has the highest share in both car fleet and new car sales in the world, and is set to ban sales of new private ICE vehicles from 2025 (IEA 2022). This has already seen ripple effects with the emergence of Norwegian BEV-integration technologies and companies[11] (NFD 2022a). Moreover, the electrification of ferries across the coast of Norway has seen an accelerated technological development of battery solutions for maritime applications. This is much thanks to successful policy ambitions and combined industrial strengths concentrated in specialised clusters (Bugge, Andersen, and Steen 2022)[12]. Building on these strengths is also what the battery strategy underlines as important success factors (NFD 2022b). Furthermore, the strategy lay out ten action points for a sustainable industrialisation of the Norwegian battery value chain, see Table 2.

Table 2. '10 actions for sustainable [battery] industrialisation' (NFD 2022b, 11).

Action 1	Leadership in sustainability along the entire battery value chain.
Action 2	Promote Norway as an attractive host country for green investments.
Action 3	Enter into industrial partnerships with key countries.
Action 4	Provide capital, loans and guarantees that mobilise private capital.
Action 5	Improve access to relevant expertise.
Action 6	Pave the way for greater access to renewable power.
Action 7	Contribute to provision of suitable sites and other central infrastructure.
Action 8	Ensure predictable, efficient and coordinated public processes.
Action 9	Support pilot municipalities during the growth phase.
Action 10	Become a leader in tomorrow's battery solutions and leveraging the opportunities afforded by digital technologies.

[11] E.g., Stavanger houses three home charger manufacturers, including the European market leader Easee.
[12] It is important to clarify that these projects were heavily dependent on imports upstream.

Considering future projections for a Norwegian battery value chain, the Confederation of Norwegian Enterprise's (NHO) report "Green Electric Value Chains" estimates an annual turnover of NOK 90 billion by 2030 (Valstad et al. 2020). The report stresses that this surpasses comparable projections for offshore wind and hydrogen combined. By the same year other estimations point to a growth domestic product (GDP) growth of NOK 40 billion and 33.000 jobs across the value chain, based on a capacity of 200 GWh/year (Lund et al. 2022). By 2050, the potential annual turnover is estimated to be NOK 180 billion (Valstad et al. 2020). Not considering ripple effects, different reports estimate that Beyonder, FREYR and Morrow's planned initiatives alone will employ between 7000-8100 people when they reach full capacity (Aslesen, Vennerød, and Erraia 2022; NFD 2022a). The next section takes a closer look at these initiatives.

2.5 Beyonder, FREYR and Morrow

This section provides individual introductions to the three BCMs of interest. Each introduction briefly opens with an overview of financials and ownership. Then, the employed technology is put forth, before the company's production plans are described. It should be noted that each BCM does a variation of a pilot line, but they refer to it with different terms. For clarity, I use the term Customer qualification plant (CQP)[13] throughout and indicate with a footnote what the respective BCM calls it.

2.5.1 Beyonder

Beyonder was founded in 2016 and is based on the west coast of Norway, in the Stavanger region. Stavanger is often referred to as the energy capital of Norway, housing the lion's share of Norway's oil and gas (O&G) firms. The founders and many of the investors all have extensive experience from this sector. Østfold Energi, a Norwegian energy company, joined as owner and investor in 2019. Moreover, Innovation Norway granted the company with a NOK 100 million loan through the Green Growth Loan initiative, an initiative that aims to stimulate green technology development in Norway (Bergmann 2022). As of 2022, Beyonder has around 70 employees.

Beyonder is working on qualifying and commercialising their patented lithium-ion capacitor (LiC), which is a combination of a LIB cell and a capacitor[14]. The LiC can be cycled in two minutes, and it handles over 100.000 charging cycles (Valmot 2021). It thus offers much higher

[13] A pilot line where both the technology and production process are validated and tested for scalability.
[14] LIBs have high energy density, but limited power density. The opposite applies to capacitors (Sun et al. 2020).

power density and longer life cycle than traditional LIBs, while simultaneously being safer in the sense that it has reduced risk of thermal runaway (Beyonder n.d.-a; NFD 2022a). As such, Beyonder's LiC has the potential to meet market demands where the LIB comes to short, such as in heavy transport where time is short and charging needs to happen quickly (Valmot 2021). The longer life cycle also reduces the total cost of ownership, which is an important consideration in commercial applications. Finally, opting for a more sustainable raw material combination, the active material in the cathode is made from sawdust.

The company was the first to establish a battery production facility in Norway, at their innovation centre located in the industrial district of Forus. The innovation centre functions as a research and development (R&D) hub, where they also test and produce battery cells based on Beyonder's technology. They have recently expanded the innovation centre with a CQP[15], where they will further test and fine-tune battery cells for their partners and initial commercial customers (Beyonder n.d.-b).

Beyonder has ambitions to build a gigafactory at Haugaland Business Park in Tysvær municipality, a few miles north from their innovation centre and CQP. Haugaland Business Park has been in development for 20 years and is the largest zoned industrial area in Norway. It offers several favourable attributes for a battery cell gigafactory, with access to renewable energy sources, mainly from hydropower, and good access to sustainable cooling water (Haugaland Næringspark n.d.). The area also offers a carefully planned infrastructure with dark fiber, power, wate and sewage dimensioned for heavy industry, and a deepwater port[16] in close proximity. Lastly, it is situated in an already industrial region with an array of established industry actors.

As opposed to FREYR and Morrow, Beyonder has not announced any concrete number for the planned total annual capacity for its gigafactory (NFD 2022a). Furthermore, Beyonder aims to not own the factory itself, but rather invites investors to take ownership with Beyonder licensing them the technology (Størksen 2022). It should also be mentioned that Beyonder is exploring opportunities to build additional factories in other locations as well, including in India where prospects are in the working.

[15] Beyonder uses the term "scale-up factory".
[16] A deepwater port enables access to large and heavily loaded maritime vessels (e.g. container ships).

2.5.2 FREYR

FREYR was founded in 2018 and has grown rapidly since its inception. As of December 2022, approximately USD 1 billion in total capital has been raised (FREYR 2022a). EIT InnoEnergy[17], Innovation Norway and ENOVA[18] have granted the company EUR 7.25 million, NOK 39 million and NOK 142 million in funds, respectively. It was also listed on the New York Stock Exchange (NYSE) in 2021 after a high-value business combination with Alussa Energy Acquisition Corp. Its presence in the United States was further cemented with the implementation of the Inflation Reduction Act[19], where FREYR followed up with a plan to build a 34 GWh/year gigafactory in Gorgia. This will be done in parallel with the construction of its gigafactory in Norway (see below). 212 people are employed as of 2022.

In late 2020, FREYR signed a definitive License and Services Agreement with 24M Technologies (hereafter 24M) to manufacture FREYR battery cells based on 24Ms LIB technology (FREYR 2020). 24M is a company that sprung out from the laboratories at MIT Massachusetts Institute of Technology. Its patented LIB technology improves both the LIB cell as a product and the manufacturing process behind it. The 24M LIB cell uses a semi-solid electrolyte, which simply put reduces the volume and mass of the electrodes, while keeping the high energy-density characteristic of traditional LIBs (24M Technologies n.d.). This has several upsides (FREYR 2022a). First, it reduces the material consumption of raw materials such as copper and aluminium. Second, it makes the manufacturing process more environmentally friendly and cost-effective by reducing the number of steps in the process, some of which are energy- and emission intensive. Third, the 24M LIB cell composition allows for simpler and more effective recycling, where the raw materials are more easily separated compared to traditional LIB cells.

In April 2023, FREYR opened its CQP in Mo I Rana, Nordland County. At the QCP, FREYR will sample and validate the 24M manufacturing process, while testing new material combinations and other promising technologies. A successful validation of its core technology is critical for scalability and mass-production in FREYR's gigafactory.

FREYR's gigafactory, which started construction in 2022, is placed next to the QCP in Mo I Rana. The gigafactory will be able to have a 29 GWh/year capacity. Furthermore, it is expected

[17] EIT InnoEnergy is EU backed and provides funding to sustainable energy technologies (among other mandates).
[18] ENOVA is a Norwegian public sector organisation which grants funding to sustainability-inducing initiatives.
[19] The Inflation Reduction Act provides substantial tax exemptions and rebates for green energy production on U.S. grounds.

that the 24M technology will enable the gigafactory to reduce the capital spending per GWh of capacity by 50 per cent, and increase production per employee by 200 per cent compared to traditional LIB cell factories (FREYR 2022d). Mo I Rana, and more precisely Mo Industrial Park, offer FREYR's gigafactory many of the same advantages as Haugaland Business Park does for the one Beyonder has planned. Being one of the largest industrial hubs in Norway with around 108 companies, Mo Industrial Park gives FREYR access to a well-established infrastructure for distribution of energy and water (Mo Industripark n.d.). When it comes to logistics, a deepwater port is available on location. Furthermore, utilising the geographical location by taking advantage of the hydropower surplus in Nordland County, FREYR has signed a long-term agreement with Statkraft for the delivery of renewable energy to the QCP and gigafactory throughout 2031 (FREYR 2022c).

The fact that FREYR has already signed substantial offtake agreements with multiple downstream actors, highlights the critical work which lies ahead at their QCP. However, this also illustrates how far FREYR has come in such a short time compared to the other two BCMs. As of this writing, neither Beyonder nor Morrow have secured any binding offtake agreements.

2.5.3 Morrow

Although Morrow was formally founded in 2020, its roots trace further back in time. Two researchers from the Norwegian Institute for Energy Technology (IFE) and SINTEF started Graphene Batteries back in 2012, aiming to develop new cathode materials. The environmental non-governmental organisation (NGO) Bellona came in as an instigator and mobilised investors. In parallel, Agder Energi had prospected a potential battery cell venture. The different parties found a common ground and formed Morrow together. As of 2022, Morrow has raised NOK 2 billion in capital (Boone 2022). Agder Energi and Bellona both have shares in the company, alongside a Danish pension fund and others. The company has received a total of NOK 225 million from Innovation Norway through grants and the Green Growth Loan initiative (Bergmann 2022). Morrow employs 130 people as of January 2023.

In the initial years, Morrow will manufacture the dominant LIB cell technologies NMC and LFP for BEVs and BESSs, respectively (Morrow n.d.-b). Morrow refers to these battery cells as Generation One, and they offer reduced dependence on cobalt and nickel. While manufacturing Generation One, Morrow will work on sampling and validating its LMNO technology which will be the company's market differentiator in the long run, and consequently its Generation Two battery cells. Generation Two also consists of two products, namely the

LNMO-X and the LNMO-C battery cells. The former is aimed at heavy mobility and BESSs, with fast charging capabilities, and an energy density comparable to LFP battery cells. The latter is aimed at BEVs and offers high voltage while being cost-effective. Its energy density compares to NMC battery cells. Both products require 60 per cent less nickel compared to conventional NMC battery cells (Morrow 2023a), and will tackle the current life cycle challenges the LNMO technology is facing (Morrow n.d.-b).

Morrow's CQP[20] became operational in early 2023 and is temporarily located in South Korea where it will produce 2000 LFP cells monthly. In addition to sampling and validation, the QCP functions as a training facility for Morrows engineers and operators. (Morrow 2023b). The plan is to move the South Korea-based QCP to Norway in early 2024, in near proximity to the gigafactory.

Indeed, Morrow also has a gigafactory underway. The construction is divided into four phases and will have a 43 GWh/year capacity when all phases are planned done in 2028 (Morrow n.d.-a). The phase one factory will be operational in 2024. As with FREYR, Morrow is also pursuing a range of process innovations with partners to reduce energy consumption and emissions, and plan to be the leading actor globally when it comes to low emissions from its factory. Additionally, Morrow has secured access to renewable energy from hydropower through deals with Statnett and Agder Energi. These deals were enabled by placing the factory in Agder, the region with the highest energy surplus in Norway (Morrow 2021b). More precisely, the gigafactory is being built in Arendal in an industrial hub called the Eyde Cluster. The Eyde Cluster houses a range of material- and process industry companies and promotes sustainable development therein (Eyde-klyngen n.d.). Critical infrastructure is well established in the area, with autonomous heavy transportation to the deepwater port a few kilometres away being under development.

2.5.4 Spatial delineation

As the focal TIS in this thesis is the Norwegian LIB TIS, the BCMs' ventures abroad are not considered in the analysis unless they are explicitly interlinked to the companies' Norwegian presence, and ultimately the Norwegian LIB TIS as such.

[20] Morrow refers to the CQP as its Customer Qualification Line.

2.6 Summary and challenges ahead

While the future demand for LIBs is expected to drastically grow, and projections for value creation are promising, market success is far from certain. Challenges regarding technological viability and scalability must be overcome. Moreover, the LIB market has not yet consolidated and when it is, it is expected to do so with about ten to 15 BCMs globally (Campagnol, Pfeiffer, and Tryggestad 2022), making for tough competition. Furthermore, a "perfect storm" made up of the current geopolitical situation, value chain disruptions, the European energy crisis, and material scarcity adds another layer of complexity to the situation (Business Sweden 2023, 22). To overcome these challenges, BCMs should move rapidly to become a low-cost producer, recruit skilled workers, secure raw-materials supply, improve product sustainability and form partnerships with customers (Campagnol, Pfeiffer, and Tryggestad 2022). To support this, the government should focus on "maximizing value creation by enabling strong ecosystems, and taking steps to attract individual cell manufacturers" (5).

3 Theoretical background

In this Chapter, the theoretical background for the analytical framework I apply is provided. As the theoretical background is rooted in sustainability transitions studies (Markard, Raven, and Truffer 2012), the Chapter opens with a brief introduction to the field. Second, I define TIS as a concept, introduce its structural components, and elaborate on TIS processes, so-called functions. Assessing the functions and their patterns is useful for evaluating the overall TIS performance and its progress (Bergek et al. 2008). Third, the sub-theme of system building, and the role of system builders is presented. The system building concept considers the agency of TIS actors and their ability to strategically create system resources aimed at reducing deficiencies in TIS functions (Musiolik et al. 2020). It is a fitting sub-theme to build the analytical framework on, as it allows for specific focus on certain actors. This is in line with the research gap discussed in the thesis introduction.

