Chloe Depledge

The Key to Our Energy Future?

Unravelling the transformative potential of green path creation

Master's thesis in Globalisation and Sustainable Development
Supervisor: Markus Steen
June 2022

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Abstract

The global green transition is resulting in various forms of new regional development, as a growing point of interest in academic literature and policymaking. This thesis explores the development of the Norwegian battery manufacturing industry in Arendal (Agder) and Mo i Rana (Nordland) through the lens of *green* path creation. The purpose of this thesis is to establish the enabling and constraining contexts behind this emerging path. It aims to do so by employing a broader perspective on path creation, using a mixed theoretical framework of evolutionary economic geography and global production network approaches. The qualitative case studies are informed by a series of interviews that have been triangulated with relevant secondary data. The research has revealed variations between path creation in both regions under study, but also many similarities, doing so by identifying several key enablers and constraints posed to the regional development of the industrial paths based on pre-existing structures, conditions and agents of change. Furthermore, it identifies the path creation is the product of endogenous processes based in part on firm branching, combined with extra-regional resources.

Dedication

I dedicate my academic achievement to the loving memory of Christine Depledge, who passed away before the completion of this work.

Acknowledgements

Thank you to NTNU and the staff who have contributed to broadening our minds over these past two years; to my supervisor for dealing with my annoying questions; to Reyn for helping me on my way; and to all the participants who shared their time and insights with me.

Those from the reading room, thanks for the snacks, sleepless nights and suffering in solidarity together. And those from Norway, who have helped make me feel at home here.

To everyone in the UK; to my family, who have supported me from afar; and to Grandad, who first taught me to love learning.

Kacper, I wouldn't have made it without you.

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List of Abbreviations

CO_2	Carbon dioxide
EEA	European Economic Area
EEG	Evolutionary Economic Geography
ESS	Energy Storage Systems
EU	European Union
EV	Electric vehicle
FDI	Foreign direct investment
GHG	Greenhouse gases
GPN	Global Production Network
GVC	Global (Value Chain)
IPCEI	Important Project of Common European Interest
LIB	Lithium-Ion battery
MIT	Massachusetts Institute of Technology
MOU	Memorandum of understanding
NGO	Non-Governmental Organisation
NSD	Norwegian Centre for Research Data
NTNU	Norwegian University of Science and Technology
NYSE	New York Stock Exchange
O&G	Oil and Gas
R&D	Research and development
TIS	Technological Innovation Systems
TNC	Transnational corporations
UiA	University of Agder
UiS	University of Stavanger
USN	University of South-Eastern Norway
WTO	World Trade Organization

Chapter 1: Introduction

Climate change and sustainability have become increasingly important in political discourse over the last few decades. The Brundtland Report, published in 1987, signalled an acknowledgement that critical action was needed to address manmade environmental issues, paving the way for sustainable development pathways and a shift in industrial approaches. Today, while slow progress has been lamented by many, global momentum towards a green transition is ever-growing. Structures of governance have embraced the narrative, illustrated by the implementation of the Sustainable Development Goals (UN, 2015) and commitments to the Net Zero coalition (UN, u.). Increasingly, regions are recognising their responsibility to play a part in this effort, as well as the potential opportunities that co-creating this sustainable vision could produce. This regional development has taken on many forms; with a myriad of innovative solutions, initiatives and technologies being industrialised. Green industries are largely defined as the economic activities involving the production of a product or service that contributes directly to the preservation of the environment[1]. Recent regional restructuring efforts to facilitate this new green growth and the 'greening' of existing industries provide ample examples of this, not least the development of battery manufacturing.

Battery technology powers a considerable number of applications, including electric transportation, energy grids, and everyday devices, such as smartphones and laptops. It is also rooted in major efforts towards climate action, with the growing decarbonisation and electrification of global societies closely connected to the development of renewable energy technologies. Surging demand for batteries has led exponential growth in production over the last few years, with forecasts suggesting a threefold increase in production capacity between 2020 and 2025 (Yu, 2021). Many actors have therefore recognised the potential benefits offered by tapping into this global market, providing the basis for potential economic growth and an acceleration of the green energy transition. However, this green industrial development is not without its challenges, with a complex set of factors working to propel or hamper new industries.

This thesis focuses its scope on Norway, where the shift away from the oil and gas sector remains a high priority and the development of new green industries has gained attention in

[1] United Nations Industrial Development Organization, Green Industry: Policies for Supporting Green Industry (Vienna, 2011).

social, political, and academic circles (Regjeringen, 2021A; Regjeringen, 2017; Grillitsch & Hansen, 2019). Up to now, much of the activity within the battery industry has unfolded at a regional level in Norway. Empirically, this paper examines two Norwegian regions where promising industrial development has been realised in connection with the battery industry. The case study shall shed light on these sites of green growth, in both Arendal (Agder) and Mo i Rana (Nordland). While exploring these regional cases, the paper aims to shed light on industrial development by employing an exploratory mixed-method approach to data gathering i.e., triangulation. A series of interviews with core regional actors and document analysis inform the research. These are contextualised with a theoretical framework consisting of evolutionary economic geography (EEG) and the global production network (GPN) approach. This will allow for the consideration of both endogenous and exogenous factors influencing industry development to discuss the research questions set out in the following section.

1.1 Research aims and contribution

Following on from the introductory discussion, three research questions are proposed in order to guide the research and establish a clearer picture of regional industrial development in the way of the Norwegian battery industry:

This thesis aims to expand current knowledge of new *green* industrial development in regional settings. For the purpose of this thesis, the emergence of a Norwegian battery industry is understood as path creation, in line with contemporary EEG thought. Through this empirical focus, the research contributes to a more in-depth understanding of green path creation by investigating the nuanced processes shaping green regional path development. More specifically, it intends to unpack the “enabling” and “constraining” context behind the development of the battery industry in Norway, as a process that is deeply rooted in the transformation of our energy systems. In many cases, new industries are contingent on a range of endogenous and exogenous, linkages and conditions to succeed, which is highlighted by the theoretical cross-approach of EEG and GPN. Due to the complex and lengthy nature of the green transition, forms of collaboration across the system are therefore required (Markard et al., 2012). Actors from both the public and private sectors have a hand in eliminating these constraints and leveraging drivers for the regional advantage. This thesis aims to shed light on this by answering the following research question: *What are the main enabling and constraining elements behind regional path creation in the battery industry?*

Following this, the thesis shall provide an overview of how battery industry development has occurred, doing so by shedding light on mechanisms found within its formation at a regional level. Due to the current stage of development in the Norwegian battery industry, whereby the phenomenon of path creation is still unfolding at the time of writing, challenges are presented in the lack of readily available data. However, it also presents an interesting case to explore novelty, as a concept that is relatively underexplored in spite of work on new industrial paths (Steen, 2016). In consideration of this, the last research question guiding the study is as follows: *How has industry emergence and development occurred in respect of the Norwegian battery industry?*

As the novelty of the battery industry in Norway translates to few studies focusing on this topic. It is hoped that this thesis contributes empirically by establishing a more in-depth understanding of the developing battery industry. As a source of economic growth, job creation and environmental sustainability, the sector is posited to bear a number of ripple effects in the regions under study (Menon Economics, 2021; Menon Economics, forthcoming). Furthermore, this industry has been identified as a key enabler of the green energy transition from fossil fuels to renewable sources, which alone warrants attention. As these issues are relevant to academia, industry and policy, the findings put forth in this research can be used to support green path creation at a regional level. This thesis also aims to contribute to theory in several ways: 1) theory-testing with the addition of a new case study to the field, and 2) theory-developing in the tethering of two analytical perspectives to address the perceived theoretical gaps and broaden perspectives, as outlined in the following section.

1.2 Previous research

This thesis synthesises several theoretical approaches found in current literature in pursuit of addressing all research questions. Drawing on insights from evolutionary economic geography (EEG) in tandem with a global production network (GPN) perspective, the study integrates relevant strands of literature to avoid operationalising a narrow view of green path development. In this vein, it is hoped that a more pluralistic understanding may be established. Based on this broad theoretical base, there is a multitude of research that informs the topic both theoretically and contextually.

Evolutionary Economic Geography approach

In EEG, industrial development at a regional level has received considerable attention. An existing wealth of literature in EEG offers a view of how regional conditions can favour or hamper industrial growth. An example of this is found in path dependency, with Martin and Sunley (2006: 408) offering the "path as process" approach to understand the contingence of path creation on previous economic evolution, which acts to constrain novelty. Boschma (2017) focuses on the concept of relatedness and regional branching towards new paths. This helps to further examine how regional variation can impact industry emergence and sets out the conditions necessary for path creation. Beyond the very preliminary stages of path creation, several mechanisms are expanded upon to determine what can drive path development or what a lack thereof can constrain (Binz, Truffer, & Coenen, 2016).

However, this thesis also looks to a growing body of EEG literature, where more recently, scholars have begun to deal more specifically with the topic of *green* regional path development. (Binz & Truffer, 2017; MacKinnon et al., 2019; Steen & Hansen, 2018; Trippl et al., 2016; 2019). Asset modification, resource formation and other forms of reorganisation are addressed, which in turn, highlights the actors influencing path development across multiple scales. However, there are several shortcomings of EEG in connection to the notion of such green industrial development. It is criticised for the lack of attention paid to the wider social, cultural, and institutional realities that exist within and alongside economic systems (Hassink et al., 2019). Scholars are increasingly expanding research agenda away from this hyperfocus on the micro-level (Binz, Truffer, & Coenen, 2016). To further this, the research questions will be addressed theoretically from an inter-disciplinary standpoint.

Global Production Network approach

The value of the cross-fertilisation between the EEG and GPN approaches has already been recognised. An understanding of the interregional and extra-regional linkages and processes are enhanced, a research gap identified by Rodríguez-Pose (2021). This has particular merit in relation to the battery industry, which is global in nature and supplies international electronics sectors, and as such a major strategic export market for Norway. While the authors behind GPN 2.0, Coe and Yeung (2015) offer relevant ideas over firm and market dynamics to explain location decisions, Blažek and Steen (2021) seek to explain new industrial path development in regions by applying the GPN perspective with the concept of strategic coupling. These strands of literature help to uncover the power structures between actors and the wider dynamics shaping regional industrial development.

With the ambition of gaining an overview of the entire battery value chain; literature focusing on the technical mechanics of battery production, policy and regulatory frameworks, and lead firm reports have also provided additional insights to lend ground knowledge to this thesis (see Lebedeva et al., 2016; Freyr, 2022; EC, 2020). In building upon the past research laid out above, this thesis hopes to further perspectives of new industrial development by conceptualising the phenomena through a broader theoretical lens. By applying this to promising Norwegian battery industry, an interesting case is offered for this research to explore the underlying nuanced actorial, temporal and spatial dynamics which can drive or hamper industry emergence.

1.3 Outline of the thesis

The thesis is structured in the following order; firstly, an introduction to the relevant literature found and concepts useful to understanding the phenomenon is provided in the theoretical background. Then, a description of the methodology used in the research process is detailed, along with an overview of how the data was collected and analysed. In Chapter 5, the findings from both the interviews and secondary data are analysed. Following this, the findings are discussed in Chapter 6 in relation to the theoretical contributions laid out in Chapter 3, with the aim of addressing the research questions more directly. In the final chapter, the key findings are summarised and ideas for future research are suggested.

Chapter 2: Empirical Background

Over the last decade, there has been a revolution taking place in the energy sector. Renewable, clean energy is on course to redefine our future, replacing coal, oil and gas with power from natural sources, such as solar, wind and hydropower. Meanwhile, as the world seeks to reduce its reliance on fossil fuels and reduce carbon emissions, an increasing trend of electrification amongst global societies can be found. Changing systems of how we produce, and store energy have made batteries a key enabler of this green transition. This chapter places the thesis in context by detailing a comprehensive overview of battery technology, the associated global value chain as well as highlighting the recent history of Norwegian engagement with the sector, in order to set out some of the realities the industry is facing.

2.1 Origins of the battery industry

Advances in science and technology have led lithium-based batteries to become ubiquitous following their commercialisation by Sony in the 1990s (Xie & Lu, 2020). Nowadays, rechargeable battery technology performs a crucial role in various parts of society. The predominant technology, batteries with lithium-based chemistries, offer elevated levels of power density, energy efficiency and a longer calendar life to electronics markets. There are several technological applications of commercial lithium-ion batteries (LIBs), being manufactured for personal electronics, energy storage systems (ESS) and electric vehicle (EV) markets. Though approximately 75% of LIBs are still produced for personal computers and mobile phones, the need for batteries to power electric transportation and energy storage systems is rapidly growing (Xie & Lu, 2020). As such, the industry has been identified as a source of green growth by many nations, providing the potential for both economic development and fuelling the transition to clean energy systems to mitigate the effects of climate change. A rapid increase in the production capacity of LIBs is therefore expected in the next decade to meet this demand, as seen below in Figure 1. Current estimates of global production capacity for LIBs also support this projection, ranging from 250GWh/year to 640 GWh/year as of 2022 (Usai et al., 2022).

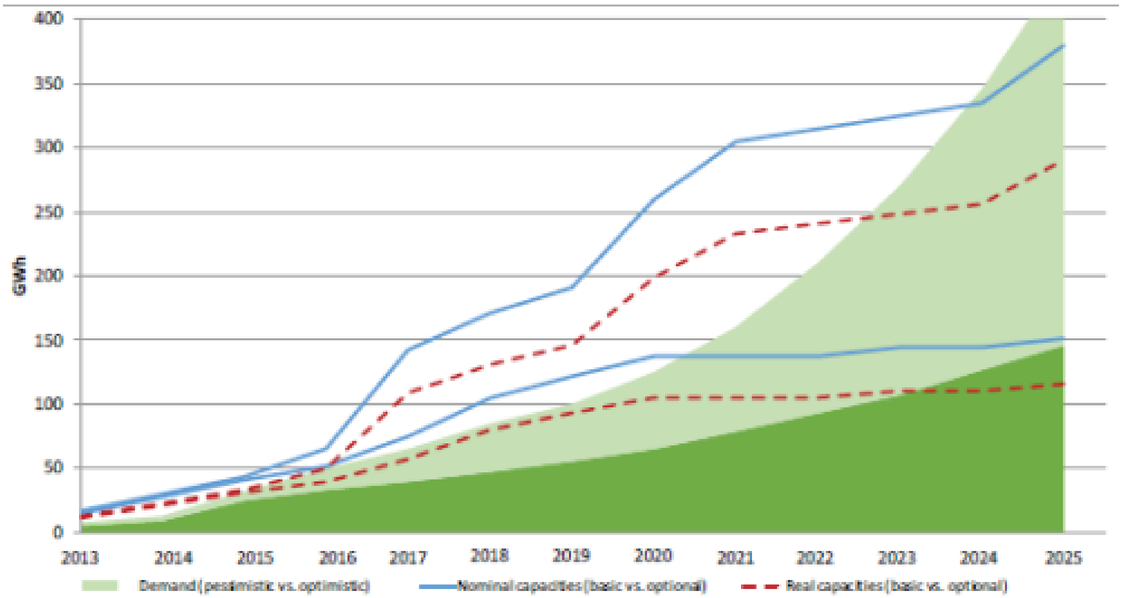

Figure 11: International LIB cell production capacity for ESS and EV and projected demand Source: EC JRC (Steen et al., 2017)

2.2 Global value chain

As the full scale of climate change has been realised in recent years, the socio-political emphasis on a green transition has led to the acceleration of green industries and technologies globally (Sovacool, 2016). High electrification scenarios predicted by global governments also correlate to Figure 1 above (EC, 2011; IEA, 2022). A major driver for the growth of European LIB production is the EV market, along with growing demand in marine and energy sectors. Recent investments in manufacturing, as seen in the emergence of producers such as Northvolt AB in Sweden and Envision AESC in the UK, have bolstered the burgeoning industry in Europe. A total of 180+ industrial scale battery projects are under development in the EU, with 47 of those in cell production. Currently as a single trading bloc, Europe comes second in an overall ranking of overall battery supply chain strength (BloombergNEF, 2021). This has been proactively facilitated by the strategies of actor networks in the Global North, as disruptive changes to energy systems and other sectors require the support of political, institutional, and regulatory regimes, sociotechnical changes which are often written into the narrative of a “green transition” (Skjoldager, 2021).

However, the manufacturing activities of many green technologies still remain embedded in Asia. This is also the case for the battery industry, wherein China, Japan and South Korea have the majority market share. China, in particular, holds the dominant role in the extraction, refining, processing, the manufacturing of components and battery cells, as well as being the biggest end-user of LIBs in the EV market. This production is headed by a number of leading firms who have achieved vertical integration, such as CATL, BYD and CALB (Usai et al., 2022). Moreover, the nation is also home to 77% of the global production capacity for batteries as of 2020 (Ribeiro, 2021). Though downstream activities are more geographically dispersed, this represents a major bottleneck in the battery value chain. As a threat to future manufacturing capabilities abroad, a so-called "battery arms race" has ensued. For this reason, Chinese production capacity is predicted to fall to 66% over the next decade, as American and European producers boost domestic capacity (CEA, 2020). Market consolidation is believed to be the natural progression of this global value chain, wherein the total market share will be comprised of ten to fifteen leading manufacturers (Campagnol et al., 2021). Hence, it is important that entry to the market occurs sooner rather than later for those wishing to participate in the race.

2.2.1 Upstream sectors

As a multi-component technology, the production of all required elements used in LIBs is carried out by various manufacturers in different industries and regions across the globe (Stephan et al., 2021). While mapping the entire value chain for lithium-based batteries is an extremely complex task, it can be divided into the six segments as illustrated in Figure 2. The first segment of the value chain is the mining and processing raw materials used in the production of batteries. A vast array of elements is used in the battery production process, including lithium (Li), cobalt (Co), nickel (Ni), manganese (Mn), titanium (Ti), aluminium (Al), tin (Sn), copper (Cu), silicon (Si) and carbon as graphite (C), though this varies from producer to producer (Lebedeva et al., 2016).

While the extraction of these materials takes place worldwide, there is an element of spatiality. Due to the natural occurrence of these resources, there is a geographical concentration of these critical materials in certain regions. This has created a dependency on some critical materials, as seen in the continuation of cobalt mining in the Democratic Republic of Congo despite human rights abuses. Furthermore, the monopolistic grip of Chinese firms over the mining and processing of these raw materials presents a direct threat to other manufacturers. For the rare-earth metals critical to production, 96% of global mining output comes from China (Silver, 2019). This has followed an intense geopolitical strategy, which saw the Chinese increasingly control resource extraction in Africa. In contempt of WTO law, their imposition of export restrictions, like quotas, duties, and licenses, has fuelled the growth of emerging downstream industries in China whilst contributing to resource shortages and price fluctuations for producers elsewhere (Wu, 2017). This has contributed to low investment rates in the mining sector and as such, could pose an obstacle to battery material supplies in the future. Instability stemming from this resource scarcity has been further reflected in other value chain activities, acting as a stimulus for innovation and research in the industry to replace these finite metals and minerals, as well as driving the move of the overall value chain closer to sites of production.

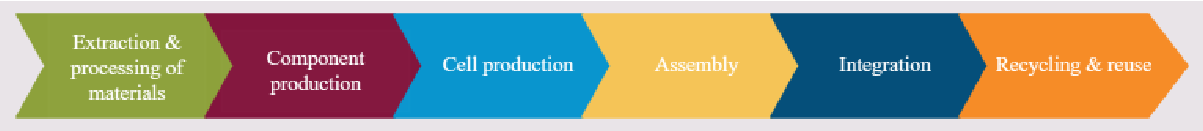

Figure 2: Battery value chain, showing upstream, midstream and downstream activities. Source: Adapted from Lebedeva et al., 2016.