3.1 Sustainability transitions studies

Transition studies is an interdisciplinary research field which is based on systems thinking. It also "emphasises the interrelatedness of social, technical, institutional and political changes, highlights path-dependency and lock-in, and points to the inevitability of conflicts among actors" (Markard 2018, 628). The focus on *sustainability* in transition studies emerged as a response to the grand challenges of society, such as global warming, environmental degradation, and resource scarcity (Köhler et al. 2019). Solving these challenges is of critical urgency if the world is to accomplish the SDGs and limit global warming to 1.5 degrees Celsius.

The ambition of this research field is thus to understand the multifaceted dynamics behind sustainability transitions and provide insights into how they can be accelerated (Köhler et al. 2019; Markard, Geels, and Raven 2020). Against this backdrop, sustainability transitions are defined as fundamental changes in socio-technical systems that "aim to address grand challenges in a way that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Markard, Geels, and Raven 2020, 1).

Having its cardinal roots in innovation studies (Smith, Voß, and Grin 2010), a prominent feature of transition studies is the emphasis on understanding the emergence of radical innovations, how they challenge- and are challenged by existing ways of doing, and how they subsequently lead to system transformations (Geels 2004; Markard, Geels, and Raven 2020). This allows for rigorous empirical contributions to "big-picture"-questions linked to the grand challenges of society (Köhler et al. 2019). As contextual factors can make transition pathways differ in different sectors and regions (Bergek et al. 2015; Markard 2018), transition studies scholars often focus on national or local levels, where the interaction between innovations and relevant actors can be coherently analysed (Markard, Geels, and Raven 2020). The dominant unit of analysis in transition studies is thus situated at the meso-level of socio-technical systems (Köhler et al. 2019; Geels 2004).

In order to understand the complex dynamics of sustainability transitions and to provide insights into how they can be accelerated, four prominent theoretical frameworks have emerged (Markard, Raven, and Truffer 2012). They are the Multi-Level Perspective, Strategic Niche Management, Transition Management, and the Technological Innovation System (TIS) framework. They all take a system perspective, but which one to apply in an analysis depends on the research question and scope. It is also important to consider the variety of elaborations and sub-themes the frameworks have received (Köhler et al. 2019). As I want to understand how battery cell manufacturers engage in building up the Norwegian battery value chain, I find the TIS framework with the applied sub-theme of system building suitable.

3.2 Technological Innovation Systems and the functions approach

The TIS framework has its roots in the Technological Systems framework (Carlsson and Stankiewicz 1991), which was developed as a response to the call by Swedish policy makers to "build a better foundation for technology policy" (Carlsson, Elg, and Jacobsson 2010, 146). Through a range of contributions and elaborations, contemporary research utilising the TIS framework focus on how new technologies play an essential role in sustainable transitions of socio-technical systems (Markard, Raven, and Truffer 2012).

TIS scholars (and innovation scholars in general) largely consider the market failure approach from neoclassical economics too narrow and not sufficient enough to cover all the aspects of the dynamic and evolutionary nature of technological innovations, and the systemic nature of innovation processes (Bergek et al. 2008; Edquist 2005; Markard, Raven, and Truffer 2012). Innovation happens more often than not through collaboration and interdependence between different types of actors (Fagerberg 2005), which dynamic and ability to progress is shaped by surrounding rules, regulations, norms and routines (Edquist 2005). The idea is then that innovations emerge in such a "system of innovation" (Edquist 2005, 182). Therefore, the TIS framework takes a broader *system* failure approach, which allows for the identification of systemic weaknesses that hinder the progression of the TIS, and consequently the progression and diffusion of its overarching technology (Bergek et al. 2008; Weber and Rohracher 2012).

It is thus an analytical tool which aims to inform policy makers by identifying systemic drivers and barriers for technological innovation (Jacobsson and Bergek 2004).

Hence, a TIS can be defined as a set of actors, networks and institutions that "jointly interact in a specific technological field and contribute to the generation, diffusion and utilisation of variants of a new technology and/or a new product" (Markard and Truffer 2008, 611; Carlsson and Stankiewicz 1991). The "new technology and/or a new product" is referred to as the *focal technology* in this thesis (Bergek et al. 2015). Actors, institutions and networks make out the structural components of a TIS (Bergek et al. 2008). Actors refer to both private and public entities. They can be profit or non-profit firms and organisations, universities, R&D institutes, governmental bodies, and financial establishments. Networks, either formal or informal in nature, can be industry alliances, interest groups, consortiums, and public-private partnerships (often R&D oriented). Institutions are the aforementioned formal laws, rules, and regulations, as well as informal cultures, norms, and routines linked to the TIS (Bergek et al. 2008).

TIS research largely focused on revealing structural weaknesses in its earlier days, with a limited focus on how key system processes drive or hinder a TISs progression (Bergek et al. 2008). The significance of these processes has since been recognised and conceptualised as *functions*, which aims to set the focus to what is actually achieved in the system (Bergek et al. 2008; Hekkert et al. 2007). The so-called functions approach has been described as the most influential refinement to the TIS framework. (Markard, Raven, and Truffer 2012).

The functions perform in symbiosis, with the current functional dynamic being shaped by both inducement mechanisms and blocking mechanisms (Bergek et al. 2008). Inducement mechanisms refer to factors that encourage the development of a TIS, while blocking mechanisms refer to factors that hinder its development. Mapping these linkages help specify key policy issues, as in how policy interventions can strengthen the former and reduce the latter. Such policy interventions can in turn shape the functional pattern in a desirable direction. Thus, the functions approach strengthens the system failure aspect of the TIS framework (Bergek et al. 2008). The six most applied functions [F] are summarised below. The summaries are based on Bergek et al. (2008) and Bergek (2019).

[F1] *Knowledge development and diffusion*: This function focuses on the knowledge base of the system and its evolution over time. It involves different types of knowledge, such as scientific, technological, production, market, logistics, and design knowledge, which are developed through R&D activities and adaptation of existing knowledge external to the TIS. The knowledge base is distributed between system actors, with new knowledge combinations emerging as a result.

[F2] *Entrepreneurial experimentation*: Entrepreneurial experimentation is a way to navigate the high uncertainty which is present throughout most of a TIS's life cycle. It is a social learning process, where some will succeed, and others will fail. As this function refers to acting under high uncertainty, entrepreneurial experimentation can be done by all system actors, not start-ups and small firms exclusively.

[F3] *Market formation*: A TIS may lack developed markets due to high uncertainty. Market formation typically goes through three phases: nursing, bridging, and mass markets, with distinct features and sizes. This function requires analysis of both actual market development and the factors that drive or hinder market formation. This is however a complex function, and the TIS literature have not provided a thorough understanding of its underlying processes.

[F4] *Influence on the direction of search*: This function is twofold and refers to the supply-side actors in the TIS. It encompasses both the inducing incentives and pressures for firms and organisations to *enter* the system, as well as the search processes *within* the TIS. These mechanisms are the outcome of various elements, such as shared visions, beliefs in growth potential, enabling and/or restricting policies, and changes in the landscape.

[F5] *Resource mobilisation*: This function involves the ability to accumulate resources necessary for innovation to happen, which is crucial in the TIS formation phase. Financial resources have been the primary focus for scholars hitherto. However, the function also encompasses, among other resources, complementary assets such as infrastructure and test facilities, and human resources such as university education, vocational education, and practice-oriented training programmes.

[F6] *Legitimation:* Legitimation enables the new technology and its proponents to gain social acceptance and compliance from relevant stakeholders. The legitimation process requires conscious actions from firms and individuals, applying strategies like manipulation (changes in institutions), conformance (adapt to institutions), and creation (develop new institutions). Legitimacy in this context concerns both *what* is legitimated and by *whom*.

3.3 System building and the role of system builders

The TIS framework have been criticised for its lack of attention on the influence of agency on functional performance (Markard and Truffer 2008; Musiolik and Markard 2011). System building is considered a critical contribution as it addresses this issue. This is because system building aims to explain how actors are able to strategically shape and influence system resources (incl. functions) (Musiolik and Markard 2011), which has previously been conceptualised as a rather emergent and uncoordinated process (Bergek et al. 2008).

A seventh function, development of positive externalities [F7], is a suitable case in point. This function refers to "the creation of system-level resources, which are available also to system actors that did not contribute to building them up" (Bergek 2019, 215). These system-level resources were early on considered as mere aftereffects of new entries to the TIS. It was thought that new entries instigated a sort of self-fulfilling reinforcement of variety and legitimacy that in turn strengthened the overall functions (Bergek et al. 2008). What the system building literature tries to make clear, though, is that these system-level resources can also be shaped strategically. For example, positive externalities are likely to emerge by developing a complete value chain around the focal technology (Andersen 2014). Indeed, deliberate configuration and re-configuration of value chains are acknowledged as important system building activities (Musiolik and Markard 2011). Additionally, co-location of firms can create positive externalities such as the emergence of pooled labour markets, specialised intermediates, and knowledge spill-overs (Bergek et al. 2008). The remainder of this chapter reviews the system building literature, which makes out the foundation for the analytical framework presented in the subsequent chapter.

Musiolik, Markard and Hekkert (2012) define system building as "the deliberate creation or modification of broader institutional or organisational structures in a technological innovation system carried out by innovating actors" (1035). Accordingly, these innovating actors are system builders, as they strategically initiate activities to address system weaknesses, shape and strengthen the TIS and build a favourable environment for their technology (Hellsmark 2010; Planko et al. 2016). The mode in which the actors do this is dependent on the the extent of the technical, financial and/or political resources available to them (Musiolik et al. 2020).

Hence, system building implements perspectives from the strategic management literature, prominently the resource based view (RBV) (Musiolik, Markard, and Hekkert 2012). In short, the RBV suggests that the sustainable competitive advantage of a firm is determined by its composition of tangible and intangible resources (Miller 2019). Tangible resources are quantifiable and visible resources such as financial assets, equipment, buildings, and land. Intangible assets are immaterial and include patents, brand recognition, routines of the firm, customer and supplier loyalty, and human capital such as employee skills and knowledge. The firm either owns or controls these resources, and they influence what the firm can do strategically to position itself better. Consequently, this sets limitations to the firm. Scarce availability of resources makes individual system building less achievable, prompting firms to pursue system building activities together with other system actors (Fischer et al. 2022). System building is therefore usually a collective process (Musiolik et al. 2020).

Correspondingly, the system building literature rely on extensions of the resource concept, specifically that resources can be created beyond a firm's boundaries (Musiolik, Markard, and Hekkert 2012). This can happen in alliances, networks or intermediary organisations where firms access partners' resources, plus those resources that emerge through these constellations (Musiolik et al. 2020). Scholars have also extended the resource concept to the industry-level, pointing to resources emerging in clusters and districts (Asheim and Coenen 2005; Porter 1998). At this level of aggregation, Musiolik and Markard (2011) draw the parallel to system-level resources in a TIS, which are beneficial to all encompassing actors. These three levels of resources can all be shaped strategically through system building activities (see [F7] discussion above). System builders accordingly "identify, develop and use resources at the organisational, network and system level" (Musiolik, Markard, and Hekkert 2012, 1035). It is in this way a means-driven process, where system builders utilise their own resources and expand them while collaborating with other actors. (Musiolik et al. 2020).

With this, the system building concept sheds light on the strategic and organised activities within a TIS, which has mostly been downplayed in earlier studies. Consequently, the concept adds depth to the specification of TIS supporting policies, and furthermore offers firm managers insight into which system building strategies to pursue (Musiolik et al. 2020). However, as mentioned in the introduction, system building is still a nascent concept and studies to date have several limitations (Fischer et al. 2022; Kukk, Moors, and Hekkert 2015; Musiolik, Markard, and Hekkert 2012; Musiolik et al. 2020): They are focused on specific cases in a specific field, in specific geographical settings. This adds uncertainty to which degree the concept is transferable in its proposed configuration. Furthermore, the BCMs are young companies, navigating a rapidly growing TIS, surrounded by a "perfect storm". Along these lines, I expect to also address the call by scholars to pay additional attention to dimensions such as timing, entrepreneurial notions and interactions between different system building activities, in addition to explicating the concept as discussed in the introduction (Fischer et al. 2022; Musiolik et al. 2020).

4 Analytical and contextual framework

This Chapter consists of two sections, where I present the analytical framework and the contextual framework, respectively. The analytical framework is moulded from the system building concept and focuses on the BCMs as system builders. Consequently, the scope of analysis is delineated to what the research questions concerns. It is nevertheless necessary to define the Norwegian LIB TIS and its boundaries as it serves as the level of functional analysis. As the literature review proves, the TIS framework has received an array of contributions through an increasingly extensive literature on the field (Köhler et al. 2019). While this has thoroughly refined the framework and made it a rigorous tool for analysing sustainability transitions, its complexity has been equally exposed. A complete and comprehensive TIS analysis is thus a strenuous undertaking (Edquist 2005). Although I do not conduct a comprehensive TIS analysis, it is nevertheless important to consider the scope of the research questions at hand and make conceptual and analytical delineations thereafter, while still taking into account the broader context and external influences (Bergek 2019). With the aim of adding clarity to the analysis, these considerations make out the contextual framework.

4.1 Analytical framework

I base the analytical framework the one applied by Musiolik et al. (2020) in their system building case study of stationary fuel cells in Germany. The analytical framework in Musiolik et al. (2020) has been refined through three research papers, all investigating the same case (Musiolik and Markard 2011; Musiolik, Markard, and Hekkert 2012; Musiolik et al. 2020). The refinements have considered other contributions to the system building concept, as well as being fine-tuned and updated in accordance with broader scholarly contributions to the TIS framework. I therefore find their analytical framework rigorous and suitable for explication.

The framework examines the process and conditions of strategic system building by focusing on resources, in which three are identified: organisational resources (OR), network resources (NR), and system resources (SR). As discussed in the previous chapter, available ways of system building depend on available resource constellations.

Musiolik et al. (2020) further identify three modes of system building: the single mode, the partner mode, and the intermediary mode. The goal for all three modes is to create new system resources. The system builder employs single mode system building when they already have access to, and control of, the necessary input resources (OR). This mode requires the system builder to have a certain degree of power in the TIS[21]. The partner mode is when two or three system actors co-create a new system resource together. Here, they combine the input resources (OR) which are distributed across them[22]. The intermediary mode is more complex than the former two modes. The system builder then collaborates with multiple actors to set up new intermediary organisations (NR), which in turn are used to create new system resources[23]. The authors make a further distinction regarding resource *constellations*. Resources might be concentrated to- and controlled by one actor. They might also be distributed amongst some actors. The resources might also not exist in the first place. These different constellations require different modes of system building (Musiolik et al. 2020).