2.2.2 Midstream sectors

Overall, midstream activities represent a technologically complex value chain segment, wherein the stages are heavily guarded by corporate secrecy over battery technology and production processes. A basic understanding of batteries dictates that four main components are required to compose a battery cell: a positive and negative electrode - the anode and cathode, an electrolyte, and a separator. As the most expensive part of the battery, the cathode typically consists of a large variety of elements which vary depending on the chemical composition. Common configurations of commercial lithium-based cathode architecture are lithium cobalt oxide, lithium manganese oxide, lithium iron phosphate and lithium nickel manganese cobalt oxide chemistries (Lebedeva et al., 2016). Though, there is growing research into variants with a higher energy density, such as lithium-air and lithium-sulfur to replace the current lithium technology (Kufian and Osman, 2021).

The Asian region also leads the production of battery sub-components and cells, a market share distributed between China, Japan and South Korea. A high level of competition makes for a dynamic market, though this is set to expand with entry from European and America firms, as stated in section 2.1. Global production shares first signalled this shift following the start of mass production at the Tesla Giga Nevada in 2017. End-use demand, especially from the automotive industry, remains a particular driver of growth for Western manufacturers entering the market. Industrial upscaling is needed to capacitate this, with the construction of Gigafactories that produce high rates of GWh.

2.2.3 Downstream sectors

The downstream sectors refer to the assembly of components and their end use. In the assembly stage, individual cells are placed together to form modules in order to develop a higher voltage. Following this, modules are integrated into the overall battery system, including a battery management system, power conversion system and cooling system, which varies according to end-use (Lebedeva et al., 2016). Here, the market is becoming increasingly concentrated as EV producers are moving upstream to guarantee a better security of supply and economies of scale. Many end-use manufacturers have opted to incorporate this segment into their in-house capacities.

A growing sector is the recycling, repurposing and reusing batteries, linked directly to the scarce resources and growing industrial regulations. In EVs, the battery is classified as end-of-life when about 70-80% of the total capacity remains (Zhu et al., 2021). From this sector and others, the residual active materials present opportunities for both second-life usage or resource recovery. Though this entails a complex and high-cost process, largely due to the lack of standardisation in batteries (Gaines, 2018). Many of these technological challenges relating to circularity may determine the future of the industrial leaders.

2.3 Industry status in Norway

Since striking oil in the late 1960s, Norway has had a high dependence on the petroleum industry. Oil and gas remain the biggest sector in the Norwegian economy based on value creation. These activities have significantly contributed to the economic development of the nation. However, in light of the shift away from these finite resources, there is impetus to find other opportunities in green industrial development. Over the past decade, Norway has become home to innovation and production in maritime battery technology with Corvus, as well as the assembly of batteries for both Corvus and Siemens. Though, it was not until very recently that the nation has seen significant developments within the battery industry. Currently as it stands, there is no material battery cell production. This contrasts with Chinese domination of the battery industry, while the role of Norway in the value chain remains in relatively early development, the myriad of opportunities posed by this global industry make it an attractive prospect for domestic actors.

According to BNEF, Norway takes 6th place globally in their 2021 lithium-ion battery supply chain ranking, though a fall to 8th place is expected by 2026. Nationally, the environment and regulations, innovation and infrastructure are cited as the strongest assets for establishing a domestic supply chain. While Norway is set to gain manufacturing capacities, it is indicated that reduced strength in the areas of raw materials and battery demand may affect their standing in the global industry, particularly considering the international shift towards green mobility (BloombergNEF, 2021). Despite this, the prospect of integration into the global battery value chain appeals to both industrial and political agendas. The battery value chain has been identified as a “key strategic area” by the Norwegian government (Regjeringen, 2021b), with the Norwegian battery value chain estimated to generate a turnover of 90 billion NOK by 2030 (NHO, 2021) and in turn create numerous jobs.

The Norwegian Government, we have big ambitions for the Norwegian battery industry.

(Jan Christian Vestre, Norwegian Minister of Trade and Industry at the time of writing, on visit to FREYR Battery Pilot Plant, Feb 2022)

As a source of green industrial growth, the industry is hoped to contribute to the national 2030 emissions reduction target of 55% (Regjeringen, 2021b), as well as facilitate the transition away from oil and gas-heavy exports to create a more sustainable balance of trade[2]. With an official proposal expected by Summer 2022, the National Battery Strategy remains in the works, though the national strategy for a green, circular economy signals the strong pool of assets that could be used to fuel the industry (ibid).

A central advantage offered by Norwegian regions to battery manufacturers is centred around Norway’s role as “the green battery of Europe” (Steen, 2016). Access to cheap, stable and green electricity powers the energy-intensive manufacturing processes entailed in battery production. Furthermore, an established base of technological knowledge and a productive workforce is attractive to incoming firms, paired with the stable regulatory environment. A high volume of end-of-life batteries available for downstream segments elevates the prospect of Norwegian battery manufacturing, by allowing further investments in downstream segments. Norway also hosts entities in nearly every supply chain segment, from material providers to second-life reuse and battery recycling. The country also supplies the EU with 21% of aluminium, 13% of nickel and 8% of cobalt imports, highlighting the ready supply of sustainably produced raw materials (The Explorer, 2021).

Cell production is considered to be the most crucial segment of the value chain and appears to be the main focus for Norwegian actors, with this thesis focusing on the emergence of industrial development in this segment in particular. In 2021, national media outlet NRK stated that regions were vying to "become battery-municipalities" (NRK, 2021), with promises of economic growth and regional development to those that manage to host

[2] https://www.ssb.no/en/utenriksokonomi/utenrikshandel/statistikk/utenrikshandel-med-varer

Gigafactories. Several battery firms have released plans to begin large-scale industrial battery manufacturing operations across Norway, including Morrow, Freyr, and Beyonder.

2.4 Main actors in the Norwegian battery industry

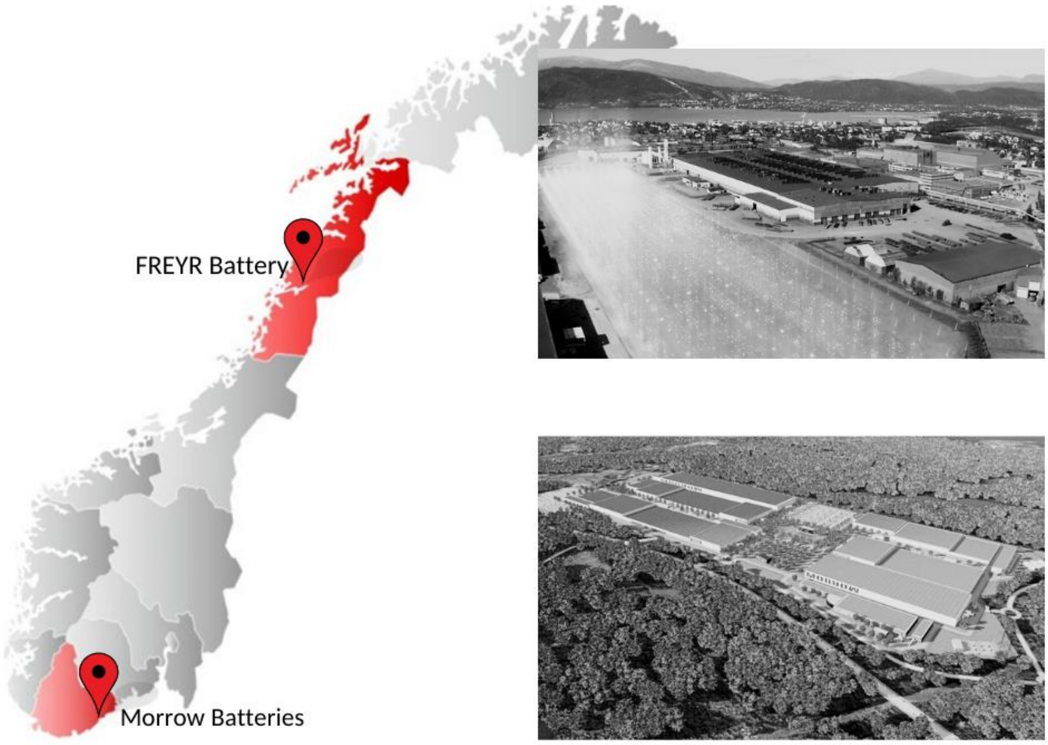

Figure 3: The locations of key battery manufacturers in Arendal (Agder) and Mo i Rana (Nordland) are highlighted above. Source: Modified from Wikipedia, FREYR Battery and Morrow Batteries.

Following on, one can see the burgeoning interest in further development of a Norwegian battery industry to supply important sectors, such as EV and ESS markets. Two key firms in the battery industry are taking the lead to manufacture lithium-ion batteries in Norway. Freyr Battery is currently constructing their first Gigafactory in Mo i Rana (Nordland) and Morrow Batteries is doing so in Arendal (Agder). This provides the research with a more specific regional scope, as it seeks to understand industry emergence and development in the context of these firms and regions.

2.4.1 Arendal (Agder)

The region of Agder has approximately 310,000[3] inhabitants and is known by some as the "drilling bay" due to the prevalence of the oil and gas sector (Kyllingstad, 2021). These

[3] Note: Municipality populations are provided. https://www.ssb.no/statbank/table/01223/tableViewLayout1/

industries were central to the local economy during the latter decades of the 20th Century. Energy producers have since sought to move into cleaner energy pathways, with national debate regarding Norway's "life after oil" for much of the last decade.

Within this county lies the coastal city of Arendal, which has been the site of battery industry activities recently and is home to a population of around 45,000[9]. There is a long maritime history across the municipality, with many connections to the oil, gas and offshore sectors, including the presence of the GCE Node nearby. Nowadays, small shipbuilding is a well-developed industry, along with the process industry, which is centred around the NCE Eyde Cluster. As the municipality with the largest renewable energy surplus, Arendal has a clear strength in energy in supplying new industry with a stable energy flow.

Cell manufacturer Morrow Batteries was first formally established in 2020, owned by both Agder Energi, NOAH AS and the Danish Pension Fund. The firm was based on an idea from the Norwegian environmental NGO Bellona, who recognised the vast potential and slow commercialisation of green technology. Morrow now leads battery manufacturing developments in Arendal, with plans to open a 43 GWh Gigafactory that will be ready for production by 2024 in the Eyde Energi Park. Other battery related activities also take place nearby; Corvus Energy is partnered with Arendal-based Kitron for the manufacturing of their battery management control systems. Alongside this, an innovation centre in Grimstad is also in the process of being built, which aims to forge collaborations between UiA and Morrow to develop competencies key to the battery industry. This is part of the "Battery Coast" initiative (Emanuelsen, 2020), which aims to localise the value chain to Southern Norway. The Eyde Material Park is also key to this plan, in order to develop the sustainable materials needed for production.

Initially, the firm will focus on producing batteries for ESS until they can become certified for EV battery production. Morrow is also heavily committed to developing in-house innovations to remove the unsustainable elements from the battery technology, with plans to produce manganese based LNMO batteries firstly, followed by the development of in-house lithium sulfur technology in the long term. In doing so, they have formed partner agreements: with Elkem, Halvor Topsøe, ABB, and Siemens for technology and materials (Appendix B).

2.4.2 Mo i Rana (Nordland)

The other region of focus is Nordland, an area of Northern Norway, which has a total of 240,000 inhabitants and can be characterised by a heavy industrial background, though this varies geographically due to the 38,155 km2 land area. In recent years, positive growth has been derived from the aquaculture industry. Nordland is known for its vast hydropower reserves, maintaining an energy surplus for many years.

In particular, the city of Mo i Rana lies in the middle of the county, with population of 26,000. The municipality found wealth in iron mining and steel production due to their natural resources (Slottemo, 2007). After the cornerstone ironworks was shut, the restructuring of the local economy occurred from 1988 onwards, several years after the global steel crisis of 1975 (Grønland, 1997). Following this, the process, mineral and workshop industries have dominated the employment market in the area. Mo Industrial Park, one of the largest Norwegian industrial parks, hosts 110 companies and provides dynamism to the industrial environment, whilst the emergence of Campus Helgeland has spurred on the growth of an academic community.

Mo i Rana has seen large scale construction recently, with FREYR Battery choosing a local site for their pilot plant, with further development in Mo Industrial Park. The company was formed in 2018, and are focusing on battery cell production of up to 43 GWh capacity by 2025. This is one part of five Gigafactories planned by the company in the immediate area, who envisage a "Nordic Battery Belt" across Scandinavia, with Northvolt operating across the border in Sweden. This is supported by their aim of building up an entire battery value chain around the region, in order to provide batteries for ESS and grid systems during the initial phases of production. Recently, Freyr also received rights to build production facilities in Vaasa, Finland, and are planning to build capacity in the US following a joint venture with Koch industries, demonstrating their rapid plans to scale up in order to contribute to decarbonisation globally.

In partnership with 24m, Freyr are licensed to produce semi-solid batteries using US patented technology developed at MIT, which is a "disruptive technological innovation" (Cision, 2020). The business strategy followed by Freyr is partnership-based, with more than 40 different agreements (Appendix B), and have recently attained a NYSE listing and raised significant capital to fulfil their ambitious plans.

However, while this represents an exciting opportunity, both lead firms face major challenges in embarking on this new Norwegian industrial adventure.

Chapter 3: Theoretical Approach

This chapter provides a theoretical framework to examine regional green path creation, providing a base with which to analyse the development of the battery industry in Norway and outline the future prospects. At a basic level, industry emergence is defined as a new or reformed industry that has been established out of technological innovation, consumer needs, or other socio-economic changes (Phaal et al., 2011). Key concepts from the EEG theory are drawn upon to better understand the emergence and development of industries at a regional level. In addition, useful GPN literature is employed to contextualise the exogenous processes behind regional industrial development. Using these theoretical strands, an analytical framework shall be composed and employed in this thesis.

3.1 Evolutionary Economic Geography (EEG) Approach

The evolutionary lens

Globalisation has undoubtedly affected the cross-border flows of capital, technology, and people, reshaping the spatial and temporal contours of our societies. Some go as far to say that geography has been rendered obsolete, like Friedman (2005), who famously stated that "the world is flat". In contrast, economic geography points to the uneven locational patterns in trade, production, and development; mirroring the ongoing spatial dynamics behind manufacturing activities. Beyond this, shifts towards regionalisation are argued to represent a new phase of deglobalisation, depicted by the changing configurations of global production and supply chains (Gong et al., 2022). The success of industrial hubs and clusters in some regions, such as the Silicon Valley, in contrast to the economic decline experienced by others, has sparked interest in understanding change at a regional level. This suggests that in spite of the global nature of some industries, a strong regional environment is required for growth. Considering the regional embeddedness of certain industries and actors, it is therefore useful to study the interplay between regional dimensions and industries, for which the evolutionary economic geography (EEG) perspective provides a valuable approach.

Deriving from the seminal works of Joseph Schumpeter (1942), EEG seeks to explain how economic landscapes change over periods of time (Boschma & Frenken, 2006). Four major branches can be identified in EEG: generalised Darwinism, complexity science, geographical political economy and path dependency, with a range of theoretical and conceptual debates ongoing within (Boschma, 2022). This 'evolutionary turn' (Grabher, 2009) therefore offers us with a wide and established base of literature. More specifically, this study finds interest in literature exploring the intersection between place and new economic change (See: Martin & Sunley, 2006; Boschma & Frenken, 2006; 2015; Essletzbichler & Rigby, 2005; Hassink et al., 2014, Pike et al., 2016). Applying such theoretical strands can help enhance understanding as to how the formation of new industry paths may be either enabled or hindered by processes at a regional level (Boschma et al., 2017).

3.1.1 Conceptualising green pathways

When referring to the economic and industrial changes that occur in a region from past to present, EEG defines this evolution as a path. Industrial development paths are defined as a "set of functionally related firms and supportive actors and institutions that are established and legitimised beyond emergence and are facing early stages of growth and developing new processes and products" (Binz et al., 2016: 177). Discursively, this coincides with the narratives of the green transition, which are increasingly being realised via shifts to "greener" economies and industries, as "the challenge of envisioning and moving towards desirable decarbonised futures has increasingly been framed in terms of pathways" (Rosenbloom, 2017). In pursuit of environmental sustainability, the forging of these new green growth paths can be found across many regions. How, though, do these green pathways take form in regions?

Endogenous path dependent development

It is posited that existing regional industrial bases can either offer supportive or restrictive environments for new green paths. This links to path dependence, a constitutive concept in EEG which argues that future trajectories are contingent on regional history. Following this, the geographical distribution of new development paths is related to the inherited industrial structures and capabilities found in a region (Martin, 2010). A clear focus on economic novelty in relation to path dependence is illustrated in the work of numerous scholars (See: Trippl et al., 2016; Isaksen, 2015; Martin, 2010; Martin and Sunley, 2011).

In canonical literature (David, 1989), the core assumption cites new paths as a result of historical accidents which gives one technology or industry an advantage over others. According to Martin and Sunley (2006), place-specific dimensions are therefore rendered insignificant in relation to the chance emergence of new sectors, subsequently becoming dominant over time and causing "lock-in" effects to manifest in an economy. The self-reinforcing processes fuelling this, such as high technical interrelatedness in the existing regional ecosystem, economies of scale and the quasi-irreversibility of investments due to high-switching costs, are all believed to reduce the emergence of new alternative paths (Martin, 2010). Regional industries may be subject to a varying degree of path

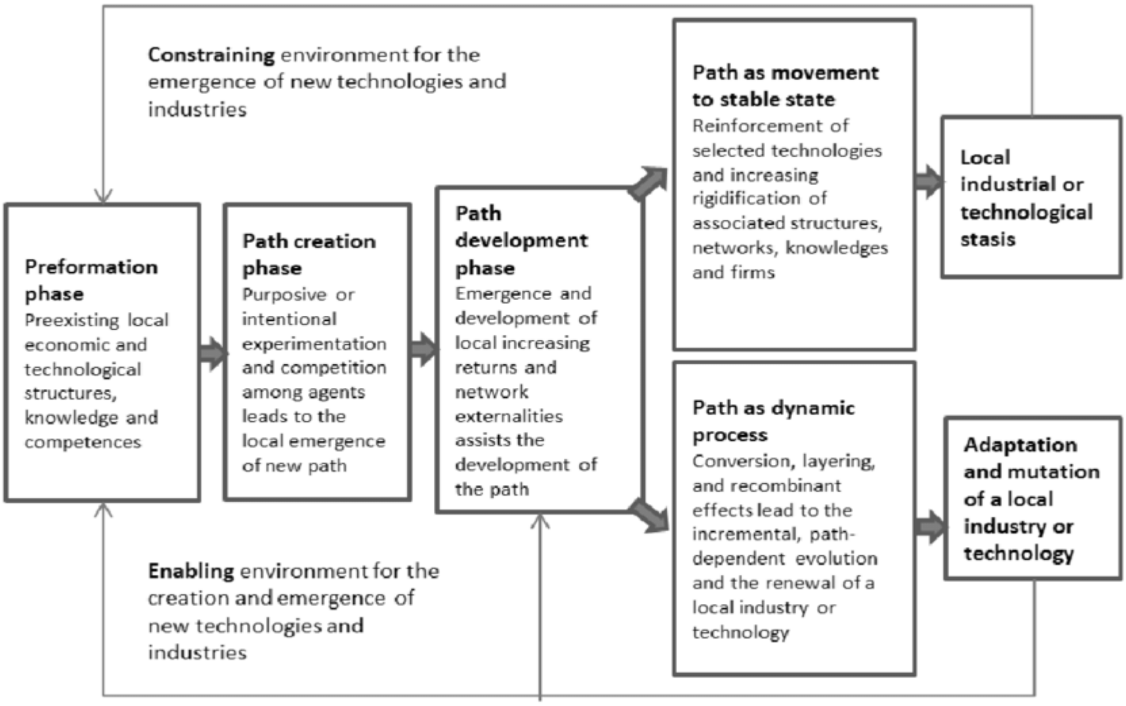

Figure 4: Toward an alternative path dependence model of local industrial evolution. Source: Martin (2010: 21)

dependence, understood as a constraining environment as per Figure 4; a state believed to continue until an external shock or force majeure causes a reactive approach and consequently, adaption in a region (David, 2001). Though, effects of this “lock-in” can be both positive and negative for an industry. Outcomes depend on the stage of local industrial development (Martin and Sunley, 2006). In earlier stages, increasing returns and economic agglomeration can benefit the path development of an industry, whereas in later stages, the hindrance of growth and renewal can lead to reduced competitiveness. Aside from this, another source of path dependence can be found at the micro-level. The competitiveness of firms can be determined by their organisational routines, which are built and improved upon over time. Routines imply a bounded rationality over the decision-making processes of firms, with change unfolding slowly due to their tacit nature (Steen, 2016). Thus, new technologies and industries appear contingent on the inherited legacies present in a region or firm, with this historicity acting as a potential enabler or constraint to future adaptation and creation.

In the case of new green industries, path dependence is generally assumed to be negative due to technological paradigms. Cecere et al. (2014) offer insight on how technological lock-in can affect the emergence of eco-innovations, emphasising that most countries and industries remain locked-in into non-renewable technologies. They identify three symbiotic sources contributing to this lock-in: cost-related factors for both industry and consumers, technological constraints that arise from the need for a complex knowledge base, and the extent of multi-actor engagement. Furthermore, Bento (2010) finds that the lack of infrastructure is commonly cited by companies seeking to justify slow investment in greener forms of technology linked to hydrogen and electricity. This can be linked to the high-cost barriers linked to the restructuring. In contrast, Simmie (2012) argues that new technologies frequently emerge in a niche and are thus shielded from path dependent structures. This refers to temporary protection from competitive market pressure and selection rules due to the novelty factor. However, regardless of the niche environment, technologies are dependent on the actors involved in its diffusion, with adequate economic agency required to reach a critical mass that marks a shift away from the current system (Bergek et al., 2008).

Towards green path development

In light of green shifts, a renewed focus on how industrial change takes place has uncovered several forms of path development. Contesting the traditional path dependence model, an alternative view of *green* path creation is advanced by Isaksen and Trippl (2016); a term that has become something of an umbrella term to represent the growth of new industries in regions (Hassink et al., 2019). Here, it is suggested that the creation of new industrial paths are no mere accidents, with opportunities instead deriving from past and current regional economic ecosystems (Isaksen and Trippl, 2016). Supporting this perspective, sociological approaches (Garud & Karnøe., 2001) point to a 'mindful deviation' away from established industrial paths.

To some, *green* path creation is a radical process, referring to newly emerging industries, firms or technologies in a region that differ from the existing actors (Isaksen & Trippl., 2016). Tödtling and Trippl (2013) argue that new firms in the region could be started with ideas that are new globally, aligning with the Schumpeterian theory of radical innovation. A second industrial path may be formed by new regional firms who bring ideas new to the region, though they are not original to the global market. Inflows of knowledge, talent, capital and the anchoring of extra-regional firms in a region characterise this type of path importation (Grillitsch et al., 2018). However, this path creation involves the purposeful establishment and reinforcement of paths by multi-scalar actors. In line with this, key agents are believed to be entrepreneurial individuals and firms who innovate new ideas or transplant them in a region by mobilising resources. Development is further fuelled through the process of co-creation between other actors, such as R&D organisations and government agencies, who generate compatible assets required for growth, as will be discussed later in section 3.1.2.

Place dependent development

As established, the nature of path development differs based on the type of region that it unfolds in, as a process subject to constraining or enabling environments (Figure 4). Conditions reflective of earlier industrial specialisations may impact this (Santoalha and Boschma, 2021). This suggests that across regions, variations of pre-existing industrial structures produce place-specific dimensions that influence path development. Hence, which regions are able to harness transformative capacity more so than others?

Studies relating to industry emergence have highlighted the concept of relatedness. While assets found in a region may vary in nature, relatedness to current regional industry and technology is a place-dependent feature that can drive new growth paths (Boschma, 2017). To this effect, pre-existing knowledge bases found in regions play a significant role in the emergence of green industries. According to Boschma (2017), while new economic activities are informed by related and unrelated knowledge, there is a demonstrated tendency of firms to develop alongside a related technological and industrial knowledge base, building upon the existing eco-system and physical infrastructure left by industrial predecessors. Based on this, regions that already host green industries are more equipped to facilitate new green path development within their territories due to the existing industrial base (Grillitsch & Hansen, 2019). This phenomenon is also termed as regional diversification, as regions are able to branch into technologically related sectors by using similar resources to exploit opportunities. Trippl et al. (2020) argue that regions with certain non-green specialisations can also provide complementary assets for new green path development. For example, an existing specialisation in the IT industry may provide the knowledge and technological capabilities needed for green path creation (See Tödtling et al., 2014). Likewise, regions with dirty industries offer the capacity of infrastructure, knowledge and in some cases, heightened opportunities stemming from societal pressure to transition away from brown sectors (See study by Fornahl et al., 2012). Variety is also a feature that can cause this type of path interdependence. As regions specialise and diversify their industrial ecosystem, economic activities become increasingly heterogenous and a more diverse knowledge base is attained, typically found in metropolitan areas. Such diverse, thick regions are generally characterised by an entrepreneurial environment and are considered to produce enabling conditions for green paths through varied skillsets, knowledge, assets and spin-off activities (Isaksen and Trippl, 2016). Conversely, thin peripheral regions have few assets, actors and knowledge organisations, seldom developing new endogenous paths and reliant on the entry of extra-regional firms (Rypestøl, 2018). To support knowledge intensive sectors, like that of the battery industry, support in this regard may therefore be necessitated to facilitate development.

3.1.2 Mobilising development

Martin and Sunley (2006) identify several drivers of industrial change away from path dependent trajectories. This concerns *endogenous path creation* based on new technological ideas; *transplantation* via the importation and diffusion of new technologies and industries; regional *diversification* into a related industrial sector; heterogeneity amongst the institutions, technologies, agents and social ecosystem, which cultivates diversity and innovation, and an upgraded regional industrial base. Initially, these were recognised in connection to the de-locking of a region from its contingent path, though more recently the mechanisms have been noted as important in transitioning from the preformation to path creation stage, when industries emerge and grow in a region (MacKinnon et al., 2019). While some of these mechanisms have already been touched upon, this section further investigates them in more depth, outlining them in connection to new green growth paths.

Modification of pre-existing industrial structures

As outlined previously, regional asset bases are indicative of earlier rounds of path development, from which future paths build upon (MacKinnon et al., 2019). While there are differentiated views of how evolutionary path processes unfold, all point to the uneven conditioning of regions in fostering industrial growth and development from asset bases. In initial stages of path development, many new industries and related clusters are found to be dependent on regional assets (Binz and Truffer, 2017). Baumgartinger-Seiringer et al. (2021) set out the types of assets that new paths may require: natural assets (resources), material and infrastructural assets, industrial assets (competencies), knowledge and skill-based human assets, and institutional mechanisms that include norms, rules, and regulations.

Yet, regional innovation systems are rarely prepared to support the radical changes entailed by path creation and transformation. In lieu of this, considerable asset modification processes are needed to enable and support new paths (Trippl et al., 2020). Several forms of this may take place, including the reuse of existing assets, the creation of new assets and the strategic destruction of pre-existing assets that could otherwise constrain change. Furthermore, a process of alignment between system and firm-level assets, and also inter-firm assets, drives path development; a state that may be particularly necessary in the sense that new green paths require more regional industrial restructuring. In a similar sentiment, Binz et al. (2016) argue that path creation is also dependent on generic resource formation in a region, building on the premise of Bergek et al. (2008). Here, firm and non-firm actors will mobilise and anchor resources. For early movers in an industry, knowledge is an especially crucial resource. 'Sticky' flows of knowledge are place-specific and may only be circulated through local learning processes, therefore facilitating knowledge transfers is a key condition for the competitiveness of firms (Asheim and Isaksen, 2002). Likewise, financial investment is a significant resource for actors in a new industry, most obviously in capital-intensive industries, though this can be a particular barrier in early path creation due to risk and uncertainty. Markets niches, such as that found in green growth paths new to a region, give industrial firms freedom from regulative and competitive environments, which otherwise may require supportive strategic action. Lastly, the legitimation of an emerging path is also considered a significant driving force within industrial development by embedding a new technology-based industry into the existing system. To achieve this, a network of actors is needed to develop supportive linkages with the regional institutional regime. The influence of these path advocates can alter the broader institutional environment they exist within. This can be found in the example of lobbyists or interest groups who may provide narratives that legitimate a green path (Bergek et al., 2008). By aligning these resources with the existing regulative and cognitive institutional contexts, structures are more likely to adapt to sustain a new industry or technology.

To this end, Garud et al. (2010) highlights the primacy of reflexive agents and networks in determining outcomes in a region through the reorganisation the resources. From this perspective, initial conditions are not produced naturally, but instead are strategically "constructed by actors who mobilise specific sets of events from the past in pursuit of their initiatives" (ibid: 769). Path creation in this way does not presume agents to be constrained by the past nor acting in conflict of it. Future growth paths are instead realised as opportunities.

Change agency

Trippl et al. (2020) assert that a continued focus on agency is needed when examining pre-existing structures and new paths at the regional level. As economic units, regional economies can be characterised by a complex system of firm and non-firm actors, with the potential to dynamically shape outcomes (Martin, 2010). Specifically, it is emphasised that agency is imbued regionally by actor networks who may be utilising existing resources, creating new resources or transplanting non-local resources. Actors can either mobilise the knowledge and resources needed for new green paths or may, in fact, lack the competencies needed for the emergence of industries (Kyllingstad, 2021). The extent of this may depend on competition between regional paths, which can affect access to these assets depending on scarcity and industrial interdependence, though interpath linkages may also result in linkages (Fragenheim et al., 2020). However, this thesis adopts a broader view of agency. A clear picture is presented of regional industrial development as a process affected by multi-scalar dynamics and various territorial factors as illustrated by Figure 5. Here, Njøs (2018) provides a framework detailing the micro, meso and macro levels of agency and structure

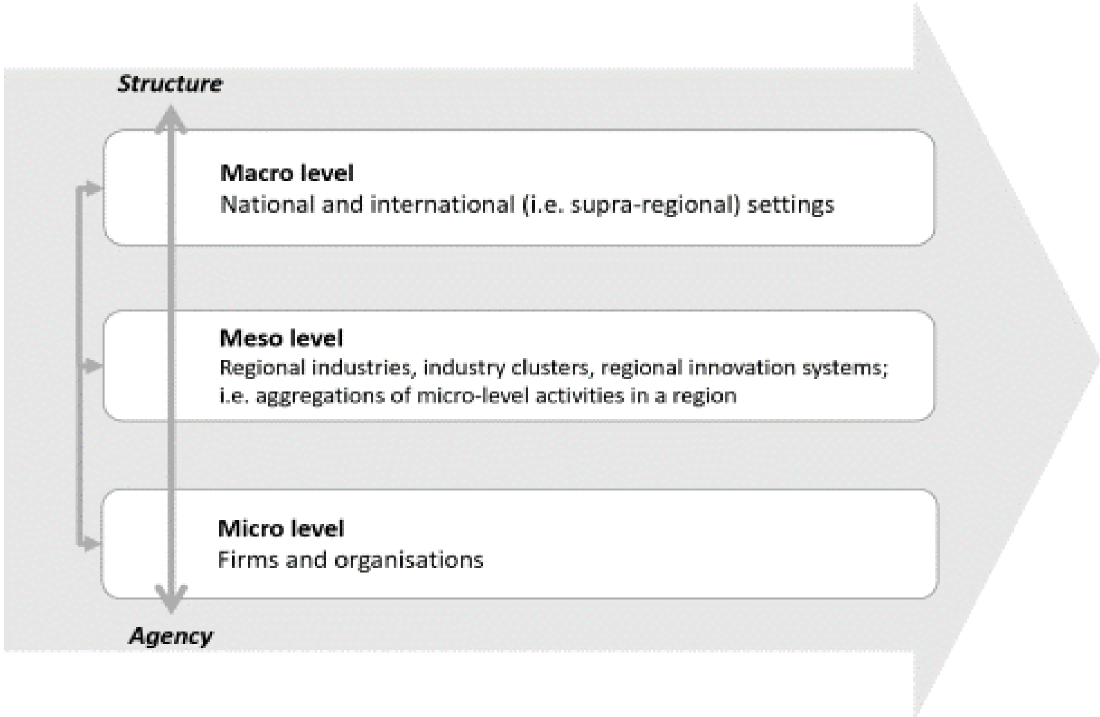

Figure 5: Multilevel approach to regional path development. Source: Njøs, 2018

impacting path creation. With the understanding of firm-level and system-level agency, one is alerted to the need for industry actors in new or existing firms to innovate, in addition to action from the regional support system in supporting restructuring (Isaksen et al., 2018). This suggests emerging technologies or industries are dependent on co-evolution within actor networks, with innovation occurring as a process between economic players and institutions across various spatial levels (Gong & Hassink, 2019); whereby institutions broadly relate to the political, economic and social interactions across a space.

However, both formal and informal mechanisms create structures which can give precedence to the "old over the new" (Trippl et al., 2019: 8). These self-reinforcing attributes can channel into future regional development trajectories and act as a barrier to broader change (Hudson, 2005). An example of institutions restricting path development in this way can be found in embedded norms and regulations (Martin, 2000). Given this, path creation may rely upon institutional change.

Fuenfschilling and Binz (2018) conceptualise industrial restructuring as a form of (de-) institutionalisation that requires adaptation or removal. Policymakers are critical to this process, deploying change through distinct approaches, the gradual bottom-up bricolage perspective that encourages collective learning across actor networks or the leapfrog breakthrough strategy that focuses efforts on the main players and can rely on the penetration of one technology alone (Garud and Karnøe, 2003). Though the value of policy in stimulating development in a specific direction, especially towards a green path, has been questioned (Njøs et al., 2020). Directionality in the way of a green shift should therefore not solely be enacted only through policy intervention, but also in system-level agency and institutional entrepreneurship to legitimate technological change. Equally, different nations and regions have certain approaches to industries symbolic of the green transition. MacKinnon et al. (2019b) understand the relationship of institutions and uneven development through variegated capitalism. Different national institutions may also affect the development of certain paths, with new green industries more likely to emerge in liberal market economies.

Recent scholarly work (Hassink et al., 2019; Steen, 2016) has investigated the influence of shared expectations and visions with new path development. This is particularly pertinent considering the socio-economic transition that battery technology both represents and is borne from. The significance of future expectations for path creation should also be addressed. By nature, they can generate interest, investments, infrastructure and directionality towards certain trajectories (Steen, 2016). Collective expectations, in line with the multi-scalar agency behind path creation, can contribute to learning alliances and more interaction between economic and social actors (ibid), highlighting that social and political pressure can work in favour of green path development or against it.

Exogenous sources of development

Typically, the endogenous focus of EEG reduces the role of actors and processes that derive externally from a region, highlighting a further need for work on global innovation network linkages (Tödtling et al., 2013). Recent efforts have been made to fill this research gap and bring attention to extra-regional linkages that are central to early path creation. Actors involved with the industry at a regional level can lack the competencies and resources to develop new knowledge alone (Kyllingstad, 2021). Therefore, in some instances, shifts towards green path development can be dependent on regional structures being part of wider extra-regional networks. External connections can come in the form of national and international channels, but also from other regions. At the micro-level, Maskell and Malmberg (2007) argue that overly localised learning and knowledge bases can often result in a heavy reliance on regional routines and over-embeddedness in social structures. This is particularly the case in energy sectors, which tend to be rigid and robust, thus impacting new pathway emergence of alternative energy technology (Simmie, 2012). Maintaining connections with external actors is, therefore, argued to prevent forms of industrial rigidification by encouraging the importation of updated knowledge and technology from other regions, described as local buzz created by global pipelines (Bathelt & Gluckler, 2014). Furthermore, imports increase the availability of inputs in a region, which correlates with rising productivity, domestic variation and upgraded production. FDI is also identified as a critical driver for regional economic development (Zhu et al., 2017). New ideas and innovations brought by foreign firms can produce knowledge spillover effects in a region, allowing for diversification away from old paths. Recalling the relatedness concept, Zhu et al. (2017) hypothesise that stronger extra-regional linkages enable the development of new industries unrelated to current industrial structures. This reduces the chances of negative lock-in occurring, which can derive from an overdependence on local capabilities and dirty specialisations (Trippl et al., 2020). However, the extent to which a firm can cultivate global linkages is dependent on firm characteristics and the regional position in a GPN (Grillitsch & Sotarauta, 2020).

3.2 A Global Production Network (GPN) Approach

An expansion of the theoretical lens

Understanding why regions are hosts to industry and what shapes the structures of value chains is important. The economic spatial dynamics behind green path creation, however, are not limited to a *regional* level. Under EEG, the current focus on regional-scale mechanisms reduces the role of extra-regional actors and processes (Boschma et al., 2017; Hassink et al., 2019). Instead, focusing also on non-local linkages is also useful due to the expectation that renewable technology paths will supply global markets. As with existing domestic energy producers, such as the offshore wind and solar sectors, industry expansion is fuelled by the growth of international opportunities (Normann & Hanson, 2015). Meanwhile, the GPN perspective views these "regional worlds" as part of wider industrial networks (Yeung, 2021). Policy interventions at national and international levels are testament to this. It also provides further understanding of the exogenous linkages and factors at play in economic spaces, as well as their effect on regional development outcomes (Coe, Dicken & Hess, 2008), and therefore can be used to study the multi-scalar and multi-actor dimensions often neglected in EEG. GPN literature already used to complement path development theories is found to provide particular value in this thesis. Empirically, though there is a growing offer of GPN literature on the clean energy sector (Bridge, 2008; Dicken, 2015; MacKinnon et al., 2019; Nilsen, 2019), there has been little extension of the framework in application to renewable energy-enabling technology markets, like that of the battery industry.

3.2.1 Firm dynamics in industries

In today's world, the globalisation of trade has undoubtedly impacted regional development, with the fate of many geographic areas still largely tied to the presence of international capital and priorities of TNCs. The configuration of global production and trade is complex yet interconnected. Globalising forces are reflected in the spatial distribution of industrial networks, with the upstream and downstream activities across value chains taking place in various countries. Supply chains, production networks, global commodity chains and global value chains are just some of the names used to describe this system of tangled relationships (Gereffi et al., 2005). This is also the case in the global battery industry, where activities within the chain take place in various countries. Equipped with this knowledge, the broader processes created by these extra-regional dimensions can be approached.