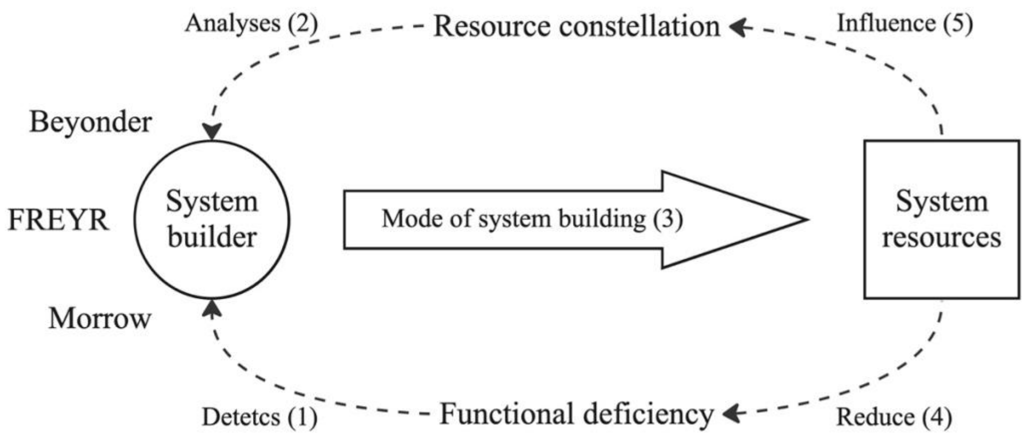

Figure 4. Analytical framework (Musiolik et al. 2020, 5).

Figure 4 illustrates the analytical framework. I aim to examine how Beyonder, FREYR and Morrow each identify deficiencies in the Norwegian LIB TIS and from there engage in different modes of system building based on available resources. The respective actor (1) detects deficits in the TIS, (2) develops strategies and analyses resource constellations, and (3) launches system building activities based on this. New system resources are created as a result, which (4) change resource constellations and improve functional performance, and (5) create new system resources (Musiolik et al. 2020, 5).

[21] E.g., a governmental body set up a national public research laboratory for the focal technology.
[22] E.g., industry actors co-create a standardised solution which other actors can use as well.
[23] E.g., the creation of an intermediary industrial confederacy for promoting industry interests.

4.2 Contextual framework – The Norwegian Battery TIS

Setting the boundaries of a TIS is important to coherently assess its functional dynamics, but it is not always a straightforward task. Hence, scholars propose a set of dimensions for drawing the unit of analysis; technology, breadth and depth, geography and time (Bergek et al. 2008; Sandén et al. 2008). I set the temporal scope from 2016 when Beyonder was founded, to March 2023 when Freyr opened their CQP, and Morrow opened their research centre with UiA. Based on the other considerations above, I define the Norwegian LIB TIS as follows:

> *The Norwegian Lithium-Ion Battery (LIB) Technological Innovation System (TIS) comprises LIBs as the focal technology and encompasses the entire domestic LIB value chain.*

Setting these system boundaries, however, quickly creates analytical problems if structures and influences outside and across the focal TIS is neglected, i.e. its wider context (Bergek et al. 2015).

First, taking the battery value chain into account, the Norwegian LIB TIS consists of a set of nested subsystems (a TIS could for example be delineated to mining of battery raw materials, or even further, to mining of cobalt exclusively). The subsystems and the focal TIS are intertwined, as developments in the former can influence the latter (Bergek et al. 2015). Furthermore, several sectors can interact with the focal TIS (Bergek et al. 2015). A sector and a TIS share structural configurations, meaning that they both consist of a technology field, actors, networks and institutions (Malerba 2002). However, a sector is more concerned with the generation of *specific* products or services for *specific* users, and thus often rely on multiple technologies from different TISs to function (Bergek et al. 2015; Malerba 2002). Elaborating on this point, Stephan et al. (2017) introduce the term "sectoral configuration", which refers to the number and types of sectors linked via the value chain of a focal TIS (710). The value chain sectors are interrelated and form functional interdependencies between them (Bergek et al. 2015; Stephan et al. 2017). This is especially pertinent for multi-purpose technologies[24], as they link previously unrelated sectors through "technology-induced" interactions (Andersen and Markard 2020, 2). Based on these considerations, Gong and Andersen (2023) build on the traditional definition of a TIS and define a TIS *value chain* as "a set of actors, networks, and

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[24] Following the definition of a multi-purpose technology as "a technology that has several distinct, economically relevant applications primarily focused on one or a few sectors" (Battke and Schmidt 2015, 336), I consider LIBs as such. They are applied in multiple applications in different sectors, each with distinct requirements to the LIB technology,

institutions distributed across multiple (inter)dependent and interacting sectors or subsystems that jointly interact in a specific technological field and contribute to the generation, diffusion, and utilisation of a focal technology" (6).

Second, external influences to the TIS must be weighed (Bergek et al. 2015). The Norwegian LIB TIS can be considered structurally coupled to the Nordic LIB TIS and/or the European LIB TIS and so on. The Norwegian LIB TIS can thus be conceptualised as a subsystem of a global TIS, where components are structurally coupled (Bergek et al. 2015; Bergek 2019). Furthermore, a TIS is structurally coupled to the political context it is located in, and is consequently influenced by alignments and misalignments to broader political structures. (Bergek et al. 2015).

Third, TIS characteristics varies depending on where it is in its life cycle (Bergek et al. 2008; Markard 2020). Markard (2020) distinguishes between four TIS development phases: formation, growth, maturity, and decline. Diffusion characterises the growth phase, where a dominant technological design has emerged, and structural components are increasingly aligned. In this case, phases differ for different segments, adding further complexity to the consideration of TIS life cycle. First, BEV application in Norway is quite advances, while the manufacturing of LIBs is emergent. Second, while the global LIB TIS is growing and arguably maturing[25], the Norwegian LIB (sub) TIS is forming, trying to catch on and be part of the global developments. Hence, the Norwegian LIB TIS is consequently dependent on its absorptive capacity and rapid expansion in order to successfully withstand global competition (Bento and Fontes 2015; Bergek 2019). In other words, actors in the Norwegian LIB TIS must focus on rapidly assimilating and improving diffusing and increasingly standardised LIB technology.

The above considerations add valuable dimensions to the TIS framework and will in this case help visualising the multifaceted nature of the Norwegian LIB TIS value chain, which is illustrated in Figure 5.

[25] C.f. the consideration of the global LIB market as unconsolidated, see previous chapter (Campagnol, Pfeiffer, and Tryggestad 2022).

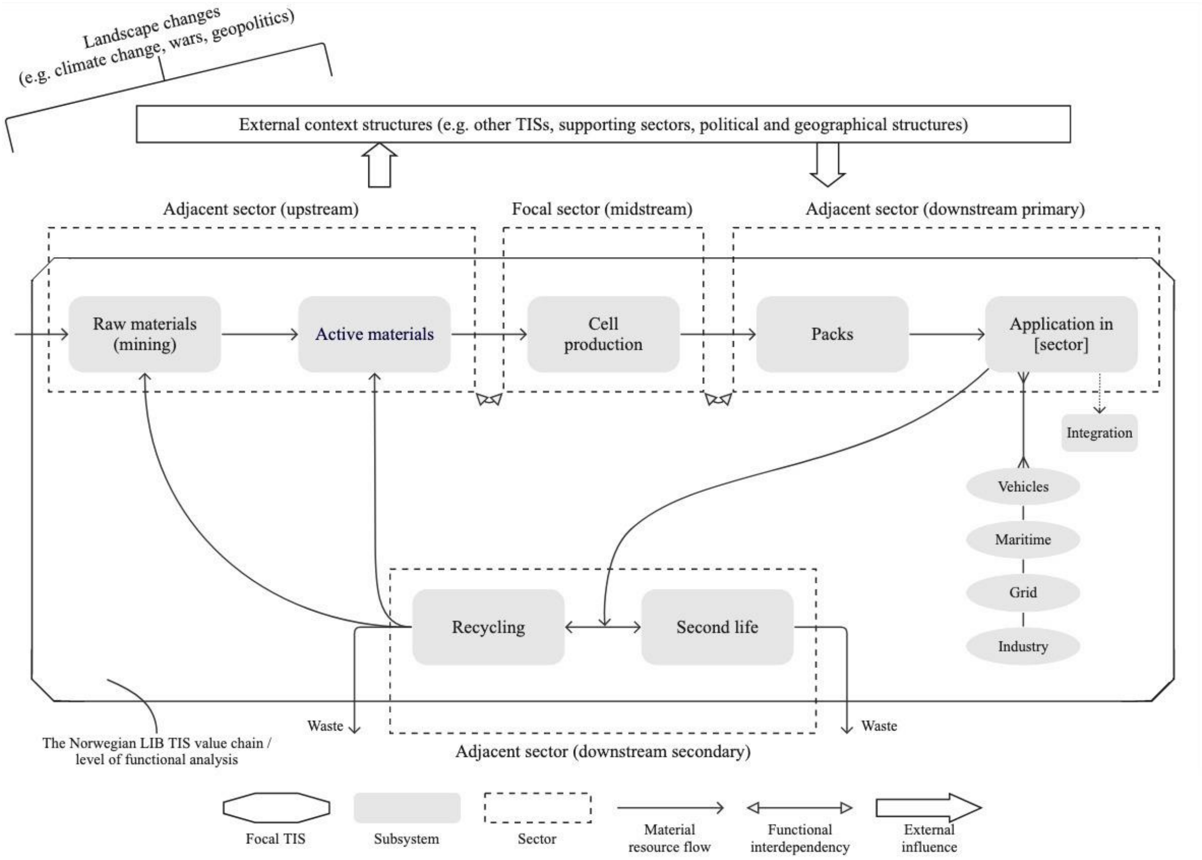

Figure 5. Contextual framework (Conceptual sources: Andersen and Markard 2020; Gong and Andersen 2023; Stephan et al. 2017). (LIB value chain sources: Lebedeva, Persio, and Boon-Brett 2016; NFD 2022b).

The focal technology is applied in the focal sector, with the production-consumption part of the value chain being labelled as adjacent sectors (Andersen and Markard 2020)[26]. The figure also includes external context structures, which in total makes out the contextual framework for this thesis. Details are addressed when explicitly necessary in the analysis, but I do not provide a full breakdown of all the components and their interactions. That would go beyond the analytical scope and the research questions at hand. As mentioned, the purpose of the contextual framework (and the level of aggregation for the subsystems) is simply to establish system boundaries and to add analytical clarity.

[26] Battery pack assembly is often placed in the focal sector (e.g. Gong and Andersen 2023; Planko et al. 2016; Stephan et al. 2017), either as a separate subsystem adjacent to battery cell manufacturing or together as one subsystem. I choose to place battery pack assembly in the downstream primary sector, as the way in which the packs are assembled is highly intertwined with the institutional structures of the application subsystem. For example, packs for EVs are subject to different rules and regulations than packs for ships and ferries.

5 Methodology

In this Chapter, I present the methodological framework of this thesis and the rationale behind the methodological choices I made throughout the research period[27]. The Chapter opens with explaining the overall research design by situating the thesis within qualitative research generally and defining what constitutes a case study specifically. This section also explains the case selection process. Sampling is then elaborated upon, before I describe the data collection process, followed by an overview of the analytical strategy. Then, rigor and ethical considerations are discussed. A reflection on methodological limitations concludes the Chapter.

5.1 Case selection and research design

My motivation for selecting the case of the Norwegian LIB TIS has been accumulated over the duration of the master programme. The strong focus on sustainability transitions in the innovation lectures sparked my interest for both socio-technical transitions towards sustainability as a process in itself and as a research field. I found the TIS framework particularly interesting as it focuses on the dynamics of the development and diffusion for sustainable technologies. In addition, my supervisor encouraged the class to take an extra course the second semester on sustainable energy transitions, hosted by the University of Oslo's interdisciplinary initiative UiO:Energy and Environment. This further strengthened my interest for the energy transition, with an extra motivational push coming from a lecture focusing on batteries in the global energy mix specifically.

I therefore became curious about Norway's active approach to batteries, especially regarding its seemingly favourable position in the market, as described in chapter two. I therefore realised that by investigating the Norwegian LIB TIS, I could empirically contribute to an under-researched phenomenon. In accordance with this, The Norwegian LIB TIS value chain can be considered a *unique* case (Yin 2018). Thus, selecting the case as such has been a mix of general- and theoretical interest on the one hand, and the case "finding" me on the other (Stratford and Bradshaw 2021). The way the case selection process happened therefore made it easier to ask "that categorical question of any study: 'What is this a case of?'" (Flyvbjerg 1998, 8). The selected research design provides further insight to this question.

[27] I repurpose some of the material from my thesis outline in this Chapter, which was submitted for the University of Oslo course TIK4040 *Research and Design Seminar*, spring 2022. The repurposing is clarified with appropriate parties at the TIK centre and is done in compliance with the University of Oslo examination guidelines.

As made clear in the previous chapters, it is a complex task to understand the multifaceted socio-technical mechanisms of sustainability (energy) transitions. Moreover, considering that the thesis takes a closer look at the agency of specific actors in a TIS, it is necessary to gain an understanding of their motivations, beliefs, and perspectives. A qualitative research design is therefore fitting, as it aims to uncover meaning and context behind complex and nuanced human behaviour by investigating subjective experiences and perspectives (Cope and Hay 2021). Moreover, qualitative research is apt for understanding what actors do, why they do it, and uncover what instigates change in actors and the context they are located in (Stratford and Bradshaw 2021). The approach is therefore often referred to as intensive (Cope and Hay 2021), and is suitable to apply in interdisciplinary research aiming to understand the "whys" and "hows" behind the solving of wicked problems (Stratford and Bradshaw 2021).

I thus find it appropriate to apply a case study design, as it is indeed an intensive research approach (Baxter 2021). Moreover, case studies are concerned with investigating "cool" yet under-studied phenomena (Eisenhardt 2021, 149), which this thesis does. The thesis also meet three basic criteria for when a case study design is applicable (Yin 2018, 13): (1) It asks a "how" and "why" research question (2) concerning a contemporary phenomenon, (3) over which the researcher has little or no control.