Firms are posited to make location decisions based on their competitiveness. The main dynamic capabilities behind this are cost, flexibility and speed (Coe and Yeung, 2015). While

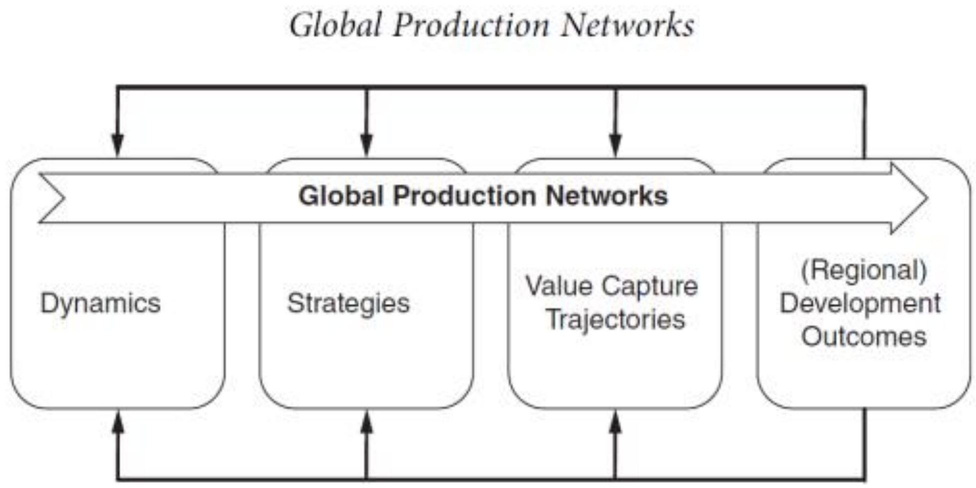

Figure 6: Causal mechanisms under GPN 2.0. ***Source****: Coe and Yeung (2015)*

manufacturing is known to be offshored and outsourced, growing concerns, over intellectual property, transit logistics, environmental, and social issues, have led to the reshoring or localisation of production in some manufacturing industries (Engström et al., 2018), with several supply chain weaknesses revealed in our post-Pandemic world and favour turned to domestic production (Yeung, 2021). However, GPNs are still subject to the same strategies and dynamics at play

Competitive organisational decisions consider regional assets; a common feature in both EEG and GPN literature. Similarly, assets act as endogenous preconditions that enable firms and regions to engage with a GPN. The assets found in a regional context may therefore also affect the bargaining power held in a GPN (Coe, 2008). Coe and Yeung emphasise that they "become an advantage for regional development only if they fit the strategic needs of global production networks" (2015: 20). This is especially important considering, according to the dynamic capabilities mentioned earlier, firms wish to renew the competence base to adapt to the ever-changing environment. Along with technology and specialised knowledge, other assets may relate to the social relations, territorial politics and industrial organisation of a region (Coe & Yeung, 2015). Further development of such assets can be facilitated through regional institutional networks, with the likes of educational organisations, government agencies and labour unions helping to foster regional assets to meet the strategic needs of GPN actors before coupling processes take place (Lund & Steen, 2020). Hence, this is considered as an important driver in both innovation and industrial development.

This shows that beyond the transactional level, co-learning processes can be particularly important between GPN manufacturers, suppliers or other units. Such collaborations can take place through different firm-specific strategies deployed by lead firms, for example: intra-firm coordination, inter-firm control, inter-firm partnership and extra-firm bargaining (Coe & Yeung, 2015). While Coe and Yeung argue that one of these configurations may be particularly linked to an industry, there may also be multiple found in one sector, as these strategies can evolve with time. This is indicative of the power structures between firms, with dominant actors affecting where the activities are located at a regional level and how an industry grows.

3.2.2 Power of local spaces in a globalised world

As an explanation for new regional economic development, strategic coupling provides an idea of why some regions experience more industrial activity than others (Coe, 2008). Yeung refers to this as "a mutually dependent and constitutive process involving ties, shared interests, and cooperation" between regional firms and institutions with relevant actors in a GPN (2017:54). In essence, this term refers to the process whereby regions possess local assets, such as firm-specific or institutional capabilities, that match GPN demands, drawing parallels with the path development model. These linkages are subject to change though, with strategic coupling unfolding as an ongoing sequential process; thus, regions may undergo shifts between coupling, decoupling, and recoupling over time (Xu et al., 2020). GPN scholars generally argue that strategic coupling will result in economic development amongst regions who integrate into the global market, through various value creation, enhancement and capture opportunities that can be capitalised upon by regional and national actors (Coe & Yeung, 2015). This coupling does not occur through economies of agglomeration but by purposeful agency, typically in fragmented locational decisions (Boschma, 2022). This can affect the role a region plays and value captured from a GPN and ultimately, the regional development outcomes.

Under GPN 2.0 theory, this is conceptualised through different strategic coupling modes (Coe & Yeung, 2015). As illustrated in Table 1, three key coupling modes can be distinguished: indigenous coupling, functional coupling, and structural coupling, as well as their relational link to EEG (Blažek & Steen, 2021). Indigenous coupling refers to an inside-out process, whereby actors act outside of their region to develop GPNs. In this case, regions are able to retain autonomy and high value capture. Path creation, diversification and branching are found in connection to this coupling process. Functional coupling occurs when a region

Mode of strategic coupling	Key features	Cost-capability ratio	Market development	Financial discipline	Type of RIS	Typical evolutionary pathways
Indigenous/organic	Endogenous companies (typically lead firms) reach actors outside their home region to form GPNs	Lead firms tend to command high capabilities based on specialised assets and know-how	Lead firms sustain brand recognition and shape the final (often decentralised) markets	Frequently listed on the stock-exchange, hence operating under the 'shareholder value paradigm'	Advanced (thick) and diversified in core regions	New path creation, unrelated path diversification, path branching
Functional mode (International partnership)	Efficient and effective coupling between regional companies and needs of GPNs	Higher-tier suppliers command highly specialised assets and capabilities	Higher-tier suppliers usually supply to a limited number of lead firms	Listing on stock-exchange is less frequent	Advanced (thick) and specialised in non-core regions	Path branching, niche development
Structual mode	Low value capture and high dependency of regional actors on external buyers	Generic assets and weak capabilities, competing on costs	Lower-tier suppliers deliver more generic components to multiple production networks	Rather exceptional listing on stock-exchange	Thin in non-core regions	Path importation, path upgrading

Table 1:Relationships between modes of strategic coupling and the new path development model. Source: Adapted from Blažek and Steen., 2021: 10.

actively attempts to meet the demands of GPNs, leading to both inside-out and outside-in development, with some autonomy and value captured. Lastly, structural coupling takes place when external actors, typically the lead firms, plug a region into a GPN (Xu et al., 2020). In addition, structural coupling leads regions to have more dependency on TNCs, especially in the peripheral regions or nations, wherein power relations become more asymmetrical. These forms of strategic coupling highlight how non-firm actors can negotiate the positioning of a region or state in a GPN. This, to a certain extent, depends on the relative bargaining power of lead firms and the state hosting it, wherein each actor has their own interests at stake (Henderson et al., 2002). Hence, power structures that exist between network actors can both depend on their current state of industrial development and determine future trajectories.

3.2.3 Governance over GPNs

Lead firms tend to have few local linkages in lower value regions due to low competencies, whereas a high degree of technical relevance between lead firms and local firms can produce the opposite (Xu et al., 2020). Though regardless, as a firm engages with a region or nation, it can lead to several forms of embeddedness (Dicken, 2015). Territorial embeddedness occurs when the 'anchoring' of GPNs in nations or regions takes place and accordingly, alters the development prospects of these spaces. In this sense, firms in a network may become embedded as they are subject to the diverse cognitive, economic, social and political contexts of host territories, which may act to constrain a GPN (Henderson et al., 2002). This also works in reverse, with embedded characteristics from the country of origin being reproduced by a lead firm, affecting the business model and corporate strategy (Dicken, 2015). Another aspect is network embeddedness, where GPNs can be affected by the connections amongst network actors. Closer ties can provide firms trust-building for more stable and long-term relationships, as well as with external resources to complement existing resources and form a competitive advantage. This aspect is particularly pertinent for long and complex value chains, where cooperation is perceived as a key driver for innovation and green growth behind its development (De Marchi et al., 2013).

As shown, firms do not exist in an "institutional and regulatory vacuum" but are shaped by the place- strategies employed by a state and the specific conditions found there, a reality which can ultimately alter development outcomes (Gibbon & Ponte, 2005: 84). Neither does the state act a unitary entity but consists of a web of agencies and functions (Neilson et al., 2014). In new industrial spaces, regional development is assumed to occur through interactions by these aforementioned territorial actors and the global lead firms (Coe & Yeung, 2015). For example, successful green industrial and technological development may require the enforcement of environmental regulation and policies (Glanchant et al., 2013). This can be found in the form of carbon taxation, regulations for GHG emissions, and the strategic funding of green growth projects. Though, economic governance is undergoing a restructuring with a shift of international policymaking and multilateral alliances towards more decentralised and localised solutions, in line with the 2030 agenda (Zhan, 2021).

Nonetheless, varieties of capitalism found in nation states undoubtedly influence systems of economic organisation, control and market dynamics (Hess, 2013). In GPN literature, the state can play a major role in facilitating the strategic coupling processes that can represent industrial growth in a region, themselves causing the coupling shifts through the role of facilitator, regulator, buyer or producer (Coe & Yeung, 2015).

3.3 Conceptual framework

As elaborated on above, both EEG and GPN theories provide necessary conceptual framing when seeking to understand the central enablers, constraints, actors and mechanisms behind industry formation. By combining them, one is equipped with a relevant analytical framework to discuss the research challenge in consideration of the empirical focus described in Chapter 2.

While EEG paints a picture of the conditional processes at play and the steps taken to produce change at a predominantly regional level, the GPN approach informs a broader understanding of extra-regional influences which impact industrial development. While this thesis draws on all aspects of the theory presented, key elements provide particular value.

Several main concepts can be distinguished in application to the development of the Norwegian battery industry.

Firstly, the concept of new green path development provides important grounding to understand how industrial trajectories are informed by the past, and consequently, how organisational- and system-level agency can enable modifications to this. This is paired with the technological innovation system (TIS) functional approach to path dependency, with path creation being determined on the strategic formation of resources; namely, legitimacy, market formation, knowledge development, and resource mobilisation (Binz et al., 2016). Finally, strategic coupling from the GPN approach is a useful aid when seeking to put a global industry in the context of regional assets and firm strategies.

Chapter 4: Methodology

The following chapter outlines the methodology employed in the research of this thesis. Firstly, it shall explain the research design, including the choices of data collection and analysis. For the purpose of this thesis, a mixed-method approach was adopted. This consisted of 8 semi-structured interviews with core actors, in addition to document analysis of secondary data sources. The chapter follows on this by reviewing the research quality and limitations. Finally, the chapter concludes with a discussion of the ethical considerations.

4.1 Research design

There is a wealth of methodological approaches used to gather and analyse data. As such, several considerations led to the final choice of data collection. Qualitative research tackles questions relating to both social structures and individual experiences (Hay, 2016). This relates closely to the aims of this thesis, which seeks to explore the complex social interactions and multi-faceted processes behind green path creation, while focusing on the enabling and constraining forces posed to development of this kind. According to Cope (2010), qualitative methods also involve the integration of context and causality into geographic research, enriching our understanding of the social realities behind such processes. Hence, these techniques represent a useful tool with which to reflect on the contextual dynamics existing in the industry and regions under study. For this purpose, a combination of mixed-method qualitative methods has been utilised for this thesis. Interviews were then combined with secondary data collected from academic sources and grey literature. This triangulation was used to develop a broader understanding of the regional green path creation represented in the battery industry (Bryman, 2012).

For this thesis, two case studies were used. The reasoning for this was due to the limited number of empirical studies to support recent theoretical developments in the way of *green* path creation. In addition, there are presently no academic case studies into the formation of the Norwegian battery industry due to its relative infancy. On the subject of choosing a case study, Flyvbjerg (2004) argues that case selection is strategic due to the explanatory demands that come with studying a particular topic. By narrowing down the terms of engagement, a holistic and nuanced account of phenomena can be offered (Cope, 2010). By its nature, a case study requires the detailed examination of subject matter and allows researchers to contextualise theoretical approaches to specific locations. Hay (2016) notes that a phenomenon can transpire differently across spatial territories. In this logic, by choosing to include two case studies in my research, a broader basis for exploring theoretical concepts and phenomena is provided. This provides particular value considering the lack of current research, as a common critique of using a single case study refers to the difficulty in being able to generalise the findings, largely due to their interpretive nature (Mintzberg, 2005). When generalising case studies, then, the research aims not to state statistical facts, but build on theoretical assertions by support of the hypotheses through "analytic generalisation" (Yin, 2012: 18). Hence, in my own research, it is acknowledged that the ever-evolving, unique spatial processes at play will not be identical in other spaces. Instead, the case studies seek to test theory and provide a basis for understanding green industry formation at a regional level by generating relevant insights that can be applied to other cases. This is especially pertinent given the green industry innovation and technologies that are becoming more important to Norway and further afield (Skjoldager et al., 2021).

4.1.1 Sampling

The sample involved in research creates the foundations from which the study is built on. It is, therefore, extremely important to consider who is involved in the data collection process and the total sample size. When starting the project, the initial goal for the number of interview participants was 8 – 10. This resonates with the suggestions of other qualitative scholars, who recommend a minimum of 8 participants (Hill et al., 2005). Participants were mostly identified through criterion sampling, which refers to interviewees meeting certain criteria. In line with this, key informants were selected according to their familiarity with the topic under investigation and their position. Partial snowball sampling was also used, which refers to gaining contact or access to participants through a common third party. In this case, contacts from the Agder region were suggested by a researcher working with batteries in the area. As a result, this led to a total of 8 participating key actors from within the Norwegian battery industry and those who have worked closely with the industry's development in both regions under study. Below, Table 2 shows the positions of the participants and denotes how they were coded in the analysis.

Organisational actors	Regional location	Coded pseudonym
Local government	Agder	Participant A
Research organisation	Agder	Participant B
Network organisation	Agder	Participant C
Leading firm	Agder	Participant D
Local government agency	Nordland	Participant E
Regional government	Nordland	Participant F
Network organisation	Nordland	Participant G
Leading firm	Nordland	Participant H

Table 2: Overview of participants and associated organisational affiliations.

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4.1.2 Semi-structured interviews

Interviews were then used to expand on the initial findings of the case studies. In total, my primary source of data consisted of 8 in-depth interviews that lasted from 40 minutes to around an hour long. As presented by Hay (2016), this method presents several advantages long recognised by social scientists; to effectively fill knowledge gaps, to understand complex motivations and behaviours, to establish a diversity of opinions and experiences, as well as to show respect and value towards individuals sharing their insights. As an interpretive methodology that is typically associated with case studies, interviewing produces fewer, but more richly detailed results as opposed to large scale sampling (McDowell, 2010)**.** By conducting these interviews, localised insights were able to be gathered that would not typically be accessible through other participatory methods or secondary sources. This is largely due to the many contextual conditions and behaviours relating to firm and non-firm actors, which differ between regions and industries, and therefore cannot be gathered from "desk research" alone. A critique of the interviewing method is that they do not occur naturally but are instead "constructed" by the interviewee. As such, the interpretation of experiences can be shaped or misrepresented by the researcher (Hay, 2016). To avoid this bias, the interviews were semi-structured using a set of questions to guide the conversation (Appendix C). This produces the freedom to communicate in a conversational manner and digress from the list of questions into related areas of knowledge held by each interviewee.

When conducting all the interviews, I used the videoconferencing platform Zoom to facilitate and record them. Videoconferencing software allows multiple people to communicate with audio and video in real time, with numerous platforms for researchers to choose from, including Skype, Google Meet, Slack and Webex (Gray et al., 2020). Zoom was found to offer several merits when compared to other services, as the programme does not need participants to create an account and can be run on internet browsers. Whilst literature in social science tends to favour face-to-face interviewing (Hay, 2016), there are various benefits of holding interviews online. Namely, given the geographical dispersion of participants, the ease of access and cost-effectiveness of digital methods were found to be preferable in consideration of time constraints (Gray et al., 2020). Participants have also been found to appreciate the flexibility and convenience of online mediums. Though it should be noted that as the method is digital, interviews are unfortunately subject to issues regarding the platform, video quality and sound quality, dependent on the internet connection of participants and researcher. These problems are reflected in the study of Archibald et al. (2019), who found that 88% of participants in their case study experienced difficulties joining the online session. Regarding my own interview experiences, I did not encounter these issues first-hand. This may be attributed to the familiarity of participants with Zoom, particularly given the prevalence of online communication technology in a professional capacity following the global pandemic. By using Zoom, the software came with an additional feature that allowed for the recording of audio and video meetings for later analysis.

Following this, all interviews were transcribed shortly after they took place, as recommended by qualitative researchers (Hay, 2016; Crang and Cook, 2007). This allows any non-audible exchanges to be noted and the potential misinterpretation of speech to be reduced. While it is notoriously time-consuming aspect of research, the transcription of the interview recordings is an important step, allowing the collected data to be sorted and coded. By utilising the voice-recognition software Rev, the recordings were able to be uploaded and swiftly transcribed by AI. Following this, I was able to correct the transcription draft, meticulously checking for errors and annotating the with additional details. As this was a live time transcription option, it allowed me to account for "dynamics that are often lost in complete audio-to-text transcription" by editing the text as I was listening (McMullin, 2021:3). Though, it should be noted that this did not always save time due to efforts spent verifying the accuracy of the transcription software. Various linguistic cues, such as filler words and hesitations, were not picked up by AI. In addition, this software is less reliable with multiple voices and accents, particularly as the interviewees were non-native speakers of English

(Bokhove and Downey, 2018). As such, I engaged in the reading and re-reading of the produced text to verify my own interpretation, as advised by Crang and Cook (2007).

During and following the interview process, notes were taken of the key themes that emerged. These proved helpful in organising and focusing responses into a more coherent data set, particularly during data analysis. A code map was also used to help in the analytical stage, with the aim of trying to capture the complex web of interrelations amongst themes.

4.1.3 Secondary data

As mentioned earlier, this thesis is based upon a triangulated approach with document analysis complementing the research process. Several types of literature were reviewed to further understanding in the empirical context of the case study, hence documents which were largely relevant to the organisational participants interviewed. This can uncover latent knowledge and a more profound understanding of phenomena. When selecting the documents, efforts were made to judge their authenticity, credibility, representativeness and meaning, in line with the guidance of Flick (2018).

Firstly, scientific articles gave a grounding of how LIB technology is created and the different segments of the value chain. This was important to give a more technical understanding of the production processes. Following this, documents from battery industry actors at the regional level were analysed. This included open access reports from leading LIB firms themselves, in addition to consulting agencies, research organisations and official government documentation. As EEG is primarily centred around the concept of contingency, research covering current industry developments and R&D projects fed into an improved understanding of industry formation, in addition to giving a broader context of the relevant GPN dimensions. Company reports and websites also gave insight into the intra-firm and inter-firm dynamics that are present. Though as corporate reports are generally made to generate a positive impression, literal meaning was not always taken from them, instead they offered empirical contextualisation. On top of this, policy documentation and government papers provided a basis to determine how industrial development of the battery sector is impacted by policy initiatives and regulations.

It is noted that a complete sampling list of the documents analysed was kept, in order to keep track of reliable sources. An attempt was made to use documents from legitimate sources, thus offering the research with an increased stability of data. By combining this with data from the interviews, any potential bias is minimised and the validity of the study is improved.

4.2 Data analysis

After completing the transcription of all interview material, the next step undertaken was thematic analysis. This data analysis method is most commonly used when seeking to understand experiences, behaviours and conjectural knowledge in qualitative data sets (Kiger and Varpio, 2020). Understood as a "patterned response or meaning", coding themes can be classified as either semantic (a superficial meaning) or latent (an underlying meaning) (Braun and Clarke, 2006: 82). As the thesis aims to establish the economic, social, and structural contexts present, it is hoped that a constructivist approach will explore the deeper, latent realities within the data. In relation to the data transcription stage, the development of software has considerably affected the content analysis produced by qualitative researchers. NVivo, a software package, assists the researcher in organising large data quantities into collections of similar findings (Figgou and Pavolpoulos, 2015). Hence, this aids the identification of patterns throughout the data, as well as linking different themes to the theories and concepts grounding the study. As set out by Braun and Clarke (2006), there are several phases involved in the processing of qualitative information through coding. Having paired this with my own experience of thematic analysis, these phases are as follows:

1. Data familiarisation

After completing the data collection, the transcribed interviews and all the notes from document analysis were taken into consideration. To become familiar with the data, engaged and repeated reading is required. This was aided by the previous task, transcription, which involved checking the transcripts for accurate scripts and thus, familiarised me with the interview responses. By re-reading over all the notes from the documents analysed, I was able to scrutinise the text with a closer eye. Any themes that stood out were subsequently highlighted and noted.

2. Generation of the initial code

Codes, or analytic labels, were then derived from the most interesting and prevalent features of the data. Coding can denote either a semantic or latent level of meaning, as mentioned before (Braun and Clarke, 2006). While recognising this need for multi-level analysis, I started out by taking notes to highlight interesting sections of text and any reoccurring patterns. This produced some initial codes, which were represented as short phrases or keywords to denote meaning. Some examples of coding included insert, insert, insert, insert,

insert, and insert. The generated labels were then used to ascribe different extracts with one or more relevant codes.

3. Exploration of data for themes

After the codes were identified, they were narrowed down into closer sets and categorised into potential themes. These themes are constructed by researchers, involving a process of analysing, comparing, and mapping how themes may be linked. Both inductive and deductive analysis can add value to this research stage (Braun and Clarke, 2006), though it is difficult to use a singular approach. In inductive analysis, a researcher develops themes directly from the coded data, an aspect which I tried to embrace in order to reflect the whole data set. On the other hand, the theoretical frameworks guiding this research also informed theme development, which is more closely aligned with deductive analysis. Kiger and Varpio (2020) assert that themes should be noted down regardless of their relevance to the research questions, a point that I tried to adhere to by using these analytical approaches in my coding framework.

4. Reviewing themes

Phase 4 is described as a two-level analytical procedure (Braun and Clarke, 2006). During this stage of the data analysis, themes were firstly checked against the corresponding coded extracts for validation. This ensured the best fit of data to maintain commonality and coherence, whilst also being able to distinguish between themes (Attride-Stirling, 2001). Afterwards, this was repeated in relation to the whole data set, making it easier to spot any inconsistencies in the data. Some themes were discarded in this part of the process, and several were combined to better capture data. Furthermore, the coding of the themes allows for their contextual positioning within the scope of the study. This highlighted any patterns existing within the data and linkages between major themes.

5. Further theme development

The next recommended step follows the completion of the thematic map. At this point I defined and refined the themes that were to be used in the final stage of analysis. In the first round, the broader themes centred around patterns of general interest (VC coordination, regional context, market pressures, political conditions etc.). Then, I developed the themes in connection to the theoretical underpinnings of TIS (Market formation, legitimacy, resource mobilisation etc). This was important to set out the ‘story’ that individual themes encompassed, and equally, to establish what was not included in the scope of the theme (Braun and Clarke, 2006). Sub-themes were also categorised under broader themes, particularly those of a more complex nature, thence providing structure to the overall coding framework.

6. Production of the report

Finally, a final analysis and description of the findings can be provided. After following all of the previous steps, the last step of my data analysis required the selection of extracts that best demonstrated the themes. This is an important step; linking the analysis to the research questions and to the literature that informs the theoretical section of the thesis.

4.3 Ethics

As this thesis is centred in qualitative research, it requires the research to travel into the personal worlds and experiences of participants (Hay, 2014). Understanding the ethical dimensions relating to the research is necessary to address.

For qualitative researchers, both attaining consent and ensuring levels of anonymity and privacy to participants is crucial. This allows for more open and honest conversations between the interviewer and interviewee, as they feel more comfortable sharing personal opinions. The method of interview conduction was via an online platform, which meant there was extra stress on maintaining privacy by holding the online interviews in private spaces. In addition, a secure storage platform during the transcription process, in accordance with The General Data Protection Regulation before file deletion could take place.

The interview guide, along with details of the handling of data, were approved by the Norwegian Centre for Research Data (NSD) before data collection began in March 2022 (Appendix C). Prior to starting the interviews, a form was sent out via email in order to obtain informed consent from participants or gained verbally at the start of the interview (Appendix D). This form communicated information about the ongoing project, data privacy and participant rights and contact details of those responsible for the project. Informants were also made aware that their details would remain anonymised in the thesis findings through the use of coding as seen in Table 2, though some references to the type of industry link possessed would be made.

4.3.1 Positionality and reflexivity

Crang and Cook (2007) set out the issues relating to power and knowledge in qualitative research. Social and cultural positions may lead to an imbalance of power between the researcher and participants, an aspect which was diminished by sharing information about my own study motivations and maintaining informality throughout the interviews. On top of this, questions did not delve into personal topics, and thus, participants were not held back from speaking freely about the subject.

Another concern is the positionality of a researcher, as with the production of knowledge, subjectivity can influence the quality of the data collected and the conclusions formed. In line with this, positionality refers to the position adopted by a researcher within their field of study (Savin-Baden and Major, 2013). A reflexive approach should therefore be taken by the researcher to continuously reflect on the research process and the findings, beginning with recognising their own preconceptions that stem from both professional and personal experiences, and which can and do change over time (Malterud, 2001). From an epistemological standpoint, while it can be argued that no research can be considered objective due to the role of the researcher in forming subjective conclusions based on the data collected, efforts were made to counter biases from affecting the research. This is relevant in the context of my research, especially when relating to sustainability, which is often interpreted differently according to normative assumptions (Horlings et al., 2020). Therefore, it should be addressed that my own perception of sustainability is affected by my socio-political position,

4.3.2 Validity

Validity refers to how accurately the research findings measure the phenomenon under study. With the aim of maximising the consistency and trustworthiness of the research (Seale, 1999), data collection was conducted through various means, from both interviews and document analysis as previously highlighted. Furthermore, the qualitative case studies covered two regional paths. External validity is based on the ability to generalise qualitative research and case studies outside of the particular research. By this logic, the researcher should identify regularities from the empirical investigation at hand, thereafter suggesting potential causal mechanisms linked to the pattern and verifying this with further empirical findings (ibid).

4.4 Reflections on the limitations

Despite the advantages of data research methods used, there were also some associated limitations. Time restrictions affected the scope of the research and as a result, I was unable to hold the number of interviews that I intended to. As there are many more actors whose perspectives would have been informative in the research process, this could have limited the inclusion of other relevant perspectives in the findings. Here, I tried to reduce this limitation by making sure that every sector was covered – public institutions, research and development organisations, and leading firms, representing the triple helix of innovation networks.

Secondary data also has certain limitations, as it is not possible to verify the accuracy of data collected from the sources to which I was able to gain access. The empirical nature of the research topic also brings difficulties, especially due to the tendency towards secrecy in the competitive stages of early market development, though general production statistics were also rather discrepant at times. This creates challenges in trying to obtain consistent and accurate data. Nevertheless, every effort was made to use the most reliable sources and the triangulation of data further alleviates the risks posed by data inconsistencies.

There were also potential challenges deriving from language barriers. While the interviews were conducted in English, all of the participants were native Norwegian speakers, which could have impacted the original meaning of data from being communicated to the researcher. Despite this, participants involved held a fluency level that meant they felt comfortable communicating in English, as confirmed before the interviews were held. Additionally, because the case studies are focused on a regional level in Norway, some of the documentation and sources used within the document analysis were only available in Norwegian. In order to minimise the validity of the data being compromised through mistranslation, all data was cross verified using each of the research data collection methods, with any anomalies excluded from the final analysis.

Chapter 5: An Analysis of New Regional Paths

The focus of this thesis is the emergence of the battery industry in the two Norwegian regions discussed in section 2.3. In this chapter, the findings from eight semi-structured interviews from regional key actors (see Table 2) and relevant secondary literature will be presented. Due to the early stage of path development realised in Norway, the analysis will not be categorically periodised. However, this thesis distinguishes between two phases of path development as per Martin (2010), attempting to reflect how the formation process has unfolded over time up to this point.

The research is presented to capture the following: preformation in a changing landscape, towards path creation in battery manufacturing, and the broader dynamics of path development. It must be noted that these aspects were highly interdependent in many cases, which presented a challenge when trying to distinguish standalone themes. As such, the analysis reflects the interrelated nature of the identified factors to illustrate the nuanced process of new green industrial development.

5.1 Preformation in a Changing Landscape

5.1.1 Initial expectations and trends

Industrial development occurs when actors are incentivised to enter a market, which may be produced by the influences on the direction of search in a system (Bergek et al., 2008). In the pre-formation phase, prior to the operation of lead firms in Norway, the period was characterised by increasing social and political pressures towards the green restructuring of energy and transportation systems. This is particularly relevant in Norway, which relies heavily on the O&G sector for its trade balance and job creation. Norwegian battery firms are affected by multi-scalar institutions, including the EU, with many policy and regulatory initiatives implemented in Norway due to the EEA Agreement. In 2017, the European Battery Alliance was launched to further the goal of establishing a battery supply chain in Europe, which stimulated a flurry of activity centred around the battery industry across the EU. Freyr, Morrow and many other Norwegian organisations have since joined as contributors to this transnational imagined future (Participant B, D and H).

For Norwegian battery manufacturers, the market formation process was fuelled by regulatory action favouring green industry and associated green transition narratives at home (Participant H). Niche support for key electrification markets initially built a receptive climate for low-carbon technologies (Ćetković and Skjærseth, 2019). Much of this has centred around the EV market, as an end use for battery technology and a future target of both lead firms. EV diffusion was spurred on by consumer incentives, toll and tax exemptions, such as the removal of import duties in 1990 (cite). As a result, Norway has become a leader in EV adoption per capita, home to more than 470,000 registered EVs (cite). Under the most recent National Transport Plan (Regjeringen, 2021c), it is anticipated that all new passenger cars and light vans sold will be carbon-neutral by 2025, creating directionality towards the use of low-carbon technology. This has created an institutionalised propensity for green solutions, encouraging environmental behaviours to become normative (Nayum & Thøgersen, 2022). In addition, the green certificate scheme, in collaboration with Sweden, provided an additional support mechanism to renewable energy technologies to reach political electrification goals between 2012-2021 (IEA, 2012). Though interestingly, demand for certification was low due to prevalence of a Norwegian hydropower complex. This was further reinforced by the scheme triggering cost-effective investment, which by far favoured hydropower projects as opposed to battery technologies, suggesting a hydro lock-in in addition to carbon dependence in the export market. Nonetheless, considerable state action has created momentum nationally towards the acceptance of green technology over prior decades.

In parallel, a creative destruction approach to O&G through control policies has been employed (Ćetković and Skjærseth, 2019). Like most countries, Norway adopted goals to reduce GHG emissions with an ambitious commitment to a 55% reduction in GHG emissions by 2030, measured against those polluted in 1990, as enshrined in the Effort Sharing Regulation with the EU. This has led to the adoption of CO_2 taxation, incentivising the use of energy efficient solutions in society. As such, industry faces mounting pressure to adapt standards as per the Paris Agreement (Bataille, 2019). The Climate Plan 2030 further reflects this, with most industries subject to an increase from 590 NOK/tonne to 2000 NOK/tonne of CO2 emissions (Regjeringen, 2021b). In line with this, research suggests that environmental innovation, such as battery technology, is found to positively respond to increased pollution reduction focused regulations, as forms of enabling technology (Brunnermeier and Cohen, 2003). This confidence is shared by Participant H, whose expectations are framed by growth potential:

These markets, driven by technological development and regulatory pressure, will grow a lot faster than most analysts think.

These collective expectations, illustrated through policies and regulations, are key in driving the development and upscaling of green industries in light of uncertainty and the need for system alignment (Steen, 2016). To a large extent, interviewed participants reflect this in motivation, with the battery industry "*taking a huge responsibility*" for ambitious political decarbonisation goals (Participant E). Participants also acknowledge that LIBs offer an export-oriented industrial path, with the capacity for a new energy-related market based on *"building societies and creating value and work, you could export this energy not in the form of electricity but in the form of batteries"* (Participant F). While the exportation of raw materials and energy is profitable, it does not always create sustainable growth, an issue commonly encountered by resource-dependent countries. This shared vision of the battery industry as a national industrial opportunity for 'life after oil' has provided a powerful narrative for garnering support and interest.

5.1.2 Emerging entrepreneurship

An extent of path creation took place in Norway before lead firms, with niche areas of the industry being targeted, such as presence of a marine battery technology industry. However, lead firms Morrow and Freyr, a title typically assigned based on the market share they command, represent the first movers in the Norwegian LIB manufacturing context (Coe and Yeung, 2015). Innovative entrepreneurship played a role in the origins of both organisations, with mindful deviation away from existing dominant structures a major force behind the battery industry (Garud and Karnøe, 2001). Tore Ivar Slettemoen had the original idea behind Freyr following years of experience in the O&G industry and renewable energy, along with the help of academics at NTNU. Subsequently bringing it to industrial scale by working with experienced individuals from Hydro and Equinor, who have had prior experience working with disruptive technology. This was followed by a merger with Koch Strategic Platforms, a subsidiary of TNC Koch Industries, who were first established in petroleum refining. Meanwhile, Morrow was inspired by the ideas of Frederic Hauge, an environmentalist at NGO Bellona. Noted for importing the first EV to Norway, Hauge became frustrated at the slow pace of green technology diffusion following the 2009 Copenhagen Summit. This led to him working with start-up Graphene Batteries, which later evolved into Morrow Batteries as a spin-off with state-owned Agder Energi and NOAH AS in 2020. Hence, while individual actors took the primary initiative, the case of industrial branching from both renewable and traditional energy sectors is illustrated in firm expansion. This further exemplifies that the future expectations of firms are centred towards the overhaul of deeply embedded path dependent regimes following years of the dominant O&G industry at a regional, national and global scale (Participant A, D, E and H).

Intensive global R&D efforts over the past three decades have produced a 97% price drop in LIBs (Ziegler & Trancik, 2021). As such, Norwegian manufacturers and their suppliers are able to use technology transfers based on pre-established technology from abroad. Two different technological paths can be identified in this case. In 2020, Freyr announced the importation of 24M technology from America to produce SemiSolid batteries. Meanwhile, Morrow have been developed technology for their own patents; while using lithium-ion chemistries for the initial phase of production in Korea, the firm will further experiment with developing sustainable in-house technology for lithium-sulfur batteries. This is depicted in Appendix B, where there have been notably more partnerships based on technology exploration.

The centrality of entrepreneurial experimentation to battery developments, which requires a wide supply chain of technologically intensive processes, may be indicated by the number of new entrants in a region (Bergek et al., 2008). A major industrial premise of lead firms is the forging of a local “battery coast” (Morrow) and a “battery belt” (Freyr) (Participant B and G). Further upstream, anchoring in the regions has resulted in key established suppliers adapting their technology or materials in order to diversify into the emerging battery industry, using regional renewable energy to maintain a low carbon footprint over the whole production process (Participant C). By using historically developed knowledge and technological knowhow, firms can modify their existing asset base to upgrade products or processes for the new battery path. Elkem, with the ‘Northern Recharge’ anode graphite production line in Kristiansand, as well as the recycled battery materials scheme between Glencore and Freyr, both illustrate this move into the Norwegian battery niche. This type of path branching has further potential for growth, as the regions can capture more value if linkages to related local firms are fostered and regional competencies are upgraded (Dawley, 2014). Though, this is also dependent on national and regional support for the emerging path, wherein institutions must align with the technology or industry (Bergek et al., 2008).

5.1.3 Norwegian industry formation

External shocks are posited as a pivotal aspect in instigating transformation. Rather, opportunities for change, understood as critical junctures, arose somewhat incrementally in the case of battery manufacturing (Martin, 2010). Two major forces can be attributed to the reorganisation of this GPN. Firstly, climate change has resulted in an expansion of green technologies (Gong et al., 2022). This is illustrated in Norway, where batteries are used widely in a growing number of end-use demand, in particular the EV, marine and ESS markets. Changing policy approaches, outlined in the previous section, have culminated in the European Green Deal introduced in 2020, wherein batteries were highlighted as a fundamental technology and growth path in achieving sustainability objectives. Thus, shifts from global to domestic networks are becoming more commonplace, in part due to the emphasis on local production to lower carbon footprint. However, trends of reshoring and backshoring also stem from instability caused by geopolitical tensions, with both the ongoing war in Ukraine and Covid-19 reminding us of the vulnerabilities of GPNs (Oldekop et al., 2020). Freyr CEO also points to the timing of entering the market right now, with the Chinese Government aiming for 25% EV penetration by 2025, requiring quantities of Chinese batteries that would have previously been exported to remain in the country (Jensen, 2021). This links to the fears of an overdependence on China for batteries and their domination of the entire value chain, outlined in Chapter 2. These factors, together, have produced a window of opportunity for Norwegian actors (Kurikka & Grillitsch, 2021), feeding into market formation processes.

In light of this changing landscape, lead firms appear to be aiming towards “leapfrogging” from the formation phase to large-scale commercial projects. This is further illustrated by several participants, who spoke of the need for speeding up production in Norway where “action is needed, the train is leaving now”, especially in light of the slow scaling up of battery technology in Europe until recently (Participant D). Though, market formation has been constrained by industrial legacies. Path destruction is still questioned in regard to O&G production, with new exploration and licensing ongoing (Kulovic, 2021), in spite of international pressure to transition to renewable energy systems. An aspect that has been escalated by war in Ukraine and subsequent European energy supply issues. My findings, therefore, suggest that this specialisation in the petroleum sector, given the relationship of battery technology with renewable energy, has slowed down the development of a Norwegian battery industry thus far. This is emphasised by Participant E:

Norway has been very successful with oil and gas for many, many years. An effect of that is that we are a little bit too dependent, not so interested and not so eager to look for new industries. We have so much funding from the oil and gas industry, so we are too lazy to be open to new initiatives.

This suggests a lack of motivation between system-level actors to develop green industries, underlining the so-called carbon lock-in when an overreliance on fossil fuel systems delay the shift to carbon friendly alternatives, which may weaken market formation. However, at a more focused regional scale, several "path-breaking" events precipitated the emergence of the battery industry. In reference to Agder, Kyllingstad (2021) comments on the thick and specialised regional innovation system, which was highlighted following an external shock, the oil price crash, in 2015. This resulted in low employment rates in Arendal itself, as the municipality experienced the highest rates of unemployment in the whole county[4], making it more open to new industrial paths. Similar events can be found in the history of Mo i Rana, following the economic restructuring in the 1990s, towards a more varied innovation system.