This base definition does not, however, cover the comprehensive mode of inquiry behind a case study design. To do so, Yin (2018) proposes a twofold definition. The first part concerns scope. A case study investigates a real-world contemporary phenomenon, where there might be a lack of understanding of important contextual conditions. The second part concerns a case study's features. The phenomenon in question prerequisites many variables of interest and the case study should therefore rely on multiple data sources for triangulation. Furthermore, to ensure theoretical relevance, the case study should be guided by existing theoretical premises (Yin 2018). By doing so, it can suggest implications that can contribute to the theoretical developments in the research field the case study is situated in (Flick 2018). Considering the applied theory, the TIS framework is well-established, but the system building concept is still nascent. As mentioned in chapter three, I therefore hope to explicate the concept. I consequently do a combination of deductive and inductive research (Baxter 2021).

The level of functional analysis is the Norwegian LIB TIS. However, the thesis focuses on the three BCMs as actors in the system. I therefore apply an embedded single-case study, illustrated in Figure 6 (Yin 2018). The Norwegian LIB TIS makes out the case, while the three BCMs function as embedded units of analysis. The broader context of the energy transition in this figure can be compared to the landscape changes in Figure 5.

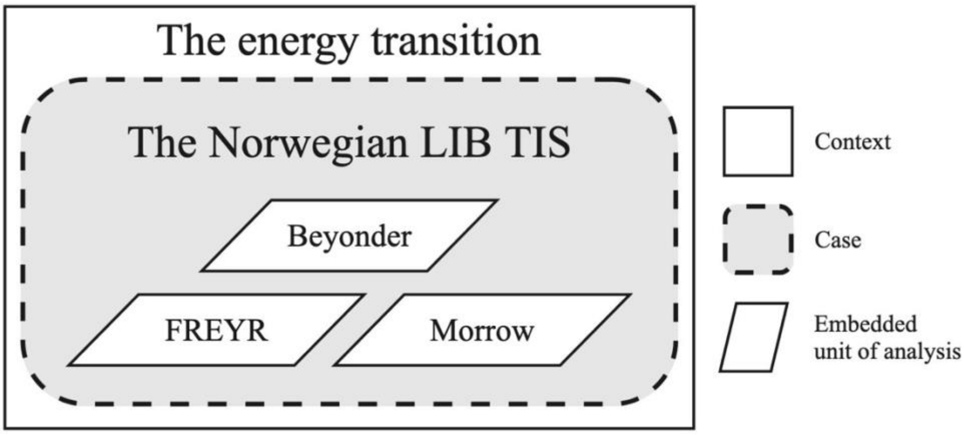

Figure 6. Embedded singe-case design (Yin 2018, 48).

Based on the above, a case study design can be seen as a theory of what can be researched, how it can be researched, and to what advantage, thus representing more an overall methodology rather than a mere method for collecting data (Baxter 2021, 110).

5.2 Sampling

Sampling in qualitative research refers to the process of selecting data sources, including participants (informants) (Stratford and Bradshaw 2021). This is a foundational part of a research project and must be handled carefully, as the sample will impact the richness of information in the data material. There are few “rules” on what makes out an ample sample size, and what is needed depends on the specific case (Patton 2015). What matters is that enough information is collected to ensure validity. More precisely, it is important to select informants that are knowledgeable about the research topic, and that can provide rich and diverse perspectives that help answering the research questions (Dunn 2021; Stratford and Bradshaw 2021).

So, informants should be selected purposefully on the basis of the issues and themes at hand (Dunn 2021, 160), which is the underlying idea of the *purposive* sampling techniques I applied in this research project (Patton 2015). Considering the focus on Norwegian BCMs specifically, I found it logical to select informants that work for these three companies, as the informants would most likely work closely with the case-relevant activities. To make sure of this, I further set a criterion that the informants should be decision makers in their companies’ management team. This starting point is referred to as doing a criterion sampling (Patton 2015). After the first informant had been contacted and agreed to participate, I applied a snowball sampling technique where the informant proposed other people I should consider talking to (Patton 2015). This included people both in the informants' own organisation and people in similar positions at the other two BCMs. In the end, I deemed the following selection of seven informants an ample sample size for this research project. Two informants from each BCMs' management team, plus a representative from the industrial collaboration platform Battery Norway. The representative from Battery Norway was suggested by the other informants because of the organisation's close connection the BCMs and their operations.

5.3 Data collection

Relying on a single data source might be limiting, especially when doing a case study where the overall motive is to provide a comprehensive understanding of a phenomenon (Yin 2018). I therefore used multiple sources for data to thoroughly understand the system building activities undertaken by Beyonder, FREYR and Morrow, and the overarching context surrounding these activities. Moreover, using multiple sources helped to identify inconsistencies and discrepancies in the data material. This way of triangulating is referred to as data triangulation (Patton 2015), which has further advantages of adding validity and reliability to the research project by minimising bias (see section 5.5) (Cope and Hay 2021). It can also enhance the level of transferability (Stratford and Bradshaw 2021). This research project relies on in-depth semi-structured interviews as primary data sources, which is triangulated with a variety of secondary data sources. The primary and secondary data sources are respectively elaborated upon in the two following sub-sections.

5.3.1 In-depth semi-structured interviews

Doing interviews allow for investigation into complex behaviours and motivations, opinions, and experiences (Dunn 2021). Moreover, interviews are suitable for suggesting explanations to the "hows" and the "whys" of wicked problems, and is therefore a fitting data collection method for this research project (Stratford and Bradshaw 2021; Yin 2018). As I want to understand how and why the BCMs engage in system building activities, doing interviews with the people involved allows the sharing of rich and detailed data material. Further motivation spurred from the potential to thoroughly understand the BCMs company behaviour, and that the informants as insiders could provide insightful input on the Norwegian LIB TIS as a whole and its surrounding context. In essence, doing interviews recognises that "the perspective of others is meaningful and knowable and can be made explicit (Patton 2015, 628).

Considering the small number of informants and their positions, I thus found it useful to apply an in-depth semi-structured interview technique. This allows for a more conversational flow than with structured interviews that follows strict interview guides (Patton 2015). Moreover, it allows the informants to engage deeply with the research topic. The interview guide was therefore structured after categories I wanted to cover, each with a set of primary questions to initiate the discussion. This flexibility enabled me to deviate from the interview guide to ask follow-up questions and ask for elaborations where needed. However, such a format is challenging as it requires confidence in the researcher to be interventionistic and to be able to formulate questions on the spot (Dunn 2021).

To prepare for that and to reveal weaknesses in the interview guide, I conducted a pilot interview with one of the informants. First, I uncovered the challenge of asking truly open-ended questions (Patton 2015). For example, I realised that by asking how satisfied the informant was with the government's efforts in realising the battery strategy, I constrained the informant to answer within a degree of satisfaction. Furthermore, Patton (2015) stresses the importance of asking singular questions. I asked a question which was essentially three questions packed into one. That caused some confusion, which in turn meddled the informant's answer. Splitting them into three singular questions resulted in more rich and meaningful answers in the primary interviews. The pilot interview is excluded from the analysis.

Researchers doing interviews should strive to build rapport, which means establishing a positive and trusting relationship between the interviewer and the interviewee to promote an open and honest communication (Dunn 2021). To do so, I made sure to start the interviews softly, by giving an overview of the type of questions I planned to ask. When the interviews had fully started, I focused on keeping a critical inner monologue and to be ready to ask follow-up questions or request elaborations. It was also important to allow time for the informants to think and reflect before giving an answer (Dunn 2021, 165).

All but one of the interviews were conducted using digital video call software. Dunn (2021) provides some useful insights in this regard. The COVID-19 pandemic made video calling a central part of people's lives and continues to be advantageous for saving time and resources regarding spatial, temporal and social barriers of doing face-to-face interviews (177). This enabled me to do the interviews over a short period of time. Another favourable feature of doing video call interviews is that it potentially reduces interviewer effects[28], thus enhancing rapport. However, important visual cues might be lost doing due to the camera framing, but I did not find that to be a particular issue here. There is also a risk of technological issues when doing video calls, which can disrupt the interview flow. I thus made sure to test the connection beforehand, and in some instances switched from Wi-Fi to 5G when the connection was troublesome. In line with the netiquette recommendations by Dunn (2021), I made sure to use the University of Oslo's Zoom license, which ensured that the video call interviews were made on a safe and research compliant platform. A password was required for entering the video call, and I started the conversation by restating the request for consent to record the interview.

All the interviews were recorded, with the exception of one primary interview where the informant respectfully declined. I combined the recording with notetaking, as that is considered to provide the most complete record of "raw" data material (Patton 2015). That is, getting the words of the informant down verbatim, while also allowing the interviewer to be more attentive to the informant, compared to being fully engrossed in notetaking (Dunn 2021). So, in the unrecorded interview, I made an effort to ensure rapport by upkeeping an attentive listening while I was taking notes.

Transcribing interviews is time consuming. I considered using automated transcription software, but such tools may miss important visual and verbal cues. It might also end up being equally time consuming to correct spelling mistakes and the like, compared to transcribing manually. So, following the preference of many researchers, I chose to transcribe the interviews myself. By doing this I maintained the understanding of meaning, which made for an easier integration of the interview notes. Moreover, it allowed for a richer engagement with the data material, which can function as a sort of preliminary analysis (Dunn 2021).

After the primary interviews had been conducted and transcribed, I identified several issues with the data material. There were deficiencies, ambiguities and sometimes a lack of follow-up questions when there should have been one. I therefore reached out to the informants, informed them of the situation, and asked them to do a follow-up interview. It was important to carefully formulate the request as to not insinuate that the informants provided insufficient answers the first time around (Dunn 2021). Fortunately, all asked informants agreed to another interview. I set up individual short interview guides with questions designed to specifically

[28] Interviewer effects refers to the shaping of answers to meet sensed social expectations (Lee 2000), which is more likely to happen face-to-face than in video call interviews (Dunn 2021).

address the respective insufficiencies, thus being considerate of the informants' time. Other than that, the follow-up interviews were handled equally as the primary interviews.

The primary interviews lasted on average 85 minutes, while the follow-up interviews had an average duration of 30 minutes. The primary interviews were conducted over a period of 45 days, from primo December 2022 to medio January 2023. The follow-up interviews were conducted ad-hoc from February to April 2023. An overview of the informants and the conducted interviews are presented in Table 3.

Table 3. Information on conducted interviews.

Organisation	***Informant pseudonym***	***Number of interviews***	***Format***
Beyonder	Beyonder representative 1	2	Primary: in person Follow-up: video call
Beyonder	Beyonder representative 2	1	Video call
FREYR	FREYR representative 1	2	Video call
FREYR	FREYR representative 2	2	Video call
Morrow	Morrow representative 1	2	Video call
Morrow	Morrow representative 2	2	Video call
Battery Norway	BN representative	1	Video call

5.3.2 Secondary data – documents

The interviews were triangulated with a variety of documents. Circling back to the intensive nature of case studies, doing data triangulation is useful for achieving a holistic and rigorous understanding of the case (Patton 2015).

One category of documents analysed are reports. The reports are sources from research institutes, analytical agencies, governmental bodies, and private companies. Furthermore, newspaper articles, press releases, legal documents, conference summaries, and keynotes from relevant actors were included.

Another important category of documents was assessed, namely company documents. These documents were publicly available and include company websites, fiscal reports, technology reports, articles, blog posts, and lastly press releases. In the preliminary phase, these documents gave me a thorough introduction to the BCMs and their operations, as well as their linkage to the overall context of the research project. The company documents also provided additional perspectives and elaborations to the data material generated from the interviews. However, I made sure to keep a critical distance, as publicly available company documents might contain bias and be overly optimistic in the company's favour.

As handling such an array of data material across different types of documents can be strenuous and chaotic, I used my research diary actively to structure thoughts and reflections regarding the documents on a continuous basis as I read them (Asdal and Reinertsen 2022).

5.4 Analytical strategy

For the analysis I found the thematic analysis approach to resonate well with overall ambition of the research project, as it aims to explicate meaning to experiences and behaviours by identifying patterns (or themes) in the data material (Braun and Clarke 2006). Furthermore, thematic analysis allows for a constructivist approach as it favours analysing what the researcher find relevant for explaining the phenomenon. This requires cautious attention, as it is indeed the researcher that constructs the themes. They are not explicitly there. To ensure a rigorous result, I therefore followed Braun and Clarke's (2006) six-step process to thematic analysis, which is detailed below.

Step 1: Familiarising myself with the data.

Considering the aforementioned advantages of transcribing manually, I got to familiarise myself with the data material early on. This enabled initial observations to be noted, which paved the way for a deeper understanding and the identification of potential themes. Further familiarisation was achieved by revisiting and re-reading all the data material.

Step 2: Generating initial codes.

Then I began denoting meaning from different pieces of data and labelled them with codes. Coding essentially serves three purposes (Cope 2021). It is (1) a form of data reduction that distils key themes, by (2) organising the data material in a way that makes (3) analysing the data material more comprehensible. To do the coding, I used the computer-aided qualitative data analysis software (CAQDAS) NVivo. Using a CAQDAS allowed me to more efficiently assess the large datasets which accumulated from the interviews and the secondary data material. Considering the iterative nature of thematic analysis and the six-step process, this also made doing changes and adding newfound codes and themes later in the process more flexible. To capture the essence in the data material, I made the initial codes as descriptive as possible, but formulated in a way that allowed for both explicit and implicit meaning to be identified. Considering the combination of a deductive and inductive approach, I made sure to construct codes that reflected the applied theory while simultaneously being aware of potential new meanings, by doing a so-called in vivo coding (Cope 2021). A careful handling of this step made the transition to step three easier, when potential patterns surfaced.

Step 3: Searching for themes.

The initial codes were then grouped together to enable elaborations on the themes that started to surface. When this stage is done, Cope (2021) advises not to consider the coding structure complete. Rather, the researcher should review the data material.

Step 4: Reviewing themes.

By reviewing the data material and refining the emerged themes, I could make sure the robustness and accuracy of the themes. I identified some overlaps between that were then merged. I also identified some inaccuracies in the coding structure, so I reassigned some of the codes to make it more coherent. By now, I started to identify linkages between themes as well as seeing more clearly how they fit into- and inform the overall objective of the research project.

Step 5: Defining and naming themes.

I then clearly defined each theme, along with an accurate and descriptive name. Ensuring a distinctiveness for each theme, the final themes were formed to each capture a unique aspect of the data material. For example, I defined a set of theory-anchored themes reflecting TIS functions and the different steps of the analytical framework.