5.2 Towards Path Creation in Battery Manufacturing

In order to drive path creation in the way of industrial battery manufacturing, strengthening functions of industry formation are still crucial given the novelty of this green industry to Norway. To some extent, this rests upon the agency and support of regional and industrial actors in achieving transformation, with the interlinkages between the functions highly correlative.

5.2.1 Mapping knowledge generation

While Norway is home to many battery value chain segments, emerging domestic manufacturing activities creates different demands across the industry. Demonstration projects, such as the proposed pilot plants of Morrow in Arendal and Freyr in Mo i Rana, will create tacit knowledge in battery production and train up operators. However, a crucial challenge for this new industrial development to move beyond this point lies in the lack of relevant knowledge and R&D currently held (Hekkert et al., 2007), particularly given the uneven capabilities amongst regions (Participant C). This is significant in connection to the knowledge intensive battery industry, with LIB production alone requiring a number of complex tasks, including electrode preparation, pack assembly and testing (Usai, 2022). To bridge this gap, learning processes are being deployed within firms themselves, with intra-firm training occurring through individual "technological gatekeepers" prior to the start of mass production. In particular, Morrow and their local suppliers "*have sessions on sites where workers teach each other because not everybody brings the competencies required*",

[4] https://www.fvn.no/nyheter/okonomi/i/6vm88/derfor-har-arendal-landsdelens-hoeyeste-arbeidsledighet

which may only be viable in the formative stages (Participant B). Over the long term, other forms of knowledge coordination are needed, as commented by one actor:

Something we have learnt is that the innovation environment, scientific competence, educational offers close to where industry is based creates more activity (…) it's important we are early enough now and build up new systems close to the industry" (Participant F).

Hence, complementary training programmes can be used to education and upgrade a labour force through a specific focus on battery manufacturing. While there are universities in Agder, the lack of higher education institutions in Arendal has created a geographic split between the East and the West parts of the region, creating a skills gap (Participant A). In response to these barriers, both regions are investing in further education. Currently, existing universities UiA, UiS and USN are joining forces to develop battery-related courses around Morrow in Agder. Meanwhile, several of the participants, led by Freyr, are opening a new battery vocational school in Mo i Rana (Participant H).

In this vein, research institutions can assist with strategic R&D projects, providing particular value to emerging industries through focused innovation efforts. For example, BattKOMP, aims to solve the problem of the lack of competence regionally, having been developed in collaboration with Norsk Industri, Prosess 21 and the Norwegian Confederation of Trade Unions, using interdisciplinary knowledge to tackle the knowledge gaps that are specific to the Norwegian context. This is particularly important early on, with Participant A asking *"what do the companies actually need?",* highlighting the need for intersectoral knowledge management. Further research on downstream activities is also recognised as key to industry formation in line with the new EU regulations. Recycling and reuse projects, such as the BATMAN, LIBRES and ELAG run primarily by UiA, are developing this untapped knowledge to achieve a more complete value chain in Agder.

Due to this very early industrial stage, however, firms are presented with an immediate need for expertise to further development which cannot be found locally. Morrow have started a test production line in Chungju, South Korea, which was chosen due to the longstanding knowledge base in battery technology found there. Participant H also notes that knowledge has been acquired from experienced foreign firms by their company. This offshoring results in knowledge accumulation from experienced engineers and operators to improve firm competitiveness in the primary phase of domestic production efforts (Participant D). This also translate into the companies' supply chains, with both firms targeting strategic ventures with Asian partners, who can provide the knowledge base for the start-ups in return for European market access.

5.2.2 Knowledge diffusion and networking

Local interactions between various regional actors are also essential for industry development for domestic producers (Liu, Chaminade & Asheim, 2013). The majority of knowledge diffusion has occurred through new R&D initiatives, with research actions playing an important role in industry formation. From an early stage, Freyr has been partnered with SINTEF concerning R&D contributions along the battery chain, and also with NTNU, funding laboratory work and working with students and researchers. Morrow is creating a similar collaborative effort close to UiA by creating a Battery Innovation Centre in Grimstad to develop technological competencies by bridging research and industry (Participant B). Highlighting intersectoral linkages, these collaborations have been key to knowledge development. Participants discuss how their organisations are therefore trying to "*foster research projects with industrial partners (...) to create this kind of battery community"* based on the triple helix model (Participant B). This is reflective of Stephan et al. (2021), who posits that knowledge spillovers within the LIB sector occur based on a high variety of sources.

For manufacturing firms like Freyr and Morrow, strong networks can significantly enhance the relationship between R&D intensity and new product performance. This process of "learning by interacting" (Hekkert et al., 2007) through local knowledge links can be found in the case of the regional clusters engaged with lead firms: Eyde Cluster, the process industry; GCE Node, the O&G industry; and Mo Industrial Park, that hosts different industries. In both regions, these clusters of industrial actors can be closely linked to the lead firms and increasing R&D around the new industry. For the last five years in Arendal, the Eyde Cluster administration have been working to contribute to the developing battery value chain. Several incumbent companies within the cluster have begun to renew activities to support the battery path (Participant C). Meanwhile, Mo Industrial Park acts as strong knowledge support system for incoming industrial players in Mo i Rana, including Freyr whose central site is to be constructed within this industrial zone (Participant E and G). Aside from facilitating local learning processes, networks of actors are recognised as being fundamental in the early stages of development by providing access to regional resources and skilled workers key to further knowledge diffusion. They also offer a space for consistent cooperation, which creates learning exchanges and trust (Porter, 1998).

Dense local networks of actors can also mobilise external knowledge flows within a system (Grabher, 1993). The establishment of knowledge diffusion via inter-regional channels between non-firm actors aids system-level changes. Local governments in Skellefteå and Västerbotten, who have been host to Swedish battery producer Northvolt for several years, sharing knowledge with both Rana and Arendal Municipalities and being used "*as a benchmark"* for regions to learn from (Participant E). This is particularly important given the significant population growth predicted in the regions due to labour migration (Menon Economics, 2021). In forging these linkages, access to capabilities relating to the battery industry may also be gained from outside of the region, which has shown to correlate to regional diversification, as a driver of industrial development (Boschma and Iammarino, 2009).

In line with this, though as the status of battery technology is relatively stable, knowledge spillovers are more likely to occur further afield (Binz et al., 2014). This can be seen in the knowledge collaborations with regional actors and extra-regional actors in the Norwegian battery VC, such as the strategic partnerships between lead firms and material suppliers, as in Appendix B. These inter-firm are considered especially important in light of the path creation stage of the battery industry, disseminating international knowledge flows between actors involved.

5.2.3 Active resource mobilisation

Natural, physical resources have been highlighted as crucial to the lead firms strategic coupling with the regions. Agder, for example, is referred to as a "*a Kinder egg*", based on a renewable energy surplus, local access to materials and proximity to the European market, which is posited to give Morrow its environmental strength (Andersen, 2020). Similarly, Nordland is the second largest Norwegian energy producer, with many critical elements for batteries mined near Mo i Rana. Participants all agree that this resource access gives Norwegian industry a competitive advantage to sell the most sustainable batteries on the market. At the same time, a lack of available natural resources can hinder industrial growth (Karltorp, 2014). In both regions under study, there are energy surpluses from renewable sources. Large amounts of hydropower fuel a flexible power mix, contributing to a stable energy system and less price variations. However, the 2022 European energy crisis – which affected South Norway with record high electricity prices - has threatened to prevent this resource mobilisation, in addition to less grid stability following the Nordlink and North Sea Link energy sharing projects. This uncertainty is echoed by Participant H, who states that the industry has “*3-4 years left to do this, after that, the window is gone*” according to changing costs of PPAs and increasing competition. Furthermore, while Participant D points to the “*strong parts of the value chain in place regionally*” already as an ancillary driver, a concern for battery producers has been the shortage and subsequent price spike of critical materials as discussed in section 2.2.1. Institutional pressure towards sustainability is causing a lack of investments in the upstream extractive segments, further highlighting the need for investments in resource recovery for reuse and recycling (Participant C). Hence, this suggests the need for the supply chain to be scaled up in line with the rest of the industry to ensure access (Participant H).

Aside from the renewable energy surpluses and pool of raw materials that battery actors have access to in Agder and Nordland, considerable financial resources are required to build up the knowledge, human competence, infrastructure and other complementary assets in any new industry (Bergek et al., 2008). Due the infantile stage of the battery manufacturing industry in Norway, particularly high investments are necessary for its industrialisation, in order to achieve economies of scale and push the cost-per-unit down (Participant D and H). So far, the lead firms themselves have been reliant on capital raising, receiving equity from regional firms and contributions from the municipalities themselves, but also through transplantation from many international sources, reflecting multi-scalar agency. Participants spoke of the difficulties in attracted venture capital due to the uncertainty towards Norwegian start-ups being able to compete internationally, with Morrow completing their first funding phase with EUR100m and Freyr raising approx. USD850m through the NYSE. Locally, regional governments have been attempting to drive FDI into the regions through investment agencies, such as Invest in Nordland, working to attract many interested TNCs for financing inflows (Participant F).

New industrial activities have been supported through various financial packages from the Norwegian Government. One key innovation instrument managed by the state (via the Research Council of Norway, Innovation Norway and SIVA) is the Green Platform Initiative. Through this, 100m NOK has been channelled to Freyr, Morrow and other segmental to establish a sustainable battery value chain. Government agency ENOVA and Innovation Norway have also mobilised grants for lead firms, and other value chain firms, like Elkem and Vianode for battery material projects. Though Participant D states that more funding is needed, pointing to deployment of state grants in England, Sweden, and Germany. Therefore, further experimentation towards more innovative and sustainable may rely upon more public support for R&D.

Much of the activity linked to battery manufacturing has arisen in regions of heavy industrial backgrounds and involved resource mobilisation from these industries. Transfers of competencies from existing industries to the new paths in the regions can also be observed. The diversification of suppliers towards new paths can be attributed, in part, to the relatedness of pre-existing structures (Boschma, 2017). Both Agder and Nordland have expertise in industrial sectors that can be transferable to the battery industry, specifically the process industry (Participant B, D and F). This sector already possesses many high-tier suppliers to technology and service sectors, providing the battery industry with manufacturing and technological knowhow. In different segments of the supply chain, technologies may even overlap with the same production processes (Sandén & Hillman, 2011). Synergies can also be found between the O&G sector and green industries, where technology transfers are one observed benefit (see Norsk olje og gass, 2014). This view is also adopted by Participant A:

What has been thinking so far is that we can use the competence and technology in the oil and gas sector in the new green sectors. This has worked in the wind energy sector and can in the battery industry.

Expertise and transferable skills from the traditional energy sectors can also drive the battery industry, particularly as the green shift will necessitate the loss of jobs of oil and gas workers in Agder, with the battery industry holding potential to provide resilience in the region through job creation. Participant H agrees as we leave the *"fossil energy era, many of those very capable people have to be utilised and retrained towards this new industry".* Expectations that the two industries; non-renewable and renewable, will "meld into a collective Norwegian energy industry", may also reasonably be applied to renewable technology industries (NPD, 2021).

Interestingly, Participant A and D noted a similarity between historical industrial development and the battery industry's development. They argue that extra-regional actors also played a role in the start of the O&G industry, when Norway lacked the competence and specific knowledge required for the sector, resulting in many American experts arriving in Norway to diffuse competence in the region of Agder. Likewise, in pursuit of establishing production in Norway, battery firms have resorted to importing extra-regional human-based assets and knowledge, as seen by their participation in the international labour market. All participants referred to the need to acquire international talent due to the novelty of the industry to Norway. Participant D argued specifically that:

The expertise and professional environments are not in Norway, they are mostly in America and Asia. We also have to get global expertise where it is today.

This can be seen in the managerial structures of the firms, both of whom have international talent with global experience in LIBs. However, Participant B referred to the very competitive labour market for battery experts, with actors realising that this requires them to attract prospective employees must go beyond offers of employment. On this topic, participant F states that competition for experts from the growing European market poses a threat. Suggestions, then, that Agder and Nordland need financial investments upgrade Rana and Arendal municipalities in terms of infrastructure, welfare and education to accommodate population growth, highlight significant challenges. However, participants were positive about the prospects of job creation, economic growth and the environmental benefits, which provides legitimation to this public spending.

5.2.4 On the creation of legitimacy

In light of the transformative and industrial potential proffered by domestic battery manufacturing, mobilising support for the industry is considered to be instrumental. One aspect of this is creating widespread legitimacy for both battery technology and the associated industry.

At an institutional level, there is growing directionality between policymakers in targeting issues relating to the green shift. The rising number of fiscal incentives linked to deterring carbon intensive technology, the high adoption rates of EVs and prevalence of renewable energy in Norway make markets more viable to green technology producers; suggesting that the green transition is embedded in Norwegian leadership ambitions. Norwegian Minister of Trade and Industry, Jan Christian Vestre, has also promised loans and guarantee schemes, as well as maintaining a personal relationship with the lead firms. Confidence in the industry was further invoked when the municipalities and county councils made decisions to invest directly in Morrow and Freyr (Participant A, F and G), shaping legitimacy for the industry.

Participants point to the slow pace of adoption of ESS due to the lack of state investment in energy infrastructure. Over the past years, interest organisations, like Energy Norway, have been lobbying for better state procurement to upgrade the national electricity grid, which would create a larger market for LIBs. Following this, Statnett and regional grid companies have shown a willingness to invest in a more sustainable system, though whether this will culminate in widespread adaptation of LIBs remains to be seen. However, the increasing use of batteries within different Norwegian industries, such as the EV and marine sector, provides further support and legitimacy to the industry. This reflects the societal legitimation of batteries as a low-carbon technology domestically, which is considered a key element in path development by unlocking resources necessary to it. As a technology, batteries are well-known, meaning that they may not face the same hurdles as other radical technologies in the early phase of development (Bergek, Jacobsson & Sandén, 2008). Though this is not to say that the start-ups face uncertainty, with Morrow and Freyr both starting test lines to provide samples to buyers that have certain energy demands from LIBs.

When asked about the public and private support for developing a battery industry in Norway, participants all generally agreed there was no major opposition in the way that other renewable energy ventures have experienced as found in Steen (2016). Participant A hints that there has been some dissatisfaction within the planning process, as construction of the Gigafactory will destroy some nature around Arendal. While the Nordland participants were positive, media reports reveal some unease when it comes to the proposed Wind Park – Norway's largest if built – that is planned to fulfil the extra energy needs of Freyr, which was a condition of their start-up in Rana. However, this is generally seen by most as a compromise for the green potential offered by battery technology.

A major enabler of legitimacy is the sustainability advantage of Norwegian-produced LIBs. New regulations over European battery manufacturing dictate that sustainability should be central to the practices of battery manufacturers and the wider value chain. In order to remain competitive, industry stakeholders must adapt to these international developments and build sustainability focused capabilities. However, this works to legitimise the industry in a Norwegian context, with participants arguing that the domestic industry will sell the most sustainable batteries on the market (Participant C, D, H). Though the pressure to environmentally upgrade has influenced other heavy metal industrial actors in the region, with "*big businesses feeling also that pressure from the new battery initiative*" (Participant F), suggesting that there may be possible resistance in the regions. Locally, this is mitigated through the support of local municipalities sharing visions of sustainability; with Rana aiming to be the green industrial capital of Norway, and Arendal the first to join the UN Climate Neutral Now initiative, encouraging this green direction institutionally.

Strategic actions made by policymakers are significant in early path creation (Martin and Sunley, 2006). However, Norwegian manufacturers are currently awaiting renewal of state support and conducive national regulations. Participants agree that with the formulation of a National Battery Strategy this year, the battery industry will be strengthened and provided with "*the compass which will lead us in the right direction nationally"* (Terje Andersen, 2022). Many of the participants' organisations have directly been part of discussions to help inform the Norwegian Government how to best support them through this policy plan. Thus, indicating the significance of system-level agency over directionality to the industry as a whole.

5.3 Broader Dynamics of Path Development

Now the thesis turns to a macro-overview of the dynamics behind path development, including the framework conditions, global competition and firm-led market strategies, to further establish how the wider context affects formation outcomes.

5.3.1 Market strategies

Regionally, the emergence of this new industry in Agder and Nordland can be conceived as new path creation (Tödtling and Trippl, 2013). Though whilst the lead firms are establishing a green industry novel to Norway, mature battery manufacturers can be found in Asia. Freyr and Morrow can therefore be classed as latecomers in the broader context of the global market. Binz et al. (2016) argue that latecomers can form new industries through a combinatory approach; with firms anchoring in a region by building on local capabilities and mobilising extra-regional resources, as illustrated by the findings in section 5.2.

The 'strategic coupling' of GPNs to regions is driven by firm-level value capture strategies (Yeung & Coe, 2015). With mature technologies, considerations of cost-capability ratio optimisation take place at the stage of market formation, as presented in the lead firms plans to scale and industrialise production (Grillitsch et al., 2019). This is reflected by Participant H, who claims that "*with such established competition, cost-reduction strategies are very important, so we have to use these regional advantages to our benefit"*. Importantly, such accounts suggest that the strategic coupling of GPNs to regional assets are driven by the competitive strategies employed by lead firms (Yeung & Coe, 2015). Contrasting with the historical accident view of path dependence (Arthur, 1989), industry formation in Agder and Nordland is found to be based on specific locational decisions by lead firms Morrow and Freyr. Both regions had place-specific assets or resources that can be attributed to attracting industrial players in the initial phase of path formation, though this differs between the North and South of Norway due to regional variations. Participants from local institutions spoke of the "bargaining chips" used in attracting the lead firms during the site selection process.

Morrow initially had four sites in mind across the Agder region. In Arendal, this offer consisted of zoned lands, harbour access, the road system, a mix of skilled and unskilled labour, and how they could accommodate the families brought along (Participant A). Whereas in Mo i Rana, in addition to land, industrial infrastructure, the deepwater quay, a new airport, labourers experienced in shift work, and support for a previously unapproved wind farm was offered as the conditions for Freyr (Participant E). However, the main regional attraction, the electricity mix, is potentially time-limited, as mentioned previously. Participants worry there is not enough electricity for all of these new industrial opportunities, with other interdependent paths, such as process industries in both regions, demanding the same asset.

Furthermore, Yeung and Coe (2015) argue that in order for regions to reap positive externalities, local firms must participate in the regional coupling of lead GPN firms and regional assets, which can be found increasingly in the case of Agder, but less so in Mo i Rana. As previously highlighted, value creation, enhancement and capture trajectories are dependent on the type of strategic coupling modes (*ibid*). In both cases of regional development, one can note a trend towards indigenous coupling, wherein the "endogenous development of GPN segments" unfold as lead firms reach inside-out to non-local actors to form a GPN (Fuller & Phelps, 2018: 9). Patterns connecting this mode and new path creation are highlighted in Figure 7 (Blažek & Steen, 2021), with the co-evolution of lead GPN firms and regional assets seeing the region become a platform for these new industrial players. In this case, regions are able to maintain more autonomy, mitigate the "dark sides" of GPN coupling, and thus, exploit value creation and enhancement opportunities through the formation of supportive institutional actions.