Step 6: Producing the report.

The report in this case refers mainly to the analysis and discussion, which succeeds this Chapter. Braun and Clarke (2006) highlights the importance of writing clear and concise analysis that provides sufficient evidences of the themes and how they relate to the research question. It is in other words important to be theoretically and empirically argumentative when presenting the themes.

5.5 Rigor, ethical considerations, and reflections on methodological limitations

5.5.1 Ensuring rigor

Rigor refers to the trustworthiness of the research project (Stratford and Bradshaw 2021). Three underlying concepts are important to ensure the rigorousness of a research project, and I made sure to include them in every step of the research project.

The first concept, *critical reflexivity*, can be seen as a continuous self-review of the researcher (Stratford and Bradshaw 2021). An active approach to critical reflexivity was taken, as I followed common practice of keeping a research diary (Catungal and Dowling 2021). This allowed me to continuously acknowledge my own *positionality* in the research project by reflecting on my own subjectivity and preconceived views, recognising that my own views and values have influence (Stratford and Bradshaw 2021). In addition to the reasons described in section 5.3, the pilot interview was conducted to examine, authenticate, and scrutinise my own preliminary viewpoints (Dunn 2021).

Validity concerns the accuracy and relevance of the research project, i.e. the research project's usefulness (Flick 2018). Doing a pilot case study is often recommended to clarify the conceptual and contextual aspects, and to refine the research design (Yin 2018), thus adding validity to the research project by it being informed and well-planned. However, due to the temporal scope of the project, I did not have time to do a full pilot case study. Nevertheless, I made sure to comprehensively prepare for the project. This naturally included reading up on the context and the case, as well as the theoretical aspects. To engage myself in the initial phase, I also participated in a number of case-related seminars and events (see Table 4).

Table 4. Information on preliminary activities.

Participated seminars and events		
Organiser	***Name (date), place***	***Description***
Fridtjof Nansens Institute	Norwegian energy and climate policy (March 1st 2022), Oslo	90 minutes lecture on trends and driving forces.
TØI Institute of Transport Economics	Mobility 2022 (May 23-24th 2022), Oslo	Annual conference on Norwegian transport and mobility developments.
ONS Foundation	ONS 2022 (August 29-31st 2022), Stavanger	Biennial international conference on energy technology and innovation. Attended several battery-specific seminars.
Stavanger Region European Office	Fitfor55: Energy (October 21st 2022), digital	One hour webinar on EU policy in a Norwegian energy sector context.
Stavanger Region European Office	Fitfor55: Maritime (November 25th 2022), digital	One hour webinar on EU policy in a Norwegian maritime sector context.
University of Oslo	Towards transformative investment? (December 6th 2022), Oslo	Two hours seminar on the role of the financial sector in net-zero transitions.
Pilot interview		
The pilot interview was conducted with one of the participating informants.		

Closely related, *reliability* concerns the research project's consistency and transferability (Flick 2018). Described above in this Chapter, I have taken measures to ensure transparency and to create a rigorous research design that can hopefully be transferable to other theoretical and empirical settings.

5.5.2 Ethical considerations

This research project complies with the Norwegian National Committee for Research Ethics guidelines in the Social Sciences and the Humanities. Furthermore, as personal data is handled, the research proposal was approved by Sikt[29] before I started the data collection. In compliance with Sikt guidelines and scholarly recommendations, each informant received a description of the project and a consent form via e-mail before their interview took place (Dunn 2021). The consent form detailed how their personal data would be handled. It also informed them of their right to refuse recording, to change or withdraw statements, and to withdraw from the project entirely either during the interview or any time afterwards. To this extent, I am confident that the informants gave informed consents (Catungal and Dowling 2021). Furthermore, to ensure anonymity, all the informants were given pseudonyms. However, the management teams in the BCMs and Battery Norway are small, so it is plausible that the anonymity might be compromised by readers familiar with the organisations. This was made clear in the Sikt notification. Relatedly, the informants were asked to share what is already "out there" as well as being encouraged to withdraw any statements related to organisational secrets, should that happen. Furthermore, quotes were cross-checked with the respective informants.

5.5.3 Reflections on methodological limitations

The number of interviews I was able to conduct was limited by the scope of the thesis, time restrictions and available resources. It could therefore be argued that the sample size of informants is insufficient, especially regarding number of actors involved. However, the emphasis in qualitative research is more on the analysis of meanings in specific contexts, rather than pursuing representativeness (Robinson 1998; Stratford and Bradshaw 2021).

Nevertheless, the informants might have provided positivistic answers that favour the organisation or industry they represent. Furthermore, their answers might have been deficient and not cover all aspects of the question asked. Although the thesis is concerned with the BCMs in particular, the analysis could therefore have benefited from insights from the other actors

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[29] Sikt: Norwegian Agency for Shared Services in Education and Research.

involved in the uncovered system building activities. This could potentially have exposed important nuances and bias. Moreover, as sustainability is a prominent context, the informants might have deflected important details that contradicts sustainable behaviour. Also, as discussed in the ethics section, the strong market contestation motivates secrecy. In this regard, important aspects related to the research questions might be undiscovered.

Finally, it is important to acknowledge that a single case study rarely is *entirely* representative of a phenomenon, which consequently affects its transferability (Baxter 2021). However, informed by the concept of analytical transferability, I aim to provide reliable explanations to the phenomenon I investigate by having carefully selected the case and explicating a theory that is neither too abstract nor too case specific (Baxter 2021; Yin 2018).

6 Analysis

In this Chapter, I present the empirical findings that emerged from the thematic analysis of the interviews and reviewed documents. The chapter is divided into sections that each details a specific identified system building activity. As this thesis concerns how the BCMs *initiate* system building activities, the focus is consequently on those system building activities in the Norwegian LIB TIS where they did so. As a delineation, system building activities initiated by other actors, where the BCMs joined in at a later stage, are not discussed.

The Chapter is divided into sections, each concerning a specific system building effort. The first section details the intermediary organisation Battery Norway, which were founded by all three BCMs. Section two and three looks into Morrow and Beyonder's partnership with the University of Agder and the University of Stavanger, respectively. Next, FREYR's partnership with local actors in Mo I Rana is investigated in section four. The findings will then be analysed in accordance with the analytical framework in the following chapter.

6.1 Battery Norway

Battery Norway is an intermediary organisation that was founded by Beyonder, FREYR and Morrow in 2020, together with Glencore Nikkelverk, Vianode and Batteriretur (Battery Norway 2020). The other founders are all Norwegian LIB value chain actors, where the two formers are upstream actors working with battery materials, and the latter is a parent company with three downstream companies underneath it, focusing on developing different sustainable and efficient LIB recycling technologies. Battery Norway has its own employees.

The organisation defines itself as "a national industrial collaboration platform "focused on innovation and sustainable value creation opportunities, encompassing the entire battery supply chain" (Battery Norway 2020, 1). The overall objective of the organisation is to promote the industry both domestically and abroad. It will work on expanding the value chain Norway by attracting actors to establish themselves in the country, building the right competence and infrastructure, and function as an instigator for dialogue both between value chain actors and with the industry and other stakeholders like NGOs, governmental bodies, and investors. The organisation will furthermore function as a relationship builder and focus on enabling European collaboration. It is on other words a broad mandate, but it is considered crucial by the informants to prioritise all these aspects to strengthen Norway's position.

> *"It is not like the race is starting now. The race started decades ago. So, we kind of desperately try to jump on a train that is racing by. We need to catch up on the countries that are ten years ahead of us"* (Beyonder representative 1).

All the informants point to a lack of internal resources and that it would be impossible for them as a sole company to get a foothold across all those priorities. Morrow representative 2 illustrates that they cannot operate in isolation.

> *"Okay, so we build the factory. Fine. But factories can be moved. Easy. If you do not build an infrastructure and a network around the factory, it will be out of the country sooner rather than later"* (Morrow representative 2).

The BCMs are technically competitors, but when asked on the dynamic of establishing an intermediary organisation, the informants were univocal. These quotes from FREYR representative 1 and the Battery Norway representative sums it up well.

> *"We do not see ourselves as competitors, really. The competition is with other countries. We are building an ecosystem which will help both us and others to succeed by being better together"* (FREYR representative 1).

> *"A representative from the European Battery Alliance said to me: 'cooperate where you can, compete where you must'. I see basically no one being sceptical to collaborating, especially not in this early phase"* (Battery Norway representative).

FREYR representative 1 also underscores the point that being a unified industry-wide organisation shortens the path to a close dialogue with governmental bodies and descision-makers.

> *"[Battery Norway]…. engages in conversations with the government both directly and indirectly to make them understand the industry problems"* (FREYR representative 1).

In this regard, the informants explicitly emphasise that Battery Norway played a crucial role in prompting the Norwegian government to commission a knowledge base report, which would eventually materialise the official Norwegian Battery Strategy. In June 2021, Battery Norway, Prosess21[30], and the three BCMs' CEOs formally submitted a letter to the Norwegian Minister of Trade and Industry, urging the Ministry to commission the work (Moe et al. 2021). The signatories make references to previous reports[31] assessing Norway's potential in the battery industry, and points to the subsequent lack of response and policy interactions from the government. Additionally, the letter highlights how the involvement of Battery Norway in the production of the knowledge bake would facilitate a mobilisation of valuable insights from the organisation's extensive network. A few months after the letter was sent, in December 2022, the Norwegian government proceeded to commission the knowledge base (NFD 2022a). Morrow representative 1 reflects upon the significance of the letter in making this happen.

> *"I think it was under-communicated for a while. The immense task of building a new industry in Norway. It does not exist here, and not even in Europe either really. People needed a push, so to speak"* (Morrow representative 1).

If and how much credit the letter is due for instigating the commission is challenging to prove conclusively. However, once the work on *producing* the knowledge base were initiated, the Battery Norway representative is clear in their speech.

> *"Battery Norway provided a substantial amount to the knowledge base"* (Battery Norway representative).

The degree of contribution to the knowledge base is easier to scrutinise. Battery Norway took part in a range of workshops and seminars to define Norway's position in a global perspective (NFD 2022a). The workshops and seminars, where Battery Norway contributed with pooled knowledge and insight, culminated in a comprehensive SWOT[32] analysis of Norway's position. The SWOT analysis formed the basis for the overall choices that were made in the subsequent strategy work (NFD 2022a, 58).

There are also more recent events that might be partially attributed to efforts made by Battery Norway. In March 2023, the Norwegian government made an announcement that Norway has signed up for participation in the so-called IPCEI EuBatIn initiative, with a final agreement expected to be formalised by August (NFD 2023). As an acronym for Important Project of

[30] Prosess21 is a forum initiated by the Norwegian Ministry of Trade and Fisheries with the mandate to provide guidance and recommendations on how to accelerate the sustainability transition of Norwegian process industries (Prosess21 n.d.)
[31] E.g. the Confederation of Norwegian Enterprise report mentioned in chapter two (Valstad et al. 2020).
[32] Strengths, Weaknesses, Opportunities, and Threats.

Common European Interest, IPCEI constitutes an umbrella category for a diverse range of EU-sponsored initiatives aimed at accelerating growth, competitiveness and employment for European industries (IPCEI Batteries n.d.). EuBatIn[33] represents one of two IPCEI initiatives with a specific focus on accelerating the growth of a European battery industry. By participating in the initiative, Norwegian LIB value chain actors will not only gain access to funding schemes but also be able to participate in much closer, dynamic and multinational collaborations than existing institution have thus far allowed for (NFD 2023). This strategic move thus opens up numerous funding schemes and cost-reducing channels which facilitate dynamic and transnational European collaborations. It is worth noting that participation in the initiative is contingent on the submission of concrete projects that meets the objectives behind IPCEI EuBatIn. Consequently, Morrow and Beyonder have submitted projects related to their technologies. Other participating Norwegian LIB value chain actors are Centate, Hydro, and Vianode. An interesting aspect to consider in this case is the role played by Battery Norway in bringing about the sign-up. Back in December 2022, when the primary interview with Beyonder representative 2 was conducted, there was much uncertainty regarding whether Norway would be invited to participate.

> *"The IPCEI-programme [on batteries] is for example an attractive funding channel which Norway does not have access to today. I know Battery Norway has worked meticulously to try to influence any access to it though. That is some heavy bureaucracy we certainly would not have managed to navigate through on or own. We will see how that works out"* (Beyonder representative 2).

The representative from Battery Norway substantiated to this argument[34] and made clear that fostering a tighter collaboration with the EU is a clear objective for the organisation, and further referred to the Union's "unique access to support structures, networks and collaboration platforms". To which degree Battery Norway contributed to the realisation of Norway's IPCEI sign-up, Beyonder representative 1 provides some reflections in the follow-up interview that was conducted in March 2023.

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[33] European Battery Innovation
[34] This interview was also conducted in December 2022.

> *"Battery Norway was an important advocate in that process for sure. As it [Battery Norway] is a highly competent industrial organisation, we could engage with the Norwegian government and make sure that they brought forward inputs to the European Commission with as much professional and relevant weight as possible"* (Beyonder representative 1).

A final example concerns the involvement of Battery Norway as co-project leader in the third phase of the BattKOMP project. The BattKOMP project is spearheaded by the Federation of Norwegian Industries (Norsk Industri), the Norwegian Confederation of Trade Unions (LO), and Prosess21. The project overall objective is to map out and analyse the need for competence related to the ramp-up of a Norwegian LIB value chain (Norsk Industri n.d.). It is worth noting that the BCMs participated as informants in the first two phases. The resulting reports that were produced from these two phases effectively contributed to the realisation of numerous battery-related educational programmes. Some of these programmes are operated in close collaboration with some of the BCMs and will consequently be elaborated upon in the following sections of this Chapter.

Battery Norway was invited to assume the position of co-project leader for the project's third phase, alongside Norsk Industri and LO. This phase encompasses the production of three comprehensive reports. Two out of three reports have been published as of this writing. The first report identified how to integrate battery-related courses in vocational high schools in the most optimal manner (Norsk Industri, LO Norge, and Battery Norway 2023a). The report also includes recommendations on how to utilise these channels for enticing the younger generation to pursue higher battery education subsequent to their high school education. The second report identified necessary measures required for Norway to achieve the projected expansion in capacity and flexibility in battery-related higher education, as previously put forward by phase one and phase two reports (Norsk Industri, LO Norge, and Battery Norway 2023b). The third and final report is still due for publication as of this writing. However, this report will investigate and aim to identify how Norway can collaborate with the other Nordic countries and with Europe regarding battery-related education (Norsk Industri n.d.). A series of workshops were conducted to gather information on the issues. Battery Norway and the other co-project leaders invited relevant stakeholders[35] to participate in these.

[35] Participants include a variety of LIB value chain actors, vocational schools, universities, and governmental bodies.

An interesting observation is that that all three BCMs participated in the workshop as individual companies as well, thus ensuring the possibility for them to speak their minds as such. In that regard, the inclusion of Battery Norway as an intermediary organisation and co-project leader was perceived by the informants as an advantageous move. The weight of being an industrial organisation added legitimacy to the process.

> *"It was sort of a relief. Well, I wound not say that we were suspected of promoting self-interest before [phase three]. I think it will always be a subconscious thought with many, though. Battery Norway has more weight to it. We get more 'cred', which makes it easier to front our concerns"* (Beyonder representative 1).

Morrow representative 1 was more direct when prompted on their reflections around this.

> *"No one wants to support an individual company. We have to get together and paint a common vision of what we need. To get the other stakeholders to understand that they are supporting development of the entire industry"* (Morrow representative 1).

The outcome culminating from the two finished phase three reports is a set of ambitious recommendations and propositions which have been handed over to the Norwegian government. The comprehensive reports recommends a series of concrete actions (Norsk Industri, LO Norge, and Battery Norway 2023a, 2023b). It is for example recommended to establish a pilot for high school battery specialisation courses as soon as possible. Furthermore, the reports push for a ramp-up in capacity for battery-related education programmes to 2000 students by 2024, and for the establishing of a national public research centre.

6.2 Morrow and the University of Agder

In March 2023, Morrow opened an R&D centre in Grimstad, Norway. The Battery Research Centre (BRC), as they call it, will focus on testing production of battery cells, developing new production method, exploring new technologies and driving research on technology across the entire value chain. In other words, the BRC is an R&D hub for the entire battery value chain.

> *"We have a clear R&D strategy, and we want to be involved in cutting-edge development across the value chain. The speed and scale of R&D in this industry are immense, but it is hard to predict where the technology will be in the future. That is why we want to be close to R&D. To be able to move on cutting-edge technology quickly.* (Morrow representative 2).

The BRC is placed within the campus at the University of Agder (UiA). This location has been strategically chosen to facilitate a close collaboration between Morrow and the university, with the BRC being operated by both actors. To be more precise, the collaboration will be between Morrow and the Faculty of Engineering and the School of Business and Law at UiA. The building itself spans a ground surface amounting to 2000 square meters. It has three floors, and contains advanced and state-of-the-art laboratory equipment and offices, catered to the needs of both Morrow and UiA. When the BRC reaches its full operational capacity, it will house 70 employees from Morrow, alongside 20 employees from UiA. The employees will comprise of highly trained professionals with doctorates and expert knowledge on specific fields, ranging from electrochemistry to digitalisation. From Morrow's side, the driving motivation behind the BRC collaboration is to share deep knowledge and to jointly do research on novel technologies and solutions across the value chain.

> *"The University of Agder is extremely proactive. They are highly focused on building up an innovative environment with highly skilled people"* (Morrow representative 2).

Indeed, UiA has set an ambitious goal of attaining the position as a leading academic institution for R&D in the area of battery technology (Wehus 2021). In a statement made for the Morrow press release announcing the collaboration with UiA, director of the Faculty of Technology and Science Jorunn Gislefoss says this:

> *"In close collaboration with the industry, we will build up our competence, which is something that we all will benefit from"* (Morrow 2021a, 2).

The press release cited above also links this collaboration to the Battery Coast project, which is spearheaded by UiA. In 2021, the project secured a noteworthy funding of NOK 68 million from various sources, which is set to be utilised over a five year period to establish high quality battery research at the university, and develop expertise and competence on the field (Wehus 2021). The government notably contributed with a significant portion of the funding, as a direct result of the BattKOMP initiative. Local funds from the southern region in Norway have also contributed with a sizeable amount of NOK 15 million. Lastly, Equinor, Elkem Glencore Nikkelverk, and Morrow contributed with a combined amount of NOK 7.5 million.

The overarching ambition of the Battery Coast project is to facilitate a strong collaboration across the entire battery value chain. As the mission for the Battery Coast project states: "will lay the foundation for an active battery community that spans from fundamental to functional and from enthusiast to expert” (UiA n.d.). Morrow considers this as an exceptional opportunity to cultivate and build local competence and sees UiA as an influential and unifying force for the industry. Morrow consequently took an active role early on in the project.

> *“It was no doubt from our side to participate here. Unifying academia and the industry in close proximity will be a game changer. We went on board early and helped recruiting one of the chief professors for the [UiA] initiative”* (Morrow representative 2).

Morrow representative 2 is referring to Associate Professor Johannes Martin Landesfeind, who has extensive experience with LIB research from Technical University of Munich and the Tokyo University of Science, as well as industry experience. He holds a PhD in electrochemistry. Both Morrow representatives point out the significance of securing such a high profiled associate at the university.

> *“Think about it. Who actually has extensive experience here? Outside Asia? Almost none. Europe did not even talk about batteries until a few years ago”* (Morrow representative 1).

One of the founders of the Morrow predecessor Graphene Batteries, Rahul Fotedar, is now Morrow’s Chief Technical Officer. He also has a PhD in battery technology, and otherwise holds a similar background as Landesfeind. According to the Morrow representatives, it was much thanks to Fotedar’s European network and relationships built up over the last decade that helped them and UiA secure Landesfeind.

The Battery Coast initiative has already embarked on several research projects, spanning a wide variety of topics[36]. One of the projects include an EU funded research project, which is aimed at developing more efficient and cost-effective way of recycling BEV batteries (Reinertsen 2022). Here, the university is one of 16 European partners participating taking part in the so-called Rhinoceros project. The project has been granted a considerable NOK 91 million in funding, where NOK 8.5 million is allocated to UiA specifically. Although Morrow is not directly involved with the Rhinoceros project, UiA has stated that this will ultimately benefit

[36] “I) material characterization and electrochemical analyses in laboratory scale battery cells, (II) commercial cell format investigations and use-case specific design optimization, (III) strengthening the predictive power of battery simulations, (IV) battery management and control in applied systems and second use, (V) automated battery disassembly for recycling, and (VI) analysis of sustainable business models and regulative restrictions for the battery industry”

Morrow and other industrial collaborators in the long term, once UiA is able to present results which can be tested and qualified for scale at the BRC (Reinertsen 2022, Morrow representative 1). This project in particular also highlight the benefit of being affiliated with a public institution, as UiA will have access to research funding where Morrow would otherwise be unqualified for to receive it.

The initiative involves more than conducting research, however (UiA 2022, Morrow representative 1, 2). UiA is currently offering both a bachelor and a master programme on renewable energy engineering. Starting autumn 2023, these programmes will incorporate specialisation courses on battery technology. The courses will be heavily practice-oriented, with the students being granted access to the laboratories at the BRC. Morrow will offer students thesis collaborations. Consequently, Morrow will by this be able to provide first-hand experience to the students, while also building a close relationship with potential future employees. This is a strength when it comes to securing skilled workers.

> *"This will also be a great recruiting space for us. It will definitively be advantageous to meet potential candidates early on and build a relationship with them. The competition for skilled workers in this industry is insane"* (Morrow representative 2).

Furthermore, UiA will offer a PhD programme where the candidates will be able to reap the benefits of being in close proximity to the industry, thus offering a two-way knowledge-sharing experience. The Battery Coast initiative will also be a valuable resource for the early recruited Morrow workforce, as vocational training programmes are also being launched, allowing "young professionals and experienced workers to broaden their horizons" (UiA 2022, 7).

So, the ambition certainly seems to be that the two actors will be collaborating closely together.

> *"We will work in an intense symbiosis with the university"* (Morrow representative 2).

Morrow considers the collaboration to be especially fruitful when it comes to doing research that reduce upstream costs. 70 percent of the cost of a LIB cell comes directly from upstream materials, in the form of active materials in the cathode and anode (NFD 2022a). As mentioned in Chapter two, there are many material compositions that could possibly meet energy density and power density demands while also holding a solid life cycle. However, this requires extensive R&D done in sophisticated laboratories. This is something Morrow hopes can be a successful output of the BRC and the collaborations there.

> *"If you want to reduce costs, you have to do something with the material that goes in [the LIB cell]. Of course, as a cell manufacturer it would make sense put all efforts in scaling up and make production more efficient. But I am pretty sure that the majority of that potential has been realised already. I mean, China has done this for 10 years already, in massive scale. And they are not holding back. We have to try to do something with the materials, then"* (Morrow representative 1).

Relatedly,

> *"We are focused on qualifying new material compositions in our cells. Partnerships about raw materials are crucial in that regard. We have to develop an all new upstream in parallel. We cannot do that on our own"* (Morrow representative 2).

Further strengthening and expanding the collaborative efforts with UiA, Morrow and the Battery Coast initiative is also inviting the Grimstad-based catapult Future Materials and Mechatronics Innovation Lab to participate in projects. The former is doing R&D on novel sustainable raw material chemistries, while the latter is competent in industrial 3D-printing, robotics, and automation. Morrow representative 1 underscores that this will further enable innovation across the value chain, including process innovation on machinery and auxiliary equipment.

The objectives for the BRC and the Battery Coast are certainly ambitious. However, the collaboration between a public university and private companies comes with some inherent challenges that should be acknowledged early on. The substantially high uncertainty surrounding the unconsolidated global battery market, coupled with the intense competition, makes it tough to prevail as a competitive actor once the market does consolidate. Consequently, actors are likely to meticulously safeguard intellectual property because of the competitive advantages that entails. This does in turn motivates secrecy, which can be a barrier for the collaboration. Morrow, as a principal investor and stakeholder in the BRC, naturally aspires to reap the benefits of the technological breakthroughs emanating from the centre and capitalise on them. Conversely, UiA is a public institution, thus having a certain level of obligation and societal responsibility to disseminate and publish its research to the public. In order to counter potential conflicts of interest that might arise in this regard, Morrow representative 2 provide some reflections on the matter.

> *"It will of course be certain things that we cannot have publicly spread around. It is definitely a fine line to balance in that symbiosis, but I do think that we have set up some good routines to best avoid conflicts when push comes to shove"* (Morrow representative 2).

The informant explains further that everything will be done project by project and considerations regarding openness will be made before each project. Furthermore, the BCR is built to allow both actors to do research on their own in parallel with collaborative projects. However, as of this writing, the BCR has just been operational for about a month, so the informants could not provide any experience to how this dynamic has functioned in practice. The routines described above does not seem to be fully concretised either.

> *"One rule, to put it that way, that might be deciding on whether we do it openly or not, could be that the closer to industrialisation the project is, it will less likely be open research behind it"* (Morrow representative 2).

Nevertheless, the impression from both Morrow representatives is that the overall ambition is to be as open and collaborative with the university as is justifiable from a commercial viewpoint.

> *"I think that as long as we can be open and share, we share"* (Morrow representative 2).

It will certainly be interesting to see how this dynamic of combined industrial and academic resources work once the BCR reach capacity and projects are initiated.

6.3 Beyonder and the University of Stavanger

Beyonder realised early that collaborating with local academia was crucial for the acceleration of both their own ambitions and for the Norwegian LIB value chain as a whole. Beyonder representative 2 highlights that Norway as a competitive battery nation is very much in a formation phase yet, and that a close collaboration with academia is crucial in that regard.

> *"It is not only Beyonder, the whole country is basically a start-up in regards to this [batteries]. We have to connect and pool our knowhow to develop the industry"* (Beyonder representative 2).

Beyonder representative 1 elaborates more on their own challenges as a start-up in an early phase, and the constraints limited (internal) resources put on the company:

> *"I said from early on: We have to spend the first few years to build up a knowledge environment that truly understands our technology….. There is a lot of foundational things that we need to do in the early phase, which we will not necessarily do down the road. In five years' time, there probably be functions that we are dependable on now, that will not be a part of our core business then. It would be a fantastic waste of resources to build up whole departments internally now, just for us to close them again in a few years.*" (Beyonder representative 1).

Consequently, in 2019, Beyonder engaged in a collaborative agreement with the University of Stavanger (UiS) to combine their respective resources in a pursuit for a more extensive and advanced R&D trajectory (Løvås 2019). The collaborative agreement allows for an efficient pooling of the two actors' respective resources, with a combined strength in R&D that would be hard for both actor to achieve individually. To be more specific, the collaboration involved UiS's Energy and Petroleum Engineering department. This department, located in Norway's "energy capital", has a solid reputation for providing cutting-edge education and research in engineering, particularly in the O&G industry. The department is increasingly pivoting towards an expansion of knowledge within sustainable and renewable energy sources (UiS 2023). Beyonder acknowledges the invaluable experience and knowledge that the department has accumulated over the years, and the applicability this experience and knowledge has in the field of batteries.

> *"It is a huge force to set up shop in this region. Being neighbours with the competence base built up around the O&G will be a unique resource. It definitely makes it easier to reorient the R&D priorities in the regions in favour of this industry*" (Beyonder representative 1).

From the very outset of the dialogue between Beyonder and UiS, the two actors initiated a process aimed at mapping out an educational programme for battery technology. This programme would involve the participation of Beyonder as a provider of practical guidance and training for the students. Although the programme was conceptualised from the collaboration's inception, it was the results from the BattKOMP initiative that proved to be to pivotal push that allowed for the formal establishment of the educational programme, in form of a dedicated three years bachelor programme (Beyonder 2023). As such, this programme represents Norway's first fully integrated bachelor programme dedicated to battery technology. The battery-related courses at UiA are optional specialisation courses incorporated within a broader bachelor programme on renewable energy. As such, the first cohort of bachelor students enrolled in the new programme Battery- and Energy Technology for the fall semester of 2022. Beyonder will grant the students access to their innovation centre in Forus, thus enabling the students to gain hands-on experience with battery technologies in the industry. The inaugural cohort were introduced to the innovation centre in April of 2023, where they were given a guided tour and an introduction lecture by Beyonder. The students will be given experimental hands-on education with Beyonder from the third semester. The Beyonder representatives highlights their ambition for providing as an extensive practical education platform as possible.