The variations between ownership of lead firms also point to power differences, with a 42.7% share in Morrow being held by a state-owned company, Agder Energi, who have asked the state to take on increased ownership as the role of a producer as per Coe and Yeung (2015); in contrast to the equitisation of Freyr with largely international funds. As such, different power relations will exist between the firms and regions, with the state less able to mediate the GPN with the latter firm. This points to other aspects of strategic coupling can be found in the anchoring of resources to the region. In Arendal, huge greenfield investments from several extra-regional stakeholders have been essential in allowing Morrow to construct their facilities. Freyr have also focused on finance-driven approach to driving growth, resulting in a merger with an American firm that allowed them access to the NYSE and thus, extra-regional investors, though this can lead to the crowding-out of local firms.

5.3.2 Extra-firm dynamics

As mentioned above, firm strategies go some way in explaining the relationships produced by GPN firms (Figure 6). The prevalence of strategic partnerships between battery industry players highlights the extra-firm strategies employed (Appendix B), which links specifically to inter-firm partnerships (Coe and Yeung, 2015). In this case, strategic partners offer partial or total solutions for production by lead firms, with Freyr stating that their partnership-based business model will allow for better risk management, especially considering many of these partnerships have been formed with successful industry heavyweights (Appendix B). Interactions between the two represent a form of power relations, with coordination and governance generally assumed to be equally distributed. Based on close working relations, this network embeddedness is considered key in aligning the various segments of a value chain. In a study of the high-tech industry, Lyu et al. (2019) found that at growth stage, the centrality of a firm in a network can yield inbound open innovation practices, which one can identify in the clustering of firms around both Freyr and Morrow in their regions, however this is limited in terms of the majority of knowledge being centred away from Europe.

Due to this technological knowhow existing outside of the regions, and further still, outside of Norway, a direct effect on construction of inter-firm partnerships appears. As outlined in the Appendix B, the majority of the current lead firm supply agreements are with foreign based companies, with years of experience, knowledge and competence. Two contrasting consequences may occur as a result: as linkages between the GPN leaders and local firms are considered crucial to regional value creation (Dawley, 2014), the lack thereof may cause slower economic growth than expected, affecting the bargaining position of the regions; or, new inflows of resources may be streamed into the regions, as they have been thus far in the form of anchor investments to lead firms and economic upgrades, creating trickle-down effects. Both outcomes depend on the response of actors to facilitate processes of change, which may depend on institutional environments.

Based on the concept of territorial embeddedness, multi-scalar institutional, cultural and political factors in the spaces where GPNs are engaged, all play a role in determining how evolutionary development unfolds in an industry (Dicken, 2015). As a country governed through representative democracy, stability in both the political system and regulatory environment is a key enabler for battery industry players to operate in Norway. Participant H spoke of the stable regulatory environment found in the country that strengthens Norwegian industry. This is largely due to the domestic political agenda remaining a collaborative effort regardless of the leading party in power (EIU, 2021), as consecutive governments *"lead with almost the same industrial politics when it comes to framework"* (Participant F). Links can be made to Hall and Soskice's varieties of capitalism, which classifies Norway as a coordinated market economy, with a high reliance on formal institutions (2001).

However, this overreliance means that industries are liable to the self-reinforcing nature of institutions, which challenge change. participants criticised the lengthy bureaucratic system in both Europe and Norway, because "*everything takes so long, the new regulations and policies, the process of getting the permits, it's far too slow and it holds us back from progressing as fast as we would like*" (Participant H) and how this can be counterproductive. This is particularly challenging for the battery value chain as speed is, again, considered a critical element. Though, Covid-19 has produced a notable change in the policy arena. It "*has taught policy-makers to act at speed when they're dealing with important issues"* (participant H), which is hoped to also be reflected with the same sense of urgency given to the battery industry.

5.3.3 Competition in a global GPN

While the current battery manufacturing segment is saturated by the Chinese, European producers are rapidly setting their sights on participating in the global race. Illustrated in Chapter 2, this dependency on China and Asian domination of manufacturing capabilities has incentivised European entrants to join the market, with the *"geopolitical ramifications"* of the battery GPN showing (Ewing & Penn, 2021). Participant A states that this produces the need for faster action from domestic manufacturers before mature Asian firms physically establish themselves in Europe, reflecting the slow pace of technological transitions and scaling up of battery technology in Europe until recently.

Many firms in the Norwegian LIB chain are aiming to supply European buyers, as per the changing institutional environment towards the green transition there. Hence, transnational linkages are important for firms to gain access to new markets and resources (Liu, Chaminade & Asheim, 2013), particularly in the case of the Norwegian battery industry, which offers great potential for expanding the export market in Norway in consideration of minimal domestic end-market producers. As Norwegian battery manufacturers are in the pilot stage of projects and batteries remain fairly unstandardised amongst producers; this may prevent market access in foreign markets. This competition is further intensified as car manufacturers themselves are turning to battery cell production in Europe, with increasing vertical integration found in the plans of Tesla and Volkswagen, as well as the opening of Gigafactories by industrial manufacturers CATL and Panasonic. In addition to the need for active and immediate participation highlighted by lead firms, Participant E emphasises that:

This is a board, we take part in a European competition, in global competition, and the race is today and not in October or in February next year. It's today when it needs to be addressed.

When recalling governance, international policies and regulations are crucial in shaping a GPN (Gereffi et al., 2005). While Norway is not in the EU, a lot of policy and regulatory initiatives are implemented in Norway due to their place in the EEA. Thus far, Europe has been a leading power in emphasising the centrality of green growth. This is exemplified in the Green Deal, wherein batteries are highlighted as a fundamental technology in achieving these objectives (cite). However, the increasing regulatory pressures posed by the update to the EU Battery Directive (2006/66/EC) work as both a barrier and a driver to the Norwegian battery industry. It stipulates requirements for carbon footprint passport declarations, as well as better supply chain transparency and circularity for end-of-life batteries. This has major implications for global manufacturers, driving sustainability within Europe whilst also effectively forcing the hand of foreign firms who trade with the European bloc to either adopt clean practices or receive penalties. Together with the Carbon Border Adjustment Mechanism, this will cause downwards pressure on Chinese battery imports, giving an opportunity to European producers. In the case of Norwegian battery manufacturing, common narratives are centred around the sustainable nature of production are found to be a competitive advantage in light of more stringent requirements, thanks to the renewable power and local, circular supply chain segments.

Simultaneously, it has also created uncertainty amongst European producers, including those in Norway. While the high initial costs associated with cleaner technologies compared to conventional technologies poses a major financial barrier, the need for new downstream segments will add to these financial pressures through, for example, the costs of collecting end-of-life products, waste separation, and resource recovery. Sustainability concerns are also highlighted. Eurobat (2022), representing a consortium of European producers, state that this requirement may create shortages in the supply chain and push firms to secure supplies from outside of Europe. This sentiment is echoed by Participant H, who states *"the level of recycled batteries we need for production will take years to reach an industrial level".*

Concerns over this pace appear to be linked to the difference in national leadership approaches to developing the domestic battery industry, which can ultimately affect the ability to "plug into" a GPN. In particular, several participants noted the decision not to join the IPCEI as detrimental to Norwegian industrial development. Established in 2019, the Important Project of Common European Interest (IPCEI) was formed to identify strategic value chains for European investment and highlight over-dependencies in certain markets, including access to critical materials that are central to battery production. Norway is currently unable to access the funding and collaborative resources available to other European nations, due to their lack of participation (Participant F). In parallel, that this may lead to heightened European competition following the development of capabilities under this project. The new government also recognise this, arguing that they are now *"working to get Norway into the European IPCEI (...) to have more instruments available"*, as well as establish a separate industrial partnership with the EU to benefit the battery industry (Regjeringen, 2022). Furthermore, the significance of supra-national mechanisms is illustrated in the failed strategic partnership between Equinor, Hydro and Panasonic to set up LIB production in Norway. This was ended in 2021 due to the imposition of a 10% duty on Norwegian produced batteries under the Brexit agreement, thus affecting the prospect of Norwegian competitiveness in the desired market. In lieu of this, the need for state support is emphasised in order to mediate the GPN and establish an export market.

Chapter 6: Discussion

This thesis has so far discussed the emerging battery industry in Norway, focusing on how regional and extra-regional dimensions shape industrial development. In the following chapter, pertinent findings shall be discussed in the context of the research questions by use of the conceptual framework outlined in section 3.3.

6.1 *What are the main enabling and constraining elements behind regional path creation in the battery industry?*

Following Binz et al. (2016), details of the resource formation process behind Norwegian battery path creation were laid out in Chapter 5. This revealed that there are various enabling and constraining factors behind the battery path at a regional level (see Appendix A). In order to obtain a broader overview of this, the cross-fertilisation of approaches set out under the conceptual framework is applied in line with the notion of path creation environments put forth by Martin (2010) in Figure 4. This is structured through the use of four key dimensions threaded throughout the theoretical body and findings are used: linking path creation to regional assets, key actors and agency, and institutional environments.

6.1.1 Regional assets

The analysis finds regional pre-conditions of a place-specific and temporal nature have enabled new industrial development in both case studies (Martin, 2010). Analogous with this, combined endogenous assets were identified in section 3.1.2: natural, human, industrial, institutional and infrastructural (Baumgartinger-Seiringer et al., 2021). These have provided the basis for strategic coupling with the regions under the GPN approach (Coe & Yeung, 2015).

On one hand, it is evident that natural resources play a role (MacKinnon et al., 2019). Local supplies of raw materials are a driver, particularly in Mo i Rana with its proximity to the mining sector, though this is heavily regulated institutionally under national ownership. Another regional asset is found in the cheap, renewable energy surpluses held, cited as the key motivation for by firms to produce in Norway and in these particular regions. Though the limits of this competitive advantage remain to be seen, with contention over the use of this clean electricity highlighting the need for the additional legitimation of the battery industry. This speaks to the need for mobilisation of natural resources to enable path creation, which are leveraged and mediated by actors in equal measures.

Infrastructural assets also shape the geographical emergence of paths (Maskell & Malmberg, 2007). Despite efforts to localise supply chains (Zhan, 2021), due to the current global nature of the battery GPN, battery manufacturers aim to supply end-use markets largely based in Europe. As such, locational decisions were dependent on the regions with necessary logistical infrastructure, such as port access, roads and zoned areas for construction, which in many cases are being upgraded by reactive local institutions.

Similarly, the inherited industrial legacies clearly matter in developing new paths within territorial spaces; the O&G supplier sectors linked to Arendal and metallurgical industry around Mo i Rana, as well as the contemporary process industries in both cases, have provided complementary assets to the incoming battery manufacturers in the pre-formation phase. Cognitive similarities due to similar technology, production processes and human competencies can be used in the new battery paths and therefore links to the assumption of Boschma (2017) which suggests that paths will emerge alongside related pre-existing industrial bases; otherwise known as path interdependency. These related industrial asset bases can be linked to the diversification of large industrial suppliers to the lead firms, like Elkem and their spin-off Vianode (Appendix B), who are branching their activities into new segments of the battery VC. In the same way, the presence of clusters in the regions – with a concentration of firms and workers - also offer a strengthened innovation system for firms to strategically couple with, with many cluster firms stating an interest in participating in this GPN.

However, in recollection of path dependency, pre-existing industrial structures and paths can work to constrain the rise of new industries (Martin & Sunley, 2006). This can be said for Mo i Rana and Nordland, whose innovation system is challenged by their geography. Most dominant companies in key regional markets are not headquartered locally (EU, 2018), a lack of geographical proximity that makes it harder to establish networks between firms. Difficulties in the way of trying to facilitate industrial development in such a long, sparsely populated region have compounded this challenge. Building upon this, the lack of leading national or international paths around Nordland has constrained access to extra-regional resources (Salamonsen, 2015). Whilst heterogeneity within regional systems is posited as a main force of path creation (Martin & Sunley, 2006), the region is commonly characterised as a peripheral region due to the comparative lack of diversified resources and paths (Jonas, 2019). Meanwhile, there may also be barriers imposed on innovation due to the longstanding prominence of an industry. Whilst Agder is generally classed as a 'thick' region, Herstad and

Sandven (2017) warned that Agder was at risk of becoming overspecialised in their knowledge infrastructure (Trippl & Otto, 2009), due to industrial dependence on impulses from the O&G sector. Thus, highlighting the need to develop a more diverse technological and industrial range.

6.1.2 Key actors and agency

Throughout the analysis, the importance of actors in the initial industrial formation phase through to the later path creation period has been reiterated in driving new regional industries. Though, actors and interactions amongst them can be representative of enabling or constraining environments.

In the initial phase of formation, start-ups Morrow and Freyr were key in establishing the roots of the new battery path, wherein both firms sought to exploit market opportunities by leveraging the regional assets for value creation. The origins of Morrow differ slightly from Freyr. While Freyr is the product of firm-level agency, Frederic Hauge, as a system-level agent, innovated the idea of Morrow without profit seeking motives (Trippl et al., 2019). In this case, suggesting a business idea based on sustainability (ibid) by taking a (constraining) system failure and using it as an (enabling) opportunity. This can also be noted in their experimentation, whereby Morrow is exploring more radically innovative technology. Both firms, however, can be viewed as Schumpeterian entrepreneurs in their bringing of novelty to the regions, which was followed by new regional entrants and the environmental upgrading of other firms in the market. Hence, this highlights a simple premise: more innovation in a region enables more green industrial activity.

The analysis has uncovered, in this vein, that purposeful effort by these agents is closely tied to the collective expectations (Steen, 2016), regarding both the industrial and green potential offered by domestic battery manufacturing. Again, it is also indicated by increased firm entry. In both regions, one can find the branching of other incumbent firm activities to the needs of the battery GPN with the economic promise. This suggests shared visions amongst actors enable path transformation (ibid); firstly, by forming the market and then by legitimising the industry. This legitimacy is formalised through support regimes, which has been deployed through a series of bricolage policies which emphasise collective learning to establish a varied asset base through instruments such as ENOVA (Garud and Karnøe, 2003).

However, path dependence also occurs at the micro-level, stemming from local actors in firms or organisations who operate with bounded rationality due to information constraints

(Steen, 2016b). This is true in the case of key actors under study, as in section 5.2.1. Demonstrated asset modification processes have been employed to be able to turn constraining environments, with obvious knowledge and resource gaps in the regions, into enabling environments (Trippl et al., 2019). Here, this thesis finds both firm- and system-level agency to be important to the battery path, without which, the necessary resources would not have been mobilised.

Specifically, firms have mobilised the anchoring of assets to the region, through so-called global pipelines (Bathelt & Gluckler, 2014). Inflows of capital to local research and educational institutes have created competence, as well as infrastructural upgrading and greenfield plans through extra-regional investments into the regions. Though this is found in both regions, largely in the mobilisation of foreign human capital and industrial research partnerships, exogenous resource formation is pronounced in Nordland due to internationalised firm strategies. Notably, an overreliance on exogenous resources may not lead to extensive local learning in early paths (Nilsen, 2019) due to their temporal nature, therefore policymakers are advised to create incentives for collaborative efforts to produce long-lasting regional resource development.

To avoid a firm-centric approach, this thesis also points to the role of non-firm actors (Baumgartinger-Seiringer et al., 2021), who have also enabled knowledge generation and resource mobilisation. Though public policy actors are referred to in more detail in the following section, R&D organisations have been key in enabling industrial growth, particularly in the Agder region with a closer collaboration between academic institutions and industry largely due to geographical proximity. Due to this, many new research projects key to experimentation and technological development in various segments. In line with this, findings showed that networks of actors are increasingly being formed, which serves to align organisational- and system-level agency to create self-sustaining processes of resource formation towards growth (Isaksen et al., 2018).

6.1.3 Institutional environments

In Norway, path creation is both enabled and constrained by existing the institutional environment. Firms themselves may become territorially embedded in a region, shaped by the various political influences (Dicken, 2015). In the case of the battery path, the EU sets direct regulations for Norwegian battery manufacturers through their Directive (2006/66/EC), wherein its recent replacement has been cited as an enabler of domestic production due to the focus on sustainability. Norway itself, as a coordinated market economy, is presumed to place a high value on institutions (Hall & Soskice, 2001). One enabling resource an institution can provide is the legitimation of new industries and technologies (Binz et al., 2016). This is shown throughout Chapter 5, where research points to socio-political acceptance of battery technology in Norway. Early policy incentives to EV adoption, for example, have influenced social norms towards green solutions (Nayum & Thøgersen, 2022), though this matters moreso in terms of providing second-life batteries in light of manufacturers targeting international markets. Further shaped by the state through policy and regulatory frameworks (Gereffi et al., 2005); the aim to accelerate the green shift has led to a growing emphasis placed on battery technology as a new source of value creation in light of the 'life after oil' narrative (Steen, 2016).

The role of sub-national institutions can be highlighted through their promotion of strategic coupling (Coe & Yeung, 2015). Locally, municipalities and county councils, have been heavily involved in the preliminary stages of attracting lead firms as the hosts. In this way, they have sought to enhance the local environment for the incoming businesses through "exogenous rents" (Yeung & Coe, 2015), giving access to land, energy supplies and fast-tracking permitting processes. Thus, this shows that strategic coupling is not solely mediated by the state, but at the regional level too (ibid). Decentralisation can be attributed to this, with administration divided between the central government, county councils and municipalities, which retain a high degree of regional autonomy (MacKinnon et al., 2019). This institutional diversity has fostered the most vocal support for the paths at a sub-national level, with high local commitment to battery players.

This legitimation has also led to the mobilisation of other resources towards the emerging industry. Government investment has been an important driver to the emerging industries, through funding instruments such as the Green Platform, mobilising financial resources for not only lead firms, but other associated emerging industrial actors and diversifying firms. However, research has highlighted the high costs entailed in the battery path, and in the absence of direct funding schemes to cover these large-scale ventures, path creation has been driven by industrial leaders themselves through financialisation.

However, regions may become locked into organisational routines whereby institutions become over reliant on policy measures, otherwise known as institutional hysteresis (Boschma, 2007). Through the analysis, institutional lock-in (Arthur, 1989) is derived from several sources in the case of Norwegian battery manufacturing. Firstly, path dependence in the O&G industry affects the state institutions, making them reluctant to pursue alternative large-scale export opportunities. The development of hydropower has also led to another form of lock-in. This reflects the findings of Klitkou et al. (2015), who observed that dominant renewable technologies cause lock-in and limit the diffusion of other green technology. While the latter does not directly challenge the green transition, battery manufacturers face competition from other green technologies for public funding and R&D, such as hydrogen, highlighted in section 5.1.1. Thus, suggesting that formal institutions encourage a wider variety and more experimentation within innovation systems.

In addition, bureaucratic adaption has slowed down the introduction of a national strategy supportive to the battery industry, starkly contrasting with the proactivity seen in the EU, wherein co-evolution has pushed initiatives geared towards battery manufacturing, the lack of alignment institutionally in Norway lost them the opportunity of joining IPCEI. As such, findings point to a constraining institutional environment to path creation in Norway. Hence, there is the need for co-evolution between institutions and industrial paths as new industries emerge, so that change is encouraged, not hindered and directionality is given (Garud & Karnøe, 2001).

In order to stimulate new paths, actors must recognise these pre-existing conditions and initiate change, use and mobilise assets, all in the backdrop of institutional environments. Following this, the research suggests that maintaining a dichotomy between enabling and constraining environments in path dependent literature becomes problematic in light of the temporal and multi-scalar face of path creation, with all elements highly interlinked.

6.2 *How has industry emergence and development occurred in respect of the battery industry?*

To address this research question, the two regional case studies are briefly analysed to show the main path creation mechanisms in the unfolding of this industry, presenting the regional variations. Scholars identify varying sources of new paths, understanding that regions may experience different forms of industrial birth (Martin & Sunley, 2006). However, in reality it is challenging to categorise this process so distinctly, with many converging mechanisms connected to path formation in one region. This is also the case in the emerging Norwegian battery industry, whereby several path creation mechanisms can be identified with substantial overlaps between them.

6.2.1 Contrasting the regional path creation experiences

Setting the scene, other than end-use and maritime battery niches, the regions had no overt connection to battery manufacturing prior to the arrival of these firms, and one can see that the two cases are at generally the same phase of path creation. In line with Dawley (2014), three main mechanisms can be identified in the case studies: indigenous path creation, diversification and branching, and transplantation, all explaining industry emergence and development, though the prominence of each varies.

Away from the idea of exogenous shocks (David, 2001), research hints that incremental change, within the broader context of climate adaption strategies, can be linked to path creation in the battery industry. In the way of this thinking, actors seek to move away from incumbent dirty industrial paths and technologies, through mindful deviation (Simmie, 2012). On a firm-level, the emergence of the Norwegian battery industry is conceived as a window of locational opportunity (Boschma & Frenken, 2006); whereby emphasis has been placed on acting now in light of market pressures, such as international competition, the temporality of favourable regional assets and increasing demand.

At first glance, both regional battery paths can be characterised as indigenous path creation (Martin & Sunley, 2006), with start-ups emerging for the first time in these regions and generating local knowledge. Accordingly, this assumption would suggest an organic strategic coupling mode, however it more closely aligns with functional coupling with both inside-out and outside-in resource formation processes, with the latter process more evident in Mo i Rana (Blazek & Steen, 2021; Coe & Yeung, 2015). This points to the “fuzzy” nature of these distinctions.

Diversification has also been a prominent theme throughout the analysis; with the mechanism appearing in both cases based on strong related regional assets. This mechanism was important in the preformation phase. Aside from the entrepreneurship spoken of in the previous section; a subsidiary of Agder Energi, as the main economic owners of Morrow, branched into battery manufacturing using their experience in energy utilities and renewable production. This brought a human base for Freyr, as seen in the top tiers of management, with related knowledge from various industries, including several founders from Hydro, the Norwegian aluminium and hydropower company. This has also entailed diversification processes for several established firms, with path branching on the supplier side (Martin & Sunley, 2006), furthermore, branching activities appear to exist in a niche due to the sustainability premise (e.g. battery recycling, sustainable materials). In a wider sense, the diversification of infrastructure as per MacKinnon et al. (2019) also occurs, with the upgrading of physical spaces to meet new path needs.

In line with previous work in EEG, path creation has been accelerated by the transplantation of extra-regional resources. The ability to attract foreign technology, investments, suppliers, and experienced experts to impart knowledge, is critical, especially for manufacturers catching-up to global competitors. Most notably, the need for technological knowhow has led firms to import foreign workers to impart knowledge. Similarly in this vein, start-ups appear to be highly dependent on strong research linkages at the stage of industry formation, both through formal R&D organisations or in collaboration with other firms. The Nordland region appears to be more dependent on extra-regional linkages for resource formation, particularly in terms of knowledge and financing, relying less on the existing RIS for resources. Meanwhile, the Agder region has been more successful historically, with a diverse variety of industrial actors providing useful assets for the battery industry to utilise, though in Arendal itself, they have particular gaps in knowledge and education.

Chapter 7: Conclusion

Reflecting the "path as process" notion presented by Martin & Sunley (2006), through the use of a mixed conceptual framework, this thesis has attempted to examine how the battery industry has unfolded in the two Norwegian regions of study. In doing so, the enabling and constraining elements within the regions of Arendal (Agder) and Mo i Rana (Nordland) were highlighted in reference to the new battery paths. The thesis has also sought to contribute to advance the cross-fertilisation of GPN and EEG perspectives. By using strands from both approaches, a more pluralistic account of the relationships between mechanisms, actors, and industrial environments. This has been found highly necessary due to the nuanced processes behind new industrial development, which cannot easily be categorised into distinctions of coupling modes nor mechanisms of path creation.

The empirical findings highlighted a high degree of contingency on regional pre-conditions, mostly based on those natural and industrial assets which fit the needs of the lead firms, in line with the concept of strategic coupling (Coe & Yeung, 2015). While the degree of these varied between the two regions, a commonality was illustrated in the related industrial structures that pre-existed the battery industry. In line with this, it revealed path interdependence between the process industry and the new battery path, which enabled formation, whilst path dependence was found for differing reasons in the regions, based on opposing peripheral and overspecialised structures.

As with previous research, the need for resource mobilisation and asset modification was raised, the challenges of which are presented through the linkages that actors make, with some industrial paths reliant on extra-regional resources in lieu of an established regional base. However, a combination of experimentation and expectations has clearly been a powerful tool for the battery path, and lead to an expansion of activity amongst firms and suppliers.

Simultaneously, at a system-level, a push from policymakers in both regulating carbon-heavy emissions and incentivising green solutions, has helped shape the market for the emergence of battery technologies and their end-uses by providing a vital ingredient: legitimacy, though there is still a need for increased national institutional support and co-evolution through the next stages of path development as needs change.

7.1 Future perspectives

As the path creation in battery manufacturing remains at an early stage of development, understanding the changing processes and needs behind it, in line with evolutionary thought, presents the opportunity for further study. Furthermore, diving deeper into the other segments and the wider supply chain of the battery value chain emerging in Norway would have been of great interest. However, due to the challenge of getting secondary data at this stage of industry formation, this may be revisited at a later stage, particularly following the release of essential policy and regulatory frameworks (e.g. the revised EU Battery Directive and the National Strategy on Batteries) later in 2022.

Theoretically, there are a deal of commonalities between the two approaches adopted in this thesis, with the case studies highlighting the importance of operationalising broader perspectives on regional development, due to the multi-scalar nature of industries, technology, politics and markets. I propose that it would also be of value to integrate transition-based approaches into a study of green path creation, due to the transformative nature of the technology, though the scope that this thesis could cover was constrained by time and wordcount alike.

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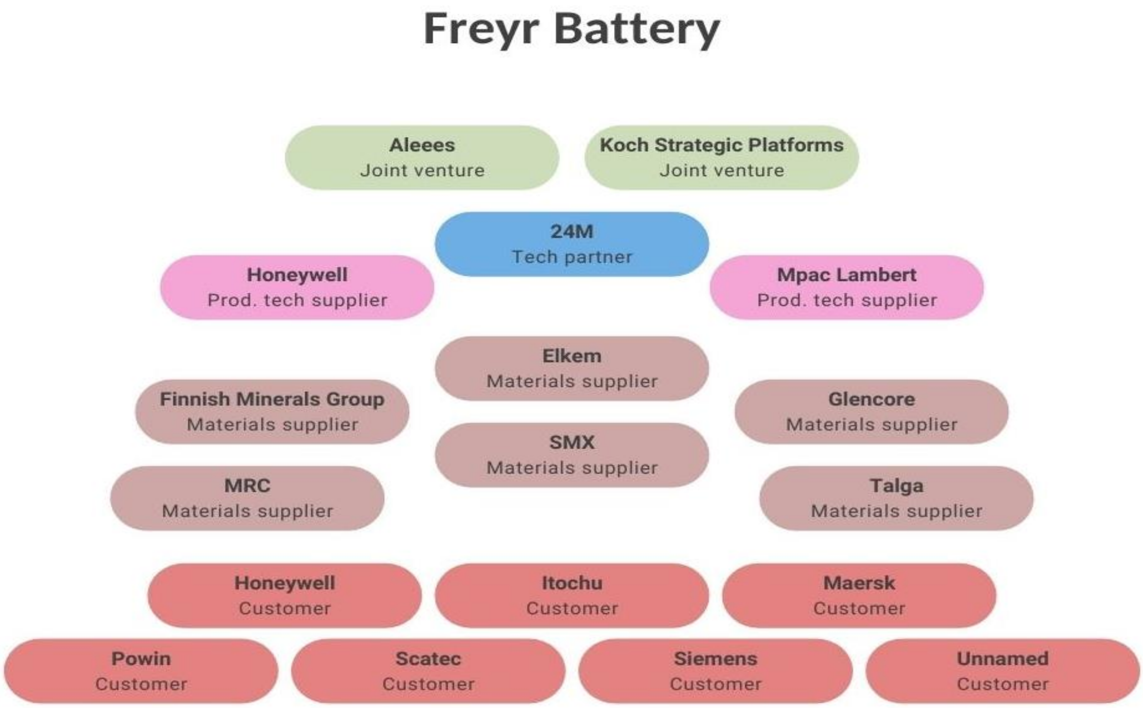
Appendix

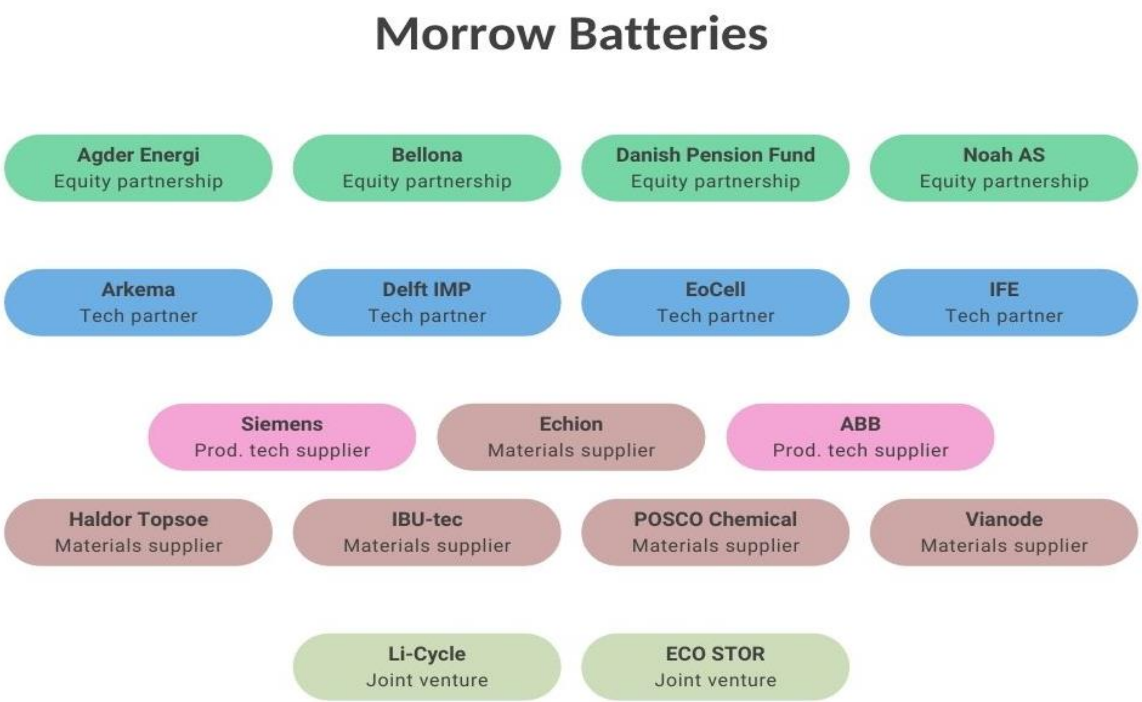
Appendix A: Identified drivers and barriers to battery industry regionally

Function	Drivers	Barriers
Knowledge generation	R&D projects, active participation of research organisations and extra-regional linkages, educational initiatives	Local knowledge gaps
Knowledge diffusion	Formal networks and clusters, intersectoral research	Lack of variety in RIS (Nordland) Rigidity in knowledge infrastructure (Agder)
Entrepreneurial experimentation	Pre-developed foreign technology, branching/diversification of established firms	Lack of new technological experimentation (Freyr)
Market formation	Shifting patterns of production, green transition narrative, growing end-uses of LIBs	O&G industry
Influence on the direction of search	Regulatory pressures and policy, positive expectations about future markets,	No clear strategy from the government
Resource mobilisation	Funded R&D projects	Lack of local human resources, lack of direct state funding
Legitimation	Increasing domestic end-use, sustainability incentive, local visions towards green transition, lobbyists for ESS	Unclear state support, policy incoherence, uncertainty
Broader context	Sustainability as a competitive advantage, strong regional assets	International competition, slow institutional change, IPCEI

Source: (Based on resource formation processes of Bergek et al., 2008; Binz et al., 2016, as in section 3.1.2).

Appendix B: Firm supply and buyer structure





Appendix C: Interview guide

Introduction: introduce interviewer, explain thesis and data privacy.

Ask participant about themselves & region.

Could you please tell me about yourself and the role you have?

How do you work with the battery industry?

Do you think the industry could have emerged anywhere else or is this environment special?

Is LOCATION characterised by a lot of industry already? What kinds of industry?

Policy:

Are you aware of how local government plays a part in innovation and development of the battery industry?

How does national government try to support green industries such as the battery industry, through policy and other initiatives?

What potential do you think Norway has in terms of opportunities to develop a strong domestic battery manufacturing base?

Has there been a lot of public support for the battery industry in Arendal and Agder? What opportunities will this hopefully bring to the area?

How is social and political pressure towards sustainability impacting the industrial development?

Drivers and barriers to development:

There are many different drivers for the development of green industries, which do you think are the most relevant battery manufacturing in LOCATION?

Particular strengths held by region to attract battery industry?

And are there any barriers that are posed to new industries within the region?

How do you propose to address these challenges?

Collaborations between different actors important for battery manufacturing in Norway and your region?

Do you think working with other municipalities and regions has any importance in this regard?

Across the whole value chain, do you think any challenges you are facing to establish cooperation between actors to develop the battery industry?

What about forging connections with leading firms in other industries?

Clusters have shown to be key in attracting business to the region, in your eyes have they impacted the development of the battery industry here?

How central do you think R&D is to further development of the industry? What role do you think innovation and R&D plays in growing this industry in LOCATION?

Global value chains:

Global trends indicate a move to domestic production of battery cells, as more institutional leaders recognise the importance of engaging with this value chain.

What do you expect a global shift of the way production is currently configurated to look like?

Norwegian battery value chain - are there any processes that aren't able to be localised currently?

Which VC segments face the largest challenges?

In the context of the global market, why do you think it is important to introduce the battery industry to Norway?

Europe has indicated their desire to engage with the battery value chain, i.e., Battery Alliance & Strategic Action Plan, with plans to build multiple gigafactories, how do you think this will impact Norway?

Problems transpiring from Brexit were highlighted, in part. the clause which levies a 10% tax on batteries produced in Norway, how important is this to Norwegian producers?

I also think recent global events - Ukrainian crisis has highlighted many countries dependence on oil and gas, leading Equinor to increase their supply of gas to Europe, and paired with the domestic prices of electricity nowadays due to Norway overselling power to Europe, do you think that this will push the battery industry forwards or we will see people reverting (back) to the traditional sectors of oil and gas as an easy economic path?

Sustainability:

At the moment, pollution from industrial sectors make up 60% of Norway's carbon emissions. Aside from the obvious shift to a greener energy system, how do you think the battery industry's growth in LOCATION can contribute to sustainable development?

We are seeing a lot more sustainable solutions crop up in the battery industry, ranging from battery chemistry that relies less on finite materials to circularity at the end of a battery's life cycle. What, in terms of sustainability, stands out for you in the battery industry?

Do you think that these will play a role going forward in the Norwegian context?

Innovation:

What are the critical factors for being innovative in the battery industry?

Do you look for innovations, knowledge and tech from other industries?

What industries are you collaborating with?

What are the main challenges to address within your organisation?

Concluding question:

What do you think the future holds for the battery industry in Norway?

Appendix D: Participant consent form

Are you interested in taking part in the research project

"The Key to Our Energy Future? Unravelling the transformative potential of green path creation"?

This is an inquiry about participation in a research project. The main purpose of this study is to determine why and how regions can play an active role in global value chains, focusing on battery production in Norway, which has been recognised as an important source of value creation and sustainable development going forward. In this letter we will give you further information about the purpose of the project and what your participation will involve.

Purpose of the project

This project is a master's thesis, in partial fulfilment of the MSc programme in Globalisation and Sustainable Development at NTNU. A brief outline is provided below:

Constituting an important tool of this ongoing decarbonisation, battery technology is commonly utilised in everyday lives as a key component in various applications, from mobile phones to e-mobility. Although, in contrast to this widespread usage, the manufacturing of battery cells is geographically concentrated in China. This has sparked competition from other nations and firms, who have indicated intentions to cash in on the global value chain. Plans for battery cell factories within Norway have emerged in recent years, with industrial leaders recognising the potential of developing a domestic industry. The purpose of this paper is to find out how regions can tap into this market, outlining the strengths, barriers and opportunities that are posed to new firms operating in Norwegian regions that wish to engage with the industry. Two empirical examples will be used in order to demonstrate regional variations of participation in global markets; studying the burgeoning engagement with battery production in Arendal, Agder and Mo i Rana, Nordland, where sites have been constructed recently.

Who is responsible for the research project?
As previously mentioned, NTNU is the institution responsible for the project.

Why are you being asked to participate?
The sample of participants in the project have been chosen based on their agency in the regions under study and/or their role in the development of battery production in these respective areas. In total, there will hopefully be a total of approx. 7 - 10 participants, all of whom are relevant individuals linked to the industry and regional development.

What does participation involve for you?

The method for data collection will consist of a series of interviews with participants. Each participant shall partake in one in depth interview, with questions centred around regional competencies, development and industry. Following the agreement of a participant to take part in the project, this will be organised with each individual. The interviews will be recorded in the form of audio and video recordings.

Participation is voluntary
Participation in the project is voluntary. If you chose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. There will be no negative consequences for you if you chose not to participate or later decide to withdraw.

Your personal privacy – how we will store and use your personal data
We will only use your personal data for the purpose specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

Two individuals in connection to NTNU, the student and the project supervisor, will have access to the personal data. However, all data shall be encrypted following recording, as well as all contact details and names being removed and replaced with a code. The data will subsequently be stored on a private research server that will ensure no unauthorised persons are able to access any personal data collected.

Participants will remain anonymous in the publication of this academic research project, with their names coded in analysis. For the purposes of research, only the occupation/role of participants and the region affiliated with each participant shall be referred to.

What will happen to your personal data at the end of the research project?
Upon the completion and submission of this project for grading, the data will be deleted. Data will be anonymised for participants to retain complete privacy over their personal opinions and knowledge shared.

Your rights
So long as you can be identified in the collected data, you have the right to:
- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your consent.

Based on an agreement with NTNU, Data Protection Services has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?
If you have questions about the project, or want to exercise your rights, contact:
- NTNU, via Markus Steen.
- NTNU's Data Protection Officer: Thomas Helgesen
- Data Protection Services, by email: (personverntjenester@sikt.no) or by telephone: +47 53 21 15 00.

Yours sincerely,

Project Leader: Markus Steen (Researcher/supervisor)

Student: Chloe Depledge

Consent form

I have received and understood information about the project *"The Future of Energy: Unravelling the transformative potential of regional development pathways"* and have been given the opportunity to ask questions. I give consent:

- ☐ to participate in an interview
- ☐ to be recorded by audio and video during the interview

I give consent for my personal data to be processed until the end date of the project.

(Signed by participant, date)

Chloe Depledge

NTNU
Norwegian University of
Science and Technology