> *"We want to take an active role in making sure that the students have a solid connection with the industry throughout the course of study"* (Beyonder 2023)

As with the Morrow representatives, the Beyonder representatives also acknowledges the advantage of being close to potential candidates who are in education. Beyonder representative 2 expands on this reflection, which can be applied to the advantage for the whole value chain of offering battery-related educations in Norway in general.

> *"The recruiting process of foreign workers is really tiresome. The UDI [Norwegian Directorate of Immigration] bureaucracy is insane. If we are lucky enough to get the attention from a candidate from Asia, it will take UDI four to six months to process the application. That's extremely long. Not only that, just setting up a Norwegian bank account can take additional months. It is banal and it costs us potential candidates. Definitely a barrier for us.* (Beyonder representative 2).

The informant further elaborates that a proper educational program on a national scale needs to be fully operational as soon as possible, stating the fact that it will still take three to five years before the students graduate. Even longer for PhD-required positions. There certainty seems to be a momentum of interest in this regard, seeing as the interest for the bachelor program at UiS was immense. The programme saw a total of 400 applications for just 25 seats (Simenrud 2022).

The collaboration between Beyonder and the university's department of Energy and Petroleum Engineering has already been fruitful, having published a number of research papers, theses, and dissertations as of this writing. Two PhD candidates are working full-time with Beyonder and the university. A third candidate did their disputation in February 2023. The candidates have all been able to take advantage of- and utilise both the university's advanced laboratories and Beyonder's cutting-edge facilities and equipment at their innovation centre, thus enabling the candidates to fully engage in the research topic at hand in a practical manner.

The first candidate finished their UiS master in petroleum engineering by doing a collaboration with Beyonder. This was done even before the formal partnership was announced. This candidate subsequently did a 10-month internship as an engineer for Beyonder at the innovation centre, before embarking on an UiS-backed PhD together with Beyonder. The research project is aiming to significantly provide new knowledge and insight on the understanding of high quality active carbon (Beyonder 2022a). The research project is furthermore looking into how to reduce electrolyte degradations, which consequently affect the battery cell stability. Beyonder aims to leverage the expanded understanding of these issues to improve their LiC technology. The second PhD project focuses on the utilisation of silicone in the LIB cell's anode and how the material combination with lithium can be made more safe and more stable (Beyonder 2022c). The third and finished dissertation delved into how solvent-free electrodes can be qualified and subsequently manufactured at scale (Beyonder 2022b). Solvent-free electrode manufacturing could potentially eliminate half of the energy consumption in this stage of cell manufacturing. Additionally, the candidates have collaborated with Beyonder, UiS, and other research institutions to co-write multiple research papers on these topics, published in peer-reviews journals[37]. The close collaboration with these candidates has led to Beyonder offering them permanent positions at the company.

Beyonder is furthermore adamant on continuing to offer PhD candidates the opportunity to work with them and UiS going forward. As to the motivation behind that, Beyonder representative 1 points back to the aforementioned statement on the extraordinary need for

[37] See for example "Revisiting Polytetrafluorethylene Binder for Solvent-Free Lithium-Ion Battery Anode Fabrication" DOI:10.3390/batteries8060057;
"Revealing Silicon's Delithiation Behaviour through Empirical Analysis of Galvanostatic Charge–Discharge Curves" DOI:10.3390/batteries9050251 and;
"Enhanced activated carbon lithium-ion capacitor electrochemical stability through electrolyte dielectric optimization" DOI:10.1039/D3SE00122A

knowledge building in the early years and how the collaboration with UiS saves them the need to build temporarily needed in-house resources.

The company was recently granted NOK 5.2 million from the local fund Ulla-Førrefondet (Beyonder 2023). Ulla-Førrefondet aims to accelerate the green transition in Rogaland county by granting funds dedicated to enable higher education on the subject matter (Ulla-Førrefondet 2023). The fund's conditions emphasises that the granted money shall be used on measures that enables technological research and education, and that it should be invested in comprehensive and long-term projects. Beyonder is utilising the support to further strengthen their innovation centre by building additional lab facilities for research and testing, and to further strengthen the practise-oriented training programs they will do together with UiS and their students. Getting access to this grant was dependent on the close connection with the university. In this regards, Beyonder representative 2 points out they and the university are a mutually dependent when it comes to getting access to certain funding schemes:

> *"Many of these research and academic institutions are dependent on having collaboration contracts with industrial actors in order to be eligible for certain types of funding. Likewise, Beyonder is dependable on collaborating with these institutions for the same reason, in addition to the knowledge sharing"* (Beyonder representative 2).

The potential conflict of interest as mentioned with Morrow and UiA in section 6.2, regarding intellectual property and the safeguarding of new knowledge, is also something that pose as a challenge in the collaboration with Beyonder and UiS. The two BCMs seems to share the same idea on how to continuously tackle this issue.

> *"It is of course important to clarify in advance what resources both we and the university brings to the table, and then discuss expectations for the outcome. The issue of setting boundaries for intellectual property and agreeing on who gets what when it comes to results, so to speak, is something we declare before embarking on said project. That said, we have great dialogue with them [UiS]"* (Beyonder representative 1).

Beyonder representative 2 adds that it has got be a positive incentive for both parties for them to embark on a specific project together. Beyonder representative 1 echoes this and elaborates further:

> *"It is certainly another deciding dimension to it. It is not only the formal contract documents and the legal considerations that needs to be in place. First and foremost, we both have to want to do this together, agreeing on how to get there, and share the same overall vision"* (Beyonder representative 1).

So, in accordance with these statements, it appears that the presence of shared values and a common vision plays an important role in facilitating new collaborative projects between Beyonder and the university. The way this dynamic works when Beyonder is in discussions with the university is hard to evaluate based on the interviews alone. On the other hand, it is worthwhile to consider the structural connection of the collaborative relationship. Morrow have undoubtedly made stronger structural connections with UiA, by building the BRC on campus at the university. Furthermore, the BRC sees Morrow and UiA employees sharing the same working space.

In contrast, Beyonder's innovation centre is situated at their own headquarters in Forus, which is both spatially and operationally independent from UiS. There is also no UiS employees permanently seated at the Beyonder innovation centre. Moreover, the university is currently constructing its own battery laboratory, which will be equipped with tools and machinery for battery research (UiS n.d.). The on-campus battery laboratory will also be used for educational purposes aimed at their students. These structural separations between Beyonder and UiS might make for an easier delineation of which shared knowledge generation should be made public, and which should be considered trade secrets and private intellectual property, than with Morrow and UiA. However, the degree of independent control Beyonder holds over the lab facilities they built with the Ulla-Førrefondet grant remains to be seen.

6.4 FREYR and the regional development in Rana

FREYR has established a strategic partnership with two other local actors in Mo I Rana. The first actor, Rana Utvikling, is an NGO dedicated to promoting and developing new commercial activities in the region. The second actor, Rana Municipality, is the municipality where Mo Industrial Park and FREYR are located. The formation of this partnership was set in motion with an overarching vision of elevating the attractiveness of Mo I Rana as a region for LIB value chain actors to come to, while concurrently being considerate of the well-being of the local community. From FREYR's perspective, a prominent motivation for initiating this partnership is the ambition of establishing as a complete value chain in Mo I Rana as possible.

> *"To do what we want to, to scale fast, we cannot do that in isolation up here. To succeed globally, we have to have long term committed partnerships across the value chain. Especially as sustainability is integral. Sustainability is becoming a deciding factor, and we cannot deliver on that with a conventional global value chain"* (FREYR representative 1).

Moreover,

> *"Downstream partners and end customers are really looking at the whole of the value chain in terms of carbon footprint. Then it matters a lot on how we have produced the batteries. That is the whole idea about Mo I Rana"* (FREYR representative 2).

In a related vein, FREYR representative 1 expounded on the underlying motivation for making other LIB value chain actors come to Mo I Rana. Particularly, the informant made a connection to the upcoming EU legislation on batteries (EP 2022). The regulation mandated the inclusion of a so-called battery passport, which will be obligatory for all battery cells distributed within the European market. It is required of each battery cell to have labelled a scannable quick response (QR) code on it, which when scanned must showcase all the environmental and social aspect throughout the manufacturing process.

> *"This includes where the lithium is coming from, where is it being refined, how it is mixed with other materials. It needs to state the cell's recyclability. Waste, human rights, labour permissions, GHG emissions. All throughout the value chain. That information is impossible to coherently gather today"* (FREYR representative 1).

Establishing close and trustful partnerships across the value chain is therefore deemed a crucial priority for FREYR. The consider that the proximity between all the value chain actors plays and important role in achieving this goal. Not only does it facilitate the co-creation of a a well-functioning and trustworthy system behind their battery passport, but it also enables a better collaborative effort to reduce GHG emissions throughout the value chain by bringing everyone close to one another. This goes not only for the GHG emissions in the different steps of the value chain. It is also particularly relevant when it comes to transportation of materials and goods between the value chain steps.

To illustrate, as the region will see increased demand for well-functioning logistics, the partnership is looking into ways of making sustainable transportation solutions that are not only environmentally friendly, but also practical and efficient. Moreover, they are striving to upgrade the local road infrastructure to meet these needs, including shorter stretches like the internal roads within Mo Industrial Park that leads to the deepwater port. Additionally, FREYR is keen on integrating the infrastructural needs of the LIB value chain to the circular projects initiated in the industrial area.

> *"They have a lot of innovation projects going on, which is about circularity. Access to renewable energy. Sharing sea warmth, for example. Many things. We want to establish a battery value chain around this. Be part of the green innovation culture that is already there*" (FREYR representative 1).

Also, as mentioned in Chapter two, the China-based company CATL has strongly focused on vertical integration across the value chain. To stay competitive and be one of the prevailing BCMs globally when the market consolidate, FREYR recognises that it is important to achieve a certain degree of collaboration between value chain actors. FREYR representative 2 include the high uncertainty of where the profit will be in the value chain in regard to this.

> *"There is of course also a question that no one really knows: in which phase of the of this equation will the margin be? I think it will move towards the end customer and whoever "owns" the end customer has the data on customer usage. Data will be the extremely valuable for ensuring competitiveness*" (FREYR representative 2).

Therefore, additional considerations are being made by FREYR regarding the enabling of an integrated *ecosystem* of locally neighbouring stakeholders. Fostering a collaborative environment between the value chain actors regarding the battery passport and the sharing of data is a priority and is considered to be a win-win for all parties. This is of course a vision, and not something to consider a certain outcome.

There is also a formidable social aspect behind this partnership.

> *"We have a strong collaboration where we invest a lot, to make sure that Rana as a municipality and the people are well off"* (FREYR representative 1).

> *"You can actually say that it is a social development project as well, of the whole region as such"* (FREYR representative 2).

Thus, another primary motivation driving all three actors' motivation for this partnership is to cultivate social acceptance for the battery industry within the local community [F6]. Indeed, attaining legitimacy is important for attraction other value chain actors, and maintaining a healthy relationship with the local community is considered indispensable in this regard. To provide an idea of how important this is, FREYR representative 2 highlights the controversies surrounding onshore wind parks in Norway and the strong opposition these parks have faced from local communities. Relatedly, the battery industry has also encountered similar challenges, with demonstrations and strong opposition emerging during the initial discussions of the placement of several of the planned gigafactories in Norway[38]. Both FREYR representatives therefore agree that it is "extremely important" to gain social acceptance in the region. To this end, the partnership has established several key performance indicators (KPI) aimed at measuring the legitimacy and social acceptance in the region.

For example, one KPI focuses on measuring local community approval, where residents, actors in Mo Industrial Park, and the municipality are surveyed. The survey measurers their perceptions of the LIB value chain's impact on the region. While this survey focuses more on the structural impact of the industry itself, the partnership has also launched a social impact study, allowing them to assess the industry's effects on the local community.

If all of the envisioned aspirations come true, and the ripple effect throughout the value chain happens as expected, it is anticipated that Rana Municipality will see an influx of approximately 5000 new inhabitants by the year 2027 (Winje et al. 2021). This number encompasses not only the FREYR and other value chain actors' workforce and families, but also people associated with auxiliary societal functions that will inevitably need expansion as a consequence. This includes employees for shops, cafes, restaurants, and the like. Naturally, meeting the housing requirements associated with such a rapid population growth represents formidable challenges in their own right.

[38] Several locations were considered by all the three BCMs. Both Beyonder and Morrow have faced opposition and demonstration on considered and decided locations. Newspaper articles for reference: Fløde (2022), (Bjørnevik 2022),

> *"All these employees and their families need housing. If we do not act early to meet this coming demand, we will most likely see increased housing prices both when it comes to buying and renting"* (FREYR representative 1).

In relation to this, both FREYR representatives are quick to highlight the significant challenge they and potentially other value chain actors may face when they are attempting to recruit potential employees to relocate and establish themselves in Mo I Rana. Consequently, the partnership is taking considerate steps to address the housing shortage in the region, by attracting housing developers and by enabling construction projects of new residential areas. However, these steps must be made with careful consideration of the people who will move to the region. Both FREYR representatives emphasise the highly competitive nature in the LIB value chain when it comes to recruiting workers. The required workforce is highly educated and in shortage. The power lies at the employees' side of the table. As FREYR representative 2 points out, getting skilled workers to Mo I Rana represents a formidable challenge.

> *"It is not like any traditional metal industry. The general educational level of workers in the battery value chain is extremely high. We have Master of Science and PhD researchers and professors working shifts on the factory floor. Their attractiveness as employees allows them to pick and choose.* (FREYR representative 2).

As a consequence of the considerable high educational level of the workforce, a substantial proportion of workers fall into an age bracket where they have established families. This raises some concerns. It creates mounting demands, not only for suitable housing accommodations, but also on making everyday life in Mo I Rana attractive for the workforce and their families. In this regard, the partnership considers various projects of importance regarding cultural amenities, leisure activities and recreational facilities, and creating job opportunities for the workforce's spouses. Additionally, the partnership has prioritised making sure that primary educational institutions, like schools and kindergartens, are capable of meeting future demand in capacity. Finally, given the reliance on foreign workers, especially in the first years, the partnership sees the integration of the workforce and their families as an important priority. As a result, the partnership has begun development on locally based language- and integration programmes.

The partnership seems to already have influenced the decision to place major investments in the region. The Japanese USD multi-billion company Nidec Corporation is establishing a battery module and pack factory next to FREYRs gigafactory in Mo Industrial Park (FREYR 2022b). Nidec Corporation is an established electrical motor manufacturer which is expanding its already considerable investments in the BESS market. The decision for Nidec was made after visiting Mo I Rana several times to do inspections and to do due diligence. FREYR director Tom Einar Jensen said in an interview with the local newspaper Rana Blad that the decision would not have gone through if it had not been for the close collaboration with Rana Utvikling and Rana Municipality on the aforementioned projects (Pedersen and Skoglund 2022). The factory will be a joint venture between Nidec Corporation and FREYR. The two companies will collaborate under the Norwegian subsidiary Nidec Energy AS to develop and manufacture competitive and sustainable BESS solutions for industrial grade applications (FREYR 2022b). As mentioned in Chapter 2, this is an immature market, so the two actors will experiment on solutions, which is made possible by the co-location and linkage of the two value chain steps. The two parties estimate a total amount of employees for the module and pack factory to reach around 300 people. Furthermore, an expected total investment of NOK 1.25 billion will in its entirety be invested in Rana Municipality (Pedersen and Skoglund 2022).

As a final and interesting point, all this work seems to have been methodologically grounded in their business strategy from the start, namely in Michael Porter and Mark Kramer's shared value concept[39]. FREYR representative 1 links the concept to their overall core stategy tenets; speed, scale , and sustainability. I will return to the significance of this point in the discussion.

> *"We integrate perspectives from the shared value concept in these processes. We analyse and map out all the stakeholders, not only in the value chain. It is important to understand the needs and challenges of the stakeholders and take these into consideration when we cement our presence in Mo I Rana"* (FREYR representative 1).

I will return to the significance of this point in the discussion.

[39] "The concept of shared value can be defined as policies and operating practices that enhance the competitiveness of a company while simultaneously advancing the eco- nomic and social conditions in the communities in which it operates" (Porter and Kramer 2019, 327).

6.5 Summary of findings

In this chapter, I have analysed the findings from the conducted interviews and secondary data review. I have identified a range of system building activities that the BCMs took part in initiating. The identified activities have several similarities in relation to the mechanisms and motivations behind them. On the other hand, they also differ in many dimensions. All these evaluations will be properly elaborated upon in the subsequent chapters. To refine the discussion, and to place the findings in the analytical framework, a conceptual analysis is provided in chapter seven.

7 Conceptual discussion

In the previous chapter, I comprehensively detailed the identified system building activities initiated by the BCMs. The purpose of this chapter is then to provide a conceptual analysis of the findings in accordance with the analytical framework (Chapter 2, Figure 4). The analytical framework is replicated below for reference. Battery Norway and the FREYR case is analysed individually. Due to the similarities between the Morrow/UiA case and the Beyonder/UiA case, I consolidate them in the same section. Table 5 depicts a summarised conceptual overview of the findings (Musiolik et al. 2020). The "SB" circles represent the system builders in the cases, namely Beyonder, FREYR, and/or Morrow. The "A" circles represent complementary actors participating in the system building activity. The circles in themselves represent organisational resources (OR), while the rhombuses and squares represent network resources (NR) and system resources (SR), respectively. Direct influence on the SR is illustrated with arrows, while indirect influence is illustrated with dotted arrows.

As I do not do a comprehensive TIS analysis, TIS functions will not be systematically reviewed. I rather insert brackets referring to the respective functions where they are relevant (e.g. [F3]) [40]. I exclude bracket insertions referring to the function regarding the development of positive externalities [F7]. This is because the generation of system-wide benefits and positive externalities at the TIS-level is an intrinsic output of system building activities (Musiolik and Markard 2011). I therefore find it superfluous to include, and I furthermore consider fewer bracket insertions to enhance the readability of the chapter.

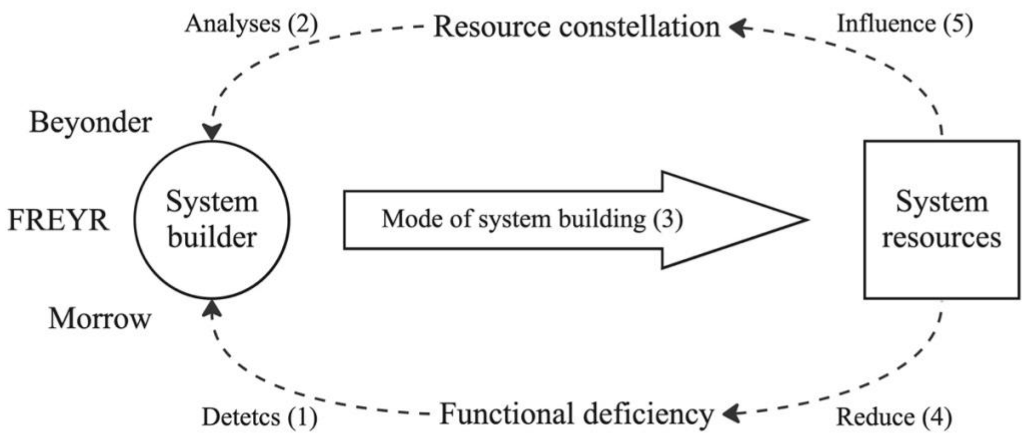
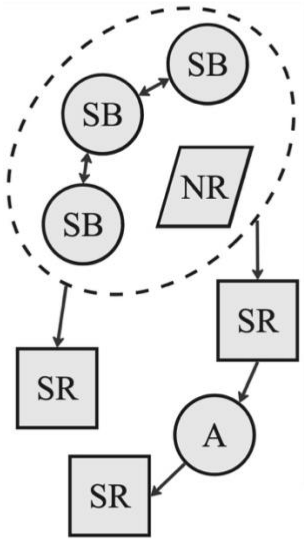
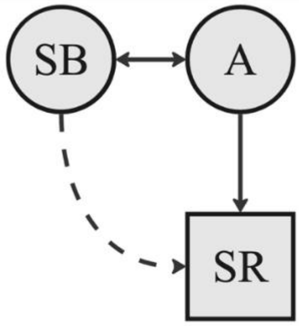
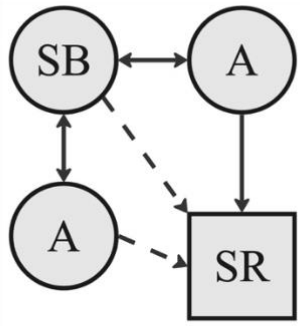
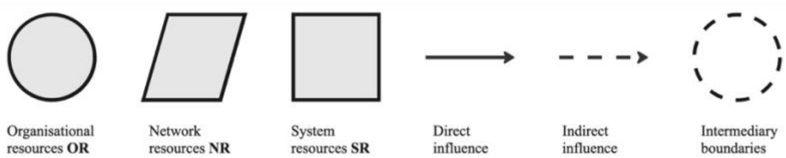


Figure 4 [replicated]. Analytical framework (Musiolik et al. 2020, 5).

[40] This method is inspired by other TIS-related research papers, e.g. (Gong and Andersen 2023).

Table 5. Conceptual overview of the findings. The setup is derived from Musiolik et al. (2020, 9).

Case	**Battery Norway**[41]	**Beyonder and UiS / Morrow and UiA**	**FREYR, Rana Utvikling, Rana Municipality**
			
Description	Co-creation of an industry organisation to enhance TIS legitimacy, promote collaboration, mobilise resources, and co-creation and sharing of knowledge.	Coordinating the creation of joint platforms and programmes for public R&D and educational offerings.	Joint efforts to identify, plan, and execute societal and infrastructural improvements to attract LIB value chain actors to the region.
Mode	**Intermediary mode** *Development and deployment of intermediate NR/SR for creation of SR.*	**Partner mode** *Distributed resources and transfer of OR to activate an alliance for co-creation of SR.*	**Partner mode** *Distributed resources and transfer of OR to activate an alliance for co-creation of SR.*
			

[41] To avoid a chaotic figure with too many elements, the other founders of Battery Norway are excluded for the sake of readability. They would represent the same position as the three BCMs inside the intermediary boundary if they were included.

7.1 Battery Norway

System-level legitimacy, shared vision and belief in growth potential and enabling policies were deemed insufficient by the BCMs and the other founding members of Battery Norway [-F4][-F6]. They thus pooled their financial resources to form an intermediary organisation, where dedicated personnel would work to promote the industry as a whole. This included enhanced TIS legitimation [F6], as the intermediary organisation represented a united industry with common goals and visions [F4]. The organisation also made up a network of actors across the LIB value chain, each with distinct knowledge and experience. Functioning also as a meeting place and an industrial collaboration platform, Battery Norway paved way for the sharing of existing knowledge and the creation of new knowledge [F1]. The legitimacy of being a "neutral" industrial actor, Battery Norway was invited to join other system building activities, which then again led to the release of the Norwegian Battery Strategy, the launch of several educational programmes, and getting Norway to sign up for battery related IPCEI initiatives [F4][F5][F6].

7.2 Beyonder/Morrow and UiS/UiA

These two cases are very similar in nature and are thus consolidated in this section. The BCMs employed their financial and organisational resources (employees, knowledge, technologies, and facilities) together with the universities' comparable resources to enable the co-creation of R&D collaborations and educational programmes [F1][F5]. The existence of these R&D collaborations and educational programmes are valuable for the entire Norwegian LIB TIS, as they focus on research across the value chain. Furthermore, the mobilisation of human resources [F5] will be crucial for recruiting enough skilled workers in the Norwegian LIB value chain, as recruiting foreign workers is both a tedious process and highly competitive. The shared vision and ambitions for knowledge creation in a university/industry partnership also enabled access to funding that the actors would not have gotten access to had they not entered these partnerships [F4][F6].

7.3 FREYR and the regional development in Rana

FREYR had a vision of creating an attractive region for other LIB value chain actors to establish themselves in. To do so, they realised the need to focus on both infrastructural and societal improvements. This required partnering up with the local governing body, Rana Municipality, and a regional development organisation, Rana Utvikling. Together, they initiated a set of measures to ensure support of the industry [F6], to enable a sustainable growth of inhabitants in the region should the industry blossom [F5], and to lay the groundwork for a rigorous and tailored infrastructure for housing a regional cluster of the LIB value chain and to make Rana the place to be for collaborating in making the Norwegian LIB TIS competitive and sustainable [F4][F5].

7.4 Analytical summary

The conceptual analysis shows that the three BCMs have initiated a range of system building activities that differ in both mode of system building and which functional deficiencies they counter. Furthermore, the different system building activities differ in what available resources the BCMs had available. The findings provide valuable insights to both the system building concept as a theoretical framework, and to the empirical context as such. This will be discussed further in the concluding chapter.

8 Discussion and concluding remarks

This thesis set out to investigate how and why the Norwegian battery cell manufacturers initiate system building activities in the Norwegian LIB TIS, and how these activities influence the Norwegian LIB TIS functions. Through an intensive embedded single case-study, the findings provide valuable empirical insight into how the BCMs navigate as key players in the LIB value chain. Furthermore, the thesis contributes to an understanding of the formation of LIB TISs outside of the well-established LIB TIS in Asia and China.

The thesis has also contributed to enhance the transferability of the system building concept by applying it to a different technological domain, with a temporal and spatial context distinct from earlier system building research. The analytical framework proposed by (Musiolik et al. 2020) provides a useful way of investigating the strategic agency of TIS actors by incorporating concepts from management literature. However, certain shortcomings and limitations were discovered.

An interesting aspect of investigating similar actors' system building activities, is the role the respective actor's business model has in influencing which type of system building they prioritise and the motivation behind initiating them. One of the FREYR informants explicitly stated that they employ the shared value concept in their strategy, which consequently seems to influence what kind of system building activities they initiate. Furthermore, FREYR is licensing their technology and thus seems to be focused on speeding- and scaling up their own production and the Norwegian LIB value chain as a whole. Conversely, Beyonder and Morrow are developing their own technology and seem more focused on enabling internal and system-wide R&D and educating skilled workers. A shortcoming of the system building concept is thus a lack of attention to the influence of system builders' business model. So, while system building already incorporate several contributions and concepts from the management literature (Fischer et al. 2022; Musiolik et al. 2020), adding concepts and aspects from business model and business model innovation literature could be a fruitful expansion of the system building concept and thus an interesting implication for future research.

Furthermore, the study did not uncover much entrepreneurial experimentation [F2] in the identified system building activities. This thesis thus comes to short in meeting the call by scholars to pay additional attention entrepreneurial notions (Fischer et al. 2022). Additionally, the thesis did not uncover other modes of system building than the ones proposed by Musiolik et al. (2020), which the authors themselves recognise as a potentially interesting future refinement of the concept. The identification of other modes of system building might be dependent on adding further dimensions to the system building concept as a whole.

For example, the system building focus of the BCMs (and other industry actors, based on the findings) seems to be heavily directed towards resource mobilisation [F5], and knowledge development and diffusion [F1]. The reasoning behind this seems to be the urgent need to catch up in the highly competitive race globally. Thus, leveraging the potential of novel LIB applications and use sectors, such as maritime, seems difficult for industry actors to prioritise on their own [-F3]. Considering the 10 action points put forward by the Norwegian government in the Norwegian battery strategy, an implication for policy intervention is thus to introduce means related to Action 10: Become a leader in tomorrow's battery solutions and leveraging the opportunities afforded by digital technologies (NFD 2022b, 11). Putting forward incentives for innovative industry collaboration, as with the electrification of ferries across the Norwegian coast, could further boost development and diffusion of these technologies and applications [F5].

This thesis has several limitations. As with previous system building case studies, I have focused on a specific case in a specific field, in a specific geographical setting. However, it differs from previous studies and might thus contribute to a strengthening of the concept's transferability. Nevertheless, system building research to date are concentrated to the European continent (Fischer et al. 2022; Musiolik and Markard 2011; Musiolik, Markard, and Hekkert 2012; Musiolik et al. 2020; Planko et al. 2016). The system building concept could thus benefit from being explicated in another spatial context. As TIS scholars in general pay an increasing attention to developing countries (Köhler et al. 2019), it would be interesting to see how the system building concept can provide insights to the technological development there. Relatedly, doing comparative system building research is an interesting direction for future research. Especially considering the LIB value chain and BCMs. Comparing the system building efforts of BCMs in two countries or regions might uncover important contextual variables influencing how, and for what purpose, they initiate system building activities.

